CONFERENCE PROCEEDINGS

26th EurOMA Conference

Helsinki, Finland

June 17-19 2019

OPERATIONS ADDING VALUE TO SOCIETY

EurOMA 2019

Helsinki, Finland

Aalto University
School of Business

HANKEN

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EUR OMA European Operations Management Association

Dear Colleague,

We are delighted to welcome you to the 26th International EUROMA conference in Helsinki, Finland, 17-19 June 2019. The conference is hosted by Aalto University School of Business, Hanken School of Economics and the HUMLOG Institute, at the premises of the Hanken School of Economics.

The theme of the 26th EurOMA Conference is:

Operations Adding Value to Society

This theme extends previous themes beyond manufacturing and services to wider societal and community implications and impact. The conference theme highlights a move beyond goods manufacturing to considerations of shared economy, circular economy, and to critical infrastructure and supply chains. EurOMA has had a tradition of tracks in various industries, and this theme specifically welcomes health care operations, humanitarian operations, and public sector management. But of course all traditional topics of the conference are well represented as well in 2019.

The conference program includes a total of 20 parallel sessions divided into the 41 EurOMA themes. Over 580 abstracts were submitted, of which 548 abstracts were accepted, and which resulted in the 409 final papers you see in the schedule. A total of 555 researchers from 44 countries will attend this annual conference. Notwithstanding Brexit, the largest number of participants come from the UK (120), with runner-ups being Sweden (46), Germany (42), Finland (38), Italy (27), and Brazil (23).

The EUROMA 2019 conference is preceded by three workshops on Sat and/or Sun 15-16 June 2019, as has been the case in many previous conferences: the EurOMA Doctoral Seminar, the EurOMA Publishing Workshop, and the EurOMA Young Scholars' Workshop. New to the conference is a developmental paper workshop, young scholars' tutoring and get-together, and many other activities that make this community so unique. The plenary speakers will be Professor Janet Godsell (Warwick Manufacturing Group), Rector, Professor Karen Spens (Hanken School of Economics), and Kalle Löövi, the Director of International Operations of the Finnish Red Cross.

The social program includes a Reception at Helsinki City Hall, Conference dinner at Finlandia Hall, and Industry visit to Finnair Cargo, where we get to enjoy a presentation of their new world-class cargo handling premises. On the way to Finnair Cargo facilities, we will spend the morning at the Finnish Science Park, Heureka, where we will also enjoy our lunch.

We thank all the researchers and authors who are contributing to the success of EurOMA 2019 Conference. Our special thanks go to the scientific committee and to the over 1400 reviewers for their invaluable and timely contribution – we are still proud of the reviews being sent out before the actual deadline, but that would not have been possible without everyone prioritising this conference in their schedules.

As always, the sponsors are a cornerstone of a successful conference. We wish to thank Paulo Foundation; the Foundation for Economic Education; Marcus Wallenberg Economic Research Foundation and the Federation of Finnish Learned Societies for their generous support.

Similarly, we thank all other sponsors and exhibitors for their financial support as well as their other contributions to the success of EurOMA 2019.

Welcome to Helsinki!

On behalf of the Organizing Committee,

Gyöngyi Kovács and Markku Kuula
Conference Co-Chairs

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Behavioral Operations

Analyzing Retailer-led Green Supply Chain Considering Fairness Concerns

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Abstract

In this study, we investigate the impact of fairness concern of a manufacturer towards the product's greening policies and the pricing decisions in a retailer-led green supply chain, where the customer's demand is sensitive to product's greening level. We show that the manufacturer's sensitivity towards fairness will negatively influence the manufacturer's effort for product's greening, the retailer's market price, and the retailer's profit. Furthermore, we find that a fairness-concerned manufacturer will put positive effort for greening when the product's marginal production cost is lesser than that of its corresponding minimum value in the fairness-neutral channel.

Keywords: Green supply chain, Game Theory, Fairness

Introduction

Green supply chain (GSC) management has recently gained attention among academicians and practitioners of supply chain management. GSC strategies involve working with suppliers and customers, analyzing internal operations and processes, reconsidering inventory decisions, reverse logistics designs, new product development, and mitigating conflicts in channel coordination to minimize the negative impact of supply chains on the environment (Corbett and Klassen, 2006; Östlin et al., 2008; Swami and Shah, 2013; Li et al., 2016; Xu et al., 2017). Many big firms, such as Wal-Mart, Dell, Patagonia invest heavily on GSC initiatives, carbon disclosure projects, carbon footprint reduction and use these strategies to attract green conscious customers and improve their global brand image (Plambeck, 2007; Plambeck and Denend, 2011; Ghosh and Shah, 2012). Apparently, when the big retailers such as Wal-Mart influence their upstream manufacturers to take initiatives for improving the product's greening level, the manufacturer's may feel unfairly treated by the retailer when there is unfavorable distribution of total profit, with retailer taking more of it (Fehr and Schmidt, 1999; Loch and Wu, 2008; Sharma and Nandi, 2018; Sharma, 2019). In view of this, there is very limited literature that studies the impact of manufacturer's fairness concerns in a green supply chain with retailer's domination. Hence, the purpose of this study is to fill this gap in the literature by studying the impact of manufacturer's fairness concerns on the product's greening policies and the pricing decisions in a green supply chain with retailer's dominance. We consider a retailer-led dyadic supply chain model, composed of

one manufacturer and one retailer, where the manufacturer invests on product's greening and sells the product to the green-sensitive customers through the retailer. We then investigate the influence of manufacturer's fairness concerns on the greening and pricing policies of the channel members.

The rest of the paper is organized as follows. The next section briefly describes recent related studies on supply chain with environmental factors under channel member's fairness concerns. It is then followed by the model description of retailer-led green supply chain and then the model with manufacturer's fairness concerns. Next, we discuss the influence of fairness concerns on different greening and pricing decisions. Finally, we conclude our work with several managerial implications and scope for future studies.

Related Literature

Swami and Shah (2013) investigate channel coordination in GSC environment in which both the manufacturer and the retailer put efforts for greening their operations. The authors find that ratio of the optimal greening efforts put in by the two parties is equal to the ratio of their green sensitivity ratios and greening cost ratios. Ghosh and Shah (2012) analyze the pricing and greening strategies, when the greening initiatives are undertaken individually or cooperatively by the players. The authors find that though the cooperation between the players lead to higher greening, however it also leads to higher market price. Ghosh and Shah (2015) establish cost sharing contractual mechanisms under manufacture's greening initiatives. Song and Gao (2018) further investigate similar settings under revenue sharing contract and find that revenue sharing contract can improve the greening level of product, and increase the total profit of manufacturer and supply chain. It is recent that the researchers have started focusing on the fairness concerns of the decision makers into the conventional supply chain models. To the best of our knowledge, Cui et al. (2007) studied in the first place the fairness concerns in channel coordination. They describe fairness concern as *distributional fairness*, where a fair-minded player would experience disutility when there is an inequitable distribution of total profit compared to the other players in the supply chain. The authors show that the manufacturer can coordinate the channel and achieve maximum channel utility with a simple wholesale price contract, under retailer's fairness concerns. Caliskan-Demirag et al. (2010) reconfirm these results by using non-linear demand function. Precisely, there are several recent studies that study the influence of fairness concerns of the channel members on the environmental supply chains. Ma et al. (2017) study closed-loop supply chains under fairness concerns and derive the optimal solutions of marketing effort, collection rate and pricing strategies for the supply chain members. Zhou et al. (2016) investigate low carbon supply chain under cooperative advertising contract and carbon emission reduction cost sharing contract based on retailer's fairness concern. Du et al. (2017) examine both manufacturer's and retailer's fairness concern in the supply chain where sustainable green technology innovation efforts are put by both the channel members. Li et al. (2018) investigate pricing and carbon emission reduction decisions under revenue sharing contract by considering only the retailer's fairness concern. In almost all the above studies, the manufacturer is assumed at the dominant position, and it is the retailer's fairness concerns which are majorly investigated. However, the extant literature is deficient in determining the manufacturer's fairness concerns in a green supply chain when the retailer is at dominance. To fill this gap, we propose a retailer-led green supply chain and investigate the impact of manufacturer's fairness concerns on the greening and pricing policies.

Model without fairness concerns

We consider a two-echelon supply chain model with one manufacturer (M) and one retailer (R), where the manufacturer puts the effort for enhancing the greening level of products and sells it to the customers through a retailer. We adopt the retailer-led (R-led) Stackelberg game theory approach, where the dominant retailer's pricing decision is based on the follower manufacturer's greening choice. Here, the retailer decides about the market price (p) and the manufacturer decides about the product's greening level (g). Similar to Swami and Shah (2013) and Ghosh and Shah (2015), we take market demand as a linear deterministic function of market price (p) and product's greening level (g), i.e. market demand, $D(p,g) = a - bp + \alpha g$, where a is market potential ($a > bp$), b is customer's price-elasticity coefficient, and α is customer's green-sensitivity coefficient. Here, we assume that the cost of improving the product's greening level is given by a convex function $C(g) = \beta g^2$, where, β is a positive scaling parameter. Let w and c are the manufacturer's per unit wholesale price and the product's marginal production cost, respectively, where $w > c$, to ensure positive profit margin for the manufacturer. Based on the above problem description, the profit function for the manufacturer (M), the retailer (R) and the whole supply chain (C) are given by:

$$\pi_M = (w - c)D - \beta g^2$$

$$\pi_R = (p - w)D$$

$$\pi_C = \pi_M + \pi_R = (p - c)D - \beta g^2$$

We first set up a centralized channel model, that can be furnished as a benchmark model in which both M and R act as a single unit (or central planner) and decide the market price and product's greening level to maximize the overall profit of supply chain. Thus, the centralized decision problem to maximize the total supply chain profit (π_C) is as follows.

$$\max_{p,g} \pi_C = (p - c)(a - bp + \alpha g) - \beta g^2 \quad (1)$$

The optimal market price, the optimal product's greening level and the optimal profitability are as shown in Table 1. All the proofs of obtaining the equilibrium results are presented in Appendix.

Table 1 – Equilibrium results

Parameters	Centralized	Decentralized (without fairness)	Decentralized (with fairness)
g^{opt}	$\frac{\alpha(a - bc)}{4\beta b - \alpha^2}$	$\frac{\alpha}{2\beta}\left[\frac{(2a\beta - \alpha^2 c)}{2(2b\beta\eta - \alpha^2)} - c\right]$	$\frac{\alpha}{2\beta}\left[\frac{(2a\beta - \alpha^2 c)\{1 + \delta - \delta\gamma(\eta - 1)\}}{2[(2b\beta\eta - \alpha^2)(1 + \delta) + \alpha^2\delta\gamma(\eta - 1)]} - c\right]$
w^{opt}	-	$\frac{(2a\beta - \alpha^2 c)}{2(2b\beta\eta - \alpha^2)}$	$\frac{(2a\beta - \alpha^2 c)(1 + \delta)}{2[(2b\beta\eta - \alpha^2)(1 + \delta) + \alpha^2\delta\gamma(\eta - 1)]}$
p^{opt}	$\frac{2\beta(a - bc)}{4\beta b - \alpha^2} + c$	$\frac{\eta(2a\beta - \alpha^2 c)}{2(2b\beta\eta - \alpha^2)}$	$\frac{\eta(2a\beta - \alpha^2 c)(1 + \delta)}{2[(2b\beta\eta - \alpha^2)(1 + \delta) + \alpha^2\delta\gamma(\eta - 1)]}$

Next, we consider the decentralized channel model in which the M and R does no longer take collective decisions, but rather consider themselves as an individual entity to maximize their individual profits. We specifically examine the R-led Stackelberg game model whose sequence of events are as follows. First, the retailer decides its market price (p). Then, observing p, the manufacturer decides the level of product's greening (g). To ensure a stable profit level, we assume that the product's wholesale price (w) at which the manufacturer sells the products to the retailer is related to market price (p) by $p = \eta w$ (where, $\eta \geq 1$ is a price-coefficient). Here, w is not a decision variable of manufacturer, but determined by the retailer's market price p. This is because, in our model, the manufacturer does not have a dominant position, rather the prices are driven by dominant retailer. In addition, for the model's feasibility, we assume that $2b\beta\eta - \alpha^2 > 0$. We solve this game through backward induction. First, the manufacturer's optimal greening effort (g) is obtained for a given market price (p) by maximizing its profit as follows.

$$\max_{g} \pi_M = (w - c)(a - bp + \alpha g) - \beta g^2 \tag{2}$$

Second, after obtaining the manufacturer's optimal greening effort (g), the retailer decides on the market price (p) by maximizing its profit function as follows.

$$\max_{p} \pi_R = (p - w)(a - bp + \alpha g) \tag{3}$$

The optimal prices, greening level, and the profit functions are as listed in Table 1.

Proposition 1. *In the retailer-led green supply chain, the manufacturer will put positive effort for enhancing the greening level of product when its marginal production cost is lesser than a threshold value, i.e.* $c < \bar{c}$, where $\bar{c} = \frac{2a\beta}{4b\beta\eta - \alpha^2}$.

Proposition 1 shows that the manufacturer will have an incentive to positively increase the product's greening level only when its marginal production is lower than a certain threshold value. Hence, greening is positive only when the cost is less and not it is possible at higher values.

Model with manufacturer exhibiting fairness concerns

In this section, we model and analyze the optimal decisions of M and R when M has fairness concerns. Specifically, the fairness-concerned manufacturer will not only care about its own profit but also compares it with that of the retailer's. Our primary objective is to investigate the impact of fairness on the level of greening effort and the pricing policies of the supply chain.

Manufacturer's decision problem

Based on the fairness model of Cui et al. (2007) the utility function of the fair-minded manufacturer is as follows.

$$u_M = \pi_M - \delta^D[\gamma\pi_R - \pi_M]^+ - \delta^A[\pi_M - \gamma\pi_R]^+$$

where, $[x - y]^+$ denotes $\max\{x - y, 0\}$, $\gamma > 0$ accounts for relative contributions of the channel players, and δ^D, δ^A are the manufacturer's disadvantageous and advantageous inequity aversion fairness concern parameters, respectively. The greater are there values, the more the manufacturer is concerned about either type of fairness. According to Cui et

al. (2007) we further assume $\delta^A \leq \delta^D$ and $0 < \delta^A < 1$. Since, it is evident from the several recent studies that the preference for advantageous inequality is much less prominent and not even found in the experimental investigations (Ho et al., 2014, Nie and Du, 2017), we substitute $\delta^A = 0$ in the above utility function and replace δ^D simply by δ and $0 < \delta < 1$, thus, we get the manufacturer's decision problem as follows.

$$\max_{g} u_M = \pi_M - \delta[\gamma\pi_R - \pi_M] = (1+\delta)\pi_M - \delta\gamma\pi_R \quad (4)$$

Retailer's decision problem

Next, after obtaining the manufacturer's optimal greening effort (g), the fairness-neutral retailer will decide the retail price (p) by maximizing its profit function as defined in Equation (3). After solving through backward induction approach, we obtain the equilibrium results as shown in Table 1. We now analyze the impact of manufacturer's fairness parameter (δ) on the optimal pricing and greening policies in the following section.

Influence of fairness concerns

We propose the following propositions on the basis of our analysis.

Proposition 2. *In the retailer-led green supply chain with manufacturer's fairness concerns, the manufacturer will put positive effort for enhancing the greening level of product when its marginal production cost is lesser than a threshold value, i.e.* $c < \bar{c}_f$, where $\bar{c}_f = \frac{2a\beta\,[1+\delta-\gamma\delta(\eta-1)]}{(4b\beta\eta-\alpha^2)(1+\delta)+\alpha^2\gamma\delta(\eta-1)}$.

Comparing the results of Proposition 1 and 2, we get that in the R-led GSC with manufacturer's fairness concerns, the threshold value of the marginal production cost required for the positive greening effort by the manufacturer is lesser than that of its corresponding value in the R-led GSC without the manufacturer's fairness concerns ($\because \bar{c} - \bar{c}_f = \frac{8ab\beta^2\gamma\delta\eta(\eta-1)}{(4b\beta\eta-\alpha^2)[(4b\beta\eta-\alpha^2)(1+\delta)+\alpha^2\gamma\delta(\eta-1)]} > 0$).

Proposition 3. *Under the manufacturer's fairness-concerned green supply chain, the manufacturer's optimal wholesale price* w^{opt}*, the retailer's optimal market price* p^{opt}*, and the manufacturer's optimal level of greening effort* g^{opt} *all monotonically decrease in the manufacturer's fairness concern parameter* (δ).

Proposition 4. *Under the manufacturer's fairness-concerned green supply chain, the retailer's profit* (π_R) *monotonically decreases with the manufacturer's fairness concern parameter* (δ).

Proposition 3 and 4 illustrate that when the manufacturer feels unfairly treated by the retailer, then it will react by decreasing the effort for product's greening. This will in turn lead the retailer to lower the market price of the product, since the customers are positively sensitive to product's greening level. This in turn, will affect the retailer's profit negatively.

Conclusion

In this paper, we evaluate the effects of fairness-concerned behavior on the supply chain decisions through a game-theoretic analysis. Specifically, we investigate the impact of

fairness concerns of the manufacturer on the optimal greening and pricing decisions in a green supply chain under manufacturer's greening initiatives and retailer's dominance. For this, we formulate a retailer-led Stackelberg game model in a dyadic supply chain setting, consisting of one manufacturer and one retailer. We then incorporate the fairness concerns of the manufacturer, by formulating its utility function according to the inequity aversion model of Cui et al. (2007). Following the backward induction approach, we derive the equilibrium strategies of each channel members and then determine the effects of manufacturer's fairness parameter on these equilibrium values. We find that the manufacturer's sensitivity towards fairness will negatively influence both the manufacturer's effort for improving the product's greening level and as well as the retailer's market price and retailer's profit function. In addition, the retailer's profit is also decreasing in the manufacturer's fairness concern. Furthermore, under certain conditions, in comparison to the fairness-neutral channel, in the manufacturer's fairness-concerned channel, the product's greening level will be positive for an even lower threshold value of the product's marginal production cost.

Contribution/managerial implications:

The author investigates manufacturer's fairness concern in a retailer-led dyadic supply chain where the customer's demand is sensitive to product's greening level. To the best of our knowledge, there is very little literature on examining the impact of fairness concerns in a retailer-led green supply chain. This paper fills this gap, which is the main theoretical contribution of this study. The results will be useful for the supply chain practitioners in understanding the social interaction behaviours when two supply chain parties interact in a business. For the retailers, the higher fairness concerns of their upstream manufacturer could negatively influence the product's greening, the retailer's market price and profit function. Hence, they should be attentive in choosing its retail price, so that the manufacturer does not feel as unfairly treated and keep putting its greening efforts. For the manufacturer, it is seen that too much fairness concerns will result them in getting a lower wholesale price. Also, if they have higher fairness concerns, then should put the positive greening effort only when the product's marginal production cost is too low.

Future research

We suggest the future studies to consider competition at either manufacturer's or retailer's level and investigate the influence of peer's fairness concerns on the greening and pricing decisions. Further, in our study we assume fairness parameter as the common knowledge to both the supply chain partners. Future studies could break this assumption and investigate the similar case information asymmetry about the fairness parameter.

Appendix

Proof of centralized channel game model:

According to Equation (1), as $\frac{\partial^2 \pi_C}{\partial p^2} = -2b < 0$, $\frac{\partial^2 \pi_C}{\partial g^2} = -2\beta < 0$, and the determinant of Hessian matrix, i.e., $H = (\frac{\partial^2 \pi_C}{\partial p^2})(\frac{\partial^2 \pi_C}{\partial g^2}) - \left(\frac{\partial^2 \pi_C}{\partial p \partial g}\right)\left(\frac{\partial^2 \pi_C}{\partial g \partial p}\right) = 4\beta b - \alpha^2$. For $4\beta b - \alpha^2 > 0$, $H > 0$ and hence, π_C is strictly jointly concave in (p, g). Setting the first order optimality conditions, i.e. $\frac{\partial \pi_C}{\partial p} = 0$ and $\frac{\partial \pi_C}{\partial g} = 0$, and solving the equations simultaneously we can obtain the optimal solutions of centralized channel supply chain as shown in Table 1.

Proof of decentralized channel game model without fairness concerns
Following the backward induction approach, we first solve for the manufacturer's profit function. According to Equation (2), as $\frac{\partial^2 \pi_M}{\partial g^2} = -2\beta < 0$. Hence, π_M is strictly concave w.r.t. g and has a unique maximum solution, $g^* = \frac{(w-c)\alpha}{2\beta}$ that can be derived through $\frac{\partial \pi_M}{\partial g} = 0$. We now substitute g^* and $w = p/\eta$ into Equation (3) and derive the retailer's market price policy (p). As, $\frac{\partial^2 \pi_R}{\partial p^2} = -\left(1 - \frac{1}{\eta}\right)\left(\frac{2b\beta\eta - \alpha^2}{\beta\eta}\right) < 0$, hence, π_R is strictly concave in p. Solving $\frac{\partial \pi_R}{\partial p} = 0$ will give optimal p and other results can be obtained further, as shown in Table 1.

Proof of decentralized channel game model with manufacturer's fairness concerns
According to Equation (5), $\frac{\partial^2 u_M}{\partial g^2} = -2\beta(1+\delta) < 0$, hence, u_M is strictly concave in g. Next, $g^* = \frac{\alpha[(w-c)(1+\delta) - \delta\gamma(p-w)]}{2\beta(1+\delta)}$ can be obtained through $\frac{\partial u_M}{\partial g} = 0$. We now substitute g^* and $w = p/\eta$ into Equation (3) and derive the retailer's market price policy (p). Then, we get that $\frac{\partial^2 \pi_R}{\partial p^2} = -\frac{1}{\beta}\left(1 - \frac{1}{\eta}\right)\left[\frac{2b\beta\eta - \alpha^2}{\eta} + \frac{\alpha^2\delta\gamma}{(1+\delta)}\left(1 - \frac{1}{\eta}\right)\right] < 0$, hence, π_R is jointly concave in p. Solving $\frac{\partial \pi_R}{\partial p} = 0$ will give optimal results as shown in Table 1.

Proofs of Propositions:
Proposition 1
From the equilibrium results of decentralized GSM without fairness concerns as shown in Table 1, we have $g^{opt} = \frac{\alpha}{2\beta}\left[\frac{(2a\beta - \alpha^2 c)}{2(2b\beta\eta - \alpha^2)} - c\right] > 0$ for $\bar{c} < \frac{2a\beta}{4b\beta\eta - \alpha^2}$.

Proposition 2
From the equilibrium results of decentralized GSM with manufacturer's fairness concerns as shown in Table 1, we have $g^{opt} = \frac{\alpha}{2\beta}\left[\frac{(2a\beta - \alpha^2 c)\{1+\delta-\delta\gamma(\eta-1)\}}{2[(2b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\delta\gamma(\eta-1)]} - c\right] > 0$ for $\bar{c}_f < \frac{2a\beta\,[1+\delta-\gamma\delta(\eta-1)]}{(4b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\gamma\delta(\eta-1)}$.

Proposition 3
Taking the first-order partial derivative of w^{opt}, p^{opt} and g^{opt} with respect to δ respectively, we get:

$$\frac{\partial w^{opt}}{\partial \delta} = \frac{-\alpha^2\gamma(2a\beta - c\alpha^2)(\eta - 1)}{2[(2b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\delta\gamma(\eta-1)]^2} < 0$$

$$\frac{\partial p^{opt}}{\partial \delta} = \frac{-\eta\alpha^2\gamma(2a\beta - c\alpha^2)(\eta - 1)}{2[(2b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\delta\gamma(\eta-1)]^2} < 0$$

$$\frac{\partial g^{opt}}{\partial \delta} = \frac{-\alpha b\eta\gamma(2a\beta - c\alpha^2)(\eta - 1)}{2[(2b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\delta\gamma(\eta-1)]^2} < 0$$

Proposition 4

Substituting the values of w^{opt}, p^{opt} and g^{opt} of decentralized supply chain case with manufacturer's fairness concern (from Table 1) into Equation (3) and taking its first-order partial derivative with respect to δ, we get:

$$\frac{\partial \pi_R}{\partial \delta} = \frac{-\alpha^2\gamma(2a\beta - c\alpha^2)^2(\eta - 1)^2}{8\beta[(2b\beta\eta - \alpha^2)(1+\delta) + \alpha^2\delta\gamma(\eta - 1)]^2} < 0$$

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The Appropriation of Trust for a Successful PPC Implementation

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Abstract

Production planning and control (PPC) systems are deployed to enable the effective management of variation and uncertainty. In spite of the advancement in technology such as big data and artificial intelligence, the complimentary roles of human and system is increasingly apparent. This paper explores the human-PPC relationship from the perspective of *trust*. This is done by investigating a recent PPC implementation in SME. In relation to this case the concept of *trust* is explored as a psychological state and it is suggested that *trust appropriation* is a continuous process achievable through the leveraging of the basis of trust: *purpose*, *process* and *performance*.

Keywords: Trust Appropriation, Production Planning and Control, Action Research

Introduction

For decades, researchers have called for better alignment between the underpinning concepts and the contextual environment in which the PPC (Production Planning and Control) system is to be implemented. The critical role of the 'socio' aspect in developing and implementing a practical PPC solution is well highlighted (Brocklesby, 2016; Burglund and Karltun, 2007; Davis et al., 2014; MacCarthy et al., 2001). Some researchers have gone further, highlighting the importance of developing positive human-system relationship in a successful PPC implementation (Fransoo and Wiers, 2008; Higgins, 2001; Jackson et al., 2004). However, the main focus has been on the complementary roles (tasks) of human and system in the decision making process. For a successful human-system relationship design, development and implementation, some researchers have suggested the pivotal role of *trust* between the human-system relationship (Fransoo and Wiers, 2008; Muir and Moray, 1996). As *trust* is 'fluid' (Hoffman et al., 2013), appropriation is necessary to avoid 'mistrust' and 'distrust' (Hoff and Bashir, 2015; Lee and See, 2004).

The remainder of this paper begins by reviewing the need for PPC to be developed into a human centred Decision Support System (DSS). This is followed by a review on the construct of 'trust' in the human-automation context. Based on the above reviews, the role and importance of *trust* in the successful implementation of PPC as a DSS will be explored through theoretical argument. The conceptual framework developed will be used as a lens to explore *trust* and its appropriation in a successful human-system

implementation. This human-automation implementation is in the context of a PPC-DSS system in a rotary moulding environment. Details of the research methodology used is discussed followed by a discussion of the findings before ending with research contribution and potential future research.

PPC, a human centred DSS system

The advancement in technology such as Internet of Things (IoT), Big Data and Robotics is reshaping manufacturing industries (Brauner et al., 2019; Brettel et al., 2014). Although automation has enabled data collection, interpretation, decision making and process control (Lee and See, 2004), the role of the human remains critical. A taxonomy has been proposed by Parasuraman et al. (2000) to describe the types and levels of automation. The four primary types of automated system includes information acquisition, information analysis, decision selection and action implementation. An automated system can be designed to fall within single or multiple types (Hoff and Bashir, 2015). Human involvement in an automated system is depicted across a continuum of autonomy levels. This is represented by a scale of 1 to 10 where level 1 refers to system which offers no assistance and level 10 where the system ignores human acting autonomously.

PPC is concerned with managing variabilities and uncertainties in a manufacturing environment as well as the wider implication on the entire supply chain. As the manufacturing strategy moves from standardisation towards customisation, the associated variabilities and uncertainties increases (Cardin et al., 2017; Olhager, 2003). With the increase in complexity of manufacturing environments there are increases the necessity for human intervention (McKay and Wiers, 2001; Nakamura and Salvendy, 1994). This is mainly due to the perception that humans are able to provide a better response in dynamic environments due to their superior flexibility, adaptability and creativity (Parasuraman, 1997). Ultimately, it is the humans who are accountable for and recipients of the decisions made (MacCarthy and Wilson, 2001). This includes accountability for ethical and legal related issues (Brauner et al., 2019; Philipsen et al., 2019). Thus, it is expected that through the development of PPC into a DSS system, the reaction time of humans will be reduced while at the same time improving decision making quality (McGuirl et al., 2006). This places PPC in the mid region of the autonomy scale, requiring partnership between human and system.

The importance of the human-system complementary role has prompted calls to develop PPC into a human centred DSS system (Arica et al., 2016; Fransoo and Wiers, 2008; Higgins, 2001; Jackson et al., 2004; McKay and Buzacott, 2000). Building upon the human roles (HR) in PPC identified by Jackson et al. (2004) and the design and development criteria proposed by Wiers and van der Schaaf (1997) for a DSS in PPC. Yeong and Stratton (2018) proposed a HR-DSS matrix to support the development process. As shown in *Table 1*, this matrix crosses DSS development criteria with the human roles in PPC. The DSS criteria are (i) Level of Support, (ii) Transparency, (iii) Autonomy, and (iv) Information Presentation. The human roles in PPC are (i) Interpersonal, (ii) Information, and (iii) Decision Making. This taxonomy explicitly requires the boundary between the roles of human and system to be defined. This is useful in both the development of new PPC-DSS and the evaluation of existing PPC-DSS. With reference to *Table 1*, the quadrants involving 'Information Presentation' mainly concern feedback given by system to human These feedback becomes part of the input to the remaining quadrants to facilitate contextual interaction between human and system.

According to Lee and Moray (1992; 1994), this interaction is determined by the *trust* and *self-confidence* of humans. The success of a human-system development and implementation requires the system to reflect the trust of humans in the capabilities of the

system (the automation part). It is also necessary for human self-confidence to be reflected in their ability to use the system manually under 'uncommon' situation which requires intervention. The critical role of *trust* has prompted researchers to call for *appropriation of trust* in order to reduce misuse, disuse and abuse of a system (Hoff and Bashir, 2015; Lee and See, 2004; Lyons et al., 2017; Parasuraman and Riley, 1997).

Trust in Human-PPC relationship

Trust has been explored from various perspectives: psychological, neurological, sociological, organizational, and interpersonal. Based on the above inter-human trust perspectives, a detailed review was conducted by Lee and See (2004) and summarised them into four broad categories: beliefs, attitudes, intentions, and behaviour. By adopting the framework developed by Ajzen and Fishbein (1980), they argued that beliefs, attitudes, intentions and behaviour are distinct. Beliefs offers the information base in which determines attitude. Attitude guides the adoption of intention. Intentions, the willingness to act, are exhibited in behaviour according to the environmental and cognitive constraints faced. Based on the above arguments, Lee and See (2004) proposes to view *trust* as *attitude* which connects the four distinct categories in the following way. *Trust* is the *attitude* based on the underlying 'beliefs'. This is manifested in various intentions and behaviours according to the levels of trust.

The definition of *trust* from their research is "*the attitude that an agent* [trustee] *will help achieve an individual's* [trustor's] *goals in a situation characterized by uncertainty and vulnerability*". By applying this definition of *trust* to human-system relationship, the authors suggest that *trust* bridges the *beliefs* on system characteristics and the *intention* to rely and use the system. *Trust* is arguably not a *behaviour* due to it being one of the many factors which influences behaviour. Other factors could be both external and internal of a person. Internals could be the workload, situation awareness and self-confidence, whereas externals could be company policy or performance measurements (Lee and Moray, 1994; Riley, 1994). According to this definition, *trust* only comes into play if trustor is dependent on the trustee to complete certain functions of relevance to trustor's goals.

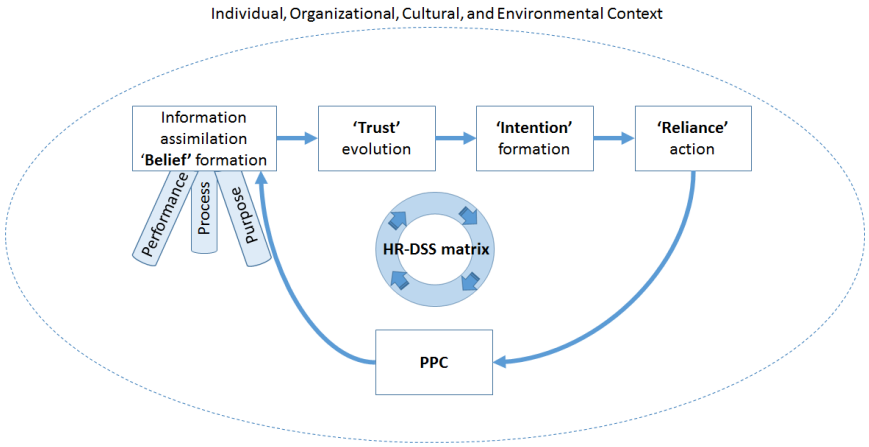

Figure 1: Appropriation of Trust and HR-DSS (Adapted from Lee and See (2004))

Due to *trust* is between *beliefs* and *intention*, any mistrust and distrust will result in negative or unwanted intension, i.e. unwillingness. 'Mistrust', also known as 'over-trust', occurs at instances where level of *trust* exceeds actual system capabilities. 'Distrust'

refers to the phenomena where *trust* is below the system capabilities. As shown in *Figure 2*, the 'level of trust' and 'system capabilities' are represented by Lee and See (2004) in a two axes chart. A diagonal line is drawn in between to depict the *appropriated trust*, where 'level of trust' matches 'system capabilities'. The region above and below the diagonal line represents 'mistrust' and 'distrust' respectively. 'Mistrust' results in 'misuse', whereas 'distrust' results in 'disuse' of a system (Lee and See, 2004; Parasuraman, 1997).

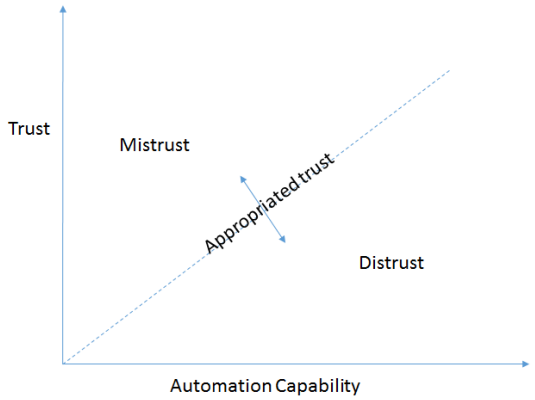

Figure 2: Trust Appropriation (Adapted from Lee and See (2004))

With the perspective that *trust* is dynamic (Hoffman et al., 2013; Lee and See, 2004; Lewandowsky et al., 2000), *trust* needs to be appropriated. This is also known as *trust calibration* (e.g. McGuirl and Sarter, 2006), *trust repair* (e.g. Quinn et al., 2017; de Visser et al., 2018) or *trust restoration* (Philipsen et al., 2019). In the appropriation of trust concept proposed by Lee and See (2004) apparently assumes automation (system) to be static in its capabilities, represented by the appropriation of trust occurring outside of automation (system). In the development and implementation of PPC into a DSS system using HR-DSS matrix, as shown in *Figure 1*, it is proposed that automation (system) to be included as part of the trust appropriation process (McGuirl and Sarter, 2006).

In the context of implementing PPC-DSS system as an intervention in a company, it is not the purpose of this paper to debate the taxonomy of trust. However, the above discussion highlights the critical role of trust and the need to appropriate trust in a human-PPC relationship. With reference to *Figure 1*, to effectively appropriate trust, it is necessary to address the 'belief' stage of this cycle. This is also known as the basis of trust. Based on a review by Mayer et al. (1995), the general basis of trust in inter-human relationship has been described as *Ability*, *Integrity*, and *Benevolence*. In human-automation relationship, Lee and Moray (1992) describes the general basis as *Performance*, *Process* and *Purpose*. The resemblance in both have been highlighted by Lee and See (2004): *Ability-Performance*, *Integrity-Process*, and *Benevolence-Purpose*. To strengthen the three general basis of trust proposed in human-automation, they reviewed thirteen other research conducted on basis of trust and discovered each of them falls into one of the three categories.

In the context of PPC-DSS, *performance* refers to both present and historical information relevant to the competency of PPC-DSS in achieving human's goals. It captures the information related to *what* the automation does. This information encompass the subjective human-PPC-DSS interaction and experience. *Process*, in the context of PPC-DSS refers mainly to the *algorithms* and *management philosophy*, which underpins the behaviour of PPC-DSS. This centres on the issue of *how* PPC-DSS works.

The third basis: *purpose* refers to information related to *why* PPC-DSS is developed. This is related to the designer or originator's intent.

The approach of appropriating trust by targeting 'belief' stage is also adopted by de Visser et al. (2014). Based on this, they proposed a trust cue taxonomy to conduct trust assessment on trust agents. In the context of PPC-DSS development and implementation, it is posit that HR-DSS matrix is able to be used to facilitate trust appropriation. As shown in *Table 1,* the *purpose* of the PPC-DSS is represented by considering the Level of Support (S) offered to accomplish the human roles in PPC. The concern on *process* is addressed by looking into the *transparency* and *autonomy* of the system in fulfilling each human role. Through *information presentation* and *level of support* exhibited, *performance* of the system can be evaluated.

Table 1 – HR-DSS Matrix and Basis of Trust (Adapted from Yeong and Stratton, 2018)

<table>
<tr><th></th><th>Level of Support (S)</th><th>Transparency (T)</th><th>Autonomy (A)</th><th>Information Presentation (I)</th></tr>
<tr><td>Interpersonal (IPR)</td><td rowspan="3">Purpose / Performance</td><td colspan="2" rowspan="3">Process</td><td rowspan="3">Performance</td></tr>
<tr><td>Information (IMR)</td></tr>
<tr><td>Decision Making (DMR)</td></tr>
</table>

The above conceptual discussion provides an insight on the potential role of *trust* and its appropriation for a successful PPC-DSS implementation. It is also the purpose of this paper to explore the relevance of *trust* and its appropriation in real life PPC-DSS implementation.

Design/methodology/approach

This research is based on a recent successful PPC implementation in an SME rotary moulding company, Company A. Simplified-Drum-Buffer-Rope (S-DBR), the latest Theory of Constraints (TOC) application for Make-To-Order (MTO) manufacturing environment (Schragenheim and Dettmer, 2000) was adopted. The PPC implementer, who worked as a business system architecture designer, was also a researcher pursuing professional doctoral degree. The dual purpose of this project has prompted the use of action research (AR) to capture practical knowledge in both 'technical' and 'socio' aspects (Coughlan and Coghlan, 2016; Shani et al., 2008). This two years project was divided into pre-change (determine context and purpose, constructing and planning action), in-change (taking action), and post-change (evaluating action) stages. Data was collected via formal and informal meetings/discussions, job shadowing, observation of actual practice, direct communication with people, and company archival data. As trust is defined as a psychological state in this research, trust level is interpreted by analysing verbal expression and the actual usage of system.

Findings

A contextually redesigned S-DBR based PPC has been successfully developed and implemented (Yeong, 2019). Of the various AR cycles in each project stage (pre-change, in-change and post-change), a few AR cycles from in-change is used to explore trust appropriation.

AR Cycle 1

To explore and exploit potential CCR (Capacity Constraint Resource), there were attempts to arrive at a detailed scheduling of potential CCR. To achieve this, it is desirable

to capture every possible machine-mould configuration. Senior management has expressed the intention to develop PPC into a strict directive tool to monitor performance of personnel. However, the researcher finds that it is impractical and impossible to code every possible scenario in this dynamic and complex environment where tacit knowledge and human intervention is necessary. From the perspective of *purpose*, shop floor personnel felt threatened by the presence of the system. It is seen as a monitoring tool which will cause them their job. In addition, p*rocess* of the proposed system is deemed impractical which cast doubt in the *performance* expected. Coupled with the bad experience with old manufacturing software which produces job tickets and pushes jobs onto the shop floor with unrealistic delivery date, comments such as '*the computer* [PPC-DSS] *system will never work'* is often heard.

AR Cycle 2

Informed by the management philosophy of S-DBR, which proposes light planning and heavy execution, it adopts the concept of buffer management (BM) to provide visual and easily understood signals to user (refer to *Figure 3a*). Each work order is represented by BM colour. Through these colours, work orders are *prioritised*, *expedited* and *escalated*. For continuous improvement purposes, it has the function of *targeting* (Stratton and Knight, 2009). Efforts are done to develop heuristic algorithm based on tacit knowledge and modus operandi under normal situation. The concept of planned load (PL) is used to represent outcome of tacit knowledge in a visual way (refer to *Figure 3b*). Multiple improvement cycles were done to obtain confirmation from shop floor personnel on the practicality of the heuristic algorithm and information presentation (*process and performance*). The use of BM and PL and its representation suggest the PPC-DSS system as only giving feedback and suggestion, without dictating the final decision (*purpose*). In the process, it increases the trust level of shop floor personnel, evident from their participation to share tacit knowledge and validate the outcome.

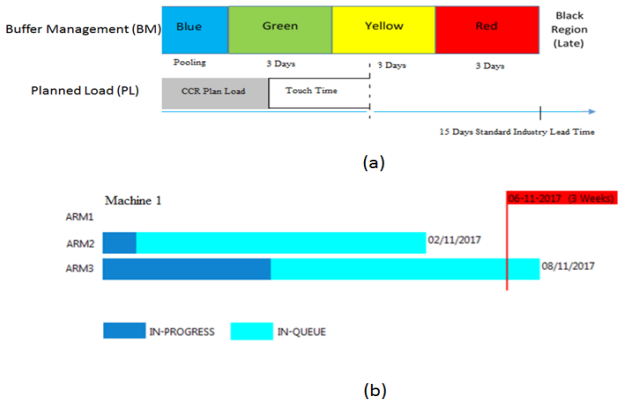

Figure 3: Illustration of: (a) Buffer Management and (b) Planned Load

AR Cycle 3

Although the outcome of AR cycle 2 has gained trust, it is still a supplement to existing manufacturing process. The machines do not have any data input/output (I/O) interface, an interface is necessary to capture the final decisions made in resource allocation and work order progress updating. Feedback information is critical for the PPC-DSS system to suggest solutions, such as promised due date in customer enquiry stage. The human role (HR) is evaluated in the context of company business process flow. As demonstrated in *Figure 4*, PPC-DSS and its associated interfaces are developed and integrated into the

business flow of company, from pre-sales to post-sales. This further enhance the *purpose*, *process* and *performance* of the system to increase human trust level towards the system.

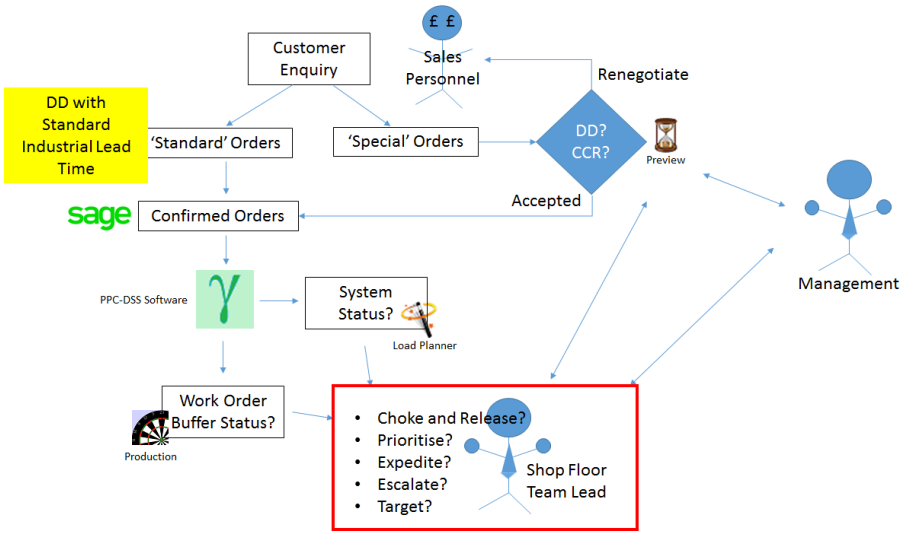

Figure 4: Integration of PPC-DSS into business flow of Company A (Yeong, 2019)

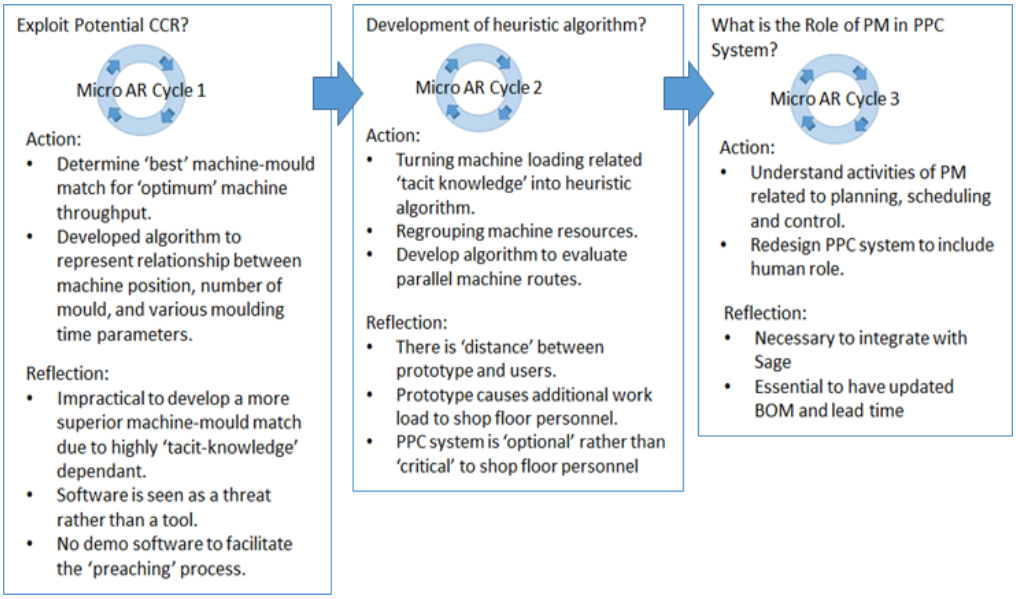

Figure 5: Selected In-Change AR cycles to demonstrate trust appropriation (Yeong, 2019)

From the above findings, trust appropriation is shown to be a continuous process. In this case, it began in the *distrust* region. Firstly, PPC-DSS with flexibility to customise according to contextual requirement places automation system into the trust appropriation process, as shown in *Figure 2*. This offers opportunities to improve trust level. Secondly, it demonstrates how enhancement in the capability of PPC-DSS is able to increase trust level. In this research, the PPC-DSS enhancement is done in accordance

to human requirements and tacit knowledge, acquired through AR cycles. Thirdly, not necessarily proportional amount of PPC-DSS capability increase will be translated to equal amount of increase in trust level. Based on the trust appropriation concept proposed by Lee and See (2004), *Figure 6* attempts to illustrate the trust appropriation process through the AR cycles discussed. The increase in automation capability, Δc_a is lesser than from AR cycle 2 to 3, Δc_b. However, the trust gained from the later, Δt_b is higher than earlier AR cycle, Δt_a. Finally, the PPC-DSS system in company A is being made known to be 'improvable'. Rather than being treated as a 'sacred cow', or requires immense cost or resources to amend, it is able to be improved according to contextual requirements.

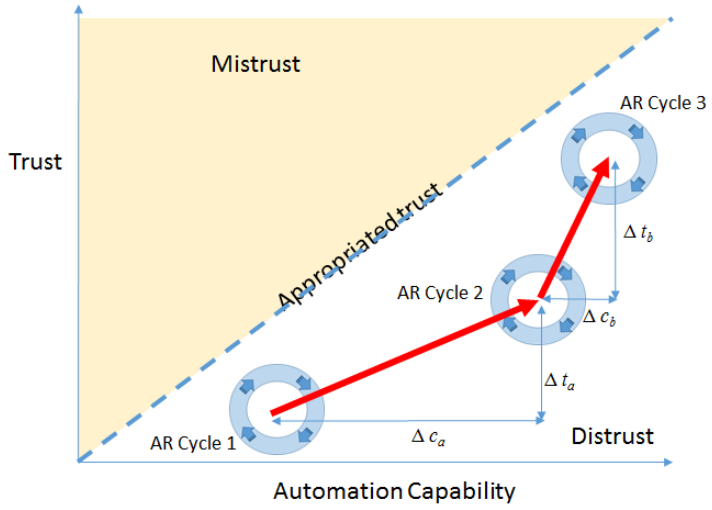

Figure 6 – Trust Appropriation illustration for AR cycle 1, 2 and 3

Conclusion

This research attempts to explore the role of *trust* and its *appropriation* in the design and implementation stages of PPC. By borrowing the literature from *trust in automation*, it is used as lens to reflect on a recently completed development and implementation of a human centred PPC-DSS system in an MTO company. In the context of PPC-DSS, the existence of such a system is to assist humans to better manage variability and uncertainties. By adopting the perspective that *trust* is a psychological state, it is suggested that *trust* can be appropriated by influencing the three aspects of *trust*: *purpose*, *process*, and *performance*. Through reflection on the selected AR cycles, it is suggested that *trust appropriation* is a continuous improvement process. This is made possible with the inclusion of PPC-DSS customisation as part of the *trust appropriation* process. In other words, the possibility of adjusting PPC-DSS capabilities contributes positively towards *trust appropriation*. *Trust* has captured the attention of researchers in the area of automation (for example: driverless vehicles, nuclear plants and flight system). Further research could be conducted to explore the significance of *trust appropriation* in PPC-DSS adoption and implementation. This may potentially narrow the gap between PPC theory and practice. In real life PPC-DSS implementation, it is not isolated from organisational related context. This implies that *trust* and its appropriation process might be influenced by other factors which requires further research.

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The contributions of leadership and employee engagement practices to CSR implementation: case studies in Northern Ireland

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Abstract
Corporate social responsibility has been recognised as a critical business function and capability to improve business performance and competitive advantage Whilst many organisations accept this, the majority of them failed in implementation, even including large conglomerates such as Target, 3M and Walmart. The lack of standardised procedures for implementation has prompted this study to explore different tools, practices and mechanisms deployed to contribute to CSR integration. Due to the exploratory nature of this study, in-depth case study was adopted to determine what leadership and employee engagement practices and tools have been adopted which allow organisations to institutionalise CSR.

Keywords: Corporate social responsibility, Leadership, Employee engagement

Introduction
As evidenced in the literature, corporate social responsibility (CSR) has evolved from environmental regulation to a more social focus until today where a new form of 'strategic CSR' has emerged. CSR has become a form of strategic investment to enhance business image and to improve organisation performance. It is believed that to attain the level of competitive advantage as a result of CSR, a coherent CSR strategy should be outlined rather than having numerous disparate, ad-hoc CSR programmes and initiatives (Rangan et al., 2012). For a firm to drive real social impact and to influence positively on the long-term competitiveness, CSR should be strategized and implemented well from the core of the business. Longoni and Cagliano (2015) supported this view and suggested that all organisations, regardless of the differing expectations imposed upon them, should outline in their corporate strategies and then execute them at functional levels throughout organisations. A report by Deloitte (2017) also highlighted that CSR can be used to get the edge in business and can help firms gain competitive advantage through various possibilities, i.e. being an employer to choose the most talented individuals, being able to access the best types of finance, and having high quality supply chain partners. Unilever is a prime example of a firm which has used these social and environmental issues as a means of creating a business advantage.

To achieve the intended objectives of CSR, there is a need for a planned process with strategic applications to the organisation mission and overall aims (Carroll & Shabana, 2010; Porter & Kramer, 2011). In formulating CSR as part of a firm strategy, organisations need to determine specific priorities and to establish immediate steps and goals. It sets out a detailed action plan on how the organisation will involve its corporate activities in developing value for stakeholders, thereby

achieving its corporate objectives (Emezi, 2015). It must be considered that CSR and sustainable development are moving targets that cannot be achieved as a one-off but must continuously be reviewed and updated, therefore this strategy should be reconsidered regularly, along with the finance strategy, HR strategy and marketing strategy (Slack et al., 2015). During the strategy review, managers must be open minded to add new priorities into business strategy and objectives where these may emerge (Kaplan and Norton, 2005). But the real challenge is to move beyond the rhetoric and ideology of CSR and to build it into a core capability of the organisation (Maon et al., 2009). Once CSR has been established at a strategic level, how to bridge the gap between CSR formulation and implementation then must be addressed (Engert & Baumgartner, 2016). Despite an abundance of CSR literature, the proliferation of CSR approaches and implementation are often unclear, confusing and lacking in uniformity (Bucur, 2013; Asif et al., 2013). There is a knowledge gap existing in understanding best practice of how to translate senior management commitment to CSR initiatives and how to implement CSR to all levels of the organisation. Therefore, this research will explore how leadership and employee engagement practices can contribute to the internal implementation of CSR in practice. In details, the research aims are 1) to identify leadership practices which positively affect the internal CSR implementation; 2) to determine employee engagement activities utilised to facilitate CSR integration; and 3) as a result of the findings, to make practical and knowledgeable recommendations to a framework for communicating mission and values to all employees (internal communications strategy) in a way which would help their companies to meet CSR targets.

The reminder paper is structured as follows: next section examines CSR literature, which is followed by highlighting the research design and research methods on case studies applied for this project. Research findings are presented with detailed discussion and implications. The paper closes by drawing conclusions and highlighting contributions in the final section.

Literature Review

Corporate Social Responsibility (CSR) initiatives have gained considerable momentum since post –World War II as companies increasingly engage in globalised activity which has interwoven both business and society together. CSR has evolved from simply doing good deeds for society in 1950s (Friedman, 1970), to a universally approved concept which has become an important, innovative, strategic management issue in the 21st century (Moura-Leite and Padgett, 2011). It is no long a legal requirement imposed upon companies, but also deeply rooted in the concept of sustainable development (Málovics et al. 2008). Due to this increasing need to merge economic growth and social responsiveness, there has been an emergence of CSR literature and research. CSR has become a key subject in both business practice and academia. For a firm to drive real social impact and to have positive impact on the long-term competitiveness, CSR should be strategized and implemented well from the core of the business (Porter and Kramer, 2002).

Despite an abundance of CSR literature, the proliferation of CSR implementation are often unclear and lacking in uniformity (Asif et al., 2013). Whilst almost all organisations can create a CSR strategy, few can move beyond the stated aims and intentions written within it, to implement objectives into effective actions and results (Orlitzky et al., 2011). It was stated that there is lack of attention on methodological and practical CSR implementation, despite the effort to the implications of CSR practices in relation to business strategy (McWilliams et al., 2006). Companies is lack of understanding of how CSR strategy penetrates the entire firm by migrating from a strategy to operations. This can also be attributed to the fact that there is no one-size-fits-all approach to the institutionalisation of CSR. Thus, there is widespread failure in CSR implementation due to the inability to develop management solutions internally and to systematically integrate CSR into business operations (Gond et al., 2012). Knowledge gaps also exist due to the emphasis on larger and international firms, and the importance placed upon the relationship between social and financial performance instead of focusing on CSR antecedents and the processes of integrating it into an organisation, consequently providing little empirical evidence (Perrini and Minoja, 2008; Johnson, 2015). Research shows that even today large

companies such as 3M, Target and Walmart miss some of their CSR targets due to implementation failure (Ward, 2014).

How organisations strategize and implement their CSR practices will differ in relation to the requirements from different stakeholders. These requirements vary depending on the organisation, industry and country which the firm is operating within. However all firms should engage not only in external CSR practices, but also internal. In fact organisations increasingly recognise that they affect employees, workers, customers and local communities through their internal business operations, whether directly or indirectly and proactively decide on the best way of managing this. Some examples of internal CSR practices include workplace health and safety, reducing unsociable working hours, employment practices, training programmes. However in the CSR literature, there is a knowledge gap in understanding best practice of how to internally implement CSR and how to translate senior management's commitment to CSR initiatives to staff at all levels of the organisation. Therefore, this research is to investigate how CSR can be implemented throughout the organisation. This research investigate the two key factors- leadership and employee engagement. This research potentially contribute to make practical and knowledgeable recommendations to create a framework for communicating mission and values to all employees (internal communications strategy) in a way which would help their companies to meet CSR targets.

Research Method

Research Strategy

A case study was adopted for this research. It allows the researcher to analyse contextual conditions which were highly pertinent to the phenomenon of internal CR. It was also useful in establishing behavioural conditions through the individual's perspective and explaining the complexities of real-life situations that often are not captured through experimental or survey research. The in-depth case study is undertaken on three business organisations to explore from a holistic view of each of these organisations. Yin (2009) supports that the use of multiple case sources of evidence provides data triangulation, increasing the validity of the research. It allows for cross-case analysis as well as within case, to check if phenomenon remain the same in other organisations. It is acknowledged that while making generalisations based on such a small number of cases can be difficult, these differences have been minimized by selecting organisations with similar characteristics to increase the generalisability of the study (George & Bennett, 2005).

Three organisations were selected from Northern Ireland. based on their similar orientation and commitment to CSR as they have all been awarded BITCNI's CORE accreditation. CORE is the standard in Northern Ireland for responsible business. CORE accreditation to date has been awarded to twenty-three organisations (BITCNI, 2017). The three organisations which were chosen to represent a cross-section of the Northern Irish industry are a public services firm, a manufacturing company and a privately-owned retail company. Two of the organisations are SMEs whilst one was chosen as it is a franchise of a multi-national enterprise, with de-centralised operations. The selection of the third company offers the opportunity for comparison with the other two Northern Irish founded companies and the possibility to highlight any similarities or divergences. The comparative framework of this study and the firms' similar characteristics allows for cross validation of results and increases the potential to make industry-wide generalisations.

Data Collection

In-depth case studies were conducted via various data collection methods. Interviews were undertaken within the case company with a mixture of both senior and junior members of staff through cross sections to gain a comprehensive and representative perspectives. A semi-structured interview framework was implemented, whereby the researcher prepared the same set

of questions to be answered by all senior staff and a separate but identical set of questions for all junior staff. Documentary analysis was undertaken to consolidate and contextualise data collected from the interviews. This method has been used in reviewing the internal CR communications techniques of all case organisations, by collecting their applications for CORE accreditation, quarterly magazines, weekly newsletters, mail updates and other company specific communications. Access to organisations was granted which allows observation to be undertaken within each of company. The researchers has been in the company on a weekly base. The researcher and employees established a relationship of mutual trust and confidence to develop a favourable relationship, ensuring that field research was both theoretically desirable and practically possible (Saunders et al. 2015).

Data Analysis

In this study, the thematic analysis technique was used to conduct interview analysis. Analysis followed the three steps suggested by Miles and Huberman (1994) for data reduction, data display and data conclusion. The data was first reduced to quotes, sentences or paragraphs which were relevant for answering research questions, known as first-order codes. Then the data was analysed and separated into second-order codes. Descriptive categories were then deduced from the second-order codes such as 'CSR strategy', 'organisational structure' and 'values'. These categories were then coded into different sub-themes which represent the different phases of implementation of internal CSR as highlighted by the interviews.

When the results underwent thematic analysis, different sub-themes emerged and the practices identified were categorised within these. Analysis of these interviews revealed many different constructs and internal mechanisms to support internal CSR implementation. The results have been synthesised into three separate phases, otherwise known as sub-themes, namely (i) Before implementation (ii) During implementation (iii) Ensuring future implementation, to better understand the role of leadership and the impact of employee engagement contribution to CSR implementation. Detailed findings have been summarised and broken down into the sub-themes and categories which fall within each sub-theme to identify the common features of management and employee engagement contribution.

Sub-theme 1: Before implementation- before an organisation can fully implement internal CSR, there are prerequisites which are essential to facilitate successful implementation. This research has found that during this phase, leadership plays a critical role in contributing to the development of these mechanisms that act as antecedents to CSR implementation. During this phase, leadership must consider: strategy, organisational structure and value.

Sub-theme 2: During CSR implementation- once the prior foundations have been laid by leadership for CSR implementation, the next step is to get employees on board and to engage and encourage them to participate. Employee engagement for implementation have been identified from the case organisations are employee voice, employee involvement and support.

Sub-theme 3: Ensuring CSR implementation- for CSR implementation to reach its fullest potential, this research highlight that leadership must take necessary steps to keep the momentum going to ensure that CSR does not occur as a one-off activity but rather integrate into the life and soul of the organisation on communication, training and culture.

Findings and Discussion

Concurrent to the literature, all companies interviewed in this study did not have a step-by-step implementation programme in place for translating CSR from a top level management to an operational level. Whilst all three organisations were found to have moved from an ad-hoc approach to CSR to a more strategic approach, they still do not have explicit implementation steps. The exploratory interviews in this study covered two significant issues: different steps the organisations proceeded for CRS implementation and the practices they adopted on leadership and employee engagements. There are three main phases presented in Figure 1.

Phase 1:	Phase 2:	Phase 3:
Purpose of each phase		
Establish the correct antecedents that will propel and facilitate CSR implementation throughout the organisation.	Encouraging employees to partake in CSR activities to work towards and bring about CSR implementation.	Ensure that momentum for CSR is maintained and to encourage employees to stay actively engaged and involved in CSR efforts in the long-term.

Figure 1: CSR Internal Implementation Phases

Phase 1: Before CSR implementation

This first phase is essential as it acts as a facilitator to underpin all CSR activities which are undertaken in the organisation. The purpose of the first phase has been recognised to establish the correct antecedents that will propel CSR implementation throughout the organisation. The companies under this study all mentioned the importance of similar second-order codes in implementing CSR which fall under the categories of CSR strategy, organisational structure and company values.

Strategizing CSR - all three case companies had in place a clear CSR strategy. Whilst they had begun implementing CSR on ad-hoc basis, in recent years they have all recognised the importance of building a specific strategy. These findings were not surprising as the literature holds that many companies find it easy to formulate a CSR strategy (Longoni and Cagliano, 2015). However, unlike the majority of firms, the case companies did not stop at developing a strategy but their management discussed how they established specific targets and developed measures to ensure these targets were being met or to investigate why not. One organisation used the balance scorecard approach to measure CSR performance within the context of overall firm performance and to gauge how well it was being implemented. Conversely, the two other case organisations developed targets and measures based on performance from previous years and measured these against one another. The important factor here is that despite the different measurement systems, all of the companies seriously measure their progress.

Organisational structure - organisational structure can be an effective tool as it acts as a medium through which CSR strategy can be recognised internally as a priority. All three case companies had changed their organisational structure over the past five years to reflect the changes of their ad-hoc approaches to CSR implementation and to display their commitment to CSR implementation. All of them stated that how they had developed new roles specifically to delegate responsibility to individuals. Company A has developed a CSR committee, made up of twelve individual operational staff who are responsible for communicating CSR initiatives to the rest of the organisation, and a member of the senior management team member who sits on this committee to give support and guidance. Company B developed a team called SENSE to develop a name for CSR within the organisation. Contrastingly, Company C, does have a centralised team dealing with CSR at the company's headquarters but it is different at a local level. Whilst they previously appointed individuals to be responsible for CSR, now they removed the roles and created a culture where the whole workforce work together to achieve CSR. This result was surprising, as it differed in contrast to Companies A and B, therefore it would be interesting to investigate and monitor how the eradication of this role will influence CSR implementation in Company C over the course of time.

The interviews also highlighted that the case organisations tend to have flatter organisational structures whereby encouraging participative leadership. Organisational structure was found to act as another antecedent to CSR implementation as it plays an important role in influencing patterns of communication and decision-making (Huang et al., 2011). It decides how power and responsibility within an organisation will be allocated, as well as how tasks will be divided and coordinated throughout the company (Daft, 2004). Delegating decision making and responsibility

to employees in more horizontal organisations has found to increase job satisfaction as individuals' higher needs are met as they achieve autonomy and self-realisation (Ghiselli & Siegel., 1972). Amongst some of the larger companies who have the best CSR reputations, i.e. Sony and Google, are also known for their flat organisational structure (Smith, 2017; Sony, 2017). This effectively allows for better information sharing and encourages innovation from more satisfied employees.

Values - in almost all the interviews, values were mentioned signifying the importance that they hold not only at a firm level, but also at an individual level. A common theme was ensuring that everyone was aware of the company values to promote the same goals, whilst understanding what the company holds to be important. The importance of training new employees in organisation values was highlighted too. Company A established that when recruiting a new staff member, the compatibility of the individual values were more important than their skillset. The interviewee claimed that the interview was 60% values and 40% skill, as they believed that it would be easier to upskill a new recruit than to shift their values. She remarked how it is important for their company to recruit individuals whose values are aligned with the company's. Another important factor uncovered in the research was the desire to transfer the company values to third-party contractors and agency staff. Company A and Company B explained how these individuals also received training about their organisation values and both companies stated that they saw these groups as an extension of their family of employees, contributing to the CSR implementation as much as the direct workforce.

In general, at this stage, the antecedents to good internal CSR implementation rest upon the leadership. How well a firm can build a CSR strategy, make effective organisation structural changes and instil the company values, is the responsibility of top manager and depends on how competent they are in carrying out these practices to facilitate company-wide implementation. Thus, leadership is vitally important in CSR implementation. In accordance with the literature review, the findings suggest that a transformational leadership approach is found within the research to be the most appropriate for engaging and energising staff because the leadership team are able to offer a purpose which transcends the short-term goals. This agrees with the Conger and Kanungo's (1998) findings and also upholds Stone et al.'s (2003) work that suggests through shared vision and values of the leadership team with employees, followers will be energised and in turn will take responsibility for creating the new reality.

Phase 2: During CSR implementation

Although leadership may drive the underlying mechanisms which facilitate CSR implementation, the actual process of implementation must also be driven by the workforce itself. Therefore, the purpose of the second phase is concerned with getting employees to partake in CSR activities and to work towards CSR implementation. For employees to do so, they must be motivated and engaged in their job role. To drive CSR implementation which produces greater value for business and society, a developmental model of engagement is required as established by Mirvis (2012). The research undertaken has uncovered similar tools and approaches used by the three case companies to engage employees in CSR, including employee involvement, employee voice and support.

Employee involvement - the interviews highlighted that all the case organisations encouraged direct employee participation for a more meaningful attachment to CSR implementation. In the three organisations, employee involvement ranged from operational staff acting as instructors at open days, giving demonstrations, delivering briefings to school children, volunteering in the community, recycling, meeting external stakeholders and participating in community projects. In many instances, allowing employees to take the lead on these activities energised them and delegated responsibility. In all case organisations, leadership was able to capitalise on the special skills of the employees and use these to engage employees in CSR activities and simultaneously achieve CSR implementation.

Through the empowerment of functional level employees and giving them authority to make

CSR decisions and to participate directly in CSR activities, some of the interviewees mentioned that they felt a great sense of reward and satisfaction in knowing that they had helped and were able to contribute and specified that they would want to do these types of activities again. These findings are similar to the research conducted by Assen (2016) who found that empowered leadership in the field of lean management across the organisation. The situation with CSR implementation is similar as the delegation of responsibility increase employees' job satisfaction which cultivates employee interest and dedication, thereby encouraging participation and contribution to CSR implementation.

Employee voice – this research revealed that all three companies were particularly interested in ensuring that employees have a voice within the company. Company A has a formal mechanism in place to facilitate this, whereby all employees have the ability to anonymously put forward any suggestions that they have to the 'Right Track Team'. The suggestions are all put forward and once a week, leadership review these and make any changes as suggested where possible. Gestures such as these allow for employees to feel valued and listened to. Another formal mechanism Company A has in place, is a 'High 5' mail chain where every month staff can give recognition to each other in an email that is passed around the entire workforce. In doing so, it recognises the effort and hard work of employees and energises them in their work environment. Company C has a formal mechanism which is an employee survey, internally known as Voice, which is distributed to all employees which gives them the space to make suggestions and recommendations for the workplace. Company B also highlighted that they have previously tried to do employee surveys, however it was difficult to complete because of the nature of the industry in which it operates and that they found it impractical as not everyone has access to an email address, thus it is difficult to ensure all staff return a completed survey. This research also revealed that all three companies are good at engaging employees by providing informal mechanisms. Company A has opened a new common room with games and a coffee machine, they often have 'Feed Your Face' Fridays where everyone comes together and in these ways, there is opportunity for leaders and staff to come together and have the opportunity to be seen and heard. However, a problem is that Company B uses only an informal approach in establishing Employee Voice, whereby every Friday morning. They do not appear to have any anonymous forum through which employees can make suggestions which may prevent organisational learning or lead to unresolved problems if the employee does not feel comfortable discussing these face-to-face (Detert & Burris, 2016), which could hinder the internal implementation of CSR.

Support - evidently employees are engaged and will participate if they are empowered and feel that they have the support from the top management team. Many of the interviewees at the functional level mentioned that their managers were mostly visible, or even on days where they were not. They feel comfortable in approaching them on a formal or informal basis. In Companies A and C, employees all noted that leadership were approachable due to the open-door and open-plan office environment. Hongisto et al. (2016) provided experimental evidence to suggest that there is a relationship physical environment and employee satisfaction. Their results found that the conditions of an open-plan office could improve employees' job satisfaction, making employees more likely to be engaged in their work. In this way, the open-door policy facilitates employee engagement to enable the workforce to better work towards CSR implementation. The visibility and approachableness of the leadership team increases the employees' Perceived Organisational Support (POS), (Einsberger et al., 1986) and allows employees to feel like they are highly regarded and valued by their employer. This POS is also linked to employee commitment, therefore if leadership fosters a higher level of POS through increased visibility and access, employees' in-role and extra-role behavioural performance is likely to increase simultaneously. As leaders are more approachable, they gain the confidence of employees and boost workforce morale. Company A was the only company to specify that they gave informal recognition every month to employees, through the 'High 5' mail chain which was previously

mentioned. This mechanism provides the opportunity for employees to receive credit for work they have done and may help in boosting self-esteem, team morale and confidence across the organisation. This was an exception as the other two cases did not mention any similar constructs. Despite this, it was a tool which the employees were grateful for and gave much positive feedback about, therefore it could be something that the other two firms seek to adopt and implement too.

Phase 3: Ongoing CSR implementation

Organisations do not only need to successfully complete CSR activities to achieve targets established by the CSR strategy for a short time period, but also to achieve long-term CSR implementation. Thus, whilst the other mechanisms and tools mentioned above act as antecedents to CSR implementation, the purpose of the third phase is to highlight other methods to ensure that the CSR momentum continues advancing and to encourage employees to stay actively engaged and involved in CSR efforts in the long-term. These have been broken down into the following categories:

Communication – all three case companies work hard to use a range of communication mediums to keep employees up-to-date about the external CSR initiatives that the company is involved in and to let them know of any new programmes or opportunities that will be available. All interviewees mentioned the importance of two-way communication between employees and leaders, with one interviewee describing it as a *"two-way street*". All companies endeavour to open that communication medium in a different way, while Company A ensures a member of senior management team sponsors the CSR Committee by giving valuable feedback, Company B has informal face-to-face meetings between one staff member and one leader every Friday as previously mentioned, and Company C promote this communication from the very outset when all staff are being inducted and they met and get to know all of the senior leaders. One of Company C's core values is 'Openness' which also promotes communication between the two parties. The research highlighted the importance of communicating with employees not just when leaders needed to communicate targets, news or deliver updates about the company, but also on a more personal level and more frequently. Whist many had meetings to deliver information regarding company updates, it is recognised in the literature that workplace meetings provide limited scope for meaningful dialogue which is a defining characteristic of employee engagement, therefore while meetings can be useful for communicating downwards. ACAS (2012) recognises that there should be avenues available to provide upward communication flow to facilitate employees' capacity to influence higher level management decisions.

Training - advanced training for all employees can foster the ongoing implementation of CSR. In all junior staff interviews, they specified that they received training which was made interesting and meaningful to them. Company B in particular discussed how they often got to choose the different courses that they wanted to attend. An interviewee from Company B specified that if a course appeared and he felt it would be valuable to him, he could approach leadership to be given permission for it. Others commented how the training they received was useful and interesting and helped them in their job role, comparing it to just receiving training for the sake of it. In receiving this training, employees feel better equipped to do their job and it creates intrinsic motivation for them, leading to job satisfaction and better engagement with better job performance (Saks, 2005), which is an enactor of internal CSR implementation. Through ongoing training, employees are upskilled and developed as which consequently should enable leaders to be confident their employees are capable of implementing CSR well. Many of the interviewees mentioned that training was given to third-party agency staff or external partners to ensure that they were aware of values and the commitment to CSR to enable them also to work towards the same CSR goals. This external collaboration is something that should be considered within this third phase in order to develop CSR from an internal level to external to maintain long-term CSR efforts.

Organisational culture - organisational culture appears to be an enactor of internal CSR implementation. Whilst none of the interviewees explicitly mentioned the culture of their

organisations, it was an underlying theme that was deduced from the first and second-order codes. All the leaders interviewed discussed how their organisations are attempting to embed CSR principles into the heart of their business operations and culture so that it CSR is not additional, but rather it will be viewed by employees as something that their involvement depends on (Slack et al., 2015). Apart from the underling values which contribute to the organisational culture, there are additional observable symbols and behaviours which create culture too. All organisations demonstrate similar behaviours as leadership attempt to advocate the message of family and togetherness through the promotion of company days away, open days where the whole family is invited, all of which work to ensure that their staff feel valued, appreciated and part of the organisation. Some of the other activities highlighted across the interviews ranged from putting on a company BBQ, building a bicycle shed for employees, creating a shared common room with games and a coffee machine or opening the facilities to show a football game for all staff. All of these activities demonstrate the values of teamwork, community, family. Another common theme stated by the interviews was the care the leadership teams take to promote the health and wellbeing of their staff. For example, Company A has introduced an email embargo, whereby staff are not allowed to respond to emails outside of working hours and working overtime is frowned upon. Company B have launched new training in mental health as they recognise the high suicide rates in their industry. Company C are also in the process of restricting the number of overtime and weekend hours that employees can work. Promoting staff health and wellbeing signals to employees that their employee cares and increases their organisational commitment. It benefits the employer too as it employees are more likely to be better placed to do their jobs effectively and to be engaged in them as the staff are not burned out, but instead well looked after.

Conclusions

This research has attempted to close a gap in CSR literature by providing empirical research on the exploration of employee engagement practices and leadership practices to find out how they can be used as facilitators of internal CSR implementation. Research undertaken found similar features and mechanisms utilised by all of the three high CSR performing organisations and synthesised these into a logical framework.

In practice, these results could be helpful for other companies who are striving to implement CSR successfully. They could follow the framework and begin to duplicate the practices and mechanisms identified and to develop their own CSR integration. It would be helpful if they could establish measures to report on the progress of their implementation which would indicate how useful and valuable the framework is in practice. It would also be helpful for those companies to share knowledge about their experiences of the use of the model, as this could help increase the framework's effectiveness. Within the academic field the findings from this research can contribute to the beginning of empirical research to attempt to close the gap in research. Obviously, given the limitations of the study and the small number of case companies in which the research was undertaken, this research will need to be expanded and developed to be able to generalise any findings. However, the in-depth study is a good starting point and give useful opportunities to understand CRS implementation by a holistic view. There is potential for each of the stages of the framework to be explored on a deeper level too, especially the third phase of the model is that which perhaps needs more focus. The third phase of the framework is concerned with maintaining the momentum for CSR implementation in the long term which would be better to conduct future research by different mechanisms longitudinally.

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Impact of asymmetric cost behavior and short-termism on costs of quality

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Abstract

The purpose of this paper is to understand organizational behavior concerning quality costs in product development and operations. It aims to contribute to the understanding of the multi-causal interdependencies of quality management on the development process and operational performance, including the quest for an overall appropriate level of cost of quality. After a structured literature review to examine the concept of asymmetric cost behavior and managerial short-termism, findings where merged into a simulation model by using the system dynamics modelling approach. This methodology allows to analyze dynamic consequences of the multi-causal reality of quality management in product development.

Keywords: quality management, asymmetric cost behaviour, system dynamics

Introduction

Although the over-all positive benefit of quality management and approaches such as TQM is generally well understood (Freiesleben, 2005), many organizations do not or only partially implement quality management methods (Prefi, 2014). A reason for this paradox could be that it is difficult to establish direct links between quality methods and operational performance due to multi-causal interdependencies in organizational systems (Jochem, 2014). More concretely, there are doubts that efforts in failure prevention are worth the benefit in terms of quality costs, and costs for failure prevention might even exceed costs of failures (Slack et al., 2016). Thus, organizations fear to not achieve their economic quality goals while increasing failure prevention costs (Boulter et al., 2005).

This uncertainty might lead organizations to overreact, possibly taking short-term decisions and showing behavior in regards of quality costs that will not lead to success (Schiffauerova & Thomson, 2006). When managers (unintentionally, due to organizational pressures, or triggered by incentive structures) concentrate on quick fixes instead of fundamental solutions their behavior can be named short-termism or fire-fighting (Bohn, 2000; Longenecker et al., 1994).

A less-than-proportional decrease of costs in relation to a decrease of activities has been named sticky costs (Brasch, 1927), an effect that is triggered by the phenomenon called asymmetric cost behavior (Reimer, 2018).

An excessive shortage or increase (e.g. in quality initiatives) of budget and asymmetric cost behavior could cause an upswing of oscillations in costs of quality (see Figure 1). We hypothesize that the developments shown in the figure are caused by two phenomena: (i) asymmetric cost behavior, and (ii) short-termism of managers. In this context, short-termism could result in either cost cutting as well as in exaggerated investment into quality initiatives.

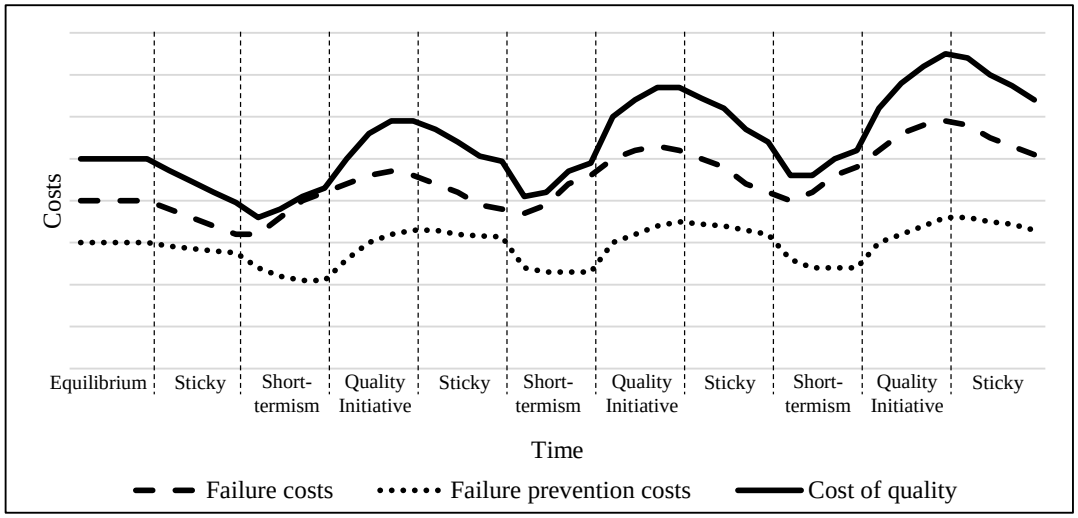

Figure 1: Illustrative development of costs related to quality management

To support this proposition, we performed a short survey by using a single mode strategy (Laaksonen, 2018, p. 30). The survey was designed under consideration of size and order of questions in the field of quality management and quality costs and the use of the Earlier Social Surveys (ESS) Scale (Laaksonen, 2018, pp. 36-39). 133 participants where contacted by mail using the business network LinkedIn. The target population was defined as experienced employees or managers as part of a quality organization in one of the top 100 automotive supplier (Chappell, 2018). The search was performed by using "company name" plus "quality management", and resulted in 16 valid responses.

Participants had to answer questions concerning quality costs and their estimation about connections between costs of failure prevention and cost of failure. A majority approved a link between failure prevention costs and failure costs but only 21% believe this link is linear or direct. Although most companies are gathering quality costs, only half of the participants confirmed a separate collection of failure prevention costs.

Half of the participants do not believe that managerial behavior in their company is appropriate to changes in quality costs, which can be seen in asymmetric cost behavior or short-termism. A slight majority can see irrational budget cuts sometimes and stronger focus on failure costs than on failure prevention costs. Most participants can see a tendency for an untargeted use of failure prevention funds. Almost 70% believe that short-termism lead to an increase of quality costs in long-term. Finally, a majority of 65 % support the hypotheses of quality cost fluctuation over time.

Problem description

A link, even if not direct, between cost for failure prevention and failure costs in operations seems to exist. However, managers seem to either ignore this context or might

have a lack in understanding the interconnections. Activities in failure prevention often seem to be implemented uncoordinated without measuring the result of each activity. That leads to an uncoordinated increase of failure prevention costs to aim for good quality in operations. On the other side short-termism or fire-fighting is still a common behavior which leads to abrupt cost cutting by manager while ignoring long terms effects on quality costs. That might lead to an upswing of overall quality costs and an inefficient managing of quality costs in long-term.

Research Question and Objectives
Taking these problems and the hypotheses into consideration, the following research question is formulated:

RQ: What kind of causes or interaction of causes could trigger an oscillation of quality costs accompanied with a steady increase?

The objective of this paper is to understand possible causes provoking the phenomena of oscillation and increasing the overall costs of quality. We aim to build a basic system dynamic model that is able to answer the research question by showing interdependencies and effects of our hypotheses.

Approach, Methodology and Contribution
This paper provides a basic literature review for an overview on cost of quality as part cost controlling, asymmetric cost behavior and short-termism followed by the description of our work in progress version of the system dynamics model.

The contribution of this paper is twofold. First, the combined effects of asymmetric cost behavior and short-termism have not been investigated in the context of quality related costs before. Second, we developed a system dynamics model, which comprises the composition of quality costs and their interaction. It might help managers to understand interdependencies within their organizations and will contribute to avoid an upswing of oscillations in costs of quality. The model can be customized for further research in the field of quality management.

This paper might also contributes to transform quality into a measurable quantity, in order to help organization to find the right balance between investment and return on quality costs.

Literature review
The literature review has been performed in a dedicated approach (Ridley, 2012, pp. 6-11) clustered by the relevant topics “definition of quality costs”, “concept of asymmetric costs” and “short-termism or fire-fighting by managers”

Cost of quality as part of quality cost controlling
Quality controlling is the planning, execution and control of quality-related activities with regard to the economic orientation of quality management (Bruhn & Georgi, 1999). The term cost of quality is defined as sum of all quality related costs in an organization and provides a major key performance indicator (KPI) to evaluate the quality performance of an organization (Jochem, 2014, pp. 28-31). The total costs of quality are summed up by prevention costs (e.g. Q-Planning), appraisal costs (e.g. planned testing, controlling) and failure costs (e.g. scrap and rework) (Schiffauerova & Thomson, 2006, p. 3; Slack, et al., 2016, p. 591). However, there are multiple approaches in categorizing quality costs (see

Table 1) but most of them are based on the prevention, appraisal and failure (P-A-F) model.

Table 1: Generic cost of quality models

Generic model	Cost categories
P-A-F model	Prevention + Appraisal + Failure
Crosby´s mode	Conformance + Non-Conformance
Opportunity cost models	Prevention + Appraisal + Failure + Opportunity Tangibles + Intangibles P-A-F (failure costs includes opportunity costs)
Process cost models	Conformance + Non-Conformance
ABC models	Value-added + Non-value-added
VDA cost of quality	Prevention (incl. Appraisal) + Failure

A common model for the categorization of quality related costs in the automotive industry is the model of the automotive association (VDA) which separates between:

Failure prevention costs: Costs for QM-system, Q-planning, planned testing and checking (including appraisal costs), supplier management.
Failure costs: Scrap, rework, claims including costs for warranty and goodwill.

The VDA models includes failure appraisal costs into failure prevention costs (Verband der Automobilindustrie e.V. (VDA), 2015, pp. 8-9). Due to a strong focus of our work on the automotive industry, we preferably use the VDA categorization in our model rather than one of the other common models above.

Asymmetric cost behavior and Stickiness of costs

Studies questioned proportional cost behavior and the traditional view of linear or proportional cost behavior was challenged in literature (Reimer, 2018, p. 7). Already in the 1920s, the banking sector showed slowness in the adjustment of labor costs during a recession and first researches started questioning proportional cost behavior (Hasenack, 1925, p. 83). Similar effects in different sectors where identified and the term "remanence of expenses" was introduced (Brasch, 1927, p. 68). Strube (1936) provides a range of sources for the remanence of expenses and introduces the term of "asymmetric cost behavior" as one of these sources (Strube, 1936, pp. 19-21).

In the recent literature, the term remanence of costs is defined as staying behind the changes by an activity level increase and decrease (Guenther et al., 2014). In contrast to the remanence of costs, the term sticky costs is defined as staying behind the changes only by an activity decrease (Malagoli, 1985). Anderson, Banker, and Janakiraman (2003) defined costs that decrease less for activity decreases as they increase for an equivalent activity increase as sticky costs and they described this phenomenon as asymmetric cost behavior (Reimer, 2018, p. 9). The work of Anderson, Banker, and Janakiraman (2003) is focusing on Selling, General and Administrative Expenses (SG&A) costs in relation to revenue. The evidence of cost stickiness is given when the change of SG&A costs with a revenue increase is greater than the change for revenue decreases (Reimer, 2018, p. 18).

Sources of cost stickiness are diverse but can be divided into two major groups, intended management decisions and unintended management decisions (Malagoli, 1985). Reimer (2018) as one of the most recent authors dealing with asymmetric cost behavior defined several dimensions of cost stickiness (Figure 2).

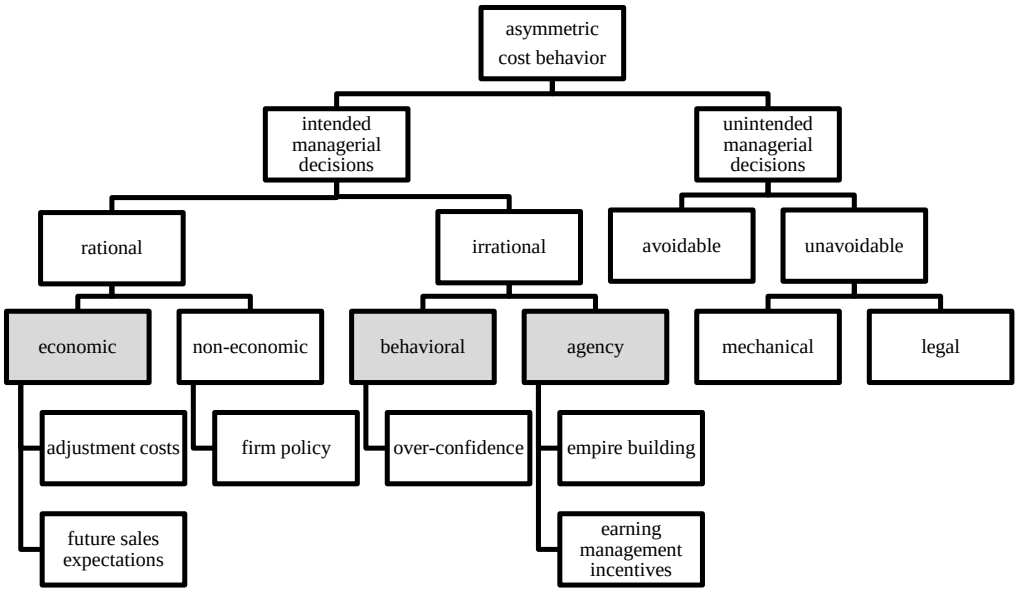

Figure 2: Dimensions of Cost Stickiness (Reimer, 2018, p. 17)

The most analyzed and discussed drivers for cost stickiness are economic sources, management behavior and agency problems (Anderson et al., 2003, p. 48). Changes in economic conditions might cause an adjustment of costs by managers as a result of a rational deliberate decision aimed on long term targets and therefore provides an example for the category of economic sources (Reimer, 2018, p. 11). A behavioral source could be overconfidence of managers who tend to overestimate future sales and therefore do not adjust redundant resources in response to a sales decrease which then can lead to cost stickiness (Chen et al., 2013). Self-interested managers who tend "to build their empire" by increasing their division size providing an example for agency problems (Reimer, 2018, p. 14).

The model of Weiss provides a firm- and period-specific measure of cost stickiness (Reimer, 2018, pp. 20-21). The model includes the costs and sales changes of a company's last four quarters, where the calculation evaluates changes in the most recent quarter. For the selected quarters, Weiss proposes to calculate the differences of the logarithmized ratios between cost and sales differentials (Reimer, 2018, p. 20). The logarithmic measure is motivated by comparability across firms and mitigation of potential heteroscedasticity.

$$(1)\ STICKY_{i,t} = -\left[\log\left(\frac{\Delta Cost}{\Delta Sale}\right)_{i,\underline{\tau}} - \log\left(\frac{\Delta Cost}{\Delta Sale}\right)_{i,\overline{\tau}}\right] \qquad with\ \underline{\tau}, \overline{\tau} \in \{t, \dots, t-3\},$$

Where $\underline{\tau}$ is the most recent period of the last four periods with a decrease in sales and $\overline{\tau}$ is the most recent of the last four quarters with an increase of sales, $\Delta Sale_{i,t} = Sale_{i,t} -$

$Sale_{i,t-1}$ and $\Delta Cost_{i,t} = (Sales_{i,t} - Earning_{i,t}) - (Sales_{i,t-1} - Earning_{i,t-1})$. A lower value of STICKY implies a higher level of sticky cost behavior (Reimer, 2018, p. 20).

Short-termism or fire-fighting by managers

Short-termism describes an excessive behavior in decisions and outcomes that focus on short-term results at the expense of long-term interests (Graafland, 2016, p. 127; Laverty, 1996, p. 831). When managers (unintentionally, due to organizational pressures, or triggered by incentive structures) concentrate on quick fixes instead of fundamental solutions their behavior can be named short-termism or fire-fighting (Bohn, 2000; Longenecker, et al., 1994). Marginson and McAulay (2007) identified four sources of short-termism: changing market situations, transparent performance measurement of managers, individual dimension, and the organizational dimension.

Pressure from investors and the capital market especially after changes in market situation seems to induce managerial short-termism (Miettinen & Stenbacka, 2018). An extreme kind of short-termism can be survival or fire-fighting (Graafland, 2016; Marginson & McAulay, 2007) due to risks of running out of resources. In addition, executives of listed companies are pressured to provide performance in order to meet stock market expectations (Marginson & McAulay, 2007).

Transparent performance measurement drives managers to take actions that are solely based on maximizing short-term results, that will affect their performance within the current budgeting period (Laverty, 1996; Marginson & McAulay, 2007).

Due to their own interests, managers are more likely to undervalue the long-term decisions when they are confronted with tradeoffs between the long term and the short term (Laverty, 1996).

The individual dimension regards an information deficiency. It describes the length of the time horizon confronting a decision maker and the information available. The greater the uncertainty, and the more likely information is deficient, managers tend to make short-term decisions accepting the risk of incomplete information available (Marginson & McAulay, 2007).

Organizational dimension describes considerable interpersonal communication, social interaction and social influence, which leads to possible short-termism (Laverty, 1996). Social influence perspective suggests that information from social referents (e.g., colleagues, coworkers, influential outsiders) can be at least as important as objective information, leading to conformity of views. In other words, an individual's views and opinions can be biased by the opinions of others (Marginson & McAulay, 2007).

Asymmetric cost behavior and short-termism in the context of quality costs

Research in the field of asymmetric cost behavior and short-termism is mainly focusing on changes in sales and costs in general. In this paper, we transfer the idea of asymmetric cost behavior and short-termism into the context of quality costs. Well know sources gathered out of the literature review where designed into the system dynamics model.

Based on the model of Weiss, cost stickiness as phenomenon of asymmetric cost behavior of quality costs can be identified as:

$$(2)\ STICKY_{i,t} = -\left[\log\left(\frac{\Delta Fp}{\Delta Fc}\right)_{i,\underline{\tau}} - \log\left(\frac{\Delta Fp}{\Delta Fc}\right)_{i,\overline{\tau}}\right] \qquad with\ \underline{\tau}, \overline{\tau} \in \{t, \dots, t-3\},$$

Using Fp as failure prevention costs and Fc as failure costs.

To transfer short-termism into the context of quality costs all four sources of short-termism of Marginson and McAulay (2007) can be applied because quality costs are directly affecting a company's result (Jochem, 2014, p. 32). Quality performance of competitor, performance measurement by using quality-controlling figures as well as individual and organizational dimensions in the context to quality costs are providing relevance for manager's behavior.

System Dynamic Model

Simulation can be defined as the practice of creating models representing existing or future systems with the purpose to experimenting in order to explain system behavior (Stadnicka & Litwin, 2019). System dynamics as a specific type of simulation that allows simulating a broad range of issues in dynamic systems (Sterman, 2010, pp. 41-42). Such models consist of interconnected stocks and flows that express the state of a system at a given time (Sterman, 2010, p. 68). The principles of system dynamics modelling, together with manufacturing issues, are widely presented in the literature (Größler et al., 2008). Sterman (2010) provides steps of the modeling process as well as examples which have been applied during the design of our model (Sterman, 2010, p. 86).

In this paper, we avoid describing the modelling process in detail but refer to a couple of Sterman's models, which provided elements of our model. The model (figure 3) is in an early phase and some areas have been designed in a basic way to reduce complexity in the first step. The model includes three main areas: employees involved, parts moving in production, and financials.

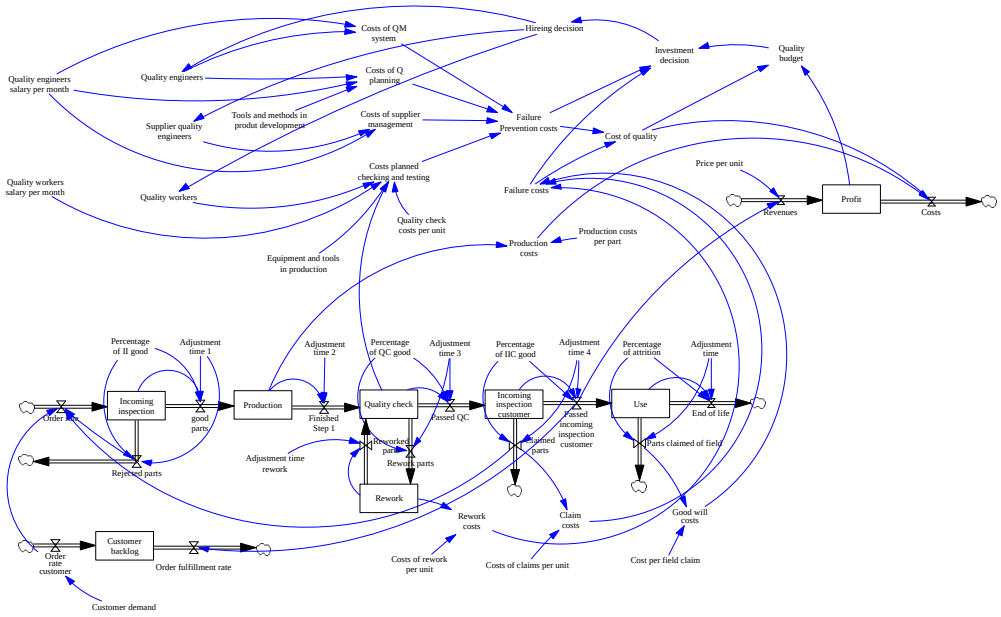

Figure 3: System dynamics model of quality costs

Failure prevention costs are manly defined by the sum of cost for QM-system, Q-planning, planned checking and testing and supplier management. The number of employees and their salary mainly defines all these elements. The area parts moving is designed by a basic stock and flow map for a basic manufacturing process (Sterman, 2010, p. 214), an inbound section (Sterman, 2010, p. 731) and delays (Sterman, 2010, p. 419).

The feedback loops for rework, scrap, claims and good will multiplied with the amount of parts in this loop are providing the failure costs. The area financials connects all types of quality costs with the financial result of the company.

Another important function is the decision-making variable. Decision are the policies and protocols specifying how the decision maker processes available information (Sterman, 2010, p. 514). The rules of these decisions have been defined by the managerial behavior gathered out of the literature review, for example, asymmetric cost behavior in regard to failure prevention costs over four quarters even though failure costs are decreasing significant.

The model is still work in progress. This basic version is able to create oscillation of costs of quality triggered by managerial behavior. In an iterative process, more details and more parameters will expand the model to test different scenarios.

Findings and conclusion

The assumption of quality cost oscillation due to managerial behavior such as asymmetric cost behavior and short-termism can be confirmed with the help of our system dynamics model. The model cannot approve a long-term increase of quality costs so far. Due to the early state of our model, the identification of main sources of the oscillation is not finished yet. We also assume that the amplitude of oscillation and the increase of quality costs is limited by organizational factors (e.g. available budget, turnover or companies result). More details in the model in the area of decision-making and further research is necessary.

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The impact of CEO stock options on supply chain stability and the moderating role of a powerful COO

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Abstract

Supply chain disruptions (SCDs) remain one of the most significant threats to firms' performance. In this study we investigate chief executive officer (CEO) stock options as an antecedent of SCDs. Based on an eleven-year sample of more than 2,000 disruptions in U.S. S&P 500 firms we conceptually and empirically explain an inverted U-shaped relationship between CEO stock options and SCDs. We contribute to research the investigation of a previously neglected antecedent of SCDs, a more nuanced view on the strategic impact of CEO stock options, and insights on the moderating effect of relative chief operating officer (COO) power.

Keywords: Supply chain disruptions, CEO stock options, COO power

Full Paper

Introduction

Business interruption risks remain a significant threat to firms' performance. Despite the high importance of SCDs for academia and practice, their causes are neither conclusively identified nor empirically well understood. Moreover, even though their decisions directly influence the supply chain, the impact of decision makers in charge of operations management is also neglected in operations management research (Hendricks, Hora, & Singhal, 2014). In this context, stock options are supposed to evoke more aggressive risk-taking by otherwise rather risk-averse executives in alignment with the shareholders' interests. The concept of stock options allows executives to participate from the potential upsides of high-risk decisions with limited downside risks due to their optionality. This also comprises an increased willingness to take risks with regards to supply chain

management. Recent studies are ambiguous regarding the effectiveness of CEO options and call for further research on contingency factors impacting managerial risk taking (Benischke et al., 2019; Wowak, at al., 2015).

By contrasting agency and behavioral agency theory, we investigate the impact of CEO options on SCDs and the moderating effects of relative COO power and market uncertainty (see figure 1). We draw upon a unique, hand-collected sample of more than 2,100 firm-year observations over the years 2006 to 2016 with more than 2,000 SCDs in 223 S&P 500 firms. To support our manual sampling process, we used a machine learning algorithm to identify potentially relevant SCDs from more than 450,000 press announcements.

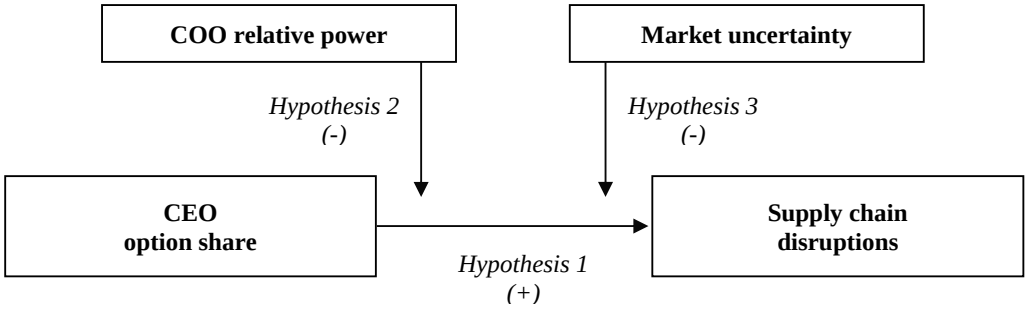

Figure 1 – Simplified research model

Our study contributes to operations management research in multiple ways. First, we identify and empirically investigate CEO options as a widely neglected organizational antecedent of SCDs. Second, we establish an inverted U-shaped relation between CEO options and SCDs enhancing research on CEO options with a more nuanced perspective on the effects of CEO options. Third, our study highlights the importance of having a powerful COO in the top management team with regards to supply chain stability. Fourth, we emphasize the necessity of adopting a contingency perspective when assessing CEO options and SCD risks. Finally, we introduce machine learning as a supporting technique to empirical secondary data research in operations management.

Theoretical background

SCDs

Prevailing research on SCDs emphasizes their harmful consequences: Hendricks & Singhal in several studies found, that SCDs diminish stock returns, market and shareholder value, and reduce sales over several years following a disruption (1997, 2003, 2005). In line with Hendricks & Singhal (2003) we define SCDs as unexpected events in the supply chain or its environment that threaten the normal business operations of a firm. Existing studies on SCDs vary strongly in the events being considered. Based on related supply chain risk literature, we use a dichotomous classification to cluster the SCDs used in our study. First, we separate micro- and macro-SCD-risks being in- and external to the organization (Wu et al., 2006). As we in this study investigate the effects of CEO stock options on SCDs, we exclusively focus on micro-disruptions which can directly be influenced by the firms. Loosely following the meta-analysis by Ho et al. (2015), we consider the following micro-disruptions in our study: demand and supply mismatches, delays, outages (of machinery or production), strikes, product quality issues, recalls, infrastructural problems, and issues of adverse business conduct. In line with Hendricks

& Singhal's understanding of supply chain management and its subsystems, we assume that executives either indirectly (through negligence of important operations processes) or directly (through active strategic decisions or conscious misconduct) effect SCDs (2014).

(Behavioral) Agency Theory and CEO Options

The basis of agency theory and research on CEO options is the separation of ownership and management in firms, leading to potentially diverging interests between shareholders (principals) and managers (agents) (Jensen & Meckling, 1976). Principals delegate the management of the business to the agent (i.e. the CEO), who is assumed to act in their best interest. In this context, agency theory assumes, that agents are risk-averse. Stock options are supposed to reduce the CEOs' risk-aversion by offering the CEO the opportunity to profit from firm success while not suffering from potential loss (Wiseman & Gomez-Mejia, 1998). Since CEO options are meant to influence a CEO's behavior, behavioral agency theorists pronounce the need to combine agency with behavioral decision theory to fully explain its effects (Martin et al., 2016). Behavioral agency theory enhances agency theory by prospect theory to explain managerial risk-taking (Wiseman & Gomez-Mejia, 1998). Prospect theory postulates that managerial decision behavior depends on individual valuation of potential gains and losses to the personal wealth (Kahneman & Tversky, 1979) with wealth being understood as current, just-received, and fully anticipated wealth. Accordingly, agents weigh anticipated future wealth against declines in current endowed wealth (Benischke et al., 2019).

Development of hypotheses

CEO options and SCDs

If not in charge of operations themselves, CEOs have a strong impact on strategic decision-making regarding initiatives that affect company operations, such as cost-reduction programs, process-oriented programs (e.g. quality management, working capital management), or budgeting (e.g. R&D spending) (Wowak et al., 2015). Overly risky decisions in pursuit of stock performance optimization, thus, have the potential to evoke SCDs. Whereas agency theorists postulate a linear relation between CEO options and managerial risk-taking, based on the behavioral agency theory we assume that the relation between stock options and risk-taking is more nuanced and driven by two latent interacting forces: the perceived benefits in case of success and the perceived costs in case of loss associated with higher risk-taking by the CEO. CEOs with a low stock option share have little incentive to take risky decisions, as they only limitedly benefit from increasing share prices if the high-risk initiative achieves anticipated results. However, they have much to lose in terms of non-financial wealth or imminent penalties. With an increasing but still moderate CEO option share, the financial incentive to take risks increases, as the fully anticipated wealth assigned to high-risk initiatives becomes more compelling. As risk-taking preferences of an agent vary depending on the executives' framing of the situation and anticipated effects on the personal wealth (Sitkin & Weingart, 1995), the CEO will constantly weigh benefits and costs of risky decisions against his current endowed wealth. Up to a certain point depending on the personal risk-taking preference, the incremental benefits of taking additional risks will overweigh the perceived incremental costs and will cause CEOs to ignore indications of project failure, to be negligent about risk mitigation, or to ignore downside risks of their decision (Wowak et al., 2015). As a consequence, we assume SCDs to increase. Following our logic of decreasing marginal benefits and increasing marginal cost of taking high-risk

decisions, we argue that with a high option share relative to the CEOs total compensation, risk-taking decreases as the CEO considers a large part of his prospect wealth at risk.

> *Hypothesis 1 (H1): CEO options exhibit an inverted U-shaped relationship to the frequency of SCDs, such that firms with low and high CEO option shares will experience fewer SCDs than those with medium CEO option shares*

CEO options, market uncertainty, SCDs

When analyzing managerial risk-taking behavior, market uncertainty being defined as the extent to which a CEO faces an unpredictable and unstable environment (Finkelstein & Boyd, 1998) is arguably of special interest. Uncertain markets are characterized by constant variations in customers, preferences, and competition and increased supply chain risks per se (Trkman & McCormack, 2009). This will enhance the perceived costs of additional risk-taking by the CEO. Moreover, research suggests that with increasing market uncertainty firms face higher complexity in their task environment and an increased need to review and adjust strategies continuously (Miller & Friesen, 1983). This increases the alignment efforts within the top management team (TMT), which restricts the CEO in making high-risk decisions. Finally, with less predictability of the market and a growing amount of personal wealth being linked to firm performance, CEOs tend to become increasingly risk-averse and seek to preserve personal wealth (Wiseman & Gomez-Mejia, 1998). As the marginal costs increase as compared to the marginal benefit related to additional risk-taking, the U-shaped relationship between CEO options and SCDs is flattened, thus SCDs decrease.

> *Hypothesis 2 (H2): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter in markets where uncertainty is high and (b) steeper in markets where uncertainty is low.*

CEO options, relative COO power, SCDs

Past research suggests that the increasing marginal cost curve counteracting the marginal benefits of CEO options might increase in the presence of a powerful COO. Power is defined as the extent to which the COO can influence the behavior of others and has the discretion to shape and implement strategic decisions in his interest (Finkelstein, 1992). The COO frequently is delegated responsibilities usually held by the CEO. He, thus, reduces power distance in the TMT and constrains the power otherwise centralized in the position of the CEO (Worrel et al., 1997). With increasing power of the COO, the CEO needs to more closely involve him when initiating strategic changes in a firm's operations. By creating a task-oriented conflict between CEO and COO, decisions are made in a process of social interactions that reveals differing assumptions and expectations (Marcel, 2009). This alignment process will arguably constrain the CEO's tendency to disproportionally focus on upside potential of high-risk decisions with regards to operations and, in turn, increase the CEOs perceived risk to be blamed with a negative outcome of a high-risk initiative if pursued against opposition. Second, power structures in TMTs can create conflicts among executives. By contending the power of the CEO, the COO takes a monitoring role towards the CEO. This is based on an inherent competition between the CEO and COO and the fact that a weak performance of the operations function being visible to the external labor market might harm future employment opportunities of the COO (Fama, 1980). Third, the functional backgrounds represented in the TMT influence the salience of certain organizational objectives and performance drivers (Marcel, 2009). While Hayward & Hambrick show that CEOs – a

role rather focused on output-oriented than internal processes – tend to be more risk-seeking with higher individual power (1997), COOs will presumably act in the foremost interest of their functional responsibility and, thus, will challenge overly risky decision based on a profound understanding of the operations function.

Hypothesis 3 (H3): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter, when the relative power of the COO is high and (b) steeper, when the relative power of the COO is low.

Data and methods

Sample

To empirically test our hypotheses, we gathered more than 2,000 SCDs from PR Newswire press announcements in the Factiva database from 223 publicly traded S&P 500 firms in the U.S. between 2006-2016. Based on the taxonomy developed above, we identified key search terms to identify first relevant disruption announcements per category, following the procedure of Hendricks & Singhal (2005). To handle the number of announcements and support our manual coding process, we developed a supervised machine learning algorithm, using python 3.6 & scikit-learn libraries, to automatically identify potentially relevant announcements based on both, title and body of the announcements. We re-read all announcements tagged as potentially relevant by the algorithm to judge the appropriateness, discussed unambiguous announcements. We, then, clustered the announcement into the SCD categories introduced above, using triple coding technique and regularly testing for intercoder reliability (Daniel & Harland, 2018). We then merged this SCD sample with TMT data from S&P Capital IQ's ExecuComp and firm characteristics from S&P Capital IQ's Compustat.

Measures

We operationalized our dependent variable (DV) *supply chain disruptions* as count variable (i.e. the number of recalls of firm i in year t), ranging from 0 to 8 in our sample. Our independent variable (IV) *CEO options* was operationalized as the share of stock options granted relative to the total compensation of the CEO as reported by ExecuComp. Following prior research, we calculated this variable as a two-year weighted average (Wowak et al., 2015).

With regards to our moderating variables, we put our focus on the presence of the COO role rather than on the title as such, following Hambrick & Canella (2004). We operationalized COO relative power as the COO's total compensation relative to the total compensation of the highest paid TMT member (the CEO). This definition implies that higher relative compensation ratios indicate higher power in the TMT (Daily & Johnson, 1997). We operationalized market uncertainty as the coefficient of variation of sales per industry on four-digit SIC code level in a given year (Tosi et al., 1973).

To increase robustness of our research model we included multiple control variables on firm-, industry- and TMT-level. On firm-level, we controlled for *firm size*, *financial slack*, *operating performance*, past financial performance using *Tobin'sQ*, *R&D intensity*, and *capital intensity*. On environmental-level, we controlled for *market uncertainty*, *technological turbulence*, and *technological sophistication*. On TMT-level we considered *TMT size*, *TMT ownership structure*, *CEO duality*, and *COO relative power*.

Since firms with a history of SCDs may be more likely to subsequently encounter problems, we included lagged DVs in all models. Finally, all research models contain *year* and *industry dummies*. We lagged all variables in our model (except for the DV) by

one year to account for the fact, that strategic decisions based on information in a given year, will take time to become effective (Souder & Bromiley, 2012). All continuous variables are winsorized at the 1.0% level to avoid bias from outliers.

Model

We use STATA's generalized estimating equation (GEE) model to analyze our unbalanced and pooled cross-sectional time-series data, following structurally similar studies based on longitudinal data (Wowak et al., 2015). GEE measures the effect on the DV "population-averaged" across all units in the data set, thus, considering both, within- and between-unit variation. Unlike alternative approaches (e.g. random- or fixed-effect models), GEE can deal with potential heteroscedasticity and serial correlation as it accounts for both inter- and intra-firm variations (Shah et al., 2016). Moreover, GEE does not (wrongfully) omit "zero SCD" firms (Sine et al., 2003).

Results

Table 1 provides descriptive statistics (unstandardized) and correlations (standardized) for all variables used in our models. The top right part of the matrix shows Spearman's rank-order correlations, the bottom left values show Pearson's product-moment correlations. The fact there is no significant correlation between CEO options and SCDs might be a first indication that the relationship might indeed not be linear rather curvilinear / U-shaped.

Table 1 – Descriptive Statistics and Correlations

Variables	M	SD	Min	Max	1.	2	3.	4	5	6	7.	8	9	10	11	12	13	14	15	16
1. Supply chain disruptions	0.77	1.52	0.00	8.00	1.00 (0.00)	0.49 (0.00)	0.00 (0.92)	0.00 (0.92)	0.29 (0.00)	0.20 (0.00)	0.29 (0.00)	-0.04 (0.08)	0.02 (0.33)	0.14 (0.00)	0.00 (0.68)	-0.02 (0.36)	0.02 (0.32)	0.05 (0.02)	0.08 (0.00)	0.05 (0.03)
2. Supply chain disruptions (lagged)	0.77	1.51	0.00	8.00	0.63 (0.00)	1.00 (0.00)	-0.03 (0.19)	-0.03 (0.19)	0.29 (0.00)	0.21 (0.00)	0.29 (0.00)	-0.04 (0.05)	0.03 (0.14)	0.14 (0.00)	0.01 (0.54)	-0.01 (0.63)	0.04 (0.08)	0.03 (0.10)	0.06 (0.01)	0.05 (0.02)
3. CEO options	0.22	0.19	0.00	0.84	-0.03 (0.16)	-0.05 (0.02)	1.00 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.02)
4. CEO options squared	0.08	0.12	0.00	0.71	-0.04 (0.02)	-0.05 (0.03)	0.91 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.01)
5. Firm Size	9.70	1.11	7.57	12.51	0.34 (0.00)	0.35 (0.00)	-0.08 (0.00)	-0.08 (0.00)	1.00 (0.00)	0.64 (0.00)	0.92 (0.00)	-0.35 (0.00)	-0.05 (0.03)	0.08 (0.00)	0.10 (0.00)	-0.01 (0.75)	0.05 (0.03)	0.03 (0.11)	0.18 (0.00)	0.19 (0.00)
6. Financial Slack	7.21	1.47	3.56	10.82	0.26 (0.00)	0.27 (0.00)	-0.04 (0.04	0.01 (0.65)	0.65 (0.00)	1.00 (0.00)	0.61 (0.00)	0.03 (0.18)	0.34 (0.00)	-0.18 (0.00)	0.24 (0.00)	0.33 (0.00)	0.35 (0.00)	0.02 (0.25)	0.17 (0.00)	0.05 (0.03)
7. Operating Performance	7.81	1.11	5.59	10.67	0.34 (0.00)	0.34 (0.00)	-0.07 (0.00)	-0.07 (0.00)	0.92 (0.00)	0.63 (0.00)	1.00 (0.00)	-0.11 (0.00)	-0.05 (0.03)	0.18 (0.00)	0.10 (0.00)	-0.03 (0.11)	0.03 (0.14)	0.02 (0.48)	0.16 (0.00)	0.22 (0.00)
8. Financial Performance	2.09	1.03	0.57	8.64	0.01 (0,73)	-0.02 (0.43)	0.07 (0.00)	0.12 (0.00)	-0.33 (0.00)	0.04 (0.09)	-0.12 (0.00)	1.00 (0.00)	0.30 (0.00)	-0.14 (0.00)	0.13 (0.00)	0.23 (0.00)	0.15 (0.00)	-0.04 (0.07)	-0.05 (0.03)	-0.06 (0.00)
9. R&D Intensity	0.03	0.05	0.00	0.68	0.03 (0.13)	0.05 (0.03)	0.09 (0.00)	0.16 (0.00)	-0.14 (0.00)	0.27 (0.00)	-0.12 (0.00)	0.33 (0.00)	1.00 (0.00)	-0,37 (0.00)	0.41 (0.00)	0.90 (0.00)	0.67 (0.00)	0.02 (0.22)	0.03 (0.09)	-0.06 (0.00)
10. Capital Intensity	0.49	0.36	0.03	1.61	0.12 (0.00)	0.13 (0.00)	-0.08 (0.00)	-0.11 (0.00)	0.14 (0.00)	-0.18 (0.00)	0.20 (0.00)	-0.17 (0.00)	-0.32 (0.00)	1.00 (0.00)	-0.09 (0.00)	-0.45 (0.00)	-0.42 (0.00)	0.00 (1.00)	0.07 (0.00)	0.19 (0.00)
11 Market uncertainty	2.60	1.74	0.32	8.21	0.03 (0.10)	0.04 (0.11)	0.04 (0.06)	0.10 (0.00)	0.10 (0.00)	0.23 (0.00)	0.13 (0.00)	0.16 (0.00)	0.36 (0.00)	0.01 (0.67)	1.00 (0.00)	0.50 (0.00)	0.40 (0.00)	0.06 (0.01)	0.14 (0.00)	-0.12 (0.00)
12 Technological turbulence	0.04	0.06	0.00	0.49	0.04 (0.07)	0.06 (0.01)	0.06 (0.00)	0.13 (0.00)	-0.00 (0.86)	0.36 (0.00)	0.10 (0.61)	0.26 (0.00)	0.74 (0.00)	-0.38 (0.00)	0.50 (0.00)	1.00 (0.00)	0.73 (0.00)	0.02 (0.49)	0.05 (0.01)	-0.10 (0.00)
13 Technological sophistication	0.31	0.46	0.00	1.00	0.00 (0.83)	0.02 (0.31)	0.11 (0.00)	0.15 (0.00)	0.03 (0.10)	0.34 (0.00)	0.02 (0.26)	0.12 (0.00)	0.58 (0.00)	-0.40 (0.00)	0.31 (0.00)	0.72 (0.00)	1.00 (0.00)	0.01 (0.80)	0.03 (0.16)	-0.08 (0.00)
14 TMT size	5.62	0.88	4.00	9.00	0.05 (0.03)	0.34 (0.11)	-0.02 (0.31)	0.00 (0.84)	0.04 (0.08)	0.02 (0.42)	0.01 (0.70)	-0.05 (0.02)	0.02 (0.31)	0.00 (0.91)	0.06 (0.01)	0.3 (0.19)	0.01 (0.66)	1.00 (0.00)	0.05 (0.01)	-0.07 (0.00)
15 TMT ownership structure	0.36	0.22	0.00	0.95	0.11 (0.00)	0.10 (0.00)	-0.49 (0.00)	-0.39 (0.00)	0.20 (0.00)	0.20 (0.00)	0.19 (0.00)	-0.04 (0.04)	0.05 (0.01)	0.09 (0.00)	0.18 (0.00)	0.11 (0.00)	0.04 (0.08)	0.06 (0.01)	1.00 (0.00)	-0.05 (0.03)
16 CEO duality	0.62	0.48	0.00	1.00	0.06 (0.00)	0.07 (0.00)	0.02 (0.26)	-0.02 (0.36)	0.19 (0.00)	0.03 (0.23)	0.21 (0.00)	-0.05 (0.01)	-0.15 (0.00)	0.15 (0.00)	-0.14 (0.00)	-0.16 (0.00)	-0.08 (0.00)	-0.07 (0.00)	-0.06 (0.00)	1.00 (0.00)

Notes: Table exhibits Spearman's rank-order correlations top right and Pearson's product-moment correlations bottom left with ρ values in parentheses; $N = 2{,}134$

As we have COO presence in only 53.6% of all firm-year observations we shrink our sample size by 990 observations with the inclusion of the COO power moderator and control variable. Accordingly, we tested hypotheses 1 and 2 ex ante in separate models without the COO power variables. We repeated the tests in a second group of models including the COO power moderator and variables to test hypothesis 3. This approach allowed us to test hypotheses 1 and 2 without a potential COO presence selection bias

(which we separately tested for as described below) and served as a first robustness test for the effects investigated in hypotheses 1 and 2. Table 2 exhibits the results of the regression analysis. Model 1-1 contains control variables only. Model 1-2 tests the main effect and model 1-3 includes the main and the first interaction effect without the COO power variables. Models 2-1 to 2-3 are identic in structure to models 1-1 to 1-but include the COO power variables. Model 2-4 additionally contains the second interaction term. Model 2-5 is the full model with the main and both interaction effects. All models are highly significant (p<0.01) and show increasing Wald χ^2 statistics with inclusion of the IV and additional moderators. Despite the drop of 990 firm-year observations between model 1 and 2 all results remain constant for both, the main and interaction effect, indicating a high robustness.

Table 2 – Regression Results: Effect of CEO options on Supply Chain Disruptions

	Model 1			Model 2					Robustness Tests					
Independent variables	**(1-1)**	**(1-2)**	**(1-3)**	**(2-1)**	**(2-2)**	**(2-3)**	**(2-4)**	**(2-5)**	**(3-1)**	**(3-2)**	**(3-3)**	**(3-4)**	**(3-5)**	**(3-6)**
CEO options		0.319**	0.423**		0.341*	0.504**	0.358**	0.507**	0.229**	0.227*	0.580**	0.402**	0.533**	0.502**
		(0.100)	(0.101)		(0.137)	(0.135)	(0.131)	(0.137)	(0.077)	(0.103)	(0.142)	(0.135)	(0.140)	(0.138)
CEO options squared		-0.270**	-0.401**		-0.349*	-0.555**	-0.371**	-0.556**	-0.240**	-0.238**	-0.751**	-0.380**	-0.577**	-0.554**
		(0.101)	(0.104)		(0.138)	(0.148)	(0.131)	(0.150)	(0.069)	(0.079)	(0.160)	(0.129)	(0.149)	(0.149)
Firm Size	0.347†	0.377†	0.356†	0.483*	0.501*	0.459*	0.493*	0.457*	0.298**	0.284**	0.498*	0.487*	0.524**	0.479*
	(0.196)	(0.193)	(0.192)	(0.221)	(0.222)	(0.214)	(0.219)	(0.213)	(0.298)	(0.055)	(0.209)	(0.216)	(0.201)	(0.202)
Financial Slack	-0.008	0.001	0.011	-0.046	-0.032	-0.015	-0.036	-0.023	-0.021	-0.020	-0.038	-0.034	-0.014	-0.027
	(0.084)	(0.083)	(0.083)	(0.109)	(0.110)	(0.109)	(0.109)	(0.109)	(0.054)	(0.057)	(0.106)	(0.107)	(0.107)	(0.110)
Operating Performance	0.159	0.127	0.134	0.061	0.032	0.042	0.019	0.027	0.030	0.044	-0.025	-0.003	0.017	0.007
	(0.194)	(0.195)	(0.191)	(0.223)	(0.224)	(0.216)	(0.219)	(0.212)	(0.107)	(0.041)	(0.209)	(0.215)	(0.203)	(0.200)
Financial Performance	0.030	0.043	0.231	0.068	0.084	0.052	0.060	0.034	0.066†	0.061*	0.048	0.034	0.012	0.027
	(0.059)	(0.062)	(0.061)	(0.077)	(0.095)	(0.075)	(0.066)	(0.064)	(0.035)	(0.031)	(0.072)	(0.074)	(0.067)	(0.070)
R&D Intensity	0.094	0.108†	0.107†	0.149†	0.173*	0.173*	0.183*	0.182*	0.058	0.058	0.193*	0.170*	0.227**	0.177*
	(0.064)	(0.032)	(0.627)	(0.077)	(0.074)	(0.076)	(0.073)	(0.074)	(0.053)	(0.040)	(0.079)	(0.076)	(0.072)	(0.081)
Capital Intensity	0.149*	0.150*	0.152*	0.116	0.113	0.109	0.113	0.111	0.046	0.045*	0.109	0.119	0.116	0.114
	(0.070)	(0.070)	(0.070)	(0.085)	(0.085)	(0.083)	(0.085)	(0.083)	(0.042)	(0.021)	(0.080)	(0.083)	(0.086)	(0.082)
Market uncertainty	0.089	0.100	0.103	0.051	0.075	0.069	0.087	0.081	-0.001	-0.002	0.040	0.048	0.066	0.097
	(0.098)	(0.094)	(0.966)	(0.113)	(0.111)	(0.108)	(0.113)	(0.110)	(0.053)	(0.033)	(0.100)	(0.103)	(0.111)	(0.109)
Technological turbulence	0.100	0.084	0.101	0.055	0.026	0.058	0.017	0.049	-0.006	-0.006	0.072	0.077	0.043	0.052
	(0.078)	(0.076)	(0.079)	(0.098)	(0.095)	(0.095)	(0.093)	(0.094)	(0.069)	(0.051)	(0.093)	(0.095)	(0.095)	(0.098)
Technological sophistication	-0.016	-0.008	-0.033	-0.153	-0.142	-0.151	-0.173	-0.178	-0.047	-0.048	-0.119	-0.184	-0.190	-0.174
	(0.206)	(0.199)	(0.199)	(0.217)	(0.214)	(0.212)	(0.212)	(0.211)	(0.118)	(0.067)	(0.200)	(0.208)	(0.215)	(0.212)
TMT size	0.060†	0.615†	0.602†	0.070	0.065	0.072†	0.073	0.079†	0.065	-0.063	0.076†	0.081†	0.106*	0.080†
	(0.034)	(0.034)	(0.034)	(0.045)	(0.045)	(0.044)	(0.045)	(0.044)	(0.035)	(0.031)	(0.042)	(0.044)	(0.485)	(0.044)
TMT ownership structure	0.013	0.518	0.054	0.067	0.099*	0.097†	0.073†	0.095†	0.084	0.086**	0.091†	0.107*	0.101†	0.092†
	(0.041)	(0.043)	(0.044)	(0.046)	(0.050)	(0.053)	(0.049)	(0.051)	(0.041)	(0.031)	(0.050)	(0.496)	(0.051)	(0.052)
CEO duality	-0.944	-0.892	-0.095	-0.097	-0.125	-0.122	-0.118	-0.115	-0.088	-0.086*	-0.081	-0.098	-0.117	-0.144
	(0.097)	(0.010)	(0.097)	(0.138)	(0.142)	(0.136)	(0.135)	(0.132)	(0.070)	(0.042)	(0.127)	(0.131)	(0.133)	(0.141)
Supply chain disruptions (lagged)	0.248**	0.246**	0.248**	0.252**	0.257**	0.273**	0.273**	(0.286**	0.606**	0.606**	0.282**	0.276**	0.274**	0.286**
	(0.043)	(0.044)	(0.044)	(0.053)	(0.053)	(0.528)	(0.049)	(0.049)	(0.061)	(0.032)	(0.047)	(0.047)	(0.050)	(0.049)
COO relative power				-0.059	-0.050	-0.059	-0.081	-0.087	-0.047	-0.047†	-0.105*	-0.106*	-0.107†	-0.087†
				(0.056)	(0.056)	(0.056)	(0.051)	(0.052)	(0.036)	(0.027)	(0.051)	(0.053)	(0.057)	(0.053)
Market uncertainty x CEO options			-0.205*			-0.347**		-0.327**	-1.44*	-0.140†	-0.5117**	-0.391**	-0.323**	-0.336**
			(0.090)			(0.125)		(0.123)	(0.072)	(0.082)	(0.127)	(0.132)	(0.121)	(0.127)
Market uncertainty x CEO options squared			0.204*			0.355**		0.338**	0.158*	0.153*	0.526**	0.356**	0.338**	0.347**
			(0.087)			(0.106)		(0.106)	(0.063)	(0.068)	(0.120)	(0.114)	(0.105)	(0.110)
COO relative power x CEO options							-0.340**	-0.316**	-0.197*	-0.198**	-0.267	-0.343	-0.314**	-0.310**
							(0.102)	(0.098)	(0.079)	(0.050)	(0.108)*	(0.117)**	(0.097)	(0.097)
COO relative power x CEO options squared							0.277**	0.243**	0.176**	0.179**	0.124	0.235*	0.243**	0.237**
							(0.097)	(0.082)	(0.062)	(0.036)	(0.103)	(0.104)	(0.081)	(0.082)
Inverse Mills ratio (IMR)													-0.106	
													(0.080)	
CEO options (predicted)														0.160
														(0.332)
CEO options squared (predicted)														-0.144
														(0.247)
Observations	2,134	2,134	2,134	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144
Number of firms	223	223	223	205	205	205	205	205	205	205	205	205	205	205
Wald χ^2 / R^2	1920.16***	2036.03***	2151.58***	467.69***	551.63***	630.06***	570.21***	654.27***	0.377**	0.377**	748.17**	572.10**	662.28**	710.75**

Notes: Robust standard errors in parentheses. Industry and year dummies included but not shown
† p<0.10; * p<0.05; ** p<0.01; two-tailed tests

Hypothesis 1 theorized an inverted U-shape relationship between CEO options and supply chain disruptions. Necessary condition for such a curvilinear relationship is a negative second-order effect of the IV in our regression model. In support of Hypothesis 1, model 1-2 shows that CEO options have a highly significant effect on supply chain disruptions and the second-order effect is significantly negative. In hypotheses 2 and 3 we theorized a flattening in the inverted U-shape relationship between CEO options and supply chain disruptions by our interaction effects. A flattening (or steeping) of a quadric relationship requires the regression coefficient between the interaction effect and the squared IV to be significant and positive (negative) (Haans et al., 2016). As depicted in our full model 2-5 the coefficients of both interaction terms are significant and negative, with their corresponding second-order effects being significantly positive. H1, H2, and H3, thus, are strongly supported.

Given the stable results of the main and the first interaction effect in both the model with the COO variables (N = 2,134) and the model without the COO variables (N = 1,144), our estimations show high robustness. Still, we conducted multiple additional checks to ensure a high robustness of our findings. Our main analysis was conducted using a

negative binominal distribution best fitting our count data DV. To ensure our results are not driven by model specifications, we reran the analysis with an ordinary least square (OLS) random effects model with robust standard errors (model 3-1) and with Driscoll-Kraay standard errors to rule out cross-sectional correlation (model 3-2) (Shah et al., 2016). Both models confirm the results presented above. Next, we reran our main model with two different specifications of our IV using an unweighted average in model 3-3 and annual values in model 3-4. Again, our estimations are confirmed.

Firms with COOs might be substantially different from firms without COOs. Unobserved factors (e.g. operations management experience of the CEO) might influence both, the decision to have a COO and supply chain related outcomes and bias the results of our study. To test for this potential sample selection bias, we applied a Heckman two-stage selection model (1979) in line with prior TMT research (Kim et al., 2016) and included an inverse Mills ratio (IMR) predicting COO presence in all our models 2-1 to 2-5. As the IMR is insignificant and all other results remain robust, our analysis does not suffer from a sample section bias. The results including the IMR are shown for the full model in model 3-5. Moreover, we drew on multiple means to lower the risk of potential endogeneity in our study. Among other measures, we created an endogeneity control by regressing CEO options in $t-1$ on eleven of its potential firm-, industry-, and TMT-level antecedents in $t-2$ and including this predicted IV as endogeneity controls in our models 2-1 to 2-5. Again, the results remained robust in all models. We show the results for the full model in model 3-6. Given the results of the tests above, reverse causality and endogeneity do not appear to be a problem in our study.

Discussion

Theoretical Implications

Our findings have important implications for research on SCDs and the extensive literature on the impact of CEO options on executive behavior. First, we extend operations management research by investigating CEO options as an organizational antecedent of SCDs. We empirically show, that CEO options – especially at medium levels – increase the frequency of SCDs. Second, we contribute to strategic management research which investigates the effects of executive stock options. While research on this topic has long been dominated by two schools of thought – agency theory expecting more risky decisions and behavioral agency theory expecting less risky decision as consequences of stock options – our research conceptually and empirically adds a more nuanced assessment of CEO options to prevailing literature. Third, this study identifies both organizational and environmental factors that have significant impact on CEO option-induced risk-taking. Both, market uncertainty and relative COO power have a flattening effect on the relationship between CEO options and SCDs, thus, diminishing the CEOs willingness to take disproportionate risks with regards to operations management. As of today, research on performance effects of COOs is ambiguous (Hambrick & Cannella, 2004; Hendricks et al., 2014). Our findings underline the importance of a COO at equal terms with regards to supply chain stability and further confirms research underlining the importance of operations capabilities in the TMT as a source of competitive advantage.

Finally, our study advances strategic and operations management research from a methodological standpoint. As the algorithm is not limited to a predefined dictionary of relevant terms but constantly evolves based on the growing training data set, this approach might be an interesting alternative to dictionary-based approaches. Especially in times of "big data" that can hardly be managed manually anymore and for relatively new areas of research where no established dictionaries exist, this approach can become increasingly relevant.

Practical Implications

Our findings bring about two important implications for decision makers. First, we advise decision makers to carefully select and combine different tools of executive compensation. Whereas CEO options might not be the best incentive used by itself, they still might be a valuable tool to induce additional risk-taking if required. However, this decision needs to be made very deliberately, keeping in mind potential risks. We, thus, recommend decision makers to balance CEO options with other means of executive compensation such as stock that also have a downside potential and reward sustainable decision making. Second, if using CEO options, we advise decision makers to embed their usage in an organizational setting that either does not facilitate strategic individual actions by the CEO or, as this study has proven, has a relatively low power distance in its TMT to enable mutual control among executives.

Limitations and Avenues for Further Research

Our study is subject to certain limitations that provide interesting avenues for further research. First, while our study focuses on the effects of CEO options, future research should investigate the interplay of CEO options with other prevailing means of executive compensation (e.g. stock ownership) in predicting supply chain stability. Second, whereas we focused on CEO compensation, it might be of interest to investigate effects of additional TMT characteristics on supply chain stability. Third, research has a strong focus on the CEO when investigating the effects of stock options. Future studies could expand this scope to other TMT members' roles and strategic outcomes in their areas of responsibility to better understand potentially diverging interests between different functional strategies.

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Linking procedural and interactional justice perceptions with organizational commitment through formation of perceived organizational support

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Abstract

Building on the social exchange perspective and organizational support theory, this study aims to evaluate the relationship between truck driver's procedural and interactional justice perceptions and their affective commitment to their employers. We set out a *Transactional Justice Interaction Reference Model* and refine it by scientific testing. The evidence is based on survey data collected at a truck-driving school near Frankfurt, Germany, providing update and safety classes to long-standing truck drivers in logistics and SCM. The results are derived by using structural equation modelling and indicate that perceived organizational support plays a mediating positive effect on developing organizational commitment.

Keywords: **o**rganizational justice in employer-employee relationships, truck drivers' perceived organizational support, relational contract in transportation industry

Introduction

Since 2010, the demand for freight transport in German road haulage has been rising steadily. Nevertheless, due to an acute driver shortage, German haulage companies and freight carriers often cannot profit from the constant growth of the German transport sector due to an acute lack of prospective job applicants (Schierge, 2014). At the same time, the phenomenon of occupational driver shortage is strongly interwoven with increasing changes in employment relations, leading to the assessment that one of the most serious entrepreneur risk for German carriers is high driver fluctuation (Peirowfeiz and Large, 2013). Additionally, the German transport industry is currently not only facing a shortage in drivers but also a competition over the quality of B2B services, of which

truck drivers, due to their boundary-spanning role, are an important part (Peirowfeiz and Large, 2013).

Employee commitment, also known as the relational contract, is known to bear beneficial characteristics for operational success. This is more so for customer-facing, boundary-spanning roles such as truck drivers. To address a gap in knowledge in the transport and logistics industry, our paper presents a quantitative assessment of employee satisfaction in German transport organizations.

Recognizing the desirability of employee commitment in their role for ensuring competitive advantage, the focus of this study shifts from remuneration (establishing merit-based distributive justice) towards information policy and treatment. The procedural and interactional qualities or justice are tested as to their significance for dedicated in-role behaviour. More specifically this research aims to answer the following questions:

RQ1: To which extent do procedural and interactional justice in organizations positively affect truck drivers' experience of being managed?

RQ2: By which justice-induced interaction mechanism is truck drivers' dedication towards their workplace significantly improved?

Based on a recent, personally administered, survey among 62 truck drivers of various employers, a structural employee commitment model based on an extensive literature review was tested. Our research is aiming at depicting potential improvements as to truck driver retention in times of employee scarcity by means of transparency, communication and courteous treatment. The subsequent sections will first provide an account on the extant literature in the field, followed by the methodological setup and the research procedures. After the discussion of the scientific results, a brief conclusion and managerial implication will be provided.

Literature Review

The driver shortage problem is not new and is also acute not only in more developed countries (Rauwald and Schmidt, 2012; Sheffi, 2015) but also in emerging countries e.g. India (Dash, 2011) or Brazil (Anon., 2014). For this reason, there has been a lot of research conducted in many countries but mostly in the US, Canada, Australia, UK, France and to a certain extend in Germany. The results of this research suggest that shortage is the result of numerous and often inter-related factors.

Some of the reasons behind driver shortage are specific to individual countries. Scholars have found increased regulation, such as in the US (Morris, 2015) or in the EU, especially in Germany (Ball, 2011) to be an impediment for employee recruitment and retention. The age structure of the truck drivers in a specific population (Soergel, 2015) varies among countries, as do infrastructural conditions e.g. the lack of parking space along highways like in Germany (Peirowfeiz and Large, 2013). Scholars have also found that general higher qualification standards and requirements may crowd out the potential for recruits in the transportation sector, as observed e.g. in the EU member states and particularly in Germany (McKinnon *et al.*, 2017). The lack of personnel is however also founded in ubiquitous attributes, low wage rates making the occupation relatively unattractive anywhere in the world (Sheffi, 2015).

To this add truck drivers' temporal and ergonomic working conditions that cause emotional exhaustion (Kemp, Kopp and Kemp, 2013) and physical strain (Robb and

Mansfield, 2007). Scholars have found the truck drivers' profession to maintain a poor public image and to undergo constant socio-technological changes, particularly due to increasingly refined driving performance monitoring by on-board devices (European Parliament, 2009; Adell, 2010; Ghazizadeh *et al.*, 2017). Finally, extant research lists employer-related phenomena as world-wide impediments to recruiting truck drivers, namely perceived organisational injustice (Cantor, Macdonald and Crum, 2011) and the lack of organisational support (Fournier, Lamontagne and Gagnon, 2012; Kemp, Kopp and Kemp, 2013).

Despite the severe impact on business operations, comparatively few studies in the German research are addressing these generic factors contributing of truck driver shortage. Investigations carried out in Germany to date focus mainly on the difficult working conditions, such as long and irregular hours or, in the case of long-distance trucking, long absence hours from home (Large, Breitling and Kramer, 2014). Furthermore, amounts of earnings/remuneration (Peirowfeiz and Large, 2013) and, in places, the time and performance pressure perceived by professional drivers (Roth *et al.*, 2004) have been discussed as a cause for driver shortage. Apart from this, the aspect of the lack of organisational support is acknowledged by Large et al. (2014). The authors carried out an investigation among professional truck drivers in German-speaking regions and inquired about emotional variables, such as perceived organizational support and affective commitment.

However, the German literature exhibits a remarkable absence of an explicit discussion of organisational justice in the context of professional drivers. Nonetheless, surveys on operational practice show that truck-driving personnel tend to churn on the basis of workplace-related interactions perceived as unfair (Gaida, 2008; Peirowfeiz and Large, 2013).

Transactional Justice Interaction Reference Model

Types of justice

This study is based on the assumption that the concept of organisational justice denotes a multi-factorial structure. Next to distributive justice, which is not being included in this work, procedural and interactional aspects play a crucial role in theory and professional practice (Cropanzano and Ambrose, 2015). This arises from the consideration that, in addition to the perception of fairness of formal structures and processes, employees of an organisation also pay attention to how they are dealt with during the execution of determined processes (Greenberg, 1993).

Procedural justice (PJ) refers to the procedure for decision-making processes. Decisive for the perception of fairness is whether the persons affected can have an influence on the procedure and the result. Moreover, consistent adherence to rules and ethical standards as unbiased managerial decisions bear further relevance (Thibaut and Walker, 1975; Leventhal, 1980).

In addition, interactional aspects of fairness assessment include two more significant aspects as follows:

(1) Interpersonal justice refers to the perception of the social interaction in the context of the decision-making process and hints toward the degree of courtesy, dignity and respect a person is treated with (Bies and Moag, 1986; Greenberg, 1993).

(2) Informational justice refers to whether the informative behaviour of decision-making persons is honest, whether justifications and relevant information is being included, and whether the information is being given in a timely manner (Bies and Moag,

1986; Greenberg, 1993; Shapiro, Buttner and Barry, 1994). In the present study, these two aspects are measured on company level which is why a high correlation can be expected (Ambrose and Schminke, 2003). Therefore, both will be considered as one dimension named perceived *interactional justice (IJ)*.

According to the agent-system model of organisational justice (Tyler and Bies, 1990) procedural justice perceptions should be associated with organizationally directed outcomes as procedures may be viewed as institutionalized while interactional justice is commonly associated with organizational agents (supervisors) enacting the procedures (Bies and Moag, 1986). Nevertheless, Colquitt et al. (2001) point out that employees may not exclusively link interactional fairness to supervisors and procedural fairness to organizations. A multi-focal perspective asserts that perceptions of unfairness can be attributed to a number of different sources (Byrne, 1999; Rupp and Cropanzano, 2002).

Perceived organizational support (POS) and affective commitment to the organization (ACO)

For the purpose of this study and based on the organisational support theory, it is assumed that individually perceived organizational justice has a close correlation to the development of feelings and beliefs (Rhoades and Eisenberger, 2002). Professional truck drivers who are convinced that their organization treats them fairly and demonstrate circumspection as to the drivers' quotidian necessities are reaffirmed that their well-being is being sought and their efforts appreciated by their organisation.

According to the social exchange theory, this POS support evokes a sense of conscientiousness and organisation in-role identification, commanding a particularly positive effect on the reciprocal relationship between employee and organization (Eisenberger et al., 1986). Overall, it can be assumed that the POS mediates between processes or the perception of organisational justice and the individual attitudes of an employee towards the organization (Allen, Shore and Griffeth, 2003).

Particular relevance for this context is attributed to the phenomenon of the ACO which describes the degree of socio-psychological connection to an organisation (Rhoades, Eisenberger and Armeli, 2001), bearing significance for an employee's continuance intentions (Gautam, Van Dick and Wagner, 2004). Accordingly, a number of studies show a positive correlation between lack of affective commitment and the intention to quit (Meyer et al., 2002). This leads to this study's claim that procedural and interactional justice – each in their own right – generate positive perceptions of being supported by the organization. This well-being we claim to foster affective commitment towards the workplace. In our claim, POS thus serves as a mediating variable between procedural and interactional justice on the one hand and affective commitment in an organization on the other.

Hypotheses

The above discussions lead to the Transactional Justice Interaction Reference Model's following hypotheses:

H1: Perceived organizational support mediates the effect of perceived organizational procedural justice on truck driver’s affective commitment.

H2: Perceived organizational support mediates the effect of perceived organizational interactional justice on truck driver’s affective commitment.

The research model is presented in Figure 1.

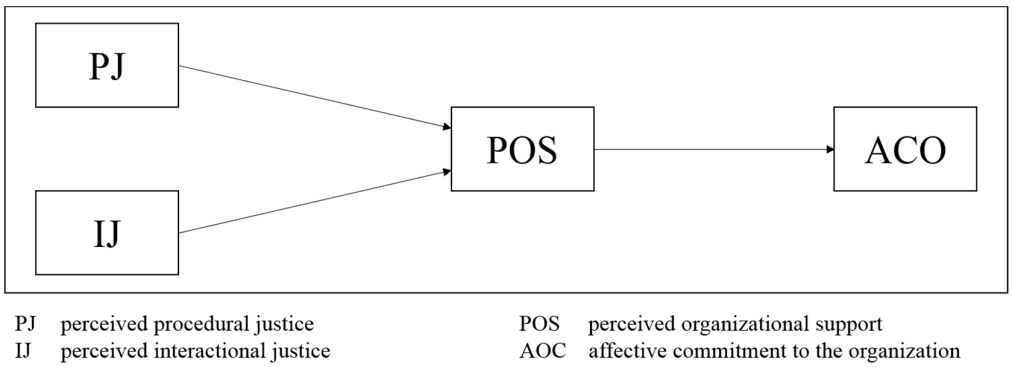


Figure 1: Research framework

Methods

Instruments

Maintaining an interpretive philosophical stance, the methodology was based on quantitative questionnaires asking for respondents' perceptions on a measured scale. A reflective measurement model based on Greenberg (1993), Byrne (1999), Cropanzano *et al.* (2001) and (Müller, Kärcher and Kals, 2011) is developed, holistically representing organizational perception as experienced by truck drivers in their respective company. The underlying factor structure is validated by a confirmatory factor analysis.

The measurement of the POS is operationalized by select qualities set out by Eisenberger *et al.* (1986). Affective Commitment is elucidated by standardized subjects described by Felfe *et al.* (2014). All dimensions are tested on a 5-point Likert scale. The applicability of all measurement scales is verified in a pretest with twelve respondents and adjusted accordingly. Control variables are set out as age, duration of organizational employment and qualification.

Sampling

As this study is about employee retention, the stabilized perception of highly desirable long-standing truck drivers is particularly relevant. 62 professional drivers were surveyed using a standardised questionnaire. The research was carried out in close cooperation with a truck-driving school near Frankfurt, Germany, providing update and safety classes to long-standing truck drivers of various logistics and supply chain companies. Therefore, the sampling consisted of safety-aware, skill-oriented drivers with a retention of at least three years in their profession. The questionnaires were distributed on-site and re-collected the same day, ensuring a high response rate. The results were administered to AMOS24 for covariant factor analysis and reliability testing.

Measurement criteria

In this section the fit between the theoretical model and the data was assessed. Five usual goodness-of-fit indices were used to assess overall model fit, namely Bentler's (1989) comparative fit index (CFI), Bentler and Bonett's (1980) non-normed fit index (NNFI), Trucker-Lewis index (TLI), discrepancy divided by degree of freedom (CMIN/df) and root mean square error of approximation (RMSEA) (Steiger, 1990) and due to the small sample the standardized root mean square residual (SRMR) as suggested by Byrne

(2016). Values higher than the 0.90 cut-off for the CFI and TLI, and a value lower than 0,08 for the RMSEA suggest an appropriate fit between the model and the data (Browne and Cudeck, 1993; Baumgartner and Homburg, 1996) while a value under 0,6 for the SRMR is appreciated in a well-fitting model (Byrne, 2016).

For scale reliability, the Cronbach's alpha was measured and a cut-off value of 0.7 was considered as suggested by (Garver and Mentzer, 1999).

Data analysis

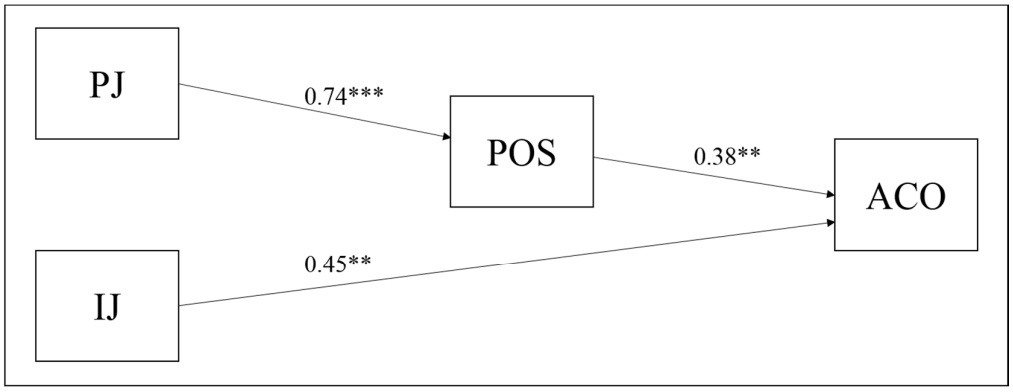
Measurement model

A confirmatory factor analyses was conducted for the constructs in order to asses one-dimensionality, validity, and reliability of the theoretical model. On the basis of the analysis and sample size, the model shows acceptable fit with the data: CFI = 0,953, TLI = 0,941, RMSEA = 0,082, SRMR = 0,060). The minimum sample discrepancy (CMIN/df = 1,414) was below the cut-off 3-0 (Simon and Paper, 2007).

The corresponding measures for scale reliability were: PJ (four items; 0.922), IJ (five items, 0.919), POS (three items; 0.853) and AOC (three items, 0.831).

Structural Model

Our statistical result showed the following degrees of significance among justice-induced qualities in truck drivers' workplace-interactions as in figure 2. On the basis of the analysis and sample size, the model shows also acceptable fit with the data: CFI = 0,924, TLI = 0,907, RMSEA = 0,099, SRMR = 0,062). The minimum sample discrepancy (CMIN/df = 1,650) was also below the cut-off.



PJ perceived procedural justice
IJ perceived interactional justice
POS perceived organizational support
AOC affective commitment to the organization

*** p < 0.001; ** p < 0.01

Figure 2: Statistical findings; Transactional Justice Interaction Reference Model

Discussion

Quantitative evidence on the Transactional Justice Interaction Reference Model as depicted in Figure 2 reveals that a direct relationship between procedural justice (PJ) and affective commitment (ACO) can not be established. However, perceived organizational support (POS) is fostered by procedural justice, while reinforcing affective commitment, thus acting as a mediator between the two qualities. This is in line with findings of Rhoades and Eisenberger (2002) who assert that the perceived organizational support will positively affect in-role dedication. It is also consistent with Bies and Moag (1986) as well as Tyler and Bies (1990) who link procedural justice perceptions to institutions. Our hypothesis *H1: Perceived organizational support mediates the effect of perceived organizational procedural justice on truck driver's affective commitment,* can thus be considered as verified.

However, as shown in Figure 2, there is a significant correlation between interactional justice (IJ) and affective commitment (ACO). The assumed moderating effect of perceived organizational support (POS) can not be established as it will not reinforce the direct influence of IJ and ACO. Notable scholars (Bies and Moag, 1986; Tyler and Bies, 1990) in fact link interactional justice with organizational agents rather than with the organization itself. It however contradicts the more general claims of Allen, Shore and Griffeth (2003) linking overall organizational justice to a dedicated attitude only if perceived organizational support can be established. Our hypothesis set out as *H2: Perceived organizational support mediates the effect of perceived organizational interactional justice on truck driver's affective commitment*, can thus not be verified in practice.

Our research questions stated initially can thus be answered as follows:

RQ1: To which extent do procedural and interactional justice in organizations positively affect truck drivers' experience of being managed?
There is strong first evidence among experienced German truck drivers that procedural as well as interactional justice will have a significant impact of in-role satisfaction.

RQ2: By which justice-induced interaction mechanism is truck drivers' dedication towards their workplace significantly improved?
Our studies in the German truck driving industries suggest that procedural justice will have a positive effect on perceived organizational support which in turn reinforces the truck drivers' affective commitment. Interactional justice will in turn directly foster affective commitment.

Managerial Implications

Our findings bear managerial implications in, but presumably not limited to, managing German truck drivers.

First, organizational procedures have to be aligned with the driving personnel's operational and socio-technological requirements in order to convey a perception of being supported within the organization. This will, according to our current findings, enable a more dedicated and conscientious in-role behaviour.

Second, managers in person have to constantly review their mode of information dissemination in the workforce and their behaviour in interaction with truck drivers. Apart from the situation in the company, this behaviour will directly influence the psychological contract their truck driving staff can develop.

Limitations and further research

Our findings contribute by identifying gaps between theory and practice against the background of non-distributive dimensions of justice, as well as the by developing a generic structural model for testing in-role commitment in the context of truck drivers.

Limitations of generalizability apply due to the regional focus in Germany, the particular industries as well as the current economic boom and the overall sample size, which is small compared to the large number of truck drivers in Germany. Another limitation is that all measures are based on respondents' situated perception, which are not only subject to interpretation but also to cultural and organisational understanding and may change over time. Finally, the habitat of truck driving schools may evoke particular responses that may have to be fortified in different settings in the future.

Finally, this research rises some managerial and academic questions for the future:

How can drivers, despite their frequent physical absence from the workplace, be empowered as to obtaining the necessary and reassuring processual and informational transparency and support that makes them dedicated towards their role?

Which socio-cultural and socio-technological factors are particularly capable of creating the strong perception of being treated in a courteous, fair, and amiable manner? Is there a corporate culture that particularly fosters such positive perceptions?

These constituents of non-distributive justice will require further academic scrutiny as well as managerial attention.

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Exploring the relationship between emotional intelligence, strategies and linkages, and operational effectiveness

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Abstract

The interaction between employees and clients is a significant factor in reaching operational effectiveness, and one of the key aspects which define the result of human interaction is emotional intelligence. However, the extent to which emotional intelligence contributes to the acceptance of innovation and therefore the improvement of operational effectiveness, still needs to be explored. Based on data collected from 150 surveys, and using Structural Equation Modeling, this study found that there is no influence of emotional intelligence on the acceptance of the strategies but it has a strong impact on the linkages and operational effectiveness.

Keywords: Emotional Intelligence, Strategies, Linkages, Operational effectiveness

Introduction

In this globalized market, competitiveness is a vital factor for the survivability and improvement of performance (Porter, 1996). Central to competitiveness is the sustainability of the competitive potential and managing the competitive process and thus the operational effectiveness. Hence, the effectiveness of management and strategies in organizing the processes and activities plays a fundamental role in the alignment of this dimension (Buckley et al., 1988). The competitiveness of the firm is based on operational effectiveness and organizations dedicate significant amounts of time and resources to develop strategies to increase performance through operational effectiveness (Santa et al., 2017). Additionally, the interaction between employees and clients is a significant factor in applying innovation strategies aimed at reaching operational effectiveness, and one of the key aspects which define the result of human interaction is emotional intelligence (Birdi et al., 2008; Bowen et al., 1990).

The existing literature on emotional intelligence in Colombia is scarce and based mainly on the effects that emotional intelligence has on human behavior and human interaction related to leadership but not on innovation or the operational effectiveness of organizations (Acosta-Prado et al., 2015; Sadri et al., 2011; Zárate Torres and Matviuk, 2012). The fact that there is a need to explore the role of emotional intelligence in work outcomes (Wong and Law, 2002), and particularly in strategy and linkages, and its impact on operational effectiveness, together with

Goleman's (1998) observation that emotional intelligence is related to job performance, motivates this study. Therefore, this exploratory endeavor seeks to investigate whether aspects of emotional intelligence impact on strategies, linkages, and operational effectiveness, based on quantitative data collected from organizations in Colombia.

Emotional Intelligence

The concept of emotional intelligence is based on the idea of social intelligence identified by Thorndike in 1920. Social intelligence is defined as the ability to understand individuals and act intelligently in human relations (Thorndike, 1920). Later on, Gardner (1993) included social intelligence into the framework of his theory of multiple intelligences and concluded that it is constituted by interpersonal and intrapersonal intelligence. The concept of intrapersonal intelligence comprises the ability to symbolize a set of different and complex feelings while the concept of interpersonal intelligence is the ability to identify, make distinctions, and notice the feelings of other individuals (Gardner, 1993). The judgement and introduction of emotional intelligence competencies started with research on talent and, initially, such competencies were considered to be abilities and part of the personality of every individual. (McClelland et al., 1958). Later, in the early seventies, research focused on these abilities and changed the label into competencies (McClelland, 1973). Hence, emotional intelligence cannot be considered as a part of an individual's personality (Law et al., 2004). According to Boyatzis (1982), competencies are defined as any underlying characteristics of the individual that lead to superior performance. Therefore, emotional intelligence is a competency related to human behavior with goal of understanding people or gaining prestige by using empathy (Boyatzis, 2008).

Emotional intelligence recognizes and uses emotional information to gain influence over other individuals and obtain a superior personal or collective performance (Mayer and Geher, 1996). Initially, emotional intelligence was thought to comprise three mental processes: assessment and expression of one's own emotions and those of others, regulation of one's own and others' emotions, and use of emotions (Mayer and Geher, 1996; Salovey and Grewal, 2005). Further refinement of the concept of emotional intelligence added a fourth dimension. Accordingly, the four key dimensions of emotional intelligence are now considered to be appraisal and expression of emotion in the self (SEA), appraisal and recognition of emotion in others (OEA), regulation of emotion in the self (ROE), and use of emotion to facilitate performance (UOE) (Mayer and Salovey, 1997; Salovey and Mayer, 1990; Wong and Law, 2002).

Appraisal and expression of emotion in the self: This concept relates to the ability of the individual to understand their own deep emotions and the ability to express them naturally (SEA).

Appraisal and recognition of emotion in others: This concept relates to the ability to perceive and understand the emotions of other individuals and react accordingly (OEA).

Regulation of emotion in the self: This concept relates to the ability to auto-regulate the own emotions (ROE).

Use of emotion to facilitate performance: This concept relates to the ability of individuals to use their own emotions to enhance personal and collective performance (UOE).

All four dimensions determine the creation of emotional linkages between different counterparts. However, this article will consider only SEA, which is defined as the ability of individuals to understand their deep emotions and to express these emotions naturally, and UOE, which is defined as the ability of individuals to make use of their emotions by directing them towards constructive activities and personal performance (Wong and Law, 2002).

Linkages

Linkages are the key element in human and organizational interaction. Both persons and organizations depend on linkages to improve organizational and personal performance and

generate operational effectiveness. Linkages facilitate the exchange of resources, capabilities, and knowledge and are vital in developing an effective strategy to increase firm performance. Linkages also are perceived to have a strong relationship with the quality of the service, the quality of the system, and performance, fundamental in operational effectiveness (Coo and Verma, 2002). Linkages play an important role in the strategic development of any organization. Without linkages, innovation is difficult to achieve. Innovation depends on how the companies are linked together. Linkage blocks can be complementary blocks made up of firms from different strategic groups with complementary capabilities or competencies, or pooling blocks composed of firms from the same strategic group. Any organization can be part of one, both, or none of the blocks (Nohria and Garcia-Pont, 1991; Roper and Love, 2018). In that context, Cassiman et al. (2010) maintains that firms that are using efficient linkages have superior innovation and organizational performance.

It has to be emphasized that organizations are made up of different persons, who interact internally and externally. Therefore, any linkages between organizations are based on personal linkages. Emotional intelligence is the key driver of behavior of any employee in any organization and plays an important role in the success of any person within an organization (Abraham, 1999; Carmeli, 2003). Linkages are closely related to emotional intelligence since human behavior facilitates or prevents linkages. Emotional intelligence improves leadership abilities and the interaction between members of different groups and organizations, facilitating the network relationship between them (Leban and Zulauf, 2004). Emotional intelligence is also a moderator to emotional and behavioral reactions with other people and defines how strategies of interaction and linkages are built up (Freshman and Rubino, 2004; Jordan et al., 2002; Lopes et al., 2004). This clearly supports a relationship between linkages, emotional intelligence, and organizational performance.

Strategies

Operational effectiveness (OE) is a primary competence of any organization in establishing processes that encourage organizations to exceed customer expectations (Santa et al., 2014). OE can also be crucial in defining the competitiveness of an organization. In that sense, organizations need to operate better and faster than their competitors, otherwise, they lose their competitive advantage (Tuturea and Rotaru, 2012). To achieve OE, organizations develop different strategies including defining long-term objectives, the methods to achieve them, and ensuring the necessary resources. How the goals will be achieved is not specified by the strategy. In this sense, planning and strategy are different concepts.

Strategies make the difference in each market for the firm (Hendela et al., 2017). As a consequence, the combination of operational efficiency and strategic flexibility is the imperative requirement for reaching peak performance (Boer et al., 2006; Johnson, 2006). Emotional intelligence facilitates the implementation of strategy in any organization. Today's business requires reducing costs, increasing customer satisfaction, and enhancing firm performance. To reach these goals, organizations implement different strategies, such as changing processes, installing project management teams, or facilitating communication between different actors inside and outside the organization. Such strategies are implemented by different individuals and require a transformational leadership style. Emotional intelligence capabilities allow the leader to use his/her transformational power to foster the strategies defined by management and therefore reach organizational goals (Kilduff et al., 2010; Leban and Zulauf, 2004).

Operational effectiveness

Markets and environment change every day, and competition is fierce. To any organization trying to survive in the market such conditions are threats and affect their performance. Organizations answer the challenge by improving internal processes, making them more

efficient and therefore reducing operational costs (Belton, 2017; Helfat and Martin, 2014; Lin et al., 2016; Pisano, 2017; Prajogo et al., 2018; Teece et al., 1997). Two different generic strategies are employed to reach sustainable competitive advantage: Cost leadership and Differentiation (Dess and Davis, 1984; Huang et al., 2015; Porter, 2004). Clearly, OE is part of cost leadership strategy and, hence, a substantial driver of the organization's performance. Undoubtedly, performance has significant impact on competitiveness. Therefore, an organization needs to focus on the dimensions of speed, flexibility, reliability, cost, and quality (Hill, 2005; Santa et al., 2014; Singh et al., 2018).

Porter defines OE as performing activities different and in a better way than the competitors. This definition includes efficiency, but it is not limited to it. Any activity that allows the firm to process its input in a more efficient or better way than their competitors can be judged as improving OE (Porter, 1996; Porter, 2013). Tuturea & Rotaru (2012) make a distinction between strategy and OE, but highlight that both dimensions are necessary to improve performance and gain competitive advantage over competitors. Therefore, organizational success is based on OE, a core capability of any organization. OE allows the firm to act better and faster than their competitors and offer value-adding services or products, exceeding customers' expectations (Namnai et al., 2015; Porter, 1996; Teece et al., 2016).

One of the key activities of the organization to enhance OE is the capability to measure, control and improve the processes. Any measure with the objective to eliminate waste, reduce costs, and use modern and efficient technologies will make better use of scarce resources (Porter, 1996). Difficulties arise when there are no valid or commonly accepted standards to measure performance. Uncertainty in measurement methodologies is more frequent within the service environment than in manufacturing sectors, since service industries are more prone to human interaction and measuring human interaction is more difficult (Phillips and Jeong, 2001). Another difficulty arises when benefits are not only quantitative, but also qualitative (Brigham and Ehrhardt, 2017; Ehrhardt and Brigham, 2015; Gomes et al., 2007; Gomes et al., 2008). Defining the primary and supporting activities of the firm at any point of the production/service process for both internal and external customers is an adequate start to solving the problem. As a second step, the organization can define how to add value at every point of the process or value chain, in accordance with their needs, objectives, and goals (Jansen et al., 2006; Najafi-Tavani et al., 2018; Rosenbusch et al., 2011).

The operational effectiveness dimension of speed refers to the answer time of the organization to adapt to changes in market condition and customers' requirements. Constant market changes require fast answers from the organization, not only in delivering new products or services, but also in process changes (Phillips and Jeong, 2001; Tidd and Bessant, 2009).

Flexibility is a key factor in any organization and is considered a core capability, whether the firm offers services or products, or is a profit-orientated or a non-profit organization (Slack et al., 2006).

Cost performance consists in being more efficient and organizing and aligning processes to generate a minimum of waste in all organizational activities (Russell and Taylor, 2008). Cost performance considers the relationship between cost and reaching the organizational goals at the lowest price (Bisbe and Otley, 2004).

Quality has many aspects. Satisfying customers' requirements and offering products they need is one facet. Zero defect production is another feature and impacts heavily on cost performance (Love et al., 1995). But quality also considers service methods, post-sale service, service facilities and location, service personnel, service consistency, response attitude, repair quality and any other characteristics that increase customer satisfaction (Yang, 2011).

Research model and hypotheses

From the perspective of work satisfaction, emotions become the mediator between emotional intelligence and commitment to the organization. Such commitment is reflected in better

behavior and performance. Therefore, a team member with a high level of emotional intelligence will have a significant impact on the team's effectiveness (Othman et al., 2008). Furthermore, a team leader with a high level of emotional intelligence recognizes emotions and is able to use this information to influence the team members (Amabile et al., 2005; George, 2000; Liu and Liu, 2013). Therefore, we propose the following hypotheses:

H1a: There is a direct impact of SEA on Linkages

H1b: There is a direct impact of SEA on Strategies

H1c: There is a direct impact of UOE on Linkages

H1d: There is a direct impact UOE on Strategies

H2a: There is a direct impact of SEA on OE

H2b: There is a direct impact of UOE on OE

Strategies define how to reach expected goals and are therefore vital to OE (Papke-Shields and Malhotra, 2001). Linkages facilitate the exchange of knowledge and resources, and have a strong impact on the quality of the service, the quality of the system, and performance, fundamental aspects of OE (Coo and Verma, 2002). In view of these aspects, we propose the following hypotheses:

H3: There is a direct impact of Strategies on Linkages

H4: There is a direct impact of Strategies on OE

H5: There is a direct impact of Linkages on OE

Appraisal and expression of emotion in the self (SEA) refers to the ability to identify, know, and understand one's own emotions and their effect on other individuals. To know oneself allows one to influence others through the use of emotions (UOE) and enhance performance and facilitate the accomplishments of predefined goals (Wong and Law, 2002). Therefore, the following hypothesis is proposed:

H6: SEA is positively related to UOE

The resulting hypothesized model is shown in figure 1.

Research method

This confirmatory-correlational research aims to determine the relationship between the different variables and explain and quantify the different observable facts. Accordingly, following Hair et al (2010) and Tabachnick & Fidell's (2019) recommendations, a survey instrument, measurement constructs, and best model-fit were developed and applied. A self-administered survey questionnaire was designed, starting with a demographic section (industrial sector, size of the company, education area, and work area) followed by a conceptualized set of variables (Strategy, Linkages, Emotional Intelligence, and OE) to build a model that was tested using both descriptive and inferential statistical analysis once the data was collected. The model's variables were rated with the use of a 5-point Likert-style scale (Strongly Agree–Strongly Disagree). 150 usable questionnaires were collected. The average mean values of the statements' ratings were used to generate the structural equation model. This methodology was chosen as it fits the requirements of this research and allows the analysis of latent variables and their relationship and the required sample is met by the collected data (Nachtigall et al., 2003).

Confirmatory factor analysis (CFA) was used to determine the relationships between observed and continuous latent variables and to check and confirm the overall model fit (Cooksey, 2007; Hair et al., 2010; Tabachnick and Fidell, 2019). Factor loadings were estimated, items loaded on only one construct (i.e., no cross loading) and latent constructs were correlated (equivalent to the oblique rotation in exploratory factor analysis). The internal consistency was confirmed using Cronbach's alpha coefficient and the items-to-total correlation. All constructs yielded alpha values greater than 0.7, which is the cut-off level set for basic research (Nunally and Bernstein, 1978).

Results

Initial results (see Figures 1 and 2, and Table 1) suggest that there is a significant predictive relationship between SEA and Strategies, confirming H1a. This result demonstrates the important role of self-emotion appraisal in the development of innovative strategies. Due to the fact that the SEA concept relates to the ability of the individual to understand their own deep emotions and the ability to express them naturally, individuals with high SEA will better formulate, understand, and apply strategies, and do so better than individuals with low SEA. SEA also has a significant impact on Linkages, confirming H1b. This finding means that the use of an individual's emotions is necessary to build up relationships with providers, customers, stakeholders, and other employees of the company. Moreover, SEA is positively related to UOE, confirming H6 and the EI theory (Wong and Law, 2002) that the ability of individuals to understand their deep emotions influences the individuals' use of emotions for a better performance. Interestingly, SEA has no impact on OE, therefore rejecting H2a.

Table 1. *Regression Weights: (Group number 1 - Default model)*

			Estimate	S.E.	C.R.	P
UOE	<---	SEA	,819	,168	4,887	***
Strategies	<---	SEA	,585	,467	1,252	***
Strategies	<---	UOE	-,254	,459	-,554	,580
Linkages	<---	Strategies	,456	,109	4,170	***
Linkages	<---	SEA	,334	,284	1,175	***
Linkages	<---	UOE	-,183	,272	-,674	,500
OE	<---	SEA	-,021	,242	-,089	,929
OE	<---	UOE	,529	,245	2,164	***
OE	<---	Strategies	,261	,095	2,738	,006
OE	<---	Linkages	,365	,151	2,411	***

The impact of UOE on Linkages and Strategies is insignificant, rejecting H1c and H1d. However, UOE has an important impact on OE and confirms H2b. The use of emotions to facilitate performance is important to the processes developed by the individual and confirms that this concept relates to the ability of the individuals to use their own emotions to enhance personal and collective performance. Individuals with a high UOE, tend to be more focused on being operationally effective, but this is not the case for SEA. However, there is an impact of SEA on OE indirectly through the appropriate use of emotions (UOE). The fact that UOE has no direct impact on linkages and networks indicates that the communication among employees and customers is impersonal. Today's relations between the individuals constituting the organization's customers and suppliers are through e-mails and electronic media, and it is not possible to read the other's emotions. Individuals with low emotional intelligence find it difficult to interact with clients and suppliers.

Strategies have no direct impact on OE, rejecting H4. However Strategies do have a strong and positive impact on Linkages, confirming H3. Additionally, Linkages has a predictive power on OE, confirming H5. Therefore, the impact of Strategies on OE is indirect through the establishment of linkages and networks in the organization.

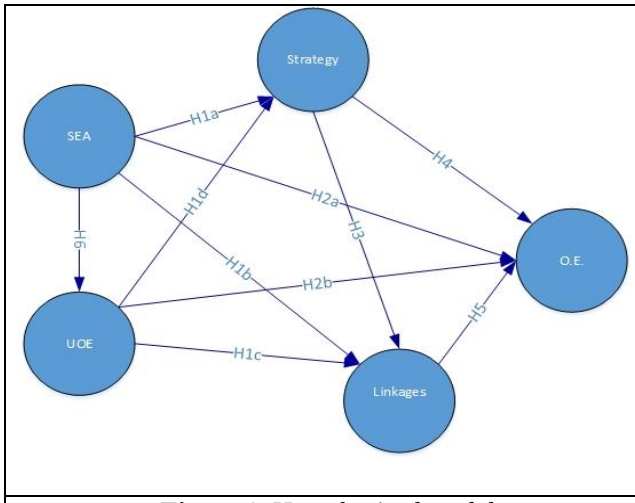

Figure 1. *Hypothesized model*

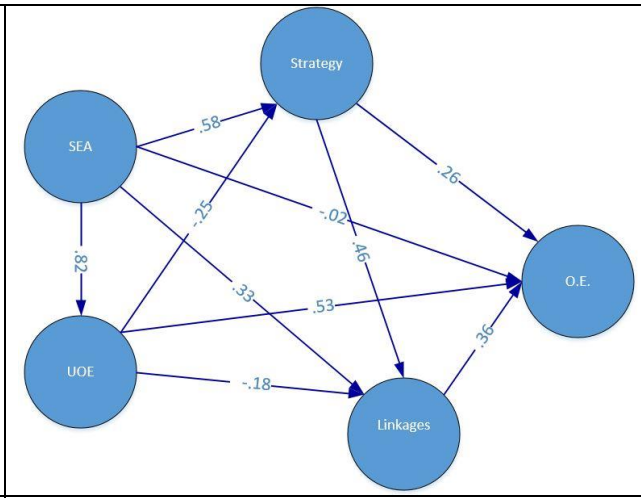

Figure 2.*Structural model*

Conclusion

This study shows the importance of emotional intelligence in strategies, linkages, and operational effectiveness. The results of this study indicate that there is a gap between what the organizations strategically planned for innovation and operational effectiveness and the emotional intelligence of the employees of the studied organizations. Additionally, this result shows a lack of appropriate introduction of innovative initiatives as explained by Tidd et al (2013), probably with a corresponding lack of appropriate dissemination of strategy, so employees do not have the opportunity to assimilate them and work towards the achievement of the strategic plans.

The fact that there is an indirect impact of strategies on operational effectiveness through the linkages, partially confirming H3, indicates that the studied organizations need to improve their strategic formulation.

Another important finding is related to the fact that there is a disruption in the communication channels between the individuals in the organizations and the suppliers and customers, probably because of the increased use of technologies. Therefore, it is necessary to improve the communication paths so individuals can interact with peers without needing to interpret the others' emotional intelligence.

It is also important to note the strong relationship between the use of emotions and operational effectiveness. This study demonstrated that individuals are paying attention to the role of key performance drivers such as cost, quality, reliability, flexibility, and speed. Therefore, organizations need to dedicate adequate training and dissemination of the strategic role of operational effectiveness to achieve a sustainable competitive advantage.

Future studies could further explore the alignment between strategies and innovative initiatives such as products or services, paradigm, position and process innovation, and operational effectiveness. Decomposing operational effectiveness into specific performance objectives such as cost, quality, reliability, flexibility, and speed could be the key to better understanding how emotional intelligence and operational strategies can interact effectively. A closer look at such interactions would certainly contribute to the sustainable performance of the organization

by achieving operational effectiveness. By gaining such understanding, strategic management would benefit from a more comprehensive insight into performance determinants.

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Smart Technologies for Smart Minds: Assessing the Emergence of Proactive Behaviours in Smart Manufacturing Settings

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Abstract

The 4.0 technological wave is re-shaping the manufacturing context, often referred to as Smart Manufacturing. The new smart technologies can foster a more human-centric approach, enabling the emergence of proactive behaviours in manufacturing context. This study aims at inquiry if a particular type of proactive behaviours – namely job crafting – is enabled by smart manufacturing technologies. Findings about two Italian manufacturing companies implementing similar technologies show that digitalization in manufacturing can enable a shift towards the autonomy and professionalism of operators, which in turn creates opportunities for workers to actively participate to processes and redefine their role, leading to improved performance.

Keywords: Industry 4.0, Job Crafting, Proactive Behaviours, Smart Manufacturing

Introduction

The widespread adoption of networked digital technologies to integrate manufacturing processes, that goes under the umbrella of Smart Manufacturing, and the new smart technologies introduced in the manufacturing processes have the traditional approach of manufacturing work. In fact, manufacturing companies are usually exploiting technology to foster standardization and control, pursuing production flexibility instead of labor flexibility (Gordon et al., 2018). However, preliminary empirical studies on the impact that Smart Manufacturing have on organization of work show that this new technological paradigm can enable the creation of new types of jobs, for which operators are more involved, having greater autonomy and responsibilities, and performing non-routinized and cognitive tasks (e.g. Romero et al., 2016; Cagliano et al., 2018).

In such scenario, smart technologies may activate the possibility for the operators to put in place proactive behaviours (Romero et al., 2016), intended as a set of actions that aim at redefine the content and tasks of one's work, together with the proactive re-definition of role boundaries (Wrzesniewski & Dutton, 2001).

The present study aims at inquiring if 4.0 technologies enable proactive behaviours in manufacturing settings, by collecting and analyzing qualitative empirical evidence in two different manufacturing companies implementing similar technologies.

Theoretical background

Proactive behaviours in job design

In the last 30 years, the emerge of new organizational forms which should be coherent with the competitive business scenarios in terms of organization of work and organizational design, has been a theme of interest for scholars (Whittington et al., 1999). In an environment characterized by hyper-competition and rapid-changing market requirements, the necessity emerged for firms to increase their flexibility and their capability to maintain a company-environment fit over time (Fjeldstad et al., 2012; Schreyögg & Sydow, 2010). In order to build their dynamic capabilities, organizations have shifted towards configurations emphasizing the role of the employee, which was brought at the centre or the organizational architecture (Fjeldstad et al., 2012). Within this context, the phenomenon of workforce's proactive behaviours has gained increasing momentum, becoming a main research field as well as a managerial focus (Rofcanin et al., 2016).

A relevant construct related to proactive behaviours is job crafting, defined as "the physical and cognitive changes individuals make in the task or relational boundaries of their work" (Wrzesniewski & Dutton, 2001). It is a proactive, bottom-up process initiated by employees without management involvement, which requires continuous adjustments of tasks and role boundaries (Berg et al., 2010). A remarkable feature of this phenomenon is that it describes the ways employees spontaneously participate in the design of their own roles (Hornung et al., 2010), complementing the more traditional perspective of job design as defined by top-down management action (Parker et al., 2017). By autonomously altering the tasks and content of their job, employees pursue satisfaction of individual needs and motivations, ultimately impacting on job meaning and work identity, i.e. how they conceive and the way others conceive their role and purpose within the organization. Wrzesniewski, & Dutton's (2001) construct therefore departs from the traditional view of job as a source of sustenance and security, towards a perspective in which people conceive their job as the locus where the individual has the possibility to develop a meaningful role and find satisfaction in life (Kooij et al., 2017; Melé, 2005; Wrzesniewski & Dutton, 2001). Wrzesniewski & Dutton's conceptualization (2001, 2010) also outlines different forms of crafting: (i) crafting physical task boundaries, altering the scope and nature of existing tasks or introducing additional tasks; (ii) crafting cognitive boundaries, redefining their perception of single tasks and relationships or reframing the perception of their job as a meaningful whole; (iii) crafting relational boundaries changing the existing relationships or creating additional relationships.

The conclusions resulting from studies on job crafting behaviours are that employees who take the initiative to change their job role and work environment are likely to contribute more to organizational effectiveness (Tims et al., 2012), and that these behaviours can be stimulated or hindered by the effective definition of job characteristics (Rudolph et al., 2017). Nevertheless, studies about job crafting behaviours have mainly explored phenomena in front-end service job roles and in contexts of relative static nature of the work environment (Bakker et al., 2012), while we lack research about manufacturing companies. A possible explanation for this aspect is the relatively high formalization and control of manufacturing jobs, which hinders the possibility of

proactively changing the boundaries of one's job (Gordon et al., 2018). The new technological wave related to digitalization and Smart Manufacturing, which can re-shape organization of work towards a more flexible environment (Hirsch-Kreinsen, 2014, 2016), may create the opportunity and interest to extend the job crafting literature to industrial settings.

Smart manufacturing and proactive behaviours

As modern digital technologies possess strong implications on job characteristics (Khatri et al., 2010; Parker et al., 2017; Tafti et al., 2007; Wilkesmann & Wilkesmann, 2018), there might be a new interest to assess the impact of digital applications over job crafting, which determines additional, often unexpected effects on organizational performance.

As reckoned by many authors, the manufacturing sector is currently under a significant paradigmatic shift – often acclaimed as a new industrial revolution, which is leading to the introduction of several smart and connected technologies within the plant. Smart Manufacturing - one of the labels used to identify the new paradigm based on Industry 4.0 technologies - refers to the pervasive implementation and application of networked, information-based technologies throughout the enterprise manufacturing and supply chain (Edgar et al., 2012; Hirsch-Kreinsen, 2014, 2016). These information-based technologies show significant variations in terms of application and complexity and, for this reason, several classifications have been proposed. For example, they can be groped in four main technological clusters: (i) data, computational power and connectivity; (ii) analytics and intelligence; (iii) human-machine interaction; (iv) and digital-to-physical conversion (Wee et al., 2015). Smart manufacturing has spread fast in European political agendas, as showed by the data about national Industry 4.0 policies and public funding in Europe, with companies showing a growing interest toward this phenomenon (European Commission, 2017). While early literature and reports point out the cost-saving and performance improving effect of the technological applications (Bauer et al., 2016; Rüßmann et al., 2015), more recent literature is directing towards the organizational changes that those technologies enable or require both at the micro and macro level (Cagliano et al., 2018; Longo et al., 2017; Seghezzi, 2015, 2016; Wilkesmann & Wilkesmann, 2018). The main underlying theoretical lens adopted when studying these aspects is the socio-technical theory (Trist et al., 2013), which sees the design of organizations as the result of the complex relationship between: (i) opportunities and constraints deriving from the available technology and the production process to be implemented, and (ii) opportunities and constraints of social nature, namely the actors involved and their objectives and needs.

While the previous industrial revolutions had the effect of automating physical and cognitive routine tasks, scholars address this revolution as automating and supporting non-repetitive physical as well as cognitive tasks, with robotics and algorithms performing increasingly better than humans in tasks as data collection and analysis, as well as physical manipulation (Berger & Frey, 2016; Frey & Osborne, 2013; Manyika et al., 2017). As a result, the skills composition of jobs is shifting towards digital and human-machine interaction capabilities (Bughin et al., 2018), but also towards soft skills as problem solving, critical thinking, teamwork and creativity (Bughin et al., 2018; Lorenz et al., 2015; World Economic Forum, 2016).

From an organizational perspective, the discussion has increasingly focused on the emergence of alternative scenarios, i.e. the automation and job polarization versus complementarity (Hirsch-Kreinsen, 2016). In the automation scenario many jobs are performed by machines and algorithms, and the remaining human activities are governed and ruled by autonomous machines. The operator's work is therefore subordinated to the

directives of the technological system and jobs are characterized by a low number of simple operational activities. Within this scenario there is still space for few jobs characterized by high autonomy and cognitive content, mainly related to the design, implementation and training of the autonomous machines. In the complementarity scenario instead, automation concerns manual and cognitive routinized task, while operators would have full control over the technological systems and would use it to collect information to better control and to improve sub-processes when the right circumstance occurs. We would assist to a reduction of low skilled jobs but there would be an increase of both highly skilled personnel and of operators with average technical qualifications, able to communicate and interact with advanced digital tools (Autor et al., 2003) and a high number of multitasking positions - characterized by a high degree of structural openness, a very limited division of labour and high flexibility (Böhle and Rose, 1992). Overall, this organizational model is referred to as swarm organization (Hirsch-Kreinsen, 2014, 2016)

Early empirical research has investigated the application of single technologies within the industrial plant in order to shed light to the organizational consequences of Smart Manufacturing at the macro-level. Wilkesmann & Wilkesmann (2018) have proposed a first attempt to map the different smart technologies according to their impact on four organizational and job characteristics, namely degree of formalization, distinctness of control authority, location of knowledge, degree of professionalization. What emerges from qualitative research is that different applications are likely to have different impacts, which can lead the organization toward more mechanic or more organic settings (Wilkesmann & Wilkesmann, 2018). Technological complexity of smart manufacturing implementation - indented as the number of technologies implemented and the level of integration between different processes enabled by the technologies – influences the adoption of more mechanic or organic forms of organization of work. In fact, a higher level of technological complexity is associated to a decentralization of decision making and a reduction in the number of hierarchical levels (Cagliano et al., 2018).

At the individual level, smart technologies are increasingly supporting humans' physical, sensorial and cognitive capabilities, enabling them to cope with an increasing complexity of the external and internal environment (Longo et al., 2017; Romero et al., 2016). At the operational levels, the operator 4.0's work results in a higher involvement in the production process, with greater autonomy and responsibilities over the plant. A characterizing feature of the worker 4.0 will be to perform non-routinized and cognitive tasks, which require real time adaptation (Romero et al., 2016). Supporting empirical research indicates strong changes in the job design at the operational levels of industrial companies, including an increase in autonomy of decision making and autoregulation, increase of teamwork and collaboration, job polyvalence, an increase of the cognitive content of work, especially when technological complexity is high (Cagliano et al., 2018). Results clearly point towards a professionalization of roles, with higher competences, more value-adding tasks and more responsibilities, decision making and problem solving. The new operator 4.0 emerges as the responsible of automated workstations, which is tasked with workstation's machines control and is able to perform operations of standard maintenance, machines' stops resolution and optimization of the process for which she/he is held responsible (Bartezzaghi et al., 2017; Cagliano et al., 2018).

Despite these findings, recent research presents several gaps related to the content of work and about the characterization of the new role of the smart operator. First, the general consensus about reduced job formalization, higher autonomy and higher complexity of work accounts for the importance to develop more studies about the proactive behaviours that are deemed to flourish within the industrial workplace. Second,

while researchers have extensively investigated the relation between job characteristics and proactive behaviours as job crafting, few studies have analysed the relation between technology and human proactivity, with even more paucity considering the smart manufacturing case. Finally, there's a need to develop further research about smart technologies' implications on organization, clarifying which organizational designs will be justified and enabled by the fourth industrial revolution.

Based on the above, the present study aims at exploring the following research question: "Do Smart Manufacturing technologies enable the emergence of proactive behaviours through job crafting?

Methodology

Sample selection

In order to gain insights on the scope of research and in line with the exploratory nature of the research questions, case studies on two different companies implementing smart manufacturing has been carried out (Eisenhardt, 1989; Yin, 2003). A case study is an empirical methodology investigating a phenomenon within its real context (Denzin and Lincoln, 1994), particularly appropriate to cope with situations where there are more variables of interest than data points and where new phenomena are inquired (Yin, 203). The two selected companies are Red, a family-owned mid-sized company located in Italy and producing mechanical components for home appliance producers, and Blue, a mid-sized company producing mechanical components for the automotive industry.

To select the companies, we looked for companies sharing similarities in: (i) the industry and the organization of work at the plant level, and (ii) in the implemented 4.0 technologies. Concerning the industry and organization of work, both companies are manufacturing companies producing mechanical components (although for different applications). Concerning the organizational structures, the two plants are characterized by a traditional hierarchical structure, in which there are four hierarchical levels: the plant responsible(s), the production departments responsible, the supervisors, and the operators. As far as the implemented technologies are concerned, we looked for companies putting in place similar technological applications among the many different Smart Manufacturing technologies. In particular, we selected two companies exploiting Internet of Things and Analytics to collect data on the production process in real time, in order to provide up-to-date data and analyses about different performance dimensions such as the Overall Equipment Effectiveness (OEE), quality performance, productivity. These analyses are available in the plant thanks to a dashboard displayed on smart screens positioned in different parts of the production plant, in order to be consulted by both managers, supervisors, and operators. In the Red case, all the workforce on the plant have also a wearable smart watch that reports the main parameters of productivity in real time and that signal them the alerts about problems and unexpected stops on a specific machine.

Data sources and analysis

In order to ensure reliability, multiple data sources were employed, namely semi-structured interviews, observations, and archival data (Denzin & Lincoln, 1994; Miles & Huberman, 1994). Semi-structured interviews were carried out with different actors and roles for both the companies, including top management, Human Resources manager, responsible of the plants, responsible of Smart Manufacturing projects and their implementation in the company, supervisors and operators. A total of 20 interviews was

carried out (11 for Red and 9 for Blue). Each interview followed a semi-structured interview protocol organized in macro-sections and aimed at gathering information on different aspects such as (i) the background of the interviewee, (ii) the Smart Manufacturing technological characteristics and applications, (iii) the characteristics of the individual jobs in the plant in terms of nature and variety of tasks performed, level of autonomy and interaction with other colleagues, (iii) the emergence of proactive behaviours, (iii) the overall quality of work and well-being of the interviewed people. Each interview lasted from 45 to 90 minutes and was recorded and transcribed. In addition, researchers and interviewees have often engaged in off the records discussion during coffee breaks and lunches, providing additional information that has been transcribed after the meeting and that added further insights about proactivity of the plant personnel interacting with the 4.0 dashboard. Observations took place in both companies after the interviews were completed and consisted in two visits, one in each of the two plants. Both visits lasted two hours and consisted in directly observing the work of the operators and supervisors on the production lines, and their interaction with the dashboards. We also had the opportunity to ask questions to the supervisors and to the operators during their breaks at the coffee machines located in dedicated parts of the plant. To keep track of our observations, we took field notes in real time that were then reviewed after the end of the visit. Finally, we reviewed also archival data such as internal company reports, organizational and plant charts, company presentations, company manuals and job descriptions. These archival material was used to further validate the description of organization of work in the two companies.

The data collected with interviews, observations and archival data were analyzed by the research team through a coding process and with an inductive approach (Strauss & *Corbin, 1998; Gioia et al., 2013).* Figure 1 summarizes the structure of the data.

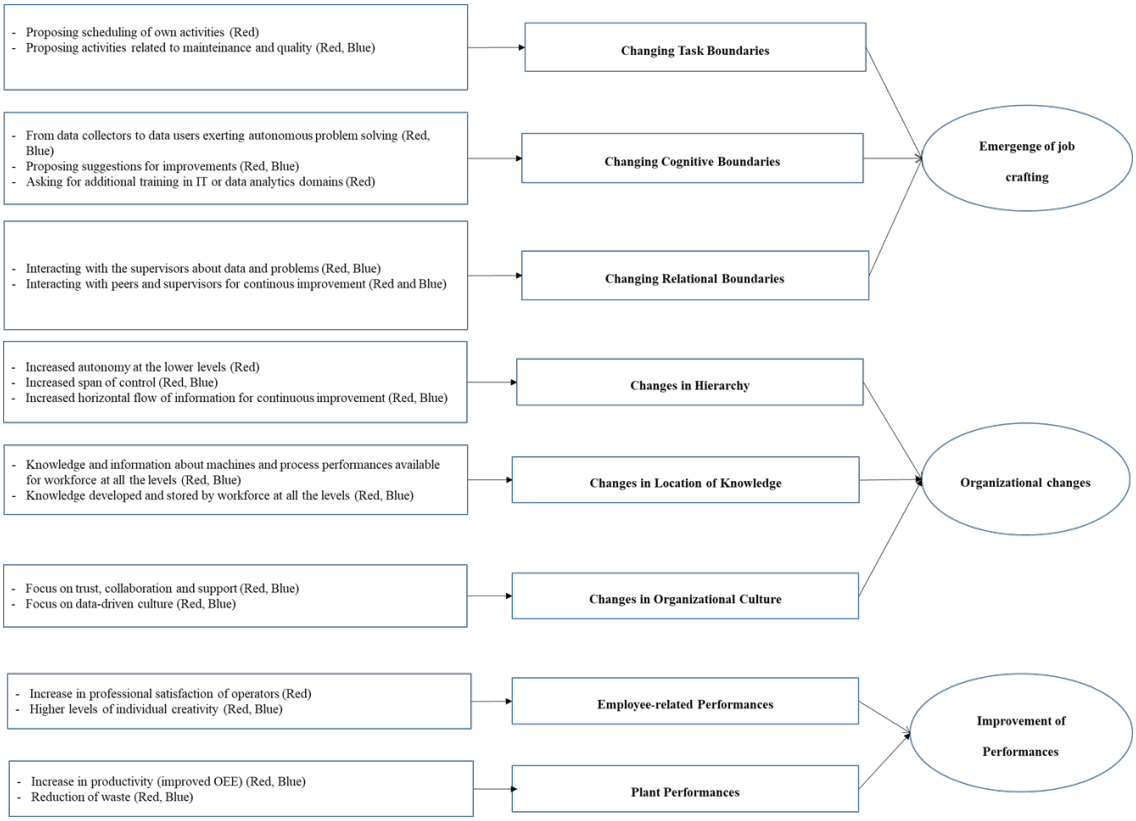

Figure 1 – structure of the data

Findings

Figure 1 summarizes the overall findings.

Empirical evidence showed how job crafting for operators was enabled both directly, thanks to the introduction of the 4.0 technology, and indirectly, thanks to changes in terms of organizational design that further foster job crafting behaviours. Moreover, findings show that job crafting enabled by 4.0 technology has also improved performance both in terms of plant productivity and efficiency, and in terms of employee-level outcomes. Findings on these different aspects will be now illustrated describing: (i) the emergence of job crafting behaviours; (ii) the organizational changes fostered by the new technology; (iii) the impact on performance both at the plant and employees level.

Emergence of Job Crafting Behaviours

Our findings show that the adoption of a smart dashboard available for all operators which provides up-to-date information about the production process, enables job crafting behaviours. In both Red and Blue cases operators are able to change the boundaries of their individual job in terms of task, cognitive and relational boundaries.

In terms of task boundaries, the better understanding of the production process leads operators to better organize their activities. The smart system implemented in the plant enabled operators to propose new tasks to be performed, altering both the number and the types of activities they carry out, in both cases, as indicated by the following exemplary quote: “The system tells me the average time of production of the unit. So I know how much does it take, I can plan my scheduling in a much more independent way, I do not have to wait for the supervisor to tell me what I should do” [Operator, Red].

Moreover, the smart dashboard and sensors system enabled a redefinition of cognitive boundaries of the tasks for operators. The availability of information and the visibility of the overall production system enabled for operators a shift towards professionalism, since they see themselves as data users and not just data collectors, consequently carrying out problem solving, proposing suggestions for improvements and asking for more professional training. The following quote is exemplary of this aspect: “Each morning, I call for a meeting with my team and I show them the analysis about their production of the day before. They are the ones that are able to explain to me why we had such a performance, and now they do it” [Supervisor, Blue].

In terms of cognitive boundaries, the smart dashboard and sensors system enabled the opportunity for operators to change some aspects related to numbers and types of relational interactions, both vertically and horizontally, as indicated by the following exemplary quote: “When I was operator 20 years ago it was difficult to interact with the production responsible or the department manager, this was possible only if there was a major mechanical problem. Now I discuss a lot with operators about data and process functioning, and there’s a strong “bottom-up” interaction with the operators, and for me the same thing happens with the manufacturing manager” [Department Manager, Blue].

Organizational changes

Empirical evidence showed that the smart manufacturing technology was acting not only directly on the enablement of job crafting behaviours, as illustrated above, but also indirectly through some other organizational changes that can further foster proactivity. In particular, these changes concern the hierarchy, the location of knowledge and the organizational culture. Here some representative quotes of these aspects: “One of the two most important activities of the HR function is to give decision-making competencies. The work that has been done was to increase line responsibilities, to let semi-important

decisions be taken a bit at lower levels" [HR Manager, Red]; "Every operator can come and see any time the performance of the plant, and of each machine, any time they want" [Supervisor, Blue]; "Having the machine trends under sight you can understand your position in respect to targets, and what are the problems that are slowing down your yield… because without data many times you make reasoning with your gut" [Department Manager, Blue].

Improvement of performances

Finally, evidence shows that enabling job crafting behaviours has a positive impact both on employee-related performance and plant performance. About employee-related performance, positive effects on employee-related outcomes, especially for operators, are highlighted by several interviewed roles. Job satisfaction seems to have increased and in some case operators express the feeling of an increased level of creativity in their daily activities: "Work now is more dynamic, and we're not strictly bound to the machine. The system signal that there is a problem, and sometimes solving it means find a new way of doing things, I can experiment much more than before" [Operator, Blue].

About the plant performance, the objective measures of productivity and efficiency show significant improvements in both cases. The perception of managers and operators is that this improvement is also connected to job crafting behaviours and to the changes in organizational design, as the following quote indicates: "Performance has for sure increased, as a consequence of the fact that not only department managers and supervisors, but also operators take proactive initiatives to solve problems. The machine is still the same. The difference is the operator that understands before if something is going wrong, and intervene before something breaks" [Department manager, Red]

Discussion

Our findings show a relation between the introduction of smart technologies and the enablement of proactive behaviours within the manufacturing plants. This is possible thanks to both the direct availability of data and the redesign of the organization towards higher job autonomy, task variety and cognitive work for the 4.0 operator. In turns, job crafting, coupled with the redesign of the organization, leads to better performance at both individual and organization level. This finding is pretty significant and novel for the literature, since it allows to broaden the literature on proactive behaviours and job crafting to the manufacturing sector, in particular within the emerging context of smart manufacturing.

Job crafting supporting the swarm organization for smart manufacturing settings

From a broader organizational perspective, this study offers an interesting contribution to the debate about the possible organizational scenarios for smart manufacturing, summarized in the polarization versus swarm organization scenario (Hirsch-Kreinsen, 2014, 2016), supporting the latter. The application of extensive analytics and the diffusion of data at the lower organizational levels through different human-machine interfaces configures a shared information infrastructure connecting the operators, and incorporates the protocols and practices for using and sharing knowledge within the organization. As each operator is held responsible for a specific part of production activities, autonomy is strong, and upper-level management and technical staff intervenes only for major problems to occur. Control authority becomes more horizontal and organized in networks of discussion about common goals and potential improvements. The redesign of work

towards a swarm organization is partly a conscious work redesign action taken by (HR) managers, but partly a consequence of job crafting behaviours enacted by operators thanks to the enabling role of 4.0 technologies. With the support of smart technologies, operators take proactive action to cope at any time with unanticipated disruptions and customized actions in conditions of high volatility.

Thus our study not only contributes to give empirical support to the emergence of the swarm organization scenario that has been theoretically postulated by some authors (Hirsch-Kreinsen, 2014, 2016), but also provides a deeper understanding of how this phenomenon occurs and relates this organizational change with the emergence of workers' proactive behaviours. Thanks to this, the literature on proactive behaviours and job crafting (Bakker et al., 2016) can inform the emergent literature on new organizational models for smart manufacturing.

Smart manufacturing and job crafting: meaningfulness of work in manufacturing setting

The results of our study also provides an additional contribution to the literature on work meaningfulness. Previous research has already outlined the role of "datification" in providing accountability for jobs, which helps professionals in gaining awareness about performance achievements and provides the possibility to showcase them to their relational network, increasing overall job meaningfulness and work identity (Stein, Wagner, Tierney & Newell, 2018; Wrzesniewski & Dutton, 2001). Similarly, this research shows a progressive professionalization of roles among operators. Professionalism was already discussed in literature of smart manufacturing, that describes the new 4.0 operators as performing non-routinized cognitive tasks that require capabilities of real-time adaptation and improvisation in order to handle rapid changes (Seghezzi, 2015, 2016b; Bughin et al., 2018; Longo et al., 2017). Coherently with the literature, in our case studies operators take responsibility over complex tasks previously solved by professionals, and are supported by information and 4.0 operation technologies in performing decision making, problem analysis and problem-solving. In addition, the "datification" of machines performance grants operators' awareness and visibility on their and others actions, with the possibility to demonstrate to the organization their professional abilities and gain satisfaction. This study contributes to show that job crafting is also used by operators to craft their jobs to accommodate their own concept of professionalism and meaningful work, and to accommodate their need of positive self-image (Berg et al., 2010; Wrzesniewski & Dutton, 2001).

These behaviours are manifested firstly in an engagement towards raising performance, which push them to "raise the bar" towards work quality and to search improvement solutions to enhance productivity KPIs. In addition, as the system shares transparently the performance of each employee, in both cases managers have assisted to episodes of positive competitions towards the highest OEE, in an attempt to self-define the owned professional identity. Finally, increased professional awareness lead to an additional involvement in the company, engaging workers in continuous improvement initiatives and activities of collaboration and information exchange.

Managerial implications

The importance of this research in informing managerial action pertains to different areas. First of all, this research has demonstrated the importance of organizational variables and their impact over proactive behaviours, which is in most cases neglected from companies during the implementation of smart manufacturing initiatives. This can lead to different unexpected results in job design and in operators' job crafting, which translates in unexpected problems and missed opportunities along the digital roadmap. An assessment

of the necessary changes on workers' roles, of their arising necessities and of the possible actions and benefits of involvement can unleash much higher performance from Smart Manufacturing projects and lower payback times from investments. Moreover, the study underlines the importance that a pervasive transformation leveraging smart technologies has over proactive behaviours via the redefinition of organizational characteristics. Consequently, the anticipated planning of organizational initiatives towards proactive behaviours can be considered as fundamental.

Second, the HR function has been shown to be a key actor in the smart change, possibly as relevant as the operations and the IT function to lead the transformation in the right direction and to organize the necessary training for workers to embrace their new smart roles. Workforce skills should be developed in parallel with smart technology in order to win the societal challenge of the skill gap (Berger & Frey, 2016; Bughin et al., 2018).

Lastly, management should be aware of the fact that the way technology is developed impacts proactive behaviours. This is particularly visible considering the importance of user-friendly design and its importance for machine-human interfaces. The design of intuitive interfaces for smart tools impacts the possibility of enabling job crafting behaviours.

Conclusions

As one of the first studies about proactive behaviours in job design in the context of manufacturing, and the first in smart manufacturing settings, this study has provided early insight about the future of manufacturing jobs and organizational models, shedding light over the possibility for the emergence of proactive behaviours in such contexts, opening the way for higher autonomy and freedom of industrial jobs. The freedom of operational decision, the responsibility towards problem-solving and the operators' involvement in the digital transformation are creating more and more opportunities to craft job roles. As operators' see the possibility to own their job and improve their work life, industrial companies acquire the unprecedented opportunity to involve more workers in the organizational life.

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Building resilience: Matching the collaboration structure of teams with disruption characteristics

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Abstract

The majority of organizations regularly face disruptions, resulting in substantial financial and reputation damages. To solve organizational disruptions, multiple teams have to effectively collaborate between each other. Contrary to the current consensus that increased collaboration benefits team performance under all disruption circumstances, we propose that teams should align the way they collaborate with the disruption characteristics. We use a social network approach to test the moderating effect of disruption complexity on the relationship between collaboration centralization and disruption duration. Research aims to generate new insights about how proper disruption management might help organizations improve their collaboration in face of disruptions.

Keywords: Resilience, Collaboration, Network analysis

Introduction

Many organizations face disruptions that can seriously affect their performance and business continuity. Dealing with such disruptions is often beyond the capacity of any single team within the organization. Indeed, several organizational teams often need to collaborate with each other to develop well-integrated countermeasures that can help minimize the disruption's adverse consequences for the overall organization (Scholten & Schilder, 2015; Hohemstein et al. 2015; Tukamuhabwa et al., 2015). While the literature within supply chain (SC) management has been optimistic about the effectiveness of collaboration, less is known about how teams can collaborate effectively during varied disruptions.

Our main insights are based upon team research (e.g. Tröster et al., 2017) and follow an argument similar to the contingency approach in SC management (e.g. Giménez et al., 2012) that shows that the type of SC integration depends on the level of SC complexity. Specifically, we examine how can teams optimize their collaboration processes to effectively deal with disruptions. We suggest that success of disruption resolution depends on the effective alignment between teams' collaboration and type of disruption. We argue that disruptions with far-reaching consequences (i.e., severe disruptions) require more centralized collaboration structures in which one or few team members orchestrate and execute collaboration on behalf of all teams. For less severe disruptions, by contrast, we expect more success for teams that rely on open and unrestricted collaboration, facilitated by more decentralized collaboration structures.

Methodology

We test our model using data from a public water-supply company. This is a suitable context, as ruptured water pipes, broken-down pumps, and other sort of disruptions regularly threaten the supply of water to customers, and accordingly, the continuity of the water supply company. In case of such disruptions, teams from the public water company have to collaborate to ensure the company's high water-delivery standards. Collected data consists of detailed information on the location, pipeline diameter, and total time of no water supply associated with over 8000 disruptions. We treat the disruption duration as dependent variable, and disruption severity as a moderator. In addition, we obtained anonymized information on the telephone communication between organizational teams that dealt with the disruptions, and used it to measure centralization of collaboration (Freeman, 1979), serving as an independent variable. We will treat these telephone records as social network data. Centralization in this study was calculated using Freeman's approach (Freeman, 1979), as the average difference in centrality between the most central actor and that of all other members in the network. In our study, actors communicating during each disruption constitute a network, and we calculate centrality of coordination for each disruption using the number of the calls from and towards each actor.

Findings

Preliminary analysis during the initial phase of data collection provided support for our main hypothesis. We found a significant interaction effect between centralization, disruption severity, and disruption duration ($B = -30616.68$, $SE = 18552.26$, $p < .10$).

Conclusion

This study contributes to existing research in several ways. While collaboration has been studied before, the present study provides a more nuanced and novel view on how can teams effectively structure collaboration processes to enhance their responses to different types of disruptions. It shows that the structure of the collaboration processes needs to be adapted to the disruption, which challenges the widely held believe that collaboration is beneficial in all situations. A second contribution lies in the empirical data used. So far, empirical work on resilience has been limited (e.g. Tukamuhabwa et al., 2015) and the scarce empirical research that is available has mostly relied on subjective data. The present study, however, employs objective data on real teams dealing with real disruptions. Practically, our study helps administrators to make well-informed choices on how to structure collaboration between teams during disruptions.

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Capacity Planning and Control

The Baton Zone Balancing (Bumping) model: A simulation assessment

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Abstract

Most of the authors who researched on workers' capacity management, in the field of Dual Resource Constrained and Workload Control, were mainly oriented to increase the overall worker's capacity of the system through subcontracting, overtime and new workers hiring. Different When, Where and Who rules have been tested when investigating worker's arrangements rules. A rule, namely Baton Bumping Zone Balancing, has been proposed by Protzman et al., (2016). However, it has never been tested in terms of numerical evidence. In this research paper, authors propose a methodology to assess the impacts of this new rule in a pure flow shop.

Keywords: Baton Zone Balancing, Labour Flexibility, Worker's Allocation

Introduction

In the light of increasing worldwide competition and uncertainty of markets, interest in manufacturing flexibility is increasing. The issue of manufacturing flexibility has long been cited as a key competitiveness measure (Boyle, 2006) and a strategic sourcing. This is particularly important in today's high-tech business environment, characterized by short product life cycles, small lot sizes, changing product mixes and quick response. In literature, there exist many conceptions of flexibility and its definition and measurement remain a research issue.

Labour flexibility, or workforce flexibility, is considered as a managerial tool to achieve volume flexibility in production. Volume flexibility is recognised as a strategic mean to face uncertainty in markets and growing global competition (Goyal and Netessine, 2009). The role of the workforce in supporting industrial objectives, like volume flexibility, is recognised in many studies (Hopp and Van Oyen, 2004; Digiesi et al., 2009).

One of the fundamentals of lean management is the multi-skilled employee, having the competences, experience and knowledge to perform many different simple and complex tasks.
The most dominant stream of research on workforce flexibility has been on dual resource constrained (DRC) production systems (Hottenstein and Bowman 1998). In dual resource constrained systems, two resources are considered to be constraining factors for the level of output: labour and machines. For smooth operation of these systems, attention should thus be given to cross-training and labour allocation rules.
The implementation of worker arrangement mainly depends on the decisions taken regarding the following three aspects:

- When rules or control rules. These rules indicate when the worker is available to move to another work station to process a task.
- Where rules or assignment rules. They define the policy by which a worker is assigned to a particular station.
- Who rules. These rules determine which worker, among the available ones, is transferred to another workstation.

A new approach for line balancing and worker's arrangement never investigated has been introduced theoretically by Protzman et al., (2016) and takes the name of Baton Zone Balancing (Bumping). It allows to obtain One-Piece Balanced Synchronized Flow. According to it, the production line follows the flow of the order regardless of the times at each station. Protzman et al., (2016) provided a theoretical description of Baton Zone Balancing (Bumping), with no empirical evidences of its benefits. The purpose of this paper is to propose a simulation model through which assessing by means of numerical evidences the impact of Bumping approach in a pure flow shop.
The remainder of the paper is structured as follows: in the literature review section, authors highlight the main findings related to worker's flexibility and the Bumping model, as theorized by Protzman et al., (2016); then in the Methodology section, the presentation of the simulation model, that will be used to collect the results, is depicted.

Literature Review
The present section will be devoted to present the survey of the literature concerning the labour flexibility, while the second part will be dedicated to present the Bumping model, as presented by Protzman et al., (2016), as a new possible labour flexibility policy.

Labour Flexibility
Labour flexibility, or workforce flexibility, is considered as a managerial tool to achieve volume flexibility in production. Volume flexibility is recognised as a strategic mean to face uncertainty in markets and growing global competition (Wernerfelt and Karnani, 1987, Goyal and Netessine, 2009). According to Małachowski and Korytkowski, (2016), a competent workforce is a source of competitive advantage for a company. Indeed, since machineries, equipment and tooling can now be purchased by anyone with the appropriate resources and all of them are readily available, the factor that differentiates companies is the know-how of their employees, which also forms the company's main asset. One of the fundamentals of lean management is the multi-skilled employee, having the competences, experience and knowledge to perform many different simple and complex tasks. Employees are a source of flexibility as they are capable of seamlessly change their roles according to the company's needs (Womack and Jones, 2010). In a company with a multi-skilled workforce, planning focuses on the needs of the customer, not on the

capabilities of the staff, and this leads to a reduction in the number of idle hours. An experienced and well-trained multi-skilled workforce translates directly into higher productivity, better quality and lower costs. Worker flexibility is desirable when Dual Resource Constrained (DRC) systems are compared directly to machine-limited systems that, by definition, have zero worker flexibility. DRC shop with a flexible workforce can have lower inventories and better due date performances than a shop with no cross-trained workers, since workers can be rotated throughout the shop to respond to changing workloads (Krajewski et al., 1987).
The introduction of the worker flexibility in production systems mainly depends on the decisions taken regarding the following three aspects:

- *When rules or control rules*. These rules indicate when the worker is available to move to another workstation to process a task. In the literature two 'When' rules are prevalently presented. The first is the Centralised rule, according to which workers can be transferred to other workstations after the completion of the current job, even if the queue in the current workstation is not empty (Darwin et al., 2009, Sammarco et al., 2014). The second is the Decentralised rule, where workers can be transferred to other workstations only when they are idle, that is when the queue in the current workstation is empty. As reported in Sammarco et al, (2014) the 'When' rule choice can affect both system and human performances. If more production is requested, the 'Decentralised' rule is a suitable assignment even if a worker spends more time in the same workstation. Thus, the switching rate decreases and the utilization increases. As a consequence, the rest time to recover from fatigue is reduced, with a negative impact on stress and musculoskeletal disease, that leads to the occurrence of safety issues (Tucker, 2003). On the contrary, the 'Centralised' rule permits many micro-breaks during more frequent changes of station. This aspect increases the variety in work tasks, but at the same time causes a reduction of flow time and WIP. Ultimately, the choice of the when rule depends on the strategic objectives of management, particularly if they push forward the optimization of throughput time or WIP. When production volume is more important, then the 'Decentralised' rule provides superior performance. On the other hand, if reduction in WIP costs is a priority (Yang and Posner, 2010), the 'Centralised' rule is superior.
- *Where rules or assignment rules*. They define the policy by which a worker is assigned to a workstation. Worker assignment rules have been extensively examined in the literature and most of the 'Where' rules investigated are based on due date evaluation, bottlenecks, amount of total processing time of products in a queue, and other product timing indicators. 'Where' an eligible cross-trained worker should be assigned has a greater impact on shop performance than the question of 'When'. In particular, the largest reduction in variance came from assigning eligible workers to queues containing the longest job in the system (LTPT), rather than to workstation with the most jobs in queue (LNQ). On the other side, the longest queue (LNQ) based rule resulted in a 20% reduction in machine and operator idleness, an increase in total output, a reduction of cost per unit of output, and an improvement in delivery performance. LTPT rule performed well in term of improvement of delivery performances and reduction of operators' idleness. Finally, the rule based on the worker efficiency (WE) proved to dominate all the others. However, the results presented above are frequently associated to pure job shop (Sammarco et al., 2014). Some authors (Sammarco et al., 2014, Bokhorst et al., 2004) argued that it is unlikely that pure jobs shops are found in real companies and the results of these studies can lead to misleading results. As a matter of fact, results achieved through simulations in

pure job shop configuration can be far from the one that can be realized when the flow becomes directed, due to the different nature of the organization. Moreover, in flow shop configurations 'Where' rules should be simpler in order to reduce the workers' reaction time (i.e. the time required to identify the next machine to go to) and to not disrupt production.

- *Who rules*. These rules determine which worker, among the available ones, is transferred to another workstation. As reported in Felan and Fry, (2001), most of the researches neglect the importance of 'Who' rules and they rather focus on the other two types of rules, although they play a key role in the daily practice of worker assignment and in almost all DRC systems, choosing between workers is necessary at a certain point. As with other labour allocation rules, the impact of the 'who' rule depends on the specific DRC shop modelled. In particular, the average labour utilization, and the types and extent of worker differences, determine the impact of the 'who' rule on shop performance. As stated in Bokhorst et al., (2004), 'Who' rules may affect flow time performance only in those systems where workers are different in terms of skills. Most of the researchers consider worker skills through two parameters: worker flexibility and worker efficiency. Worker flexibility summarizes the capability to work on different machines. While single-skilled workers are constrained to a particular machine, multi-skilled can be transferred to several machines. It results in a reduction of their idleness, an increase of their productivity and lower costs (Małachowski and Korytkowski, 2016, Felan and Fry, 2001). Concerning the worker's efficiency, it represents the proficiency of workers to run stations and to process tasks. The level of efficiency is frequently expressed by using values that range between 0% and 100%, and it represents the time workers spend processing jobs divided by the actual reduction of jobs processing times at a given station.

Małachowski and Korytkowski, (2016), demonstrated that cross training particularly fits systems with high workload imbalances as make-to-order companies, since workers can be transferred where they are required the most. Indeed, an important classification may be done between Balanced and Unbalanced production lines. Balanced lines may be defined as lines in which the processing time distribution at each workstation is identical. It is more common, but less precise, to define balanced lines as ones with equal mean processing times. As a consequence, in a perfectly balanced line, all the workstations have equal amounts of work allocated to them and variation in operation times is non-existent. In a truly ideal balanced line, buffers are not necessary since partially completed pieces move from one station to the next at the same pace. In real lines, this kind of balance is difficult to achieve, so work allocation and buffers are used to move lines as near as possible to a balance. Since in these production lines usually each stage of the assembly process takes a different average length of time to complete, they are known as Unbalanced production lines. Different sources of imbalance can be founded; the most common is the Processing Mean Time imbalance. Although several early papers demonstrated that lines unbalanced with respect to mean processing times could outperform balanced lines, many authors studied possible ways to balance these lines. One of these approaches consists in defining the optimal location of the stations according to their mean processing times. Across the Unbalanced Lines literature, most of the results show that placing the faster stations in the middle of the line gives the best performances. This is explained by the fact that the blocking and starving that occur as a result of the slower stations has the most effect on adjacent stations, and therefore, placing them at the extremities of the line only affects one station either upstream or downstream. This setting of the stations in the line corresponds to a 'bowl' shaped disposition of the mean

processing times, as described by Hillier and Boling, (1967) in the so-called Bowl Phenomenon. The opposite configuration, called 'Inverted Bowl', consists on allocating larger balances to the central stations. It generates an increasing deterioration of the utilisation of the line as the 'Inverted Bowl' becomes deeper. As alternatives to bowl and inverted bowl dispositions of the mean processing times, Romero-Silva and Shaaban, (2018) analysed a monotone decreasing order, also called 'Upstream Increasing', which arranges the operators from the slowest to the fastest, and a monotone increasing order, 'Downstream Increasing', which disposes the workers from the fastest to the slowest. Results achieved on a 5-stations line showed that the upstream increasing configuration performs significantly better than balanced lines in relation to the average amount of jobs in the buffers. On the contrary, strongly worse performances are achieved by the downstream increasing disposition. Concerning the output rate, the two best patterns have been inverted bowl and upstream increasing, which generated performances comparable with the ones of a balanced line. Those outcomes are aligned with previous research on the part of Shaaban, McNamara, and Dmitriev (2017).

The Bumping Model

This new model takes the name of Baton Bumping Zone Balancing. This topic has been introduced and analysed by Charles Protzman in his "The Lean Practitioner's Field Book", written in 2016 with Fred Whiton, Joyce Kerpchar, Christopher Lewandowski, Steve Stenberg and Patrick Grounds. In this book, they describe the Baton Bumping Zone Balancing as one of the Proven, Practical, Profitable and Powerful Techniques for Making Lean Really Work.

It moves from the concept of station balancing to open up to work balancing. It allows to obtain One-Piece Balanced Synchronized Flow (OPBSF), for which it is necessary to change paradigms and systems that exist in sit-down station balanced lines and to be open minded enough to develop a new strategy. This approach means to set up the line to follow the flow of the product regardless of the times at each station. The buffers are eliminated and the workers are no more assigned to workstations, but to work zones across the workstations. The rule is that the worker must continue to build until the operator at the following station pulls the part from him. In this system, the operators or assemblers are spread out on the line to work just like runners in a relay race. Like the baton handoff in the relay race, when an operator completes a unit, he walks back to the previous operator and bump him by taking his part regardless the amount of work already realized on it by the previous operator. The bumped operator then goes and bumps the worker before him and so on until the first operator in line starts a new part. Since the Baton Bumping Zone Balancing has been introduced in the lean philosophy branch, its main benefit is the reduction of wastes. In particular, it diminishes the workers' idle time and the WIP level in order to guarantee only the minimum amount necessary to keep the flow. Protzman (2016) provided a theoretical description of Baton Bumping Zone Balancing, while no simulations have been put in practice to assess the achievement of the expected results.

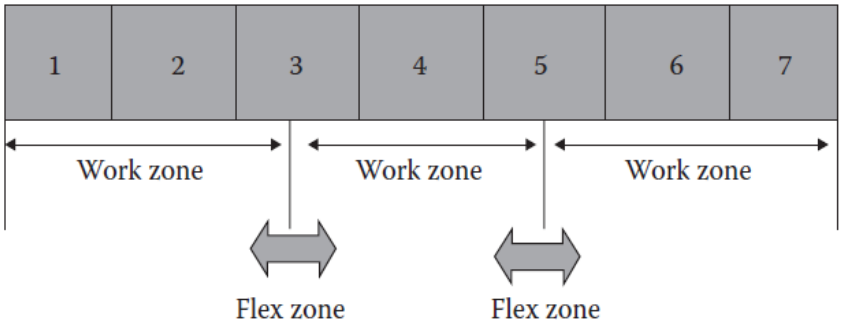

Figure 1 – Station vs work zones with bumping.

Methodology

In the methodology section, authors present job and shop characteristics of the simulation model, along with the features of the Bumping Model.

Shop floor and job characteristics

A simulation model of a pure flow shop has been implemented in Python using the SimPy module. We have kept our flow shop relatively small since this allows causal factors to be identified more easily.

Among the possible shop configurations, the *Pure Flow Shop* is the considered in this study. The reason behind this choice lies in the characteristics of the model under investigation, that is the Baton Bumping Zone Balancing. It performs better when the operators are arranged in an ordered manner, in particular with fastest person placed at the end of the line and the slowest at the beginning. Hence, to assure this condition, the flow must be directed. Moreover, another condition to successfully apply the Baton technique is to have a constant routing. All the jobs must visit all the workstations in their routing to be successfully completed, otherwise it may happen that an operator cannot take the piece of the operator upstream. If that occurs, the sequence of activities that is at the base of the theory fails and it becomes inapplicable.

It is assumed that all jobs are accepted, materials are available, and all necessary information, e.g. regarding shop floor routings and processing times, are known. If order release is applied, jobs are not immediately released to the shop floor, but retained in a so-called pre-shop pool (PSP) from where they are released to meet certain performance targets. As release rule, it is considered a periodic release, meaning that jobs are released from the PSP every 480 time units. The whole job and shop characteristics are presented in Table 1.

Table 1. Shop and Job Characteristics

Shop Characteristics	Routing variability	Fixed
	Number of work stations	5
Job Characteristics	Arrivals	Poisson (λ =1,875 orders per time unit)
	Processing times	Lognormal; mean=0,5 time units, CV=0,8
	Due date	Due date= entry time + 56 time units

In the model, all the products have the same priority when queuing in the pool upstream of the next station: thus, all the products have the same characteristics and there are no product families. In order to better focus on the objectives of this study and not to

influence the results, other factors of variation and uncertainty, such as products breakages, production of defective products, lack of capacity of the handling systems, were not considered.
The shop is designed to have five fixed stations, which perform a specific activity in the overall process. The work in process can be stacked in an input queue, which is placed upstream of the station. Five pools contain the work in process and the buffer does not have a finite capacity but can virtually store an infinite number of jobs. Figure 2 provides a better visualization about the logical arrangement of the shop floor elements.
The reason behind the choice of the number of station comes after the suggestions of different authors found in literature. Hillier and Boling (1967) demonstrated that a line with more than five stations shows performances improvements of few percentage points, basically not significant to justify a further shop floor extension.

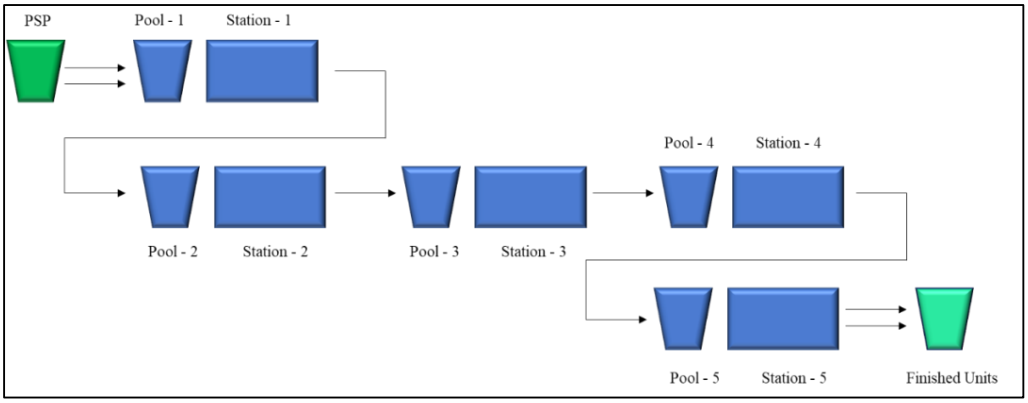

Figure 2 – Logical arrangement of Shop Floor elements

The Bumping Model
The introduction of the Bumping Model has been introduced in the simulation model as a new worker's arrangement rule to be tested. The computational model of the bumping rule strictly follows how it has been theorized by Protzman (2016). The workers, as soon as they are idle, can move to the machine upstream and take the work in process, then they go back to their station in order to continue the job. As described in Protzman (2016), workers are arranged in an ordered manner, with fastest worker placed at the end of the line and the slowest at the beginning.
The computational model performs the following steps:

1. The operator (e.g. W3) is working on a job. Two scenarios may happen:
   1.1. W3 finishes his job. Thus, he/she places the job in the pool of the machine downstream (S4);
   1.2. W4 takes the job from W3's hands.
   In both cases, W3 is not working on a job.
2. W3 has to take the next job from his/her Pool 3.
   2.1. If there are jobs in its queue, operator W3 picks a job from there.
   2.2. If there are no jobs in W3 queue and W2 is working, W3 takes the part of W2.
   2.3. If there are no jobs in W3 queue and W2 is not working, W3 is idle until W2 gets a job.

The procedure is looped asynchronously and individually for each worker.

Design of Experiments

A full factorial design has been used. The levels and the factors tested have been presented in Table 2. To reduce the variance between experiments and to focus only on the variations due to the parameters of the simulation, the common random technique has been used. Therefore, for each replication of the same experiment, different sample of jobs are used, while, the same replication in the different experiments shares the same sample of customer's jobs. The procedure used to compute the warm up period is the Welch method, presented in Mahajan (2004), and it has been performed for all performance measures. Results were collected over 4000 time units following a warm-up period of 2000 time units. To determine the number of runs, the Mean Squared Pure Error (MSPE) has been implemented for the performance measures used. The number of runs chosen, 100, is equal to the maximum that allows the convergence of the MSPE for all performance measures.

The four main system performance measures considered in this study are the following: Gross Throughput Time (GTT), the time between order entry and completion; Shop Floor Throughput Time (SFTT), the time between order release from the PSP and completion; Percentage of Tardy Orders, the percentage of orders with a positive lateness (given by the completion date minus the due date); and, Mean Tardiness, given by max(0;lateness).

Table 2 – Design of Experiment matrix: factors and levels

Workers arrangement rule	Release method	Efficiency
• Bumping Model • Static	Periodic release	Full (100% efficiency)

Conclusions

This research paper is intended to be a methodological paper that proposes a simulation model through which benefits and impacts of the Bumping Model theorized by Protzman, (2016) could be investigated for the first time.

According to the literature, preliminary results show the advantages in terms of reduction of WIP and idle time.

In the literature, the first positive impact of Baton is the maximization of the efficiency of the team members. It is the result of cross-training and of the flexibility of the operators allowed to move and work on the different stations. Thus, this kind of balancing can be also seen as a driver for the cross training of the employees. In addition, the layout resulting from this configuration makes it easy for the workers to rotate, not only to different positions of the line, but also in and out the line. This continuous rotation and variation of the tasks to be performed has a positive impact also on the satisfaction of the operators, leading to an increase of the motivation with consequent reduction of the absenteeism. In relation to the performances of the line, the main advantage of the Bumping Model is the maximization of the output and the corresponding productivity obtained by using the fastest person to create the pull.

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E-business and Operations

Supplier collaboration, e-business sustainability and market performance

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Abstract

This study focuses on the relations between supplier collaboration, sustainability, and market performance in the context of e-business. The data was collected with a cross-sectional random sampling of online store operators located in Finland. Structural equation modeling was used to test the hypotheses. The results did not promote the hypothesized direct link between supplier collaboration and market performance. Instead, supplier collaboration influences market performance via e-business sustainability.

Keywords: Supplier collaboration, E-business sustainability, Market performance

Introduction

The growth of e-business has resulted in major changes regarding how companies operate in the markets. Supplier collaboration has been specifically affected (Scuotto et al., 2017; Yang et al., 2017). E-business, defined as a concept that covers aspects relating to the selling of goods or services online, has enabled information sharing throughout the supply chain, which has made wider integration possible between supply chain members. Thus, supplier collaboration is seen as a way for organizations throughout the supply chain to distribute knowledge, network to enhance performance, and decrease total costs (Soylu et al., 2006). For this reason, the literature often refers to supplier collaboration as an essential facilitator of firm performance (Liu et al., 2009; Cao and Lumineau, 2015; Bals et al., 2018).

In addition, the rise of e-business has put the role of sustainability in the spotlight. In the context of e-business, it is often perceived that the traditional goal of firms, defined as providing profits for owners, has been complemented by more socially and environmentally sustainable goals (Klassen and Vachon, 2003; Oliveira and Martins, 2010; Blome et al., 2014; Al Omoush et al., 2018; Ukko et al., 2018). Concurrently, companies must focus on managing both internal and external relations to become more

socially and environmentally responsible, while retaining economic sustainability (Schrettle et al., 2014; Luzzini et al., 2015; Chen et al., 2017). Many scholars now acknowledge the significance of supplier collaboration in attaining sustainability in the business field (Soosay and Hyland, 2015; Chen et al., 2017). Comprehension of the influence of integrated sustainability and supplier collaboration on company performance is finite (Hollos et al., 2012; Blome et al., 2014). However, the influence of supplier collaboration on sustainability in the e-business context, as well as the impact of such commitment on performance, is empirically under-researched.

This study tests the relations between supplier collaboration, sustainability, and market performance, in the context of e-business, to address the illustrated gaps. In this study, we argue that supplier collaboration leads e-retailers to develop e-business sustainability and in turn, deliver enhanced market performance. Thus, the study contributes to research on sustainable supply chain management by investigating the relation between supplier collaboration, sustainability, and market performance in the context of e-business. The results offer implications for companies operating in e-business by supporting collaboration with suppliers and sustainability values while maintaining high market performance.

This paper begins with a theoretical background of supplier collaboration in the e-business domain. Next, the theoretical model is presented, and its hypotheses are discussed. The methodology adopted for the study is then explained, and the results are presented and discussed. Finally, contributions to research and managerial practice are proposed, accompanied by future research directions.

Theoretical model and hypotheses

Definition of key concepts

Supplier collaboration. Supplier collaboration refers to a critical business process for developing closer relationships with key suppliers to create relationship value (Autry and Golicic, 2010; Lambert and Schwieterman, 2012; Bals et al., 2018; Bals and Turkulainen, 2017). This process also demonstrates the importance of relational mechanisms in relationship activities (Jayaraman et al., 2013; Selviaridis and Norrman, 2014; Kreye et al., 2015). Relational mechanisms refer to the extent to which relationships are governed by social interactions, such as personal contacts, information sharing, mutual support, and teamwork (Jayaraman et al., 2013; Cao and Lumineau, 2015). Previous studies in operations and supply chain management identified exchanging information, joint sense-making, and integrating knowledge as important relationship mechanisms in the supplier collaboration (Selnes and Sallis, 2003; Cheung et al., 2010). Furthermore, collaboration between e-retailers and suppliers represents a critical component of service delivery processes, through which e-retailers have direct input in the development of e-services (Ngo and O'Cass, 2009).

E-business sustainability. Companies using e-business applications are more sensitive and responsive to their environment and more aware of the role of e-business applications in gaining sustainability and long-term competitiveness (Al Omoush et al., 2018). Many studies present the concept of sustainability in terms of environmental, economic, and social aspects (e.g., Pålsson et al., 2017; Rantala et al., 2018). In e-businesses, this concept may describe the extent to which the e-business application allows the company to operate in economically, socially, and environmentally sustainable ways. This definition is used as a definition of e-business sustainability in this study. When focusing on e-business sustainability from the economic perspective, the evolution of digital distribution

channels, such as software platforms, operating systems, web services or online shops (Nylén and Holmstrom, 2015), may increase the sales and market shares of the companies. From the social aspect of e-sustainability, e-service recovery is an example that can be defined as the process of electronically handling customer problems and turning them from a negative into a positive experience (Oliveira and Roth, 2012). On the other hand, in many parts of the world, an online store may be the only way to obtain a particular product or service and can, therefore, affect social sustainability. Regarding the environmental aspect of e-business, information richness that refers to the quality of information about environmental impacts presented in the e-business portal can be essential (cf. Oliveira and Roth, 2012).

Hypothesis development

The hypothesized model is demonstrated in Figure 1. The model indicates that supplier collaboration in managing the e-business provides the potential to increase market performance. However, our model suggests that such potential is realized only when attention is paid to e-business sustainability. While supplier collaboration is crucial in making the e-business work, sustainability engagement offers the channel through which suppliers and focal firms can enhance e-business sustainability and further provide the way for the focal firm for succeeding in the markets. Thus, a firm that embraces a lack of e-business sustainability may not necessarily attain enhanced market performance, even though their suppliers had "properly" informed them d concerning e-business. Thus, the model proposes that e-business sustainability act as a mediating mechanism that connects supplier collaboration practices and market performance. Next, two hypotheses are developed.

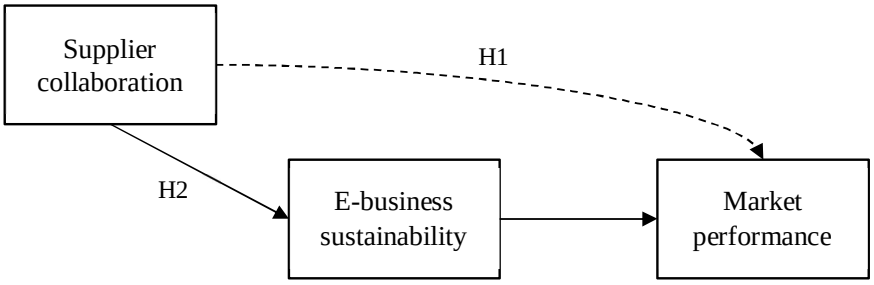


Figure 1 – Hypothesized model

The position of the firms in the market resides in the firm's competences, routines, and practices, which enable firms to perform more preferably in different marketing activities, including customer services, business brand, and sales promotion (Ho and Lu, 2015). Because development of firms' competences is executed through learning procedures, there is a need for cumulative experiences and complementary resources, which are achieved with supplier collaboration (Ho and Lu, 2015; Mishra and Shah, 2009). Furthermore, research of supply chains has revealed that suppliers could learn much from service experiences created by suppliers and different practices (Cheung et al., 2010). Moreover, gaining external knowledge and higher firm performance can be achieved by the firms' ability to leverage partners, including supplier collaboration (Gupta and Polonsky, 2014; Krause et al., 2007). Accordingly, supplier collaboration provides multiple benefits, such as new product development, operational performance, and

knowledge creation for the companies, which contributes to market performance (Cao and Zhang, 2011; Flynn et al., 2010; Mahmood et al., 2011).

In supplier collaboration, continued relationships, interactive activities, and working together help partners to deepen their understanding of restrictions, strengths, and enhancing opportunities for collaborative activities that result in improved customer services and offerings as well as market performance through quick responses (Cao and Zhang, 2011). Ho and Lu (2015) refer to supplier collaboration as a double-edged weapon that improves exploration and hinders exploitation of market performance. Ho and Lu (2015) noted that growth in firms' performance, achieved by supplier collaboration, decreases companies' willingness to enhance their internal resources, learning, and competences to improve marketing competences. Consequently, the effectiveness of exploitation to create customer value and enhance market performance will diminish. Based on the discussion above, the first hypothesis is formed as follows:

Hypothesis 1: Supplier collaboration is positively associated with market performance.

With the growing number of possibilities for product and service offerings, firms taking advantages of e-businesses today are growingly demanding sustainability engagement (Oláh et al., 2019; Aras and Crowther, 2009). As such, sustainability engagement has become more important to develop e-business operations that pay attention to economic, social, and environmental sustainability, not only to attract but, more importantly, to keep customers (e.g., Pålsson et al., 2017). The development and implementation of e-business sustainability will enable e-business operators to build long-lasting relationships with their customers and thus improve market performance. For example, the economic sustainability of e-business requires that firms should not only focus on short-term transactions and deliveries but also on long-term customer relationships. Firms should also ensure that customers can see value in their purchases and be satisfied with them (Oláh et al., 2019).

The social sustainability of e-business and its intersection with social media provides a wider audience through the rise of social commerce (Wang et al., 2019). By combining e-business with social media solutions as part of e-business operations, social commerce creates new ways to develop social sustainability, thus giving firms new mechanisms to develop customer channels for customers to improve their purchase decisions: for example, through interactions and user-generated content (Wang et al., 2019; Kim and Kim, 2018; Zhang et al., 2017). As such, social commerce provides solutions for firms to enhance the social sustainability of their e-business and increase their market performance through customer engagement (Zheng et al., 2015).

Many of the environmental harms in contemporary e-businesses are based on the transportation and logistics of delivered products and services. Thus, paying attention to logistics is an important part of environmental sustainability development. For example, Al Omoush et al. (2018) noted that manufacturing companies have a wide range of business partners, including suppliers, distributors, and logistics companies, that must share information concerning orders, production, inventory, and delivery of products and services. Sharing this information, from the aspect of environmental impacts on e-business platforms (e.g., online shops), may affect market performance. E-business platforms should be flexible and time-reliable, and both firms and their customers should be able to monitor processes to reduce carbon emissions by decreasing customer returns (Oláh et al., 2019; Yang et al., 2016).

Based on the considerations presented above, it can be said that e-business sustainability plays a crucial role in transforming supplier collaboration to gain higher market performance. As such, the second hypothesis is presented as follows:

Hypothesis 2: E-business sustainability mediates the relationship between supplier collaboration and market performance.

Research methodology

Data collection

Data were collected from a survey of companies located in Finland. The sample consisted of firms that have an online store. The respondents worked in management positions, which gave them good information when answering items related to online store operators' supplier collaboration, e-business sustainability, and market performance. Initially, the survey was sent to 2,312 online store operators, which is about 31% of the total number of online stores in Finland. Of the 2,312 surveys sent, 109 responses were returned. Of the surveys returned, 75% had five or fewer employees, and 25% had more than five employees. About half of the online stores had been established for less than five years, and half were established more than five years ago. The survey results showed a diverse range of products, including clothing, athletics, decoration, construction, information technology, and management consulting.

Measures

Prior scales informed all of the scales used in the survey. A focus group formed by the researchers was used to identify a variety of supplier collaborations and e-business sustainability practices. These views were incorporated into the survey items presented below.

Supplier collaboration: A two-item scale ranging from 1 ("poor") to 4 ("excellent") was used to measure supplier collaboration. Respondents were asked to estimate their experiences with the services provided by the supplier and their relationship with the supplier.

E-business sustainability: We examined e-business sustainability utilizing a three-item scale, ranging from 1 ("poor") to 4 ("excellent"). Respondents were asked about the extent to which their online store allows them to operate in an economically, socially, and environmentally sustainable way.

Market performance: Market outcomes were measured with a one-item, four-point scale, ranging from "totally disagree" to "totally agree." Respondents were asked to estimate their firm's position in the markets.

Control variables: Firm size (measured by number of employees), firm age (measured by the number of years since firm establishment), and competitive intensity (measured on a scale of 1 ("little competition" to 3 ("lot of competition") were controlled. Increased firm size and age may create better possibilities when competing in the markets. On the other hand, high competition may affect market performance by reducing the possibilities of competing in the markets.

Statistical analysis

Common method and non-response bias

Non-response bias was checked with an analysis of the variance test. Early respondents were compared with later respondents on several items (Armstrong and Overton, 1977).

The findings demonstrated no statistically significant differences in the variables between the two sets. Therefore, non-response bias did not exist. Utilizing only a single respondent from one company may pose puzzles relative to common method variance. This prospective puzzle was controlled via the Harman single-factor test (Podsakoff et al., 2003). Factor analysis results reveal that more than one factor emerged, and the prior factor did not explain the greatest portion of the variance. In survey design, clear and brief items, as well as different response forms, were used as recommended by Podsakoff et al. (2003). We also used a survey structure where the respondent could not identify exogenous and endogenous variables. The introductory letter assured the recipients that responses would be handled in confidentiality, and the respondents were encouraged to provide truthful responses. In sum, common method variance is not likely, due to the multiple remedies.

Measurement model

First, the data were tested to ensure unidimensionality, validity, and reliability. The item validation was made by confirmatory factor analysis (CFA) with the maximum likelihood method. Table I shows the loadings and error terms of the variables in relation to the corresponding factor. The values of the average variance extracted (AVE) were greater than 0.50, which is the suggested minimum (Hair et al., 2010) for convergent validity. Internal consistency was also supported since composite reliability (CR) measures were above the threshold of 0.70 (Fornell and Larcker, 1981). The results were also in favor of discriminant validity since the square root of the AVE (bold in Table 2) was higher than the correlations between factor pairs. In addition, reliability was checked with Cronbach's α values (Nunnally, 1967), and the values exceeded the threshold. Since all the measures were supportive, the structural model test results are presented next.

Table 1 – Reliability and construct validity

Factor	Items	Std. loadings	Error term	z-value	Cronbach's α	CR	AVE
Supplier collaboration	SCO1	0.93	-	-	0.877	0.942	0.891
	SCO2	0.84	0.14	6.86			
E-business sustainability	ESUS1	0.86	-	-	0.908	0.945	0.851
	ESUS2	0.99	0.08	13.68			
	ESUS3	0.83	0.10	10.72			

Table 2 – Correlation matrix, descriptive statistics and discriminant validity

	Mean	St. dev.	1	2
1 Supplier collaboration	2.91	0.765	**0.994**	
2 Sustainability	2.84	0.678	0.422***	**0.922**
3 Market performance	2.98	0.832	0.315***	0.575***

Note. ***$p \leq .001$, The diagonal values in bold are the square root of the average variance extracted.

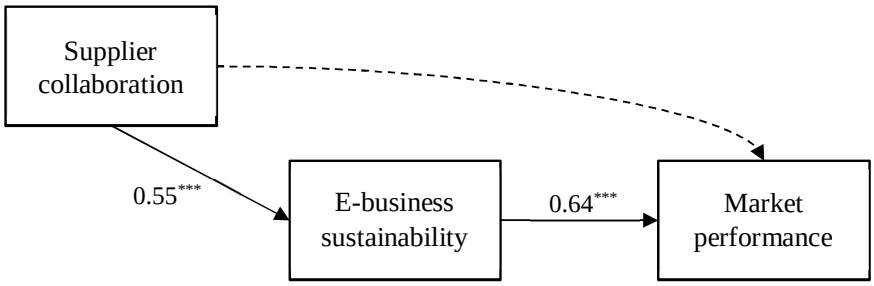
Testing of structural model and mediation

The first model that tested a direct relationship between supplier collaboration and market performance demonstrated a poor fit. The results of the hypothesized model are demonstrated in Figure 2. Goodness-of-fit measures show a good fit: TLI = 0.950, CFI = 0.978, RMSEA = 0.077, and SRMR = 0.050. The path between supplier collaboration and e-business sustainability was significant ($p \leq 0.001$) and strong (path coefficient = 0.55). Thus, supplier collaboration leads to an increased level of sustainability. E-business sustainability was also significantly ($p \leq 0.001$) and strongly (path coefficient = 0.64)

related to market performance. Firm age was proven to have a significant (path coefficient = 0.27, $p \leq 0.001$) effect on market performance, but firm size (path coefficient = -0.039, ns) or competitive intensity (path coefficient = -0.09, ns) were not significantly related to market performance. These results indicate that the relationship between supplier collaboration and market performance is mediated by e-business sustainability.

A competing model was tested to confirm this finding. A rival relationship linking supplier collaboration to market performance was tested in this model. The results reveal that a direct path from supplier collaboration to market performance is non-significant (path coefficient = 0.14, ns), whereas the paths between supplier collaboration and e-business sustainability ($p \leq 0.001$, path coefficient = 0.55) and e-business sustainability and market performance ($p \leq 0.001$, path coefficient = 0.56) were significant and strong.

Based on the above results, we found no support for hypothesis 1; thus, supplier collaboration is not directly associated with market performance. We found support for hypothesis 2, which means that e-business sustainability mediates the influence of supplier collaboration on market performance, as predicted.



Note. ***$p \leq .001$, dotted line indicates non-significant relation.

Figure 2 – Results for structural equation model

Conclusion

This study tested the relations between supplier collaboration, sustainability, and market performance in the context of e-business. In terms of structural relationships, the results reveal significant backing for the hypothesized relations between supplier collaboration and e-business sustainability, and between e-business sustainability and market performance. Contrarily, the results did not promote the hypothesized direct link between supplier collaboration and market performance. These three findings suggest that the relation between supplier collaboration and market performance is fully mediated by e-business sustainability. Firm size and competitive intensity were not shown to affect market performance, but firm age was significantly related to market performance.

Theoretical implications

The study contributes to research concentrated on sustainable supply chain management as follows. First, the study diverges from previous research by investigating the relations between supplier collaboration, sustainability, and market performance in the context of e-business. The results provide clarification of the role of supplier collaboration as a fundamental enabling factor in determining the market performance of e-businesses. The results do not mean that supplier collaboration does not have an important value in improving market performance but point to the fact that its effect on market performance is realized through a commitment to sustainability. Second, through a survey of e-

retailers, the research empirically tests the implications of integrating sustainability commitment into supplier collaboration and provides a novel contribution to existing theoretical and conceptual studies.

Managerial implications

This study provides guidance for managers of the SMEs in the e-business context on how, with the support of e-business sustainability and supplier collaboration, to enhance market performance. Managers of SME's in e-business context can scan for opportunities to enhance market performance while considering e-business sustainability in their business. Thus, while supplier collaboration is crucial in making the e-business work, its benefits are realized only when the online shop operator also pays attention to how it uses the online store in an environmentally, socially, and economically sustainable way. In addition, the results revealed that in the e-business context, companies with more experience could achieve higher market performance through e-business sustainability.

Limitations and future research

Certain limitations should be acknowledged in this study. The study was conducted in Finland, which might limit the generalization of our findings from Finland to other countries with different cultures in the e-business context. Also, the cross-sectional nature of the data may limit an in-depth understanding of how e-business sustainability mediates the relationship between supplier collaboration and market performance. Thus, further research with longitudinal data might help to enhance understanding of this topic.

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Integrated demand and shelf life-based inventory management to reduce food waste within e-grocery operations

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Abstract

This work investigates integrating demand and shelf life data in inventory management systems at e-grocery providers. A store-based delivery setting, i.e., orders are delivered to consumers' premises from regular brick and mortar stores, is considered. Consumer preferences and order patterns derived from an online survey and a conjoint analysis are loaded in a simulation and optimization-based decision support system to adjust pricing and replenishment strategies over time. Computational experiments focusing on the distribution of fresh milk highlight potentials of such integrated methods to facilitate a reduction in food waste within e-grocery operations.

Keywords: E-Grocery, Perishables, Food Waste

Background and Motivation

In a recent work on retail operations and food waste, Teller et al. (2018) highlight the importance of various business areas such as marketing, store and retail operations working closely together to facilitate sustainable processes. Among others, the authors identify interdependencies between retail store operations and consumer behavior as major obstacles for food waste reduction requiring future research. Consequently, a joint investigation considering both demand and supply specifics is required, however, related interdependencies are rarely studied in literature, particularly for e-grocery settings.

E-groceries, i.e., the delivery of food products ordered online to customers' premises, is expecting high growth rates of 20 % annually over the next years (IGD research, 2018).

Last-mile distribution of such grocery products, however, is challenging, particularly compared to traditional products ordered online such a fashion items, books and electronics. Regular market baskets are considerable larger, e.g., a single e-grocery order averages around 50 items in Germany and 70 ones in the United Kingdom (Wollenburg, 2018), and often consist of a variety of low-value items. Additionally, common characteristics of food logistics operations such as the perishability of products and their sensitivity to varying environmental conditions require special attention to deliver products to customers on time and in the desired quality (Fredriksson and Liljestrand, 2015).

Such e-groceries are often distributed through omni-channel retailing networks. This requires the simultaneous consideration of a wide range of interdependent decision factors such as picking strategies, delivery mode and time as well as the delivery area and how to handle returns (Hübner et al., 2016). The focus of this work is on inventory management strategies considering a store-based delivery concept. In such a setting, the e-grocery provider owns multiple brick and mortar stores and uses these locations to fulfil e-grocery orders. This allows the provider to enter the market swiftly at low investment costs and without requiring additional space, however, complicates inventory management systems as processes are predominantly optimized for regular store operations (Wollenburg et al., 2018).

To assist successful e-grocery operations, this work investigates integrating consumer preference data as well as various inventory replenishment and fulfillment strategies. A sample setting for highly perishable products is studied. It focuses on the option to dynamically adjust product prices and replenishment strategies based on current inventory levels to facilitate a reduction in food waste. The contribution of this work is threefold: (i) it introduces a consumer survey and a conjoint analysis to enable the modelling of individual preferences; (ii) develops a decision support system (DSS) to facilitate dynamic adjustments of product prices and fulfillment strategies; and (iii) derives managerial implications to support sustainable e-grocery operations in the future.

Related Work

Various authors study the reduction of food waste in retail operations and the development of last-mile distribution strategies for e-grocery providers. The majority of work focuses on either the supply or the demand side, i.e., on retail operations or consumer behavior respectively.

An overview of various last-mile fulfilment concepts operated by e-grocery providers is given in Hübner et al. (2016). Through a series of explorative interviews with various stakeholders and the analysis of key literature, the authors develop a strategic planning framework highlighting relevant decision factors as well as potentials and drawbacks of various fulfillment concepts. This work is further extended in Wollenburg et al. (2018) with a focus on the development of related logistics network over time. Revenue models in e-grocery operations and their environmental impacts are investigated in Belavina et al. (2017). A subscription model is compared with a per-order one through in-depth modeling of retail operations and consumer behavior. Results highlight positive impacts of a subscription business model as lower order sizes and more frequent orders result in less food waste at consumers and higher revenues for the retailer. Nevertheless, it further leads to higher delivery costs, indicating the importance of integrated approaches to consider various interdependencies present in e-grocery operations. The retailer's inventory management system was not explicitly considered in this work and per-unit prices of groceries are not varied over time. Reiner et al. (2013) investigate that the design of in-store logistics processes such as store capacity management, lead-time, order period

and safety stock lead to higher on-shelf availability combined with reduced food waste. Price-dependent purchasing quantities under consideration of reservation price, another interesting stream of relevant literature, which is derived from revenue management, is addressed in Reiner et al. (2014). With a focus on order policies for perishable products, Haijema and Minner (2019) investigate the value of integrating remaining shelf lives of products on stock in replenishment strategies. By giving lower weights to products likely to expire soon and explicitly considering waste, the authors show that costs can substantially be reduced. Root causes for food waste within retail operations are identified in Teller et al. (2018) by conducting expert interviews and providing a process simulation. Beside inefficient replenishment strategies, demand variations and inefficient store operations, the authors particularly highlight the importance customer behaviour has on food waste. Consequently, to facilitate a reduction in food waste, a closer investigation of consumer related factors is required. Several studies have dealt with this issue and identified product quality (Wilson-Jeanselme and Reynolds, 2006), delivery fees (Waitz et al., 2018) as well as the travel distance to the store (Huang and Oppewal, 2006) as important factors. Apart from the identification of such factors, previous work also reveals that there exists heterogeneity among the individual customer preferences (Horta et al., 2017).

The importance of future research on revenue management in this area is highlighted in Agatz et al. (2008), who provide a review on e-fulfillment and multi-channel distribution. The authors note that, in contrast to traditional revenue management such as airline ticket operations where order costs are marginal, shipping expenses play a major role in e-fulfillment. Such expenses are significant and interdependent on other orders, which highly complicates revenue management activities. In Agatz et al. (2011, 2013), time slot management and related revenue management strategies are discussed. The focus is on offering different time windows for scheduled home deliveries at varying prices, while the delivered product quality is not considered. In e-grocery operations, however, incorporating such quality factors is of importance as it allows one to further diversify and potentially enables providers to reduce food waste while increasing revenues and customer satisfaction. In contrast to regular store operations where consumers pick specific items based on their preferences, in e-grocery operations, this decision is mainly performed by the provider, e.g., retail chain company, which has major implications on food waste and fulfillment costs (Fikar, 2018).

Little work on related decision support to facilitate sustainable food logistics is found in the literature. Jedermann et al. (2014) highlight the impact of different inventory policies on food losses. Six suggestions for strategic food supply chain management are given, including the selection of logistics providers and the number of hubs as well as transport mode choices. Furthermore, improvements in supply and demand management as well as diversification on quality are recommended. Fikar (2018) introduces a DSS enabling one to jointly investigate order picking and delivery strategies to reduce food waste in e-grocery operations. Results highlight a trade-off between minimizing delivery distances and minimizing food waste in delivery operations. A daily study horizon is modeled and replenishment strategies are not considered. Waitz et al. (2018) extend this work by incorporating consumer preferences and focusing on a multi-period problem setting. Therefore, each consumer is modeled within an agent-based simulation and initiated with individual preferences for service characteristics such as the width of time windows, shipping fees and delivered product quality. Varying service offers of the e-grocery provider are investigated to highlight trade-offs between service quality and logistics performance. Estrada-Moreno et al. (2019) considers the option to reallocate perishable products between various stores of a supermarket chain throughout a day of

operations. By developing a metaheuristics vehicle routing solution procedure, the authors show that such strategies can contribute to a major reduction in food waste.

Method

To support integrated demand and shelf life-based inventory management system, this work develops a model-driven DSS. Based on a consumer survey and choice-based conjoint analysis, consumer preferences are derived. Such preferences enable one to model customers individually within an agent-based simulation, which is facilitated to simulate various problem settings and derive managerial implications. Additionally, a special focus is set on replenishment strategies for perishable products to allow one an integrated view on e-grocery logistics operations. Figure 1 gives an overview of the various research methods and introduces the decisions considered in this work.

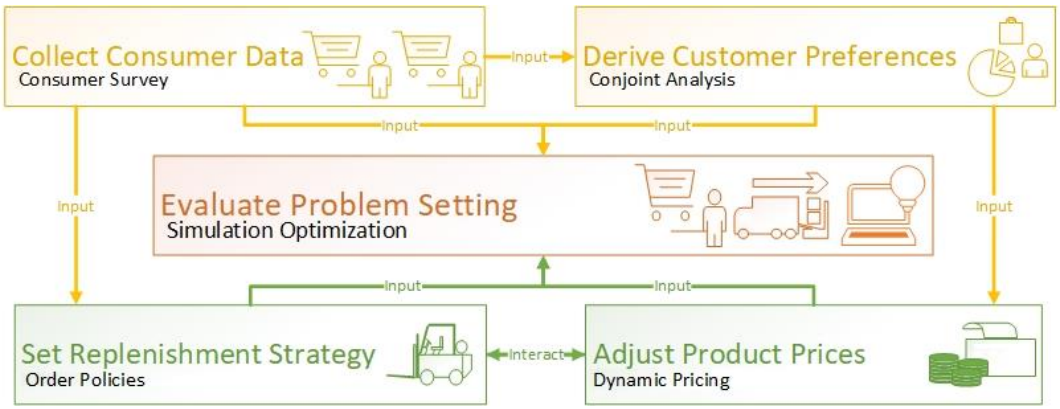

Figure 1 – Integrating demand and shelf life data within e-grocery inventory systems

The consumer data is collected for the Austrian grocery market. For the survey, 1.000 respondents have been recruited by a professional third-party panel provider and age, gender and residential area have been used to stratify the sample. The survey is containing questions regarding the general grocery shopping behavior as well as the respondents' tendency towards online shopping. Additionally, a choice-based conjoint analysis has been included to identify the individual preferences for logistics services (delivery fee, delay of delivery, time-window width and delivery day) and milk specific characteristics (remaining shelf life and product price). Table 1 shows the included attributes and attribute levels. Figure 2 gives an impression of the choice-based conjoint tasks. Five such tasks have been randomly assigned to each respondent for which they have to choose between either picking one of the two products or the 'none' option. Based on these choices, the individual preferences of the respondents for the various attribute levels are derived by using the statistical software R (R, 2019), which allows the modelling of the existing heterogeneity across e-grocery shoppers.

Table 1. Attributes and levels for the choice-based conjoint analysis

Attribute	Levels
Remaining shelf life	Not available 2 days 4 days 7 days 10 days 14 days
Price	0.69 EURO 0.99 EURO

	1.29 EURO 1.59 EURO 1.89 EURO
Time window width	0 hours (exact time delivery) 2 hours 4 hours 6 hours 8 hours
Delay of delivery	0 minutes 15 minutes 30 minutes 45 minutes 60 minutes
Delivery day	0 (same day delivery) 1 (next day delivery) 2 days 3 days
Delivery fee	0 EURO 1.99 EURO 3.99 EURO 5.99 EURO 7.99 EURO 9.99 EURO

Attribute	Product 1	Product 2	None
Remaining shelf life	7 days	2 days	
Price	1.59 €	0.99 €	
Time window width	4 hours	4 hours	
Delay of delivery	30 minutes	0 minutes	
Delivery day	1 (next day)	2 days	
Delivery fee	3.99 €	5.99 €	

Figure 2 – Overview of one choice-based conjoint task

Collected data is integrated within a simulation and optimization-based DSS to enable decision makers an integrated view of the various aspects influencing food waste within store-based e-grocery operations. The DSS, which is based on Fikar (2018), contains an agent-based simulation to model consumer behavior and integrates various heuristic solution procedures to optimize delivery and replenishment operations. Therefore, it considers an agent that applies the related replenishment method to set specialized strategies for perishable products. The basic replenishment setting assumes lost sales (no backorder of unsatisfied customer demand), a perfect supplier (i.e., deterministic lead-time) and a periodic base stock replenishment policy. This serves the basis to benchmark the extension of recently published policies for perishable products that may consider simultaneously pricing and related customer preferences. This enables one to demonstrate how pricing may influence consumer priorities to move to first-in-first-out (FIFO) instead of last-in-first-out (LIFO), potentially resulting in lower food waste for packaged products. Each consumer is modeled as an agent and acts according to his or her preferences. Additionally, collected order patterns and available time windows are used to generate demand. Figure 3 visualizes this ordering process of a customer agent within the DSS.

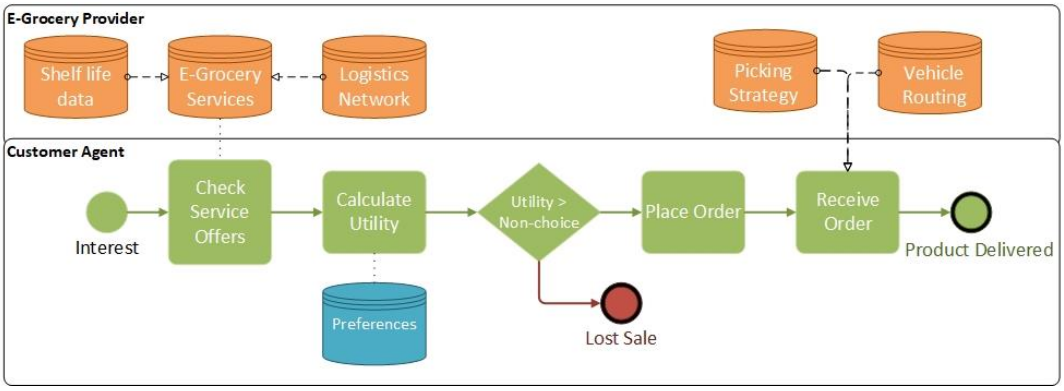

Figure 3 – Ordering process of a customer agent

Based on the collected order frequencies, an event is generated within the DSS each time a customer agent is interested in purchasing e-groceries. Therefore, the agent is assumed to visit the webpage of the provider where an offer is presented stating both the guaranteed remaining shelf life of the product at delivery and its price. Various discounts can be offered to steer the consumer into buying products with shorter shelf lives, potentially enabling the provider to increase revenue and reduce food waste. To decide which offer is selected by the consumer, the utility of each offer is calculated by adding up derived preferences from the conjoint analysis for each of the investigated categories. The service offer scoring the highest utility is selected and subsequently ordered. If no offer scores higher than the non-choice options, no order is placed and the event is counted as a lost sale. Through the simulation of multiple weeks of operations and various problem settings and solution strategies, the DSS returns statistics on key figures such as revenue, food waste and inventory costs. This assists the decision maker to investigate benefits of integrating both demand and shelf life data within e-grocery operations.

Results and Discussion

To test the developed system, validate findings and derive managerial implications, a real-world based sample setting of a major e-grocery provider in Vienna, Austria is considered. The provider operates 255 stores throughout the city, which fulfill online orders of customers. Fresh milk, i.e., milk with an average shelf life of 6 to 10 days if refrigerated, acts as a sample setting for a highly perishable product. If stored longer, the product cannot be sold by the provider anymore and is recorded as a food waste within the study. The DSS is developed with AnyLogic 8.4 (AnyLogic, 2019) with all solution procedures coded in Java.

Preliminary results discuss the trade-off among various key figures based on simulated data as the consumer survey is still ongoing at the time of submission. Consumer behavior is shown to be of virtual importance to both reduce costs and food waste. If consumers employ a LIFO picking strategies, i.e., select products with long shelf lives first, a high amount of food waste occurs as older products cannot be sold before expiration. This requires either an adjustment in the replenishment strategy or results in substantial amounts of stock outs and lost sales. By adjusting pricing and steering customer to a FIFO selection, i.e., picking items with shorter shelf lives, costs and food waste can be substantially reduced. This trade-off between a reduction in costs due to lower food waste and changes in the revenue due to adjusted prices is of particular interest for future experiments conducted with real-world demand data. Additionally, guaranteeing the consumer a specific remaining shelf life of products at delivery has major implications on delivery operations, particularly when demand is high and only few products are

available. Delivery vehicles are highly utilized in such settings and may be required to travel additional detours to collect items with short remaining shelf lives located at distant stores, resulting in additional travel distances and potentially late deliveries. Such further impacts on delivery costs are shown to require special attention within the experiments to enable an integrated view of e-grocery operations and their impact on food waste.

Conclusions

This work introduced a framework on how to model the integration of demand and shelf life data within inventory management systems to facilitate a reduction in food waste. The focus is on store-based e-groceries and highly perishable products with fresh milk acting as the sample setting. To model demand, an online survey and a choice-based conjoint analysis is run in which customers are evaluating various service offers based on personal preferences. Derived order patterns and utilities both influence the replenishment strategies and delivery processes within a simulation and optimization-based DSS. First computational experiments with simulated data highlight various trade-offs of interest, particularly between logistics costs, revenues and food waste. Consequently, by integrating remaining shelf lives of products on stock within a DSS and facilitating collected consumer preferences to dynamically adjust pricing and replenishment strategies, decision makers can investigate various strategies to derive managerial implications and facilitate sustainable operations.

Future work focuses on integrating the collected consumer preferences within the DSS to develop strategies on how to use such data to enable flexible e-grocery operations. Therefore, a close consideration of current inventory stock levels and remaining shelf lives of products is required. Furthermore, investigating the impact of promotional activities and evaluating various adjustments of consumer behavior over time in response to the delivered service quality is of interest.

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On Building a Business Ecosystem of E-commerce Companies: An adaptive structuration perspective

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Abstract

This study aims to explore how e-commerce companies utilize platform technology to build a business ecosystem. A multiple-case study is adopted and four successful county-level e-commerce companies are examined. Six main themes are identified as platform technology, internal and external factors, e-commerce strategy, managerial activities, economic outcome, and new business ecosystem. Through discussion from an adaptive structuration perspective, a conceptual framework associated with five sets of propositions is built. This study contributes to adaptive structuration theory through extending it to an inter-organizational focus in e-commerce context. The proposed framework provides potential guidelines for companies to implement their e-commerce business.

Keywords: E-commerce, business ecosystem, adaptive structuration perspective

Introduction

E-commerce industry has been growing dramatically worldwide and new e-commerce markets are continuously springing up. China, as the most fastest growing and largest e-commerce market, its e-commerce adoption in rural area is booming considering a large number of rural population of 589 million, accounting for 42.65 percent of the total population according to the National Bureau of Statistics report. Obviously, the domestic rural market is a large consumer group and stakeholder in China. Although there are ample articles that analyse the county level e-commerce in China in the point of view of economic development, government policy, driving factors and future forecasting, studies adopting e-commerce technology to build the business ecosystem are limited. Hence, in this research, we attempt to explore the following research question:

How do e-commerce companies utilize platform technology to build a business ecosystem?

To answer this question, we ground our research in Adaptive Structuration Theory (DeSanctis and Poole, 1994), which is the theoretical tool to explore how new structure occur through utilizing the advanced information technology (AIT) in action within and across organization (Rains and Bonito, 2017; Holweg and Pil, 2008; Lewis and Suchan, 2003).

The rest of the paper is structured as follow. Next section provides the literature review of e-commerce and business ecosystem, and the theoretical background of adaptive structuration theory; methodology section presents the case research method; findings and discussion section discusses the case findings against the reviewed literature and develops a conceptual framework and a number of propositions. Finally, this study is concluded through summarizing the contributions and limitations.

Literature Review

Discussion on e-commerce and business ecosystem

The essential element of e-commerce business is the platform. After "two-sided markets" theory came out, the platform has become an important research topic in different fields such as social networks, operating systems and transaction systems (Armstrong, 2006; Caillaud & Jullien, 2003; Roson, 2005). According to Evans and Schmalensee (2007), platform has a decisive role in ICT industry, distribution, finance, media and even urban planning. Cooke (2012) stated that platforms offer firms a significant potential for innovation.

Platforms are vitally important in creating value (Jacobides et al., 2006). Rochet and Tirole (2004) stated that platform strategy creates value through interacting with interconnected users in a two-sided market. Meanwhile, Evans et al. (2006) claimed that platform strategy is able to help strengthen platform with the network effect. Furthermore, Eisenmann et al. (2009) proposed that the adoption of suitable platform strategy enables firms take the lead in the market. In particular, Kim (2016) suggests that platform providers should consider quality management and revenue structure when building the business ecosystem in the two-sided market.

The study of business ecosystem focused on the interaction process among companies and the surrounding business environments. Moore (1993) suggested that all companies are as part of an ecosystem, and this economic community is established through a loosely interconnected network of actors including interacting organizations, individuals and other entities, cooperating, competing and coevolving their capabilities around an innovation, sharing knowledge, technologies, skills and resources to satisfy customer needs. Following the work of Moore, Iansiti and Levien (2004a) proposed that business ecosystems are formed through the interaction activities among entities in networks, including products or services providers, technology providers, outsourcing firms, a host of other organizations, distributors and suppliers. The ecological perspective does not view the economy as a machine but a living, evolving ecosystem (Rothschild, 2004). Various stakeholders of the ecosystem evolve and tend to align themselves (Gobble, 2014). Adner (2012) suggests a wide lens strategic tool for business managers seeking to assess, build or reshape business ecosystems.

Adaptive structuration theory

The theoretical lens adopted to investigate the research question is adaptive structuration theory (AST), which is first proposed by DeSanctis and Poole (1994) as a framework to examine the interplay between expected structures for behaviour that designers of IT systems has predicted or built into their systems and the structures that

actually emerge. It explains the outcomes of technology use in groups and organizations by focusing on the dynamic relationship between technology design and organizational practices (Rains and Bonito, 2017). Scholars argue that AST has been adopted largely at the intra-firm level, but it also a significantly useful theoretical framework that can help understand the relationship between technologies, the organizations who interpret them, and the new structure generated from the interpretation (Holweg and Pil, 2008; Lewis and Suchan, 2003; Ghoshal and Moran, 1996).

AST, in the original work of DeSanctis and Poole (1994), provides a model that describes the interplay between AIT, social structure, and human interaction to understand how technology structure can trigger organizational change. The model is investigated from three main segments that are AIT as social structure, group decision making in action, and new social structure. According to DeSanctis and Poole (1994), AIT offers social structure consisting of features and spirits. AIT features indicate the specific capabilities of a given technology and AIT spirits refer to the preferred set of actions and interpretations of technologies (Rains and Bonito, 2017), which represent the characteristics of AIT.

The action indicates the act of bringing the characteristics of AIT into specific decision-making activities through AIT appropriation (DeSanctis and Poole (1994). Rains and Bonito (2017) further adapt the action proposed by DeSanctis and Poole (1994) in the e-commerce context, and propose the e-commerce in action is the extend of use of web technology in facilitating e-commerce strategies and activities. E-commerce strategy is a consequence of structured behaviours to utilize the web technology in strategies for attracting new customers and creating new channel. E-commerce activity indicates the use of web technology for enabling customer-facing activities such as sales, market, service, distribution, etc. (Chatterjee and Sambamurthy, 1999; Chatterjee et al., 2002).

This research focuses on building the new e-commerce business ecosystem through the adoption of platform technology, which includes the investigation of platform technology, how companies utilize the platform technology in action, and the new business ecosystem established during this process. Thus AST is well positioned to explain the phenomenon and answer our research question.

Methodology

Interpretive case study was selected as a detailed research strategy, which includes interviews, archival records, documentation and field trips. According to Eisenhardt (1989), through analysing the context of a case study, the theory being studied can be illuminated. Yin (2009) states that a case study methodology is appropiate for investigating real-life context and contemporary events with the use of multiple data sources. Since this research aims to answer how e-commerce companies utilize platform technology to implement e-commerce towards building business ecosystems, the case study methodology would be valuable in providing explanations in an empirical and real-life context. Herriott and Firestone (1983) states that the multiple case design is more persuasive than the single case design and it can produce a more solid research. Hence, this study adopts multiple case methods and follows the corresponding processes recommended to conduct case study research and ensure the rigor.

After conducting an in-depth study of all the chosen companies, four typical cases are eventually selected in order to analyse and understand common issues in the county level e-commerce from the AST perspective. The four case companies represent the pioneers and the most successful cases of China's county level e-commerce, and the Chinese government awards them as the national exemplars of county level e-

commerce. County level e-commerce service providers can be categorized either by private platform operators or public-service-based platform operators. The four case companies selected are identified as the latter type that cooperates with the government and serves a large population of given areas. The basic information of the four case companies is profiled in Table 1.

Table 1 – The basic information (until 30 August 2017)

	Ganjie	**All City**	**Wenyuan**	**Mingyu**
Started In	2010	2014	2013	2015
Coverage				
- Province	16	19	12	5
- County[1]	40	189	33	67
- Village	5800	60,000	4000	941
Amount of Service Station[2]	6200	15,000	500	/
Service Population	8,300,000	80,000,000	6,800,000	2,230,000
Uplink Platform Turnover	6,076,000	22,188,000	1,520,000	202,297
Downlink Platform Turnover	5,724,000	3,612,000	/	25,003
Overall Turnover (in USD)	31,800,000	25,800,000	1,520,000	227,300

Notes: The slash (/) symbolizes inexistence of corresponding business.

The data is collected between June 2016 and August 2018. Semi-structured interviews are conducted as the primary data source. 23 qualified interviews of the four case companies are selected out of 32 interviews conducted. The researchers visit the sites of all four companies and key stakeholders. To triangulate the information, archival data are also collected from company websites, news, internal company documents, and public reports. After data collection, data are coded and analysed. We analyse the data following an iterative process, carrying out a within-case analysis and a cross-case analysis successively. On many occasions we consult the interviewees and archival information in case of ambiguity. To illustrate the overall coding process, a data structure is provided in Figure 1.

[1] It also represents the number of county level operation center.
[2] It includes all the service stations in township, town and village.

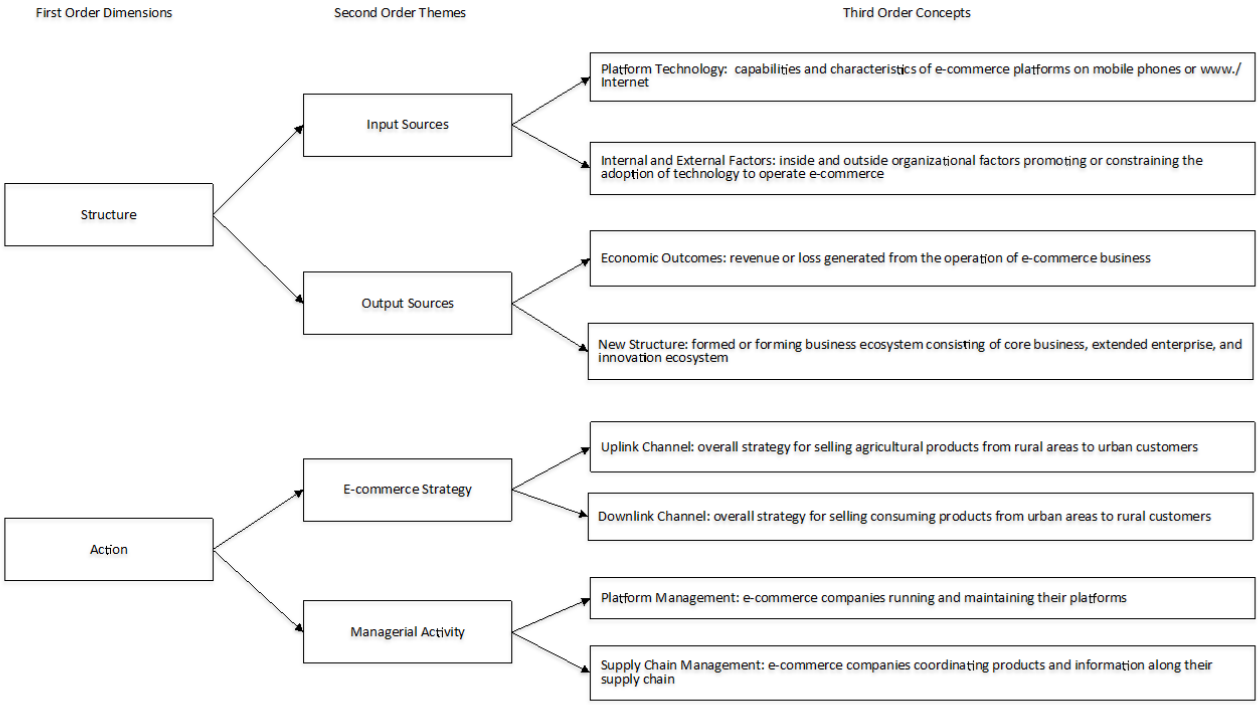

Figure 1 – Data Structure

Findings and Discussion

Six main themes are identified from the within- and cross- case analysis as platform technology, internal and external factors, e-commerce strategy, managerial activities, economic outcome, and new business ecosystem. After discussing and further making sense of the findings through comparing them with the literature, a conceptual framework is proposed with five sets of propositions to answer the research question (see Figure 2).

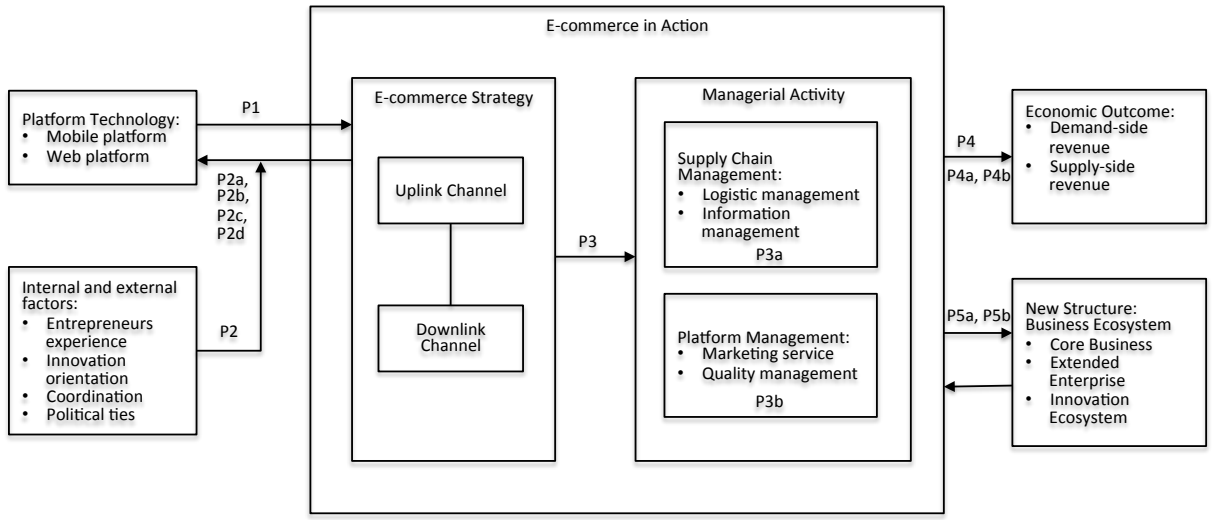

Figure 2 – Conceptual Framework

Interplay between input sources and e-commerce in action

We found that an interacting relationship between the characteristics of platform technology and e-commerce in action. According to DeSanctis and Poole (1994), AIT brings social structures (features and spirit) that enable or constrain social interaction. The platform technology of the case companies consists of mobile platform (Wechat) and web platform. Comparing to traditional computer systems that supports accomplishment of business transactions and discrete work tasks, such as billing, inventory management, financial analysis, etc. (DeSanctis and Poole, 1994), the capabilities (features) offered by Wechat and Web platforms are far beyond. In addition to above activities, they can further support coordination and interaction among actors who use these platforms and provide procedures for accomplishing the information exchange. The utilization of these platform technologies enables the case companies to open uplink channel meeting the needs of city, and to build the downlink channel serving the villages.

Meanwhile, the uplink and downlink channels further create new characteristics for the platform technology. For instance, in the uplink channel, three main segments are generated as sales, marketing, and supply chain service. One way of the sales is operating through social commerce, which indicates the additional sharing and spreading actions on Wechat to facilitate the sales of the uplink platform. In contrast with the initial capabilities of platform technology, the utilization of platform technology further creates new preferred set of actions and interpretations (spirit) of the mobile platform (Wechat) and web platform. This supports the study of DeSanctis and Poole (1994) that suggests the output of technology adoption emerges as the new source of structure. Combining these two aspects, thus, we propose that:

P1. Platform technology enables the uplink and downlink channel in e-commerce strategy; and the development of strategy, in turn, creates additional sources of platform technology.

Furthermore, we also identified four moderators that influence the interplay between platform technology and e-commerce strategy. Based on the internal and external factors analysis, we found that Ganjie performed best in entrepreneurs experience, innovation orientation, coordination, and political ties. This influence the utilization of platform technology in building the uplink and downlink channel. Ganjie sets up the most comprehensive segments in both uplink and downlink channels. In contrast, Minyu indicates the lowest level in terms of the four factors, and is able to establish the least segments in uplink and downlink channel. Meanwhile, the outputs of utilization of platform technology also vary depending on these factors. For example, when the outputs of generated from Ganjie uplink channel as the information from sales, marketing, and supply chain service segments, it requires the coordination among Ganjie internal teams to translate these information into the new characteristics of the mobile and web platform. Our findings do not support the direct relationship between group internal system and AIT appropriation proposed by DeSanctis and Poole (1994), and extend the study of Chatterjee et al. (2002) that indicates the positive influence of top management and coordination on web technology assimilation. Therefore, we propose our second set of propositions below:

P2. The interplay between platform technology and e-commerce strategy varies depending on internal and external factors.

P2a. The richer entrepreneurs experience in e-commerce, the greater interplay between platform technology and e-commerce strategy will be facilitated.

P2b. The higher level of innovation orientation, the greater interplay between platform technology and e-commerce strategy will be facilitated.

P2c. The better coordination among intra-organizational teams, the greater interplay between platform technology and e-commerce strategy will be facilitated.

P2d. The stronger political ties with local government, the greater interplay between platform technology and e-commerce strategy will be facilitated.

E-commerce in action

According to Chatterjee et al. (2002), the utilization of platform technology facilitates e-commerce strategy and activities. We found that all case companies, enabled by their mobile platforms and web platforms, build up the uplink channel and downlink channel as the overall strategies. The uplink channel facilitates three segments as sales, marketing and supply chain service; and logistics system, local service and service station are generated from the downlink channel. We further identified two categories of managerial activities from these segments, i.e., supply chain management and platform management (Johnson and Whang, 2002; Iansiti and Levien, 2004b; Kim, 2016). Regarding supply chain management, we found that Ganjie and All City perform better than Wenyuan and Minyu in both logistics management and information management. In respect to platform management, Ganjie and Wenyuan perform better than All City and Minyu in terms of quality management and marketing service.

This also supports similar argument by DeSanctis and Poole's (1994) that indicates the AIT appropriation in strategy can be evidenced in the group decision-making activities. But extending it to e-commerce context, the managerial activities are categorized into supply chain management and platform management with each category further consisting of two sub dimensions. Through examining each sub dimension, the performances of different e-commerce companies can be realized. Therefore, we propose our third set of propositions:

P3. E-commerce strategy enabled by platform technology leads to various managerial activities that can be categorized into supply chain management and platform management.

P3a. Supply chain management of platform-based e-commerce can be conducted through focusing on logistics management and information management.

P3b. Platform management of platform-based e-commerce can be carried out through focusing on marketing service and quality management.

Outcomes of e-commerce in action

We identified two revenue structures of the case companies, the demand side and supply side. Through the uplink and downlink channels, and supply chain management and platform management, all case companies can generate revenue from demand side and supply side given the established platforms. This supports the proposition of Rains and Bonito (2017) and DeSanctis and Poole (1994) that the desired outcomes of the utilization of technology can occur when ideal appropriation occur and decision making activities match the task. Here, we further identify the ideal appropriation in e-commerce context is the uplink and downlink channel. Thus, we propose our fourth set of propositions below:

P4. E-commerce in action including both e-commerce strategy and managerial activity can generate revenue as the economic outcome.

P4a. Uplink channel strategy associated with managerial activity generates the revenue from the demand side.

P4b. Downlink channel strategy associated with the managerial activity generates the revenue from the supply side.

Interplay between E-commerce in Action and New Structure

We finally identified an innovative business ecosystem as the development of the case companies, which consists of three main components (Moore, 1993) and six sub sectors (Heikkilä and Kuivaniemi, 2012). This innovative ecosystem indicates technological change from Wechat to innovation technology, which also supports the similar argument by DeSanctis and Poole's (1994) that the technology structure will be produced and reproduced during its adoption in group interaction. Their study grounds in group decision-making process in an organization, but e-commerce actions are more related to the interacting among organizations.

Considering the inter-organizational interaction of e-commerce, in addition to technology change, the innovative ecosystem of case companies also indicates collaboration with diverse stakeholders like research institute, information system, competition with other e-commerce companies, cooperation with local community and government, etc. Various types of actors and sources continually evolved during the process of the case companies operating e-commerce in actions. From core business to extended enterprise to innovation ecosystem, the case companies may change the ecosystem intentionally, such as All City expands the sales channel, or unintentionally, such as the ecosystem attracts research institute and universities.

Once the innovative ecosystem emerges, it serves as the new structure for case companies and provides them additional structure sources for operating e-commerce, such as technology, other actors, and environment. Therefore, in e-commerce context, we extend the proposition by DeSanctis and Poole's (1994) through further considering a diverse group of actors and sources, and propose our fifth set of propositions:

P5a. New structure emerges as the characteristics of various sources and actors are produced and reproduced in e-commerce in actions over time. The sources and actors include platform technology, politics, social environment, and stakeholders.

P5b. Through producing and reproducing characteristics of sources and actors, new structure evolves both intentionally and unintentionally from core business to extended enterprises, and then to innovation ecosystem, finally, a business ecosystem can be formed.

Conclusion

This multiple case study aims at analysing the county-level e-commerce companies on how they utilize e-commerce technology to establish the innovative business ecosystem. We ground the investigation in adaptive structuration theory, and propose a conceptual framework associated with five sets of propositions to answer the question. By answering this question, several important theoretical and managerial contributions could be drawn.

First, this study identified six themes of e-commerce as e-commerce AIT, internal and external factors, e-commerce strategy, managerial activities, outcomes, and new business ecosystem. The conceptual framework proposed reveals various relationships among these themes. In particular, four moderators are identified that facilitates the interplay between e-commerce AIT and actions, i.e., entrepreneurs experience, innovation orientation, coordination, and political ties. The conceptual framework contributes both for academia and practitioners. Second, this study may be the first to explore e-commerce from an AST perspective. The AST perspective is proven as a useful tool to analyse the theme and building a theory of e-commerce business. Therefore, we contribute to the AST by applying it to an e-commerce context.

There are some limitations of this paper. As many county level e-commerce companies are disorientated in how to continue their businesses, this study lucubrates

the development pattern of four successful county level e-commerce companies. More cases may be required to further illustrate and refine this conceptual framework.

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Impact of disruption in currency supply chain on farming operations in India: A social media analytics approach

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Abstract

Demonetisation occurred in India in 2016 and impacted the population by restricting access to cash. To understand how people were impacted tweets were used. Advanced sentiment mining techniques were applied to understand key positives and negatives about the implementation of demonetisation. The proposed approach for analysis differs from prior papers by focusing on the farming sector which is pivotal to Indian economy. Through demonstrating value added through social media modelling this paper provides a technique for policy makers to utilise social media data to adapt future policy changes more effectively.

Keywords: Digital economy, social media analysis, agriculture sector

Introduction

The Indian Government announced demonetisation of India's 500 and 1000-rupee notes, which made up 86 percent of the country's currency on 8th November 2016 (BBC News 2016). The intention of this drive was to address tax evasion, eliminate black money and promote a cashless economy. Agriculture sector, which contributes 23% of the GDP and employed around 59% of the Indian workforce (World Travel and Tourism Council 2018), saw severe impact on the individuals working in the industry as well as consumers, which ultimately affected the Indian economy. Specifically the majority of farmers depend on

cooperative banks for their loans to finance their day-to-day activities, which were not functioning following the demonetisation announcement. Social media platforms such as Twitter was flooded with the public feedback/opinions post demonetisation. Analysing social media data quickly and reliably to inform government on major issues faced by the sector can be critical to the success of such policy measures. The paper utilises the social media data from Twitter, collected during the demonetisation period to understand the impact of this disruption on the farming operations.

Literature Review

Previous research efforts in the area used social media dataset to understand the impact of demonetisation in India (Gupta et al. 2017, Singh et al. 2017, Vaid et al. 2017). These studies tried to analyse how social media behaved post demonetisation by twitter data from all the sectors without focusing on any specific one. The results from these analyses provided a general overview of the public sentiment but failed to highlight specific government operational implementation issues during demonetisation operation. Therefore, this paper focuses on studying the impact of demonetisation on the agriculture sector specifically by identifying specific government policy and operational considerations. Modelling methodology from the aforementioned papers are summarized in table 1.

Table 1 – Selected Past Literature and Features used for Model Development on demonetization

	Outcome variable	Features
Gupta et al. 2017	Positive, negative or neutral sentiment based on emoticons and hashtags	Unigrams and bigrams
Singh et al. 2017	Number of retweets	Unigrams and bigrams
Vaid et al. (2017)	Two models one for emotion and the other for polarity	

Gupta et al. (2017) analysed sentiments of social media data arising from different regions of India in response to demonetisation. First they classified tweets into positive, negative and neutral using emoticons such as ‘:)’ and then included hashtags to represent views for trending hashtags such as '#ModiFightsCorruption’ to further identify sentiment of the tweet. After developing view on whether the tweets with emoticons or trending hashtags were positive, negative or neutral, they applied a naïve Bayes and SVM model to develop a model to predict the value for tweets that couldn’t be labelled. The analysis was limited to frequency and visualization considerations.

Singh et al. (2017) use the Valence Aware Dictionary for sEntiment Reasoning (VADER) approach to get positive, neutral and negative sentiment values for tweets. Typically positive and negative scores would be associated with 1 and -1, the VADER approach was used by Singh et al. (2017) because it assigns a more granular score. For example a score of 0.5 would be more positive than a score of 0.2. In addition to sentiment analysis they consider how to predict the most popular retweets using unigrams and bigrams through support vector machine (SVM), decision tree, logistic regression, multinomial naïve Bayes, random forest, Bernoulli naïve Bayes and K nearest neighbours. They do not use insights from VADER to support popularity of retweet analysis.

Vaid et al. (2017) used a naïve Bayes model to classify emotion and polarity based on a lexicon sample dataset and also utilise word clouds to suggest that sentiment towards

demonetisation has changed from November 2016 to March 2017. Their approach was focused more so on visualisation of frequencies of different emotion and polarities and representing the word clouds over two dates. It showed the time sensitive nature of perceptions towards tweets and the idea of using emotions to represent tweet content. Vaid et al. (2017) focused on visualization and word clouds over two dates.

The notable research gap is current papers on demonetization have not considered the operational management perspective of how to implement a change of this magnitude more effectively going forward. Additionally the other papers have not focused on the farming industry specifically, which is of primary concern in an agriculture dependent economy like India where 59% the Indian workforce is employed (World Travel and Tourism Council 2018).

Methodological Approach

A methodology is developed to analyse Twitter dataset through the innovative combination of bigrams (two word combinations) as well as emotions-based opinion analysis. The analysis uses social media data from Twitter to better understand the reaction of the Indian public towards demonetisation and its impact on the agriculture sector. The data comprises of tweets containing #demonetisation between 8th November 2016 and 2nd January 2017. The analysis of the data involved three main steps (i) data cleaning, (ii) feature selection using word combinations and emotion identifiers and (iii) opinion mining through support vector machine (SVM). When using the proposed methodology, the prediction model was able to achieve more than 74% accuracies for negative opinion tweets. Using this model, we classified the social media data into positive and negative set (depending opinions indicated in the tweets).

I. Data Cleaning

The data was pulled through the Twitter API and was in a text format. A number of steps were involved in the data cleaning stage in order to allow for ease in bigram analysis. In literature, we found that bigrams play a key role in training SVM and therefore proper data cleaning will ensure more interpretable results and higher predictive performances. Through the use of Natural Language Processing (NLP), the data was pre-processed by removing- URLs, punctuation and numbers with the intention to only keeping words, retweets (RT), any @ symbol targeted individuals, hashtags and stop words. Furthermore the tweets consisted of English and other languages. However, we simply considered English tweets for analyses.

II. Feature Selection

Sentiment analysis was performed on the data through two steps. The first was to understand the emotions behind tweets and this involved looking up the words used within tweets against the National Research Council (NRC) Emotion Lexicon (Mohammad and Turney 2010; Mohammad and Turney 2013). The lexicon divides emotions into anger, anticipation, disgust, fear, joy, sadness, surprise and trust. One limitation is that the lexicon based approach does not consider negating words (Jia et al. 2009), for example ‘not happy’ would have a significantly different meaning to ‘happy’ without any preceding words. To account for this, we have used an approach proposed in Rinker (2018) where the sentiment mining procedure takes preceding words and modifies sentiment accordingly depending on if the word is considered a negator, amplifier, de-amplifier or an adversative conjunction and assigns a score. Note that that emotions are represented by the number of emotive words used in a tweet and positive/negative

sentiment is assigned a score.

Another step in the proposed analysis is to develop bigrams. It is possible to use more than two words however this has not been considered due to the limited sample size. For example the frequency of three words together reduces as sample size decreases since there are less words being examined. These bigrams are useful features to be included into the SVM model from the perspective of interpretability and better fit while considering the limitation of relatively small sample of 16,120 tweets. When identifying the bigrams, the main consideration was how frequently it occur in the tweets. This was achieved by counting all available bigrams from the sample dataset.

Additionally, the two word combinations were considered in the context of each tweet. For each tweet all pairwise combinations were filtered to see which words frequently occur together. Following this, these words were then checked for pairwise correlation and the higher correlation values were kept. Intuitively this means understanding whether or not pairs of words occur concurrently in the dataset. Unlike considering the frequency of bigrams, it is possible to capture general trends in the tweets. Another differentiating factor of this analysis from the bigram frequency is the words do not have directional impact since it involves correlation.

III. SVM Classification

By developing features it is possible to develop a SVM model to classify tweets into positive, neutral or negative towards the demonetisation with respect to the agricultural sector. The sample size is 4031. In order to train SVM, 1000 of these tweets were manually labelled for being either positive, neutral or negative towards demonetisation. We divided the dataset into two sets – training (75%) and testing (25%). After testing the model after training on 25% of the sample, we used it for classifying entire 4031 tweets.

As the tweets can be classified into positive, neutral or negative class. Each outcome class was modelled separately. This leads to three different binary classification models each for positive, negative and neutral class. The final class label was assigned based on the maximum probability of the three models. This is also known as the one-vs-rest methodology (Hsu and Lin 2002).

The features used for training the SVM model are the emotions identified through National Research Council (NRC) Emotion Lexicon (Mohammad and Turney 2010; Mohammad and Turney 2013), the positive and negative sentiment scores, the most frequently occurring bigrams and the most highly correlated two word combinations. The emotion and sentiment values are scaled and centred while the frequently occurring bigrams and two word combinations are treated as binary feature representing whether or not they occurred within each tweet.

One of the issues with the data is it is unbalanced with much more negative sentiment tweets than neutral or positive sentiment tweets. To solve for this issue to ensure the SVM fits well (while avoiding overfitting and biases), the Random Over-Sampling Example (ROSE) technique was applied (Mernadi and Torelli 2014). ROSE uses bootstrapping to generate a more balanced dataset based on the less frequent variable value. Once the balanced dataset was developed, a radial SVM approach was applied to train the model. SVM was applied since it has been successfully used in literature (Singh et al. 2017, Gupta et al. 2017).

Results and discussion

When analysing tweets classified with negative opinions (negative set) through word combination network diagrams (see Figure 1), following main operational issues were

identified:

A. farmers or small traders were not able to use digital platform for payments/transactions and resulted in lenders exploiting farmers.
B. due to cashless scenario post demonetisation, farmers were unable to buy seeds in the sowing season, feed for livestock and to hire labour, which resulted in increased food prices. This was mainly because seed sellers were not willing to accept old notes.

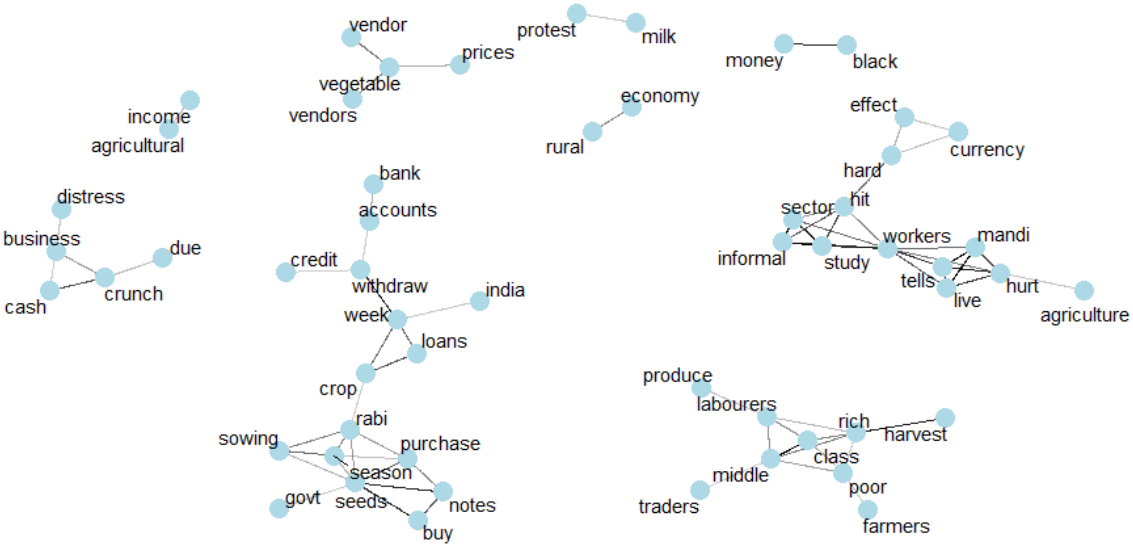

Figure 1 – Network diagram for most correlated two word combinations within -'ve set

Similarly, in case of positive set shown in Figure 2, following steps of the government were supported:

A. some tweets supported government's step towards helping farmers by allowing them to use old currency notes

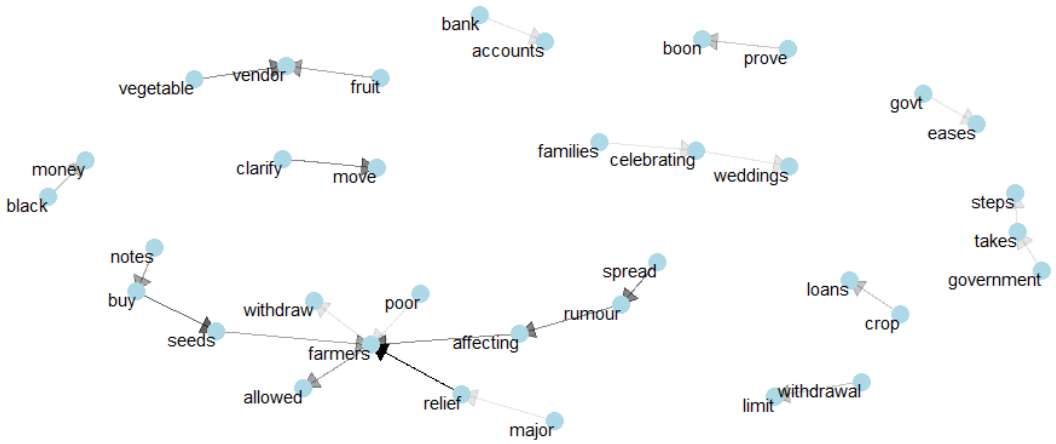

Figure 2 – Network diagram for most correlated two word combinations within +'ve set

Overall, based on opinion analysis, the impact of demonetisation on agriculture sector was significant as there were more than 80% negatively classified data in the whole dataset collected. There were little positives other than when demonetisation policy was eased for farmers for few days.

An SVM approach was applied to better understand drivers behind positive and negative sentiments for demonetisation. The model was trained on hand labelled tweets and this methodology allows for non-labelled tweets to be assigned to a predicted class label. Therefore, there were 4031 tweets on demonetisation within the agriculture industry, 1000 of these were manually labelled and the other 3031 tweets were labelled using trained SVM. The SVM model trained used the bigrams suggested earlier as well as emotions as features. The validation statistics for each individual model classes are presented in Table 2.

Table 2 – Individual Model CV/Test

		Gini %			Accuracy %		
		Negative	Neutral	Positive	Negative	Neutral	Positive
Emotion included	CV	**62.7**	**77.3**	**72.5**	**69.1**	**84.2**	**79.4**
	Test	**61.5**	**76.2**	**68.0**	**62.1**	**80.1**	**76.8**
Emotion excluded	CV	**60.9**	**64.4**	**68.9**	**71.6**	**84.9**	**81.6**
	Test	**61.5**	**67.3**	**70.8**	**67.5**	**83.1**	**79.2**

The Cross-Validation (CV) was partitioned to be performed on 75% of the manually labelled data, while the other 25% was kept out to test performance. Notably, the models provide an acceptable level of Gini and Accuracy for the sample size used and are consistent across CV and Test stages. After aggregating the three models into a single outcome class label identifying if a tweet is negative, positive or neutral, the overall performance of the model is 69% when emotion is included. This shows a significant increase from the 57% when emotion is not incorporated while training the SVM model.

For the SVM approach variable importance was compared, and outside of emotion the most common phrases to influence negative, neutral and positive views is captured in Table 3.

Table 3 – Key Takeaway from Top 10 Variable Importance Plot

	Positive	Neutral	Negative
Key phrases excluding emotion	"Real estate": Increase in real estate values as black money potentially gets funnelled there "Relief farmers": Government back-tracking on policy to allow farmers to use old currency notes	"Crop loans": Loans are required in order to purchase crops. "India farmers": News articles discussing those that were effected.	"Hurt farmers": Describing that farmers have been hurt by what was perceived as poor policy implementation.
Key emotions in order of importance	Anger Anticipation Surprise	Fear Trust Sadness	Anger Sadness Fear

In particular emotions are consistent across different dependent variables such as anger appearing in both positive and negative tweets. The reason for this is that while Table 3 captures importance of the variable it doesn't capture directional impact. To represent this Table 4 performs a logistic stepwise regression which shows what type of influence the

variable has, with positive coefficient corresponding to a supporting argument for the given classification.

Table 4 – Emotion Directional Impact within Logistic Stepwise Regression

Classification	+'ve sign coefficient	-'ve sign coefficient
Negative	anger, sadness, joy	
Neutral		fear, trust, anticipation, sadness, anger
Positive	surprise	Anger

In Table 4 anger is shown to be more likely to appear in negative comments, and less likely to occur in positive comments. Any emotions shown are less likely to make the comment neutral. Additionally surprise seems to be the most common emotion represented in positive comments.

This methodology can be further applied out of sample to label the 3031 tweets that were not manually labelled. An example of this is shown in Table 5.

Table 5 – Out of Sample Most Intense Perceptions towards Demonetisation

	Raw text
Negative	RT @subyroy: Collapse of transport, trade, agriculture, employment, caused by deliberate monetary error #DeMonetisation #ModiJai
Neutral	bahut badhiya .worth to waste my 5 min for this song ,played in our market #delhi #DeMonetisation
Positive	Don't worry about cash! Shop cashless with amazing discounts and cash back offers. #currencyban #DeMonetisation...

The tweets shown in Table 5 have the highest probability of being negative, neutral or positive respectively. Notably the example tweets in Table 5 capture the general view of the tweets that were manually checked. Negative perceptions towards demonetisation tended towards issues with money being available and its impact on farmers. They suggested that the lower class was being harmed and there was no impact on actually removing black money. The neutral perceptions towards demonetisation were more concerned with stats and figures, for example announcing a news broadcast. The positive perceptions towards demonetisation were about considering the long run, it also shows why features such as fear would appear in the variable importance plot and indicates the shortcomings of not including negation.

Conclusion

Based on the proposed analytical methodology utilising emotions, it was able to accurately classify social media data into positive and negative sentiments, which was later used for identifying issues with the Government's implementation of demonetisation drive across India. Network diagrams were applied to identify the word combinations/bigrams which revealed better understanding/summary of the information contained in the social media datasets.

The results identified key concerns about demonetisation relating to sowing season, difficulty in purchasing seeds and interaction with banking. The model also implies that anger, anticipation and sadness were the most informative emotions within the tweets.

This information can be utilised to understand key concerns of those that are related to how the government can better manage key concerns and emotions related to demonetisation.

The proposed methodology can be applied in other areas such as consumer online feedback analysis for improving product features and related operations. The advantage of this type of analysis is it is possible to automate the analysis process of textual information in big data era. This research could be applied to any government policy changes for e.g. impact of Brexit on various industrial sectors. Nevertheless, to derive the full benefits, this approach should be implemented on a suitable software platform in which all the methodology components of the text analytics can be integrated holistically.

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Empirical Modeling and Simulation

The impact of information and communication flow structures on logistics performance in Industry 4.0 production systems with distributed control

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Abstract

This paper studies the influence of accessible information and communication in distributed control systems for Industry 4.0 applications. To this end, we compare a purely decentralized and a hybrid heuristic in a multi-agent system in order to solve graph colouring dynamics. By means of simulations, both heuristics are compared, and while no heuristic clearly dominates the other, insights on design challenges in distributed control are derived.

Keywords: Graph Colouring Dynamics, Distributed Control, Scheduling

Introduction

The future of digitalized and networked manufacturing systems is currently envisioned under a multitude of names, such as Industry 4.0, Manufacturing 2.0, Internet of Things, and many others. They share the vision of distributing tasks of production control to ‘intelligent’ machines, parts and products in order to attain higher flexibility, adaptability, counteracting increasingly complex and dynamic environmental conditions, and thus yielding higher logistic performance. The envisioned gain however, comes at a cost: With system behavior left to selfish actors, both the stability and the quality of the attained solution can deteriorate. The apparent trade-off has lead researchers to believe that a combination of centralized and distributed control may lead to improved logistic performance by the interplay of local and global decision-making. Moreover, it has been stated that the performance gain from a combination of centralized and distributed decision strategies increases with higher levels of decision task complexity (Scholz-Reiter et al., 2009). When implementing such a system in production in light of Industry 4.0, intelligent objects and distributed control create a new trade-off situation in production system design. Such trade-offs include new problems, such as deadlocks due to selfish actors (Thomas et al., 2012). During the design stage, a certain degree and form of combination between centralized and distributed control has to be determined. Therefore, the designer has to accept a certain

degree of myopic decision-making in exchange for positive, emergent system characteristics, such as higher adaptability, quicker response, etc. (Bendul & Blunck, 2018). However, the optimal degree of distributed control in a hybrid decision strategy remains an open question thus far. In the interest of approaching such a hybrid decision strategy, we aim to answer the following research question:
Which insights can be gained through a comparison of a purely decentralized approach and a hybrid approach, utilizing a broker of global information?
In production planning, Multi Agent Systems (MAS) are a common tool for modeling the usage of decentralized control. We use a minimal model based on Graph Coloring Dynamics in conjunction with MAS to study how communication and information flow structure affects the performance of decision strategy. By means of simulation, we compare a purely decentralized decision system with a hybrid decision system, which allows agents to access global information through a central information broker.
The rest of the paper is structured as follows: The next sections gives a briefly refers to literature in connected research streams, followed by a description of the applied methods in section 3. In section 4 the findings are presented, followed up by the conclusion in section 5, which discusses theoretical and practical contributions.

State of the Art

The fourth industrial revolution, commonly referred to as Industry 4.0, describes the technological impact of connected production systems. Expectations of the impact of Industry 4.0 include among others new levels of visibility, transparency, adaptability and better forecasting throughout industrial production (Lasi et al., 2014). This vision of production is characterized by so-called Cyber Physical Systems (CPS) (Monostori, 2014; Jazdi, 2014). Such systems exhibit a level of connectivity that allows communication with humans as well as with other CPS. In theory, embedding a multitude of CPS into a production network, such setup would allow for machines to act with regard to other, i.e., a CPS could tolerate a downside in its own productivity for the sake of increasing the entire systems productivity. This appealing vision however raises the question of coordination (Panetto et al., 2019; Olfati-Saber et al., 2007). Distributed control promises advantages over conventional concept such as improved agility (Trentesaux, 2009). Such distributed control concepts are also deployed in holonic production systems (Brennan, 2001). The common approach to realize such distributed control is the use of MAS. In these systems, so- called agents are deployed at every point in the distributed system where a decision can be made. Leitão (2008) gives an overview on the use of agent-based decision systems in manufacturing control. In the context of Industry 4.0, such agent-based decision systems are seen the proper tool to realize the vision of a more efficient, flexible and agile production systems (Whitbrook et al., 2018; Zhang et al., 2017; Barbosa et al. 2018, Shujka et al., 2018, Shukla et al., 2018). Furthermore, such approaches of distributed control allow a new level of adaptability in the manufacturing process (Kim et al., 2019). In literature, different configurations of distributed control concerning the degree of distributed control have been proposed (Monostori et al., 2015; Kozjek et al., 2018). The question for the optimal degree of decentralized in such hybrid decision systems however, has not been answered thus far. Blunck et al. (2018) studied the impact of elevated agents that assume a leader role due to having a greater connectivity in comparison to regular agents, and thus assessed one approach to determine an optimal degree of decentralization. This paper tries to gain further insights from the comparison of a purely decentralized approach and a hybrid approach, utilizing a broker of global information.

Methodology

We use a minimal model based on Graph Coloring Dynamics, as this model has been shown to be feasible in order to model Production Planning and Control (Blunck, 2018). In Graph Coloring Dynamics a given graph **G**:=(V,E), defined by its vertex set V and edge set E, requires a coloring C = {c_1, …, $c_{|V|}$} such that every pair of vertices that are adjacent have different colors (i.e. n,m ∈ V, (n,m) ∈ E => $c_n \neq c_m$). The minimal amount of colors required for a coloring that is free of conflicts is called chromatic number λ_G and is depending on the structure of the graph G.

For the application of this model in Production Planning and Control the number of available colors is equal to the number of parallel, identical servers that are available.

Every Vertex i ∈ V is associated with an order, and every edge (i,j) ∈ E is associated with a conflict between the corresponding orders, i.e. orders that are close in space or time and therefore can not be processed on the same server.

For this study, we look at regular ring-graphs with 24 vertices that are based on used small-world graphs (Watts & Strogatz, 1998). Such small-world graphs exhibit both high clustering as well as short average path length. Similar to Watts and Strogatz we study graphs in which every vertex v is adjacent to "index neighbours" v-2,v-1,v+1 and v+2 (mod |V|), thus making them actual neighbours. (Compare figure 1).

An overview of all parameters of the model can be found in table 1.

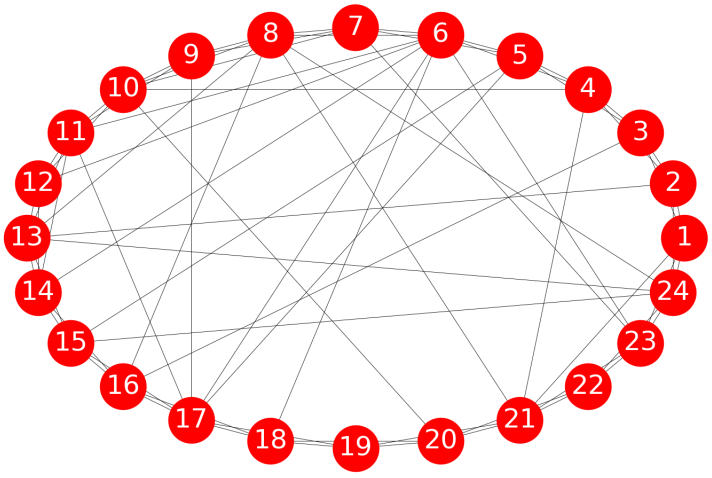

Figure1: Exemplary Ring-Graph (from Set1)

The circular structure of these graphs is chosen to avoid artifacts otherwise to be expected at the boundary of the grid. Contrary to original small-world graphs the edges are not randomly rewired, instead additional edges are inserted in order to model further dependencies. This approach can be formalized as the following procedure.

1. Create regular Ring-Graph with N vertices
2. Add edges between every vertex and his two upper and lower "index neighbours"
3. For every pair of edges that are not adjacent and for which the degrees of both vertices are lower than mL, add an edge with probability p

Table 1: Model Parameter

Parameter	Domain	Description
N	$\mathbb{N}$	Number of vertices
ml	$\mathbb{N}$	Maximum number of links per node
NoC	$\mathbb{N}$	Number of Colours available
λ	$\mathbb{N}$	Chromatic number
p	[0,1]	Probability of adding additional edge

In order to compare the two heuristics, five sets of graphs were generated with the following parameters, presented in table 2. Each set consists of ten graphs generated with aforementioned procedure, and each graph has the chromatic number six.

Table 2: Parameterization of evaluated graphs

Name	N	Noc = λ	p	mL
Set1	24	6	0.1	23
Set2	24	6	0.2	20
Set3	24	6	0.4	15
Set4	24	6	0.5	10
Set5	24	6	0.5	20

In order to find a suitable, conflict-free coloring for the studied graphs, a MAS is applied, as commonly used for the modeling of distributed control. With this approach an agent is deployed for a vertex of the graph G. In order to answer the research question, we compare two different agent heuristics, with the first one only having access to information about its direct neighbours, thus being purely decentralized. The second heuristic however can access additional information via a central information broker that keeps track of the global colour usage.

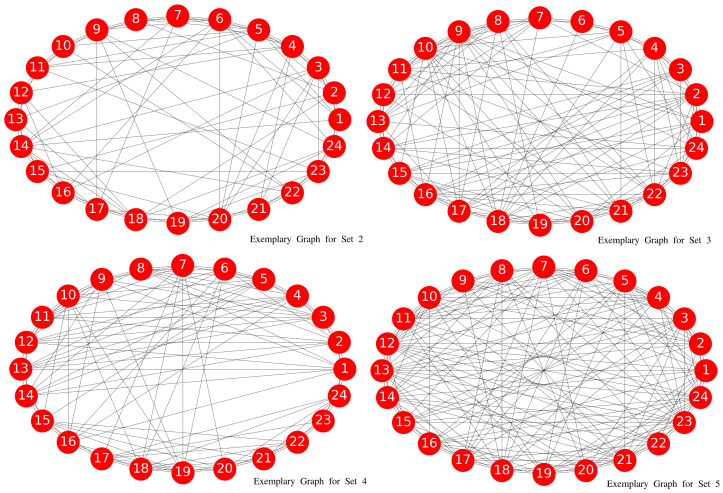

Figure 2: Exemplary Graphs from Sets 2-5

Both heuristics are visualized by means of flowcharts in figure 3 and 4. For the first heuristic, every agent acquires the coloring of every adjacent vertex and then chooses from the set of colours with the least amount of conflicts, thus relying purely on the locally available information.

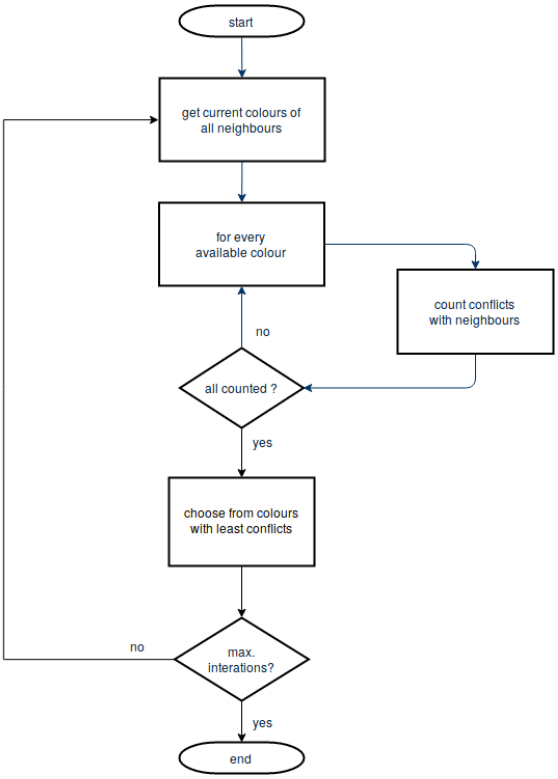

Figure 3: Flowchart - purely decentralized heuristic

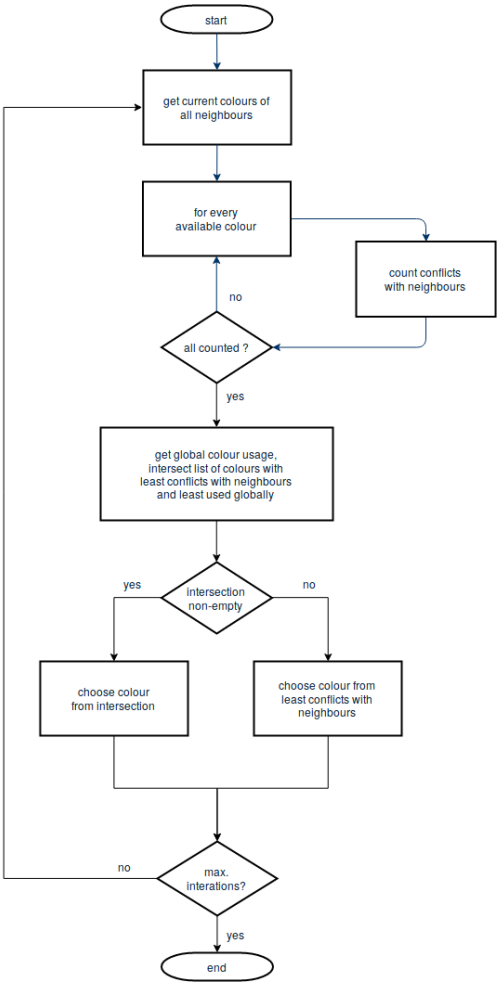

Figure 4: Flowchart - hybrid heuristic that utilizes a broker of global information

Heuristic two starts similar by also acquiring the coloring of all adjacent vertices. In the next step however, it accesses global information about cumulative use of every colour. By intersecting the set of colours with least local conflicts with the set of colours globally least used, the resulting set contains only colours that fulfill local requirements and appear to be a sensible choice in order to reach a globally conflict-free colouring of the graph. If the intersection is non-empty heuristic two chooses the colour from this set, otherwise it falls back to choosing a colour from the set of least local conflicts.

With this setup in mind, both heuristics were applied to all five sets of graphs with a maximum number of 250 iterations each. Within these iterations, the agents for each vertex can sequentially apply the heuristic and thus determine their colour.

Since each graph has the chromatic number six, there is a conflict-free colouring with six colours.
This approach however does not come without drawbacks, as only a limited number of graphs were evaluated. Thus, only a small number of possible graph structures is evaluated.

Findings
With both heuristics applied for 250 iterations to each set of graphs, the following results emerge. For 35 graphs a conflict-free colouring was found by at least one of the heuristic and for 19 graphs it was found by both heuristics. Table 3 gives a detailed overview of all results. For the remaining 15 graphs, neither of the heuristics was able to find a conflict-free colouring within 250 iterations. In the 19 cases in which both heuristics found a conflict-free colouring, the hybrid heuristic needed more iterations in only five of these cases. With these results, it becomes apparent, that neither of these two heuristics is even close to strictly dominate the other.
It appears that the performance of the heuristics is very dependent on the structure of the graph. As the vertices in all sets always have a least four edges due to the underling ring structure, we focus on the inner edges that were randomly chosen in the aforementioned manner based on the parameters p and mL. To quantify these edges the average degree of the vertices in each set of graphs has been determined an is listed in table 3. Table 3 further shows the results for each set in particular.

Table 3: Simulation Results

	Average Degree	Solved by neither heuristic	Solved by both heuristics	Only solved by purely decentralized heuristic	Only solved by hybrid heuristic
Set1	6.26	0	9	1	0
Set2	7.83	0	5	4	1
Set3	11.01	6	2	1	1
Set4	9.11	1	3	3	3
Set5	12.78	8	0	1	1
Sum		15	19	10	6

Out of the 15 graphs for which neither heuristic was able to find a conflict-free colouring within 250 iterations, 14 belong to either Set3 or Set5. Both these sets feature the highest average vertex degree with 11.08 and 12.78 respectively.
In order to better understand the behavior of the heuristic, we review the results for a graph from Set3 in Detail. In figure 5 said graph is displayed, while figure 6 shows the performance of both the purely decentralized (in blue) and the hybrid (in red) heuristic, which utilizes a broker of global information. The performance of both heuristic is measured as the mean of remaining conflicts for each vertex, hence if the mean is zero, a conflict-free coloring has been achieved (every vertex has zero conflicts with its neighbours).

Within the first 48 iterations, each of the 24 agents (one for each vertex) can determine its colour twice, and most of the conflicts in colouring are already resolved for both heuristic. The purely decentralized heuristic has conflicts between six pairs of adjacent vertices to resolve, while the hybrid heuristic has conflicts between two pairs of adjacent vertices to resolve. The resulting colourings for this exemplary graph is visualized in figures 8 and 7, respectively.

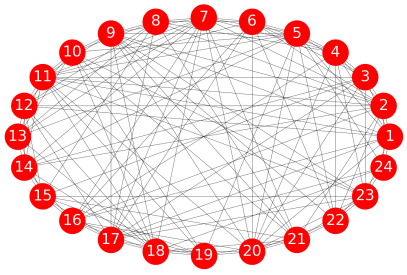

Figure 5: Graph from Set3, Chromatic Number 6, p 0.4, mL 15, Average Degree 11.5

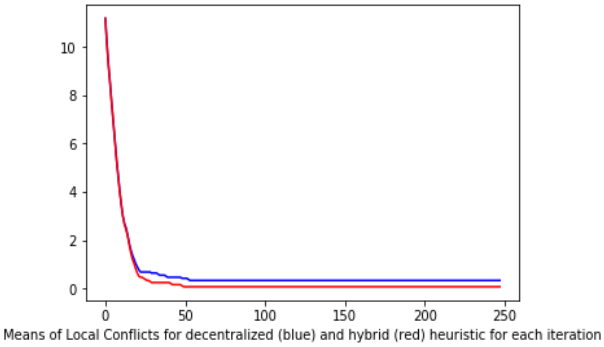

Figure 6: Performance for Graph X, comparison between purely decentralized (blue) and hybrid (red) heuristic

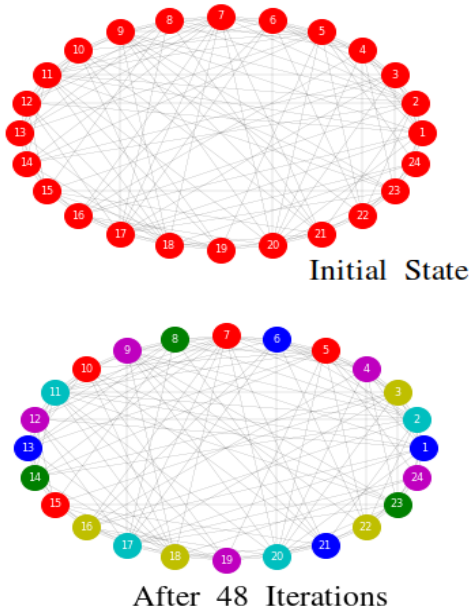

Figure 7: Initial colouring and colouring after 48 iterations of the purely decentralized heuristic

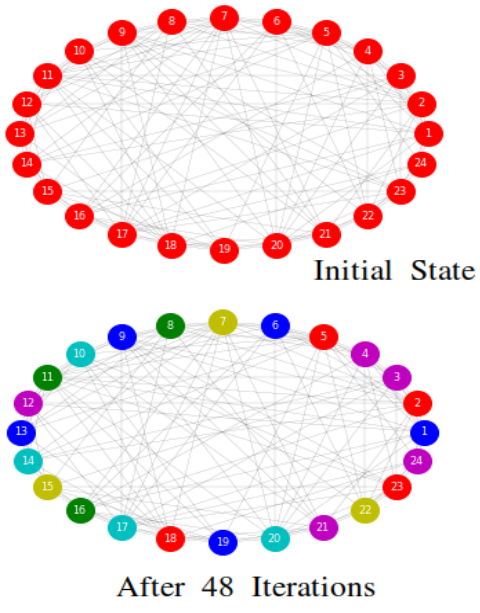

Figure 8: Initial colouring and colouring after 48 iterations of the hybrid heuristic

However, one characteristic striking our attention is that for both heuristics, the mean of conflicts per vertex is falling monotonously. Hence it becomes apparent that for this graph, both heuristics fall into a local minimum – and since every agent is always minimizing the conflicts for one vertex, the heuristics are unable to leave said local

minimum. Consequently, both heuristics are unable to find a global minimum, which has no remaining conflicts in the vertex colouring.
This yields insights for the design of Industry 4.0 applications as to the design of such systems. In order to reap the possible benefits of distributed control (such as better logistic performance, more reliable and agile planning), the coordination between agents and their behavior is critical. This becomes apparent for those graphs, in which a conflict-free colouring was not achieved due to a deadlock, stemming from the selfish behavior of agents. This coincides with Thomas et al. (2012), who list the prevention of deadlocks as a requirement for the successful cooperation between agents. With the increase of available information and increasing deployment of CPS in light of Industry 4.0, decision problems grow larger and larger – thus limiting the use and efficiency of central control approaches while increasing the attractiveness of distributed control at the same time. For future research, options range from the modification of the usage of global information, the expansion of available global information to the coordination between agents.

Conclusion

The application of both the purely decentralized heuristic as well as the hybrid heuristic, which additionally utilizes a broker of global information, allows for some interesting insights.
While neither of these two heuristics strictly dominates the other, most of the graphs were solved by both heuristics. Due to the fact that there are graphs in which the purely decentralized heuristic is better as well as some in which the hybrid heuristic is better, this paper concludes that the performance of either heuristic is quite dependent on the structure of the graph, which is primarily describe by the mean vertex degree in these simulations. Moreover, the vast majority of graphs, which were not solved by both heuristics are those with the highest mean vertex degree, but trapped the heuristic in local minima that do not represent a conflict-free colouring. This can be explained by the selfish attitude of each agent that aims to reduce the conflicts of the vertex it represents. From a managerial perspective, this underlines one of the challenges of the coordination of distributed control: Deploying primitive agents for each logistic object that only act in the interest of the respective logistic object greatly increases the risk of being drawn into the sphere of a local minimum, thus missing the solution that yields the optimal logistic performance.
The aforementioned model and simulation setup however are not without drawbacks.
For only a limited number of parameters graphs were created and evaluated, and both heuristics have been applied to only 50 graphs in total.
For future research, a multitude of option presents itself. Firstly, the hybrid heuristic can be modified in the way in which it evaluates local and global information. Secondly, the global information delivered by the information broker could be modified or expanded, for example by the mean vertex degree. Lastly, and most apparently, both heuristics can be modified to allow for an increase in conflicts, in order to escape local minima.

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Household food waste simulation model: Investigation of interventions for staple food items waste

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Abstract

Decreasing food and drink waste in the home can have a significant positive environmental and economic impact. However, few empirical studies have been performed on this issue, largely due to the cost and resources involved. This study describes a modelling method that can incorporate complex household dynamics and allow challenging questions regarding household food waste levels to be answered. The results can help governments and businesses to prioritise the actions that will be the most effective and efficient in reducing the amount of food being waste in the home.

Keywords: Discrete Event Simulation, Household Food Waste, Food Waste Intervention

Introduction

Globally, food production accounts for 70% of water use, 90% of land use and 30% of greenhouse gas emissions. By only eliminating food waste, up to a third of these resources could be saved (Global Food Waste Not, Want Not, 2013). In high-income countries, the largest contribution to food waste is generated from households (Parfitt et al., 2010). As a result, decreasing food and drink waste in the home can have a significant positive environmental impact. Various factors can affect the amount of food wasted in households. These factors include but are not limited to how food is sold, how often it is purchased, its shelf life, how it is stored in the home, and activities relating to the preparation, serving and consumption of food (Quested et al. 2013).

Given this, the amount of food waste in the home can be influenced by businesses supplying food to the home (e.g. food retailers and food processors / manufacturers) as well as the decisions and action of people in the home.

Changes that could be made by businesses in the supply chain with the potential to decrease the food waste in households include increasing the shelf life and open shelf life of the food items, selling the items in smaller packages, introducing smart labels etc. (Schanes et al., 2018). The behaviours and practices that householders can adopt to decrease the amount of food being wasted are often grouped into planning, shopping, storing, preparing and consumption (Wunder et al., 2019). Specific actions include planning meals, making a shopping list, avoiding impulse purchases, storing certain fruit and vegetables in the fridge, preparing an appropriate amounts for meals, and storing and using leftovers (van Geffen et al., 2017).

However, the impacts of these changes and actions on household food waste levels are not certain. Ideally, pilot studies would be conducted and empirical data obtained to investigate the effects on household food waste levels. Though, few empirical studies have been performed, largely due to the cost and resources involved (Reynolds et al., 2019 and Stöckli, 2018). This makes it difficult for governments and businesses to prioritise the actions that will be the most effective and efficient in reducing the amount of food being waste in the home.

In order to overcome these challenges, a preliminary discrete event simulation (DES) model has been tested and is currently being developed further using empirical data as input. This household food waste simulation model (HHSM) can incorporate complex household dynamics and allow challenging questions regarding household food waste levels to be answered. It simulates the purchase, storage, consumption and waste of a specific food item (e.g. milk) within a household over time.

In the remainder of this paper, the structure of the HHSM is explained, followed by a sample of findings on how changes in package sizes, shelf life, open shelf life and date labels affects the waste levels for staple dairy items namely milk, hard cheese and yoghurt in UK households. Implications for policy makers and other decision makers relating to household food waste are also discussed.

Methodology

The amount of food items consumed in a household each day is not constant but varies from day to day (Evans, 2012). Moreover, many cases of food waste in households are associated with random events such as buying a product with a shorter shelf life than usual, changes in plans (e.g. a work-related commitment). These random events can lead to ingredients for a meal being bought but not prepared and consumed, and so are, often wasted at a later date (WRAP, 2007). Methods that only include an average level of consumption (e.g. system dynamics) that do not include variation over time would fail to incorporate an important dynamic within the system and, accordingly, the modelling results would be less realistic (Quested, 2013).

For this study, a DES model that embraces the complexity of household dynamics related to the purchasing, storage, consumption and wastage of staple food items has been developed. DES is a system-based approach that can incorporate stochasticity of a real-life system and models a system as a sequence of events over time (Delaney and Vaccari, 1989).

The interdependencies created in the modules (purchasing, storage, demand, consumption) of the model reflects many of the features that are important to household food and drink waste. Different variants of the model can be adjusted for different staple food items, household sizes and other household characteristics. Both quantitative and

qualitative research was used to inform the model. In addition, data from national surveys relating to food items such as purchasing levels and available shelf life has been used as input to the model. Verification and validation of the model is achieved through the investigations on milk waste.

Household Simulation Model (HHSM) Set-Up

The model consists of four modules. These modules are shopping, storage, demand and consumption. Each module can be customized for household size and the behaviour of various household archetypes decisions on shopping, storing and consuming numerous staple food items.

Note that HHSM models a single food product and single household in any given simulation. To model the effects of changes (e.g. to products) across a population, a range of household types are required – these have been developed to help model the impact in the United Kingdom (UK), the country of interest for this project. The user also needs to customize the model for specific products.

The model also focuses on food that is wasted because it has not been used in time: thrown away because it has gone past the date on its label, gone mouldy or become rotten. This may be because too much was purchased, pack sizes were too large for a household's needs, date labels were misinterpreted, items were not stored correctly in the home, or the shelf life of the product was relatively short. The model does not include food that is wasted because too much was prepared or served, rejected (e.g. due to a fussy household member), accidentally dropped on the floor, or due to appliance failure. It only focuses on food waste in the home; it does not model food waste in the supply chain.

Next, the description of each HHSM module is given briefly.

Shopping Module: Households can purchase food items from main shops and top-up shops. Main shop visits occur mid-week on either a Tuesday, Wednesday or Thursday, as randomly determined at the beginning of the week as the most households in the UK do a main shop approximately weekly. The amount of food item purchased at a main shop is fixed for every visit since people tend to have set habits when they shop for staple foods. The size and number of packages that will be purchased from the main shop can be set by the user regarding the household archetype and food item. If the household checks the fridge before shopping, the amount bought is adjusted accordingly by the model. For instance, if a household buys 4 pints of milk regularly on a main shop, but if they already have 2 pints in their fridge, they only buy 2 pints at this main shop visit. The probability of checking the fridge before shopping is another variable that can be set by the user for the household archetype under observation. A top-up shop is triggered if the household runs out of or is about to run out of the food item. This trigger level can be defined by the user. If the amount of food item in the home falls below the trigger level, there is a chance that the top-up occurs on that day or on the following day, provided no main shop occurs. The size and number of packages that will be purchased from the top-up shop is also fixed and can be varied by the model user.

Once the packages purchased from the main shop and top-up shop are set, the shelf life and open shelf life of the item is assigned to each package. Available shelf life and open shelf life is set by the user for the product. Available shelf life is the difference between the date the product is purchased and its use-by date. The shelf life of a product is defined as a probabilistic distribution to represent the case in real life. Open shelf life is the advice on the packs that is usually stated as 'once opened use within x days'. Open shelf life can be defined as a deterministic value by following the guidance on the packages. Moreover, these values can be altered for different household archetypes to

reflect the degree to which the household adheres to these date labels; previous research has shown that many households are prepared to eat food after the dates on the packaging (WRAP, 2011).

Storage Module: Food items can be stored either in the fridge or freezer. After the shopping, packages are put in fridge or pantry depending on the staple food item. It is not common to purchase the staple food items frozen. However, depending on the household behaviour, staple food items can be frozen after purchase. The user can define the likelihood that the household will freeze the items that are about to expire. In that case, both unopened and previously opened packages can be put in the freezer. Once a package is put in the freezer, the frozen shelf life and thawed shelf life is assigned to that package. Frozen shelf life is the guided storage time of the food item in the freezer. Thawed shelf life is the recommended timeframe that the item needs to be consumed within once it is defrosted.

At the beginning of each day the fridge and freezer are checked for items that are expired and about to expire. The expired items become waste and the total waste is reported. In the case that the household choose to freeze the items that are about to expire, these items are put in the freezer. The likelihood that the household choose to freeze the items can be defined by the user.

Demand Module: Demand for the food item under consideration is created in this module. In this context, demand is how much of the food item in question the household would like to consume. If the household has a sufficient amount of that food item, then the amount consumed will equal the demand. If there is insufficient, then consumption will be less than the demand, and the demand that was not fulfilled is recorded as an output of the model.

There are options to enter the daily consumption distributions for adults and children between ages 0-6 and 7-17. Once daily demand is generated, it is sent to consumption module.

Consumption Module: Once a demand signal is received from the demand module, the amount in the current open package is checked. If the amount in current open package is enough, the demand is satisfied and the amount in current open package is updated. In case that there isn't enough in current open package, a signal is sent to storage module to open a new package. First, the fridge is checked for available packages. In case there are no packages in the fridge, the freezer is checked for available packages. Once a new package is opened, a signal is sent to consumption module that informs the new package is ready for consumption. The demand will not be satisfied if no packages are available both in fridge and freezer.

Input Parameters: The model requires a large range of input data to function. These include:

- Household size including number of adults and number of children between ages 0-6 and 7-17
- Probability of consuming the item daily for adults and children
- Daily consumption amount (as a probabilistic distribution) for adults and children
- Regularly purchased package size of the item, number of packages purchased at each main shop visit, number of packages purchased at each top-up shop visit

- Probability of shopping list making and adjusting the amount being bought accordingly
- Average shelf life of item (deterministic or random), open shelf life of item
- Trigger level for top-up shop, likelihood of visiting the top-up shop on the day that the top-up shop visit triggered (if not visited on the same, it is visited on the next day)
- If the product can be frozen: Turn on/off freezing, Frozen shelf and thawed shelf life of the item, Likelihood of freezing the item that is about to expire (either open or unopened package), Probability of consuming a frozen item

Output Parameters: The model records various information from each run of the model. Of primary interest are the headline indicators:

- Total amount purchased
- Total amount consumed
- Total requirement/demand
- Total requirement not fulfilled due to no product in fridge or freezer
- Total amount wasted and the details on cause of the waste: Total waste caused by available shelf life, Total waste caused by open shelf life, Total waste caused by frozen shelf life ,Total waste caused by thawed shelf life

Each of these variables are recorded for the whole of the model run (usually set to 10 years).

Application of HHSM on UK population

The challenge is that the HHSM models a single household in any given simulation. However, it is useful to use the model to understand how an intervention affects the food waste generated from a range of households across a given population. Therefore, the changes relating to an intervention need to be modelled for several different household types. The use of household archetypes is being investigated as the most promising route to bridging the gap between individual simulations and creating inference for a whole population. In order to use the HHSM to obtain insight on waste levels for UK population, first, different household archetypes and their weights were defined so that the UK population is reflected by the archetypes. Based on WRAP's consumer segmentation research, 7 household archetypes were created to provide a range of households encompassing different numbers of occupants, and a range of practices relating to food and food waste (WRAP, unpublished). Weighting factors were determined to ensure that the average number of occupants in the households reflects the UK average. Description of these archetypes and their weighting factors can be found in Table 1.

For the baseline models of each product, the simulation model was set up with the inputs determined based on characteristics of these archetypes such as the number of people in the household, shopping patterns, consumption patterns, the attitude to food safety and date labels, and the management of food in the household. These inputs were gathered from the subject matter experts and following sources:

1. WRAP's retailer surveys (WRAP, 2012; WRAP, 2017), which is a survey across UK retailers of a range of factors believed to influence household food waste for a selection of products,
2. The National Diet & Nutrition Surveys (Gov.uk, 2019) which assesses the diet, nutrient intake and nutritional status of the general population of the UK,

3. Customer segmentation survey conducted by WRAP, which includes shopping and consumption patterns, the approach to food safety and date labels, freezing behaviour, and handling of food in the household

Table 1- Household Archetypes in UK population based on consumer segmentation research conducted by WRAP

Household Archetype	**Brief Description**	**Weighting factor**
Aspirational Discoverers (AD), Family	4-person HH, younger children, willing to take more risks, confident, good planning, moderately likely to throw away leftovers, moderate portioners.	7.8%
Functional Fuellers (FF), Single	1-person household, less willing to take risks,, low confidence in the kitchen, poor planning, likely to throw leftovers, moderate portioning.	14.3%
Functional Fuellers, Couple	2-person household, no children, less risk averse, low confidence in the kitchen, poor planning, likely to throw leftovers, moderate portioning.	10.7%
Spontaneous Creatives (SC), Single	1-person household, less risk averse, moderately low confidence in the kitchen, poor planning, leftovers likely to be thrown away, poor portioning.	13.7%
Spontaneous Creatives, Couple with one child	3-person household, one child, more risk averse, moderately low confidence in the kitchen, poor planning, leftovers likely to be thrown away, poor portioning.	16.0%
Ideal Advocates (IA), Couple	2-person household, no children, less risk averse, high confidence in the kitchen, good planning, leftovers will be used, good portioning.	24.3%
Pressured Providers (PP), Family	4-person household with (generally older) children, medium confidence in the kitchen, good planning, leftovers will be used, good portioning.	13.2%

Once the baseline models were set and validated for each product under investigation, the necessary scenarios were defined to understand first the magnitude of the effect of the input parameters and second the possible interventions to decrease food waste. These interventions include, but are not limited to, changes in package sizes, changes in food labelling terms (i.e. use by date vs. best before date), changes in freezing guidance, extensions on shelf life and open shelf life with new technological developments on smart date labels etc.

The next section summarizes a sample of possible findings that can be acquired by employing HHSM for the UK population.

Findings

The results of this tool can be explored to help inform public engagement on the issue of food waste in the home, and discussions with the food industry on changes to products, packaging and labeling that could help reduce food waste at home. This section provides a sample of findings from the HHSM for dairy products' waste levels. The waste level is defined as the percent of purchases wasted due to not being consumed in time (i.e. during open shelf life that is guided on the package, before expiration date). The quantitative results presented in this section are strictly only applicable to households that act as those described. Real households will differ from this simplified behaviour. As a result, the quantitative results in this section should be seen as indicative rather than exact.

Hard Cheese: Hard cheese, such as cheddar and parmesan is one of the dairy products that are subject to substantial variation in how people store it once opened. Development of smart packaging for hard cheese products and giving the right storage guidance is highly valuable. As a result, the waste level caused by open shelf life for hard cheese is of high interest. The HHSM is employed to understand the effect of open shelf life on waste level for hard cheese across the various household types and whole population. For instance, open shelf life guidance for hard cheese in the UK is 7 days. Figure 1 summarizes the changes in the waste level as the open shelf life varies from 7 to 14 days. According to the modelling results, single-occupancy households have the highest waste level per person which is expected and in accordance with previous research. The results suggest that open shelf life impacts strongly on waste. Note that the magnitude of the effect of the open shelf life on waste level decreases as the open shelf life period increases. Innovations that increase the open shelf life of hard cheese by one week can decrease the waste level by approximately up to 15 percentage points, from 17% to 2.3%.

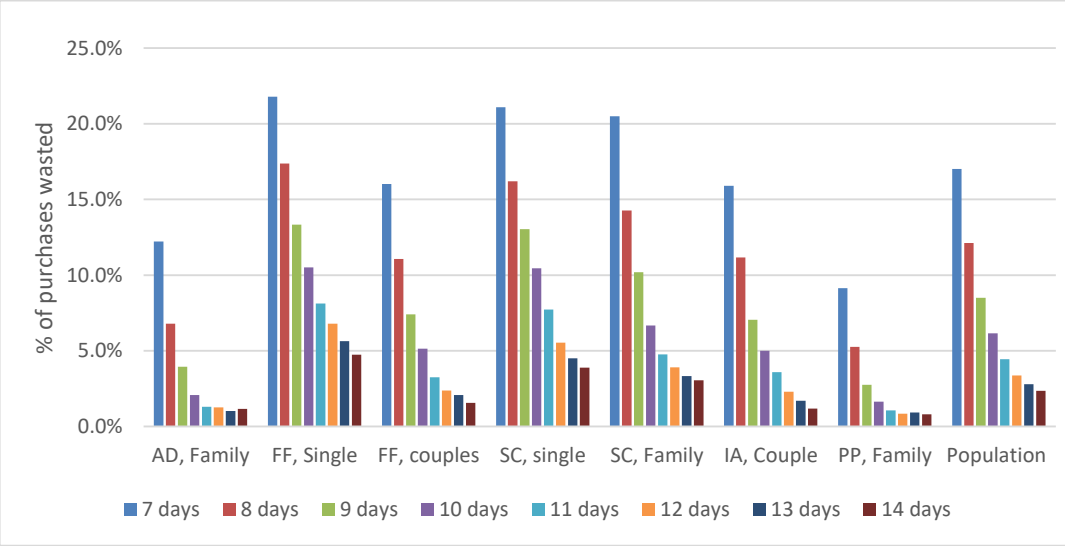

Figure 1 - Waste level outputs of hard cheese across the household archetypes and whole population as the open shelf life varies from 7 to 14 days

Milk: People's use of dates is linked to their understanding of what is meant by those dates and also factors in their perceived needs according to particular products (WRAP, 2008). Currently, milk can be found carrying a "best-before" date in UK. HHSM is used to measure the change of waste level in milk hypothetically if all milk bottles displayed with best-before date label. The experiments took into consideration the understanding of the households what is meant by those dates. Across the population, changing from "use-by" to "best-before" date label, on average, leads to extending the consumption period in the home by one day which is calculated based on the findings of Thompson et al., 2018 and the discussions with subject matter experts. This leads to decreasing the waste level for each household archetypes as seen in Figure 2.

According to the results in Figure 2, switching the date label from "use-by" to "best-before" can decrease the percentage of milk purchases that are wasted from 4.4% to 1.8% for the population– which is about 8 tonnes of milk yearly. Note that this is a hypothetical example and the safety of consuming milk one day beyond the use by date and extending open shelf life by one day needs to be confirmed with competent authorities.

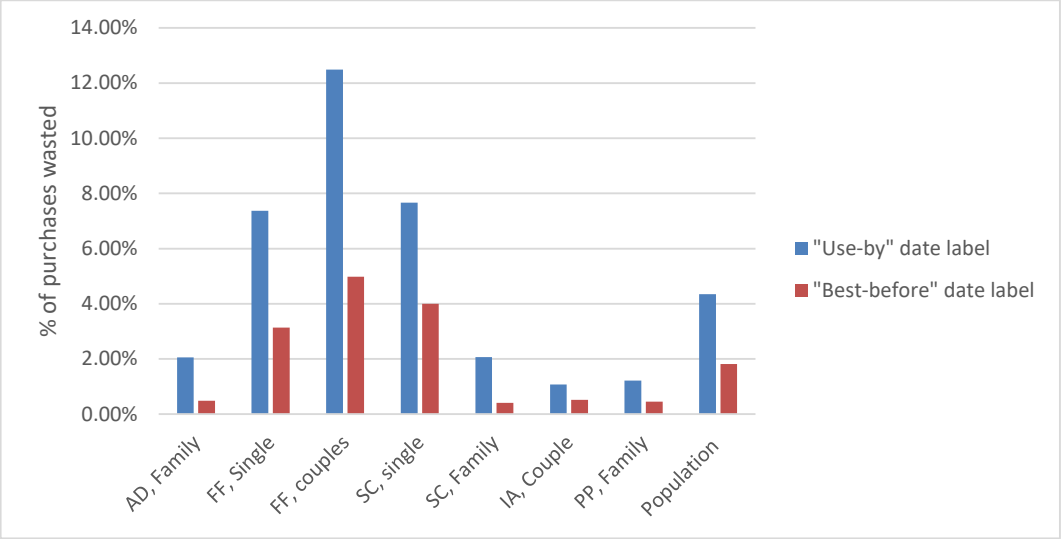

Figure 2 - The change in waste level of milk by switching the date label from "use-by" date to "best-before"

Yoghurt: Yoghurt is considered a staple food for several cultures. In the UK, it is one of the dairy items that is purchased regularly. In general, 6-7% of the yoghurt purchased by UK households is wasted because it is not used in time (i.e. before it is thrown away because it went mouldy / off or it deteriorated in quality) (Quested and Liam, 2014).

The size of packs available to consumers can influence whether or not they are left with surplus food. One of the main interests for yoghurt was to see the effect of purchasing smaller multi-packs versus single big pots on the different household archetypes and the whole population. The waste levels for these two extreme scenarios where household only buy multi-packs or big pots are summarized in Figure 3.

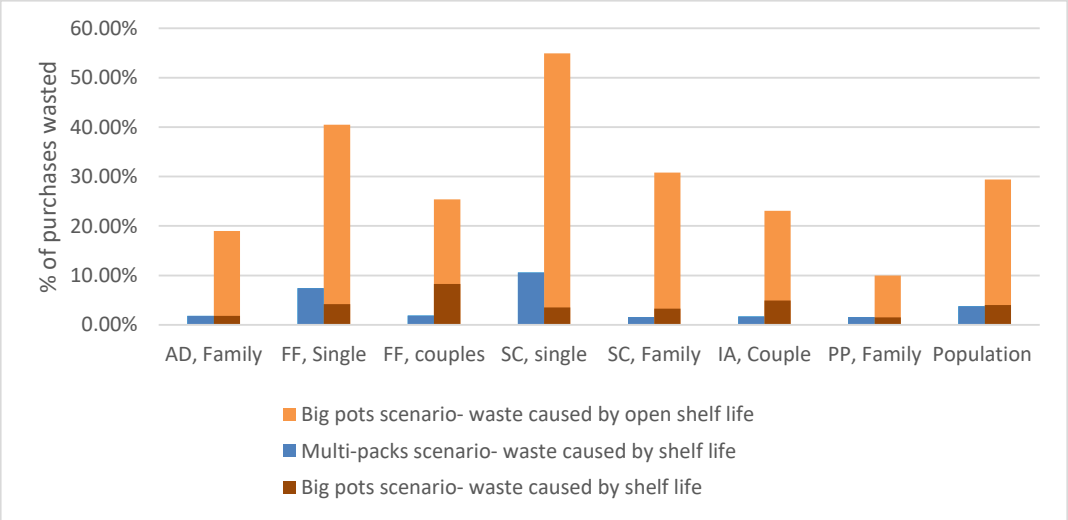

Figure 3 - Waste levels from purchasing "small multi-packs" vs. "single big pots"

As it can be seen, one-person households have the highest waste percentage per person and four-person households have the lowest waste percentage per person for both scenarios. Buying yogurt in smaller multi-packs eliminates the waste caused by open shelf life since the small pots are usually consumed immediately once opened. For single

big pots, the main generation of waste is caused because the item is not consumed in time once the pack is opened. Overall, consuming only smaller multi-pack yogurt can decrease waste level by 25%, compared to only consuming single big pots.

To summarize, the household food waste model reflects the probabilistic nature of the dynamics of food related activities within a household. Consequently, it gives results on the effects of waste prevention actions that are sufficiently accurate to base many decisions. The magnitudes of the effects of waste prevention actions can be estimated by setting and employing this tool.

Conclusion

The generation of waste in the home requires an understanding of both the flow of food through the home and social factors (i.e. how people interact with the food). This work suggests that system-based approaches to considering waste prevention in the home can increase understanding of the issues and determine the approximate impact of potential interventions. This research delivers a quality assured method for rapidly testing many food waste reduction interventions and provides an evidence base with which policy makers, industry and governments can act upon. The modelling technique (DES) is not new, but its application to food waste in the home is novel and provides many useful insights. The developed model can incorporate a wide range of products and household dynamics critical to food waste. Moreover, this model can act as a tool for explaining how waste generation can be conceptualised. The results from this ongoing study will provide guidance on the most effective actions to reduce household food waste.

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Oil procurement in spot and forward markets for integrated operational and financial hedging

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Abstract

Oil refinery procures oil from supplier to meet the customer's oil demand. Thus, one of the most important decisions that oil refinery has to make is to allocate amount of oil procurement in spot and forward markets to meet the all the demand. Under the uncertain demand, difference between realized oil demand and forward oil quantity can be procured in the spot market. By introducing procurement flexibility such as inventory and financial derivatives like bilateral contract in the forward market, oil refinery can obtain desired balance profitability and risk tolerance with CVaR.

Keywords: Optimal oil procurement, spot and forward markets, financial hedging, Conditional value at risk

Introductions

This study intends to model the optimal quantity for maximizing the profit and minimizing the risk of oil price volatility. In addition to traditional JIT procurement, spot and forward contracts have emerged for oil procurement. By entering the advance markets which are called forward and future markets, oil refineries can purchase their optimal quantity and meet the uncertain stochastic demand. Also, they can hedge their fluctuation of stochastic oil price. Due to the soaring volatile oil markets, oil procurement problems have received increasing attention. Jan and Stefan (2010) already proved the benefit of participation in advance procurement markets and derivative markets. The reason for entering advance markets is primarily for meet the uncertain demand. After meeting the demand of the oil, we can partly hedge the fluctuation of oil price in advance markets. To the oil refinery, the fluctuation of oil price is significant to their oil procurement activity. In the US oil industry, 85 percent cost of operating activity is oil procurement cost. In the end, oil refinery can reduce oil procurement cost by entering spot and forward market. By introducing procurement flexibility such as inventory and financial derivatives like bilateral contract, put option, and call option in the forward market under the uncertain demand.

We analyze oil procurement problem under uncertain future procurement oil prices and oil product demands. An optimization model is presented that finds best quantity of advance procurement of oil and spot-market procurement. Also, derivatives such as

bilateral contract and call option and put option in the forward market can hedge the volatility of oil prices.

The rest of this paper is organized as follows. In section 2, literature review is presented. In section 3, Base model and parameters are described. In section 4, the conditional value model is presented. In section 5, a Conditional value at risk is presented. Finally, the conclusions are discussed.

Literature Review

In the petroleum industry, crude oil procurement has been a critical issue for refineries, as it involves volatile demand and oil prices. The previous literature in crude oil procurement of the refinery can be divided into three streams: maximizing profit, minimizing financial risk in spot and forward markets, and integration of the two. While there have been many studies in finding an optimal quality of crude oil procurement to reduce costs and to maximize profits (e.g., Zimberg and Testuri, 2006) or to minimize financial risks through spot and/or forward market buying (Gaur et al. 2007; Secomandi and Kerke, 2012), recently a few studies have emerged in integrating these two important operational and financial aspects. Therefore, this study intends to develop a mathematical model for finding the optimal quantity of crude oil procurement in order to maximize an oil refinery's profit and minimize the risk of oil price volatility. To do so, we extend the previous integrated single-period model (Ji et al., 2015) to a multi-period model by incorporating trade-off between profit maximization and financial hedging.

Fluctuating oil price needs to manage risk with Conditional value-at-risk. Oil refinery tolerate different levels depending upon their objectives and capital. The adequate representation and manage of risk are a critical test task for business success. A typical approach in risk management is to estimate and control VaR with a specified confidence level. Many papers already analyzed and considered CVaR as risk measure (Standislav, 2002; Xiaoping and Chen, 2002; James and Ahmed, 2008).

Base model

We develop the mathematical models that determine optimal order quantity to purchase both in spot and forward markets. Our mathematical models incorporate the major parameters of oil refineries where oil refineries can buy oil vial forward contracts and spot markets.

We propose an integrated mathematical model of determining the optimal quantity and frequency of crude oil procurement in multiple periods in order to maximize an oil refinery's profit and minimize the financial risk from demand and price uncertainty. The model incorporates the major parameters of oil refineries, such as procurement, transaction, transportation, inventory and production costs as well as demand price, which can buy crude oil in the spot market and/or through forward contracts. The model is nonlinear in nature, involving geometric Brownian motion (Secomandi and Kerke, 2012; Chen et al., 2015) and Martingales (Ji et al., 2015) functions.

- *Assumptions*

According to risk averse economic agent, we can maximize profitability which is originated from bid-ask spread with equivalent probability measure. Under the absence

of arbitrage, transaction cost in spot and forward markets is equivalent to the existence of at least one probability measure. This bid-ask process follows the martingale condition.

- *Variables*

We denoted by F(0) the time 0 nominal price of a forward contract with time T delivery, and simplify it to F. This price evolves during the time [0, T] as a known stochastic process $F(t) \in \Re+$, $t \in [0, T]$. However, we focus on the time T forward nominal price, which is the spot nominal price f; that is, $F(t) \cong f$.

Trading in spot and forward markets incurs transaction costs, that is, bid-ask spreads. Consistent with models studied in the finance literature (e.g., Constantinides et al., 2007), we model these costs as proportional. Let A and $B \in (0,1)$. If the firm purchases spot one unit of oil at time T, it pays the spot ask price (1+A)f; if the firm sells spot unit of oil at this time, it receives the spot bid price (1-A)f. At time 0 the firm can forward purchase one unit of oil at the forward ask price (1+B)F. we do not allow the firm short sell oil forward. As this is suboptimal in the no arbitrage valuation framework that we use. However, a forward sale at time 0 of one unit of oil can be made at price (1-B)F. Consistent with the theoretical work and the empirical evidence on the structure of transaction cost are larger than the forward transaction costs; that is, A > B.

The firm's time 0 forecast for its time T demand is D(0), which we simplify to D. As the forward price, this forecast may evolve as a stochastic process, denoted by $D(t) \in \Re+$, $t \in [0, T]$, which is correlated with the forward nominal price stochastic process. However, we focus on the spot demand d at time T; that is $D(T) \cong d$. Since, the demand forecast and forward nominal process are correlated, so are the spot demand and nominal price.

For notational convenience, we define $E_t[.]= E[.|D(t), F(t)]$, $\forall(t, D(t), F(t)) \in [0, T] \times \Re+$, expectation given D(t) and F(t) with respect to a probability distribution. Notice that $E_t[.]$ is not random variables at time t because D(t) and F(t) are known at this time. That is, our notation does not distinguish between random variables and their realizations; which should be clear from the context. We simplify E_0 to E.

The firm needs to decide how much supply q to procure forward at time 0. Such an optimal procurement decision can be obtained by solving the following optimization problem.

- *Objective function*

$$V : \max_{q \geq 0} E[\ (1 - A)f(q - d)^+ - (1 + A)f(q - d)^- - (1 + B)Fq]$$

Where $(.)^+ := \max\{., 0\}$ and $(.)^- := -\min\{., 0\}$. The first and second terms inside the expectation in optimization problem equation are the revenue collected from selling excess contracted supply on the spot market and cost of any supply shortfall. The third term is the forward procurement cost. The objective function in optimization problem equation and its optimal value V are both expressed in time T money, as money exchanged only at this time.

Due to the presence of the spot market, the firm always achieve 100% service level. Indeed, q=0 is a feasible solution to objective function. This solution corresponds to simply waiting until time T, observing the realized demand, and procuring this amount on the spot market. We denote the value of this spot procurement policy as $V^S := -E\{(1 + A)fd\}$. We define the value of the forward procurement option, V^P, as the

additional value obtained by optimally procuring both in the forward and spot markets than only in the spot market.

$$V^P := V - V^S$$

Risk measure and Objective function

For the risk measure, we conduct a CVaR, which is known as Mean Excess Loss or Mean Shortfall. According to Rocafellar and Uryasev, given a return distribution, the α-CVaR is the conditional expectation of loss above the lowest amount for which the loss will not be exceeded with probability α; it is the expected loss in the worst α% of the distribution. In this paper, because we consider CVaR associated with total cost, it is defined as the conditional expectation of expenses above the larger cost for which the expenses will not be exceed with the probability of α. Figure 1 demonstrates the 95% CVaR of the total cost.

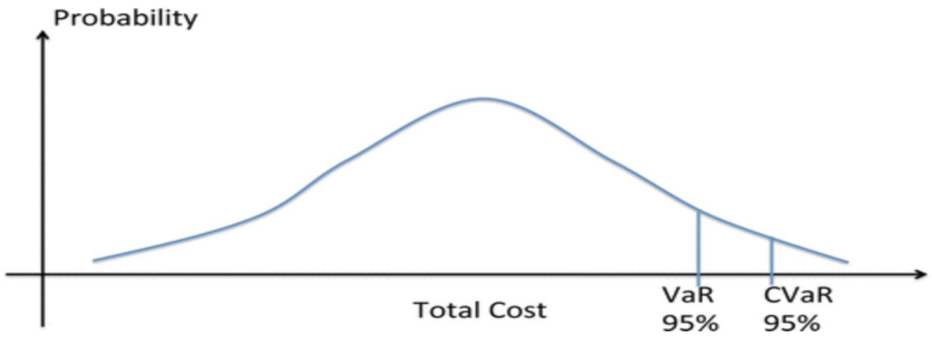

Figure 1 –CVaR with total cost

According to Pflug, CVaR is calculated as

$$CVaR_\alpha = \inf_{\alpha \in R}\{q_\alpha + \frac{E_{s\in S}\,[(cost - q^\alpha)^+]}{1-\alpha}\}$$

Where the optimal q_α is the corresponding VaR_α shown in the figure. Note that α is the confident level and typically set to 95% while $q_\alpha$is the associated α level value-at-risk. By minimizing the right-hand side of equation of CVaR. CVaR is as well as VaR can be obtained simultaneously.

As compared to VaR that lacks subadditivity and convexity as is ill-behaved, CVaR is a coherent risk measure with the following properties: translation invariance, subadditivity, positive homogeneity, and monotonicity. Hence, we use CVaR as the risk measure, and the objective function is to minimize the CVaR associated with total cost as

$$\text{Min } CVaR_\alpha$$

Conditional value-at-risk was recently developed in previous papers. This method is quite general and can be used for any application involving optimization of quantiles. Also, development of this approach is mostly stimulated by finance applications.

Therefore, it will be explained in the framework of the financial contents. By optimization with conditional value-at-risk, our paper reduces risk which is consistent with fluctuating oil price.

Results

Each oil refinery tolerates different level of risk, depending on their objectives and capital. Fluctuating oil price can be a critical risk to oil refinery. Depending on oil price, their procurement cost which is 85% of the operating cost is affected significantly. In the end, a typical approach in risk management is to estimate and control VaR with specified confidence level such as 0.95,0.99 or 0.999.

Conclusions

The results from solutions and sensitivity analyses are expected to provide important practical insights related to the optimal combination of spot and forward buying in multiple periods. The problem is highly relevant for the strategic decision making of crude oil procurement by oil refineries in the petroleum industry. Theoretically, the contribution may lie in developing a more comprehensive multi-period model of crude oil procurement by integrating both profit maximization and financial hedging issues. The results from solution and sensitivity analysis are expected to provide significant managerial insights to practicing managers.

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Empirical Research in Operations Management

Drivers of Industry 4.0 implementation: An experimental analysis

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Abstract

This study uses an international survey to explore experimentally what drives Industry 4.0 (I4.0) in manufacturing companies. For this exploration, we hypothesize that, *ceteris paribus*, companies that are insightful as to the contributions of I4.0 to their management objectives, are aggressive in their I4.0 implementation. These companies are expected to adopt innovator-type behaviors in practicing I4.0 and move forward more quickly in their I4.0 implementations. Companies with an organizational culture aimed at intensively focusing on practices to improve some value creation capabilities are confirmed to be the most aggressive implementers of Industry 4.0.

Keywords: Industry 4.0, Absolute supply chain orientation, Product development capability

Introduction

Industry 4.0 (hereafter, I4.0) is an initiative taken by the German government. It has been referred to as the Fourth Industrial Revolution, aimed at making manufacturing sectors globally competitive by way of digitization. This comprises emerging enabling technologies such as cyber-physical systems (CPS), the Internet of Things (IoT) and cloud computing (Kagermann et al., 2013). Although there is still no well-accepted definition of the concept (Lu, 2017; Xu et al., 2018), the aim of I4.0 has been clearly stated: "I4.0 is focused on creating smart products, procedures and processes" (Kagermann et al., 2013, p. 19). CPS-based management is expected to greatly improve industrial processes linked to manufacturing, engineering, material usage, and supply chain and life cycle management (Kagermann et al., 2013). Its impacts on companies and industries are perceived to be strategically significant and pervasive (Porter and Hippelmann, 2014, 2015). The implications of Industry 4.0 forecast by these reports and articles are promising and significant for companies.

I4.0 implementation generates benefits by renovating the value creation process under the umbrella of connectivity (Kagermann et al., 2013; Porter and Hippelmann, 2014, 2015). Emerging new technologies supporting I4.0, such as IoT and related technologies, cloud computing and CPS (Kagermann et al, 2013; Xu et al., 2018) enable the value creation process to be integrated vertically, horizontally and end-to-end to enhance the effectiveness and efficiency of the process (Kagermann, 2013). Westerman et al. (2014) define the challenge of renovating the value creation process through digitization in three phases: Creating a compelling customer experience (identifying new customer values), exploiting the power of core operations, and reinventing business models. Westerman et

al. (2014) also advocate the concept of transformation leadership as a driver of renovation. Transformation starts with the reenvisioning of the customer experience, operations, and business models and then moves on to the implementation stage per se. We are specifically concerned with the first two aspects here: reenvisioning, i.e., new value concepts and the operations to deliver them. Reenvisioning is a trigger of the renovation process by digitization. In this study, we focus on the capability to design a desirable configuration of new value creation processes that is commensurate with this reenvisioning. If this capability is weak, the thrust that drives renovation is also weak. We hypothesize that this capability determines the capability to carry out process renovation. This is the company's capability to constantly seek desirable value creation processes and transform existing processes.

Based on a survey of IoT researchers, Haddud et al. (2017) ranked the benefits and challenges related to IoT usage for individual organizations as well as entire supply chains. However, given general technological progress such as emerging information technologies, the extent to which these benefits are actually realized differs from company to company. For example, the benefit level from better control and management of inventories, which is one of the most highly perceived benefits (Haddud et al., 2017), clearly depends on achievable lead time and the company's demand variability levels. As for the challenges, the second-ranked difficulty, a lack of a clear understanding of IoT benefits (Haddud et al., 2017), which is a fundamental barrier to IoT adoption, is largely dependent on the company's ability to understand which factors are currently disrupting existing supply processes and how these factors can be improved.

In this study, we focus on the enablers of I4.0 implementation. If companies understand what needs to be improved in the value creation process and how this can be done, they are motivated to implement appropriate Industry 4.0 practices due to the contributions that they make to any improvements, and are open to more aggressive implementations than would otherwise be the case. We explore what the drivers of I4.0 implementation might be. The following section is a literature review of possible drivers of I4.0 implementation. Then, in the third section, we develop our research framework and research hypothesis. The fourth section presents the results of the statistical analyses and the research implications, and the final section offers some conclusions.

Literature review

One enabler of I4.0 is clearly the emergence of new digital technologies that are triggering I4.0, including IoT (Kagermann et al., 2013; Yu et al., 2016; Lu, 2017; Zhong et al., 2017; Ardolino et al., 2018; Buer et al., 2018; Dalenogare et al., 2018; Xu et al., 2018). Apart from the papers cited above, a large number of engineering approaches that present applications of the new technologies can be found in this research category. This is possibility theory. In reality, final adoption and implementation of the technologies probably depend on the perceived benefits, perceived costs, and external pressures (Tu, 2018; Tu et al., 2018; Tu et al., 2018). Another enabler is management culture and, especially, the culture behind innovative activities drives I4.0 implementation (Yu et al., 2016; Mohelska and Sokolova, 2018). Digital transformation leadership advocated by Westerman et al. (2015) is considered to be part of this enabler. A conservative management culture can indeed be a barrier to the push to I4.0 (Westerman et al., 2014; Yu et al., 2016; Mohelska and Sokolova, 2018). Together these two drivers imply that the existence of promising technologies and innovative leadership can be a driver of I4.0's renovation of the value creation process. This is persuasive but not clear in operational terms. We inquire into enabling factors that render innovative leadership reliable and confident of success through the preparation of operating conditions designed to avoid

risks. In this study, we are concerned with more tangible and normative managerial drivers than the innovative culture that drives companies to take advantage of new technologies to renovate their value creation process.

One such enabler of I4.0 that has been stated in the research is the lean orientation prevailing in the organization (Rüttiman, and Stöckli, 2016; Mrugalska and Wyrwicka, 2017; Tortorella and Fettermann, 2018; Buer et al., 2018; Yin et al., 2018). Tortorella and Fettermann (2018) proved empirically that lean orientation is positively related to I4.0 implementation in Brazilian companies. A lean orientation constantly focuses on supply process efficiency as an organizational culture. I4.0 focuses on the value creation process with the supply process regarded as an important part of this and seeks continuous resource productivity and efficiency gains under changing competitive and ecological environments (Kagermann et al., 2013). With respect to the relationship between I4.0 and lean principles, Rüttiman, and Stöckli (2016) clearly state that the lean production capability or knowledge is a prerequisite of I4.0 and that I4.0 has the potential to make lean production work better. The present research also focuses on this enabler. It also explores the enabler on the other side of value creation processes, i.e., the process of identifying customers' new values (Westerman et al., 2014; Porter and Hippelmann, 2014 and 2015). Lean orientation is more closely related to supply processes. Value creation processes comprise these two processes. I4.0 aims to renovate the value creation processes (Kagermann et al., 2013; Westerman et al., 2014).

This study hypothesizes that the intensity of organizational orientation toward strengthening the value creation process, including its lean orientation, drives I4.0 implementation. This study is based on previous research (Morita et al., 2018) that showed that the product development and supply chain process capabilities lead to long-run high-performance manufacturing in an integrated way. This study proposes and proves empirically that these capabilities, including lean orientation, can be drivers of the implementation of I4.0 practices. Companies characterized by high capabilities of these two processes are expected to better understand organizationally how I4.0 practices can be related to strengthening these capabilities for future competitive situations than would otherwise be the case.

Analysis framework and hypothesis formulation

When considering value creation processes, we assume two generic processes to work. They are new value creation (value concept creation and its packaging for the market) and value delivery processes (Westerman et al., 2014). Below we recap the equation based on Little's Law (Hopp and Spearman, 1996; Little, 2011) that comprises these two processes (Morita et al., 2015; Morita et al., 2018). Based on this equation, Morita et al. (2018) deduced two capabilities: Product development and supply chain management. The supply chain capability reflects the strength of a culture or strategic focus constantly executing four initiatives: lead-time reduction, just-in-time (pull) control, demand variability reduction, and enhanced quality conformance. It has been given the name *absolute supply chain-oriented strategy (ASCOS)* (Morita et al., 2015; Morita et al., 2018). Morita et al. (2018) defined the *product development capability (hereafter, PDC)* as the capability of integrating the wisdom of customers, suppliers and the company's relevant functions into product development. Strengthening PDC implies companies are constantly improving knowledge integration among these key players to introduce new values into products and services.

$$Vs^* = D\,(TT+RT) + Bs \qquad (1)$$

Where:

Vs* = The volume to be secured in an entire supply chain
TT = The time to fully transform a unit of product in the chain with no waiting time (Hopp and Spearman, 1996)
RT = The interval time between inventory reviews for replenishment measured in the same time unit as TT
D = The estimated average demand rate per time unit defined in the same time unit as TT for the future period of (TT +RT)
Bs = The buffer stock level, to be determined depending on TT +RT with an allowable stock-out level

This equation can be interpreted as showing Vs* as a theoretically ideal level of inventory in the entire supply chain, given TT, RT, an assumed average demand rate and an allowable stock-out level such as 1%. This equation is defined as a whole controllable supply chain process extending to upstream and downstream partners. Any surplus over Vs* is waste and any shortage under V*, opportunity losses. Vs* should be minimal given D. So, shorter TT and RT, lower demand variability, fewer quality defects, and an appropriate replenishment mechanism are desirable in order to maintain the level of Vs*. It can, therefore, be said that there are four focuses that underlie the supply chain management capabilities (ASCOS): shorter lead-time focus, demand stability focus, quality conformance focus, and just-in-time focus (JIT or pull-control focus).

High ASCOS can increase value added by increasing D and price as well as reducing waste by improving throughput time, quality conformance, speed and reliability of delivery, and stable operations. On the other hand, PDC also contributes to the growth of D by introducing new values to products and services in addition to improvements to existing products and services. Also, high ASCOS and PDC capabilities may multiply the above effects by their interactive fit, such as refining product strengths and designs, including modular architecture for manufacturability (Morita et al., 2018). Enhancement of both of these capabilities results in improvements to the four above-mentioned ASCOS focuses in the value creation processes and leads companies to high-value creation. So, companies that always make efforts to improve these two capabilities in order to build more effective value creation processes (condensed in the above equation) are expected to relate the potentialities of I4.0 concepts and technologies to the improvements to the ASCOS focuses more easily than would otherwise be the case, as they understand what the existing barriers to renovating or improving the value creation processes are and what needs to be solved. Also, the aims of I4.0 overlap with their intentions in the sense of streamlining and renovating the value creation process, which is prone to disruption and inefficiency due to many factors, including increasing market requirements for customization, chronic fluctuation of demand due to saturated markets, unreliable and untimely data, slow and inappropriate decision making, and unpredictable machine malfunctions caused by smart digitization, and are exemplified by I4.0 concepts such as smart factory, smart product and CPS (Kagermann et al, 2013; Haddud et al., 2107).

High performer companies, characterized by high ASCOS and PDC, continue to make efforts to renovate or improve their value creation processes to adapt to competitive requirements by focusing on demand rate and variability, lead time, quality conformance and replenishment synchronized with demand (Morita et al., 2018). In this paper, this will be called the high performer approach (hereafter, HP approach). On the other hand, the approach under the I4.0 concept (hereafter, I4.0 approach) aims to strengthen the value creation process by focusing on creating smart products, procedures, and processes by taking advantage of digitization (Kagermann et al, 2013). A common aim of these two approaches is to seek optimal competitive value creation processes. The HP approach

focuses on the physical process factors of the value creation process and the I4.0 approach on digitization exemplified by concepts such as “smart factory”, “smart product”, and CPS. The configuration of the value creation process under the I4.0 concept as a whole is still in flux although its aims and potentialities through optimization by “smart” and “connectivity” have been theoretically stated (Kagermann et al, 2013; Porter and Hippelmann, 2014, 2015; Lu, Y., 2017; Buer et al., 2018; Xu et al., 2018).

This study proposes that the *HP approach drives or supports the implementation of the I4.0 approach* as a framework of navigating focuses for digitization. From the viewpoint of the HP approach, the lead time focus requires improvements in times for physical activities such as manufacturing and engineering, the physical movement of goods, set-up or changeover of machine tools, processing and transmission of data and information, decision making and judgments, breakdown and malfunction of facilities and machines, rework, procurement delivery and elimination of bottleneck phenomena. The quality conformance focus requires improvements in, e.g., the working conditions of people and machines, design for manufacturability, quality control systems and supplier relationships. The pull control focus demands improvements in activities such as a grasp on inventories, adaptation of the inventory level to be held or secured at each stage of the supply process, including manufacturing and replenishment order release to secure the inventory level (Monden, 1991). The demand variability focus requires increasing demand predictability and product strengths such as product dignity (Clark and Fujimoto, 1991), as well as the robustness of processes such as postponement (Walter and Bowersox, 1988), together with other focuses such as lead time reduction.

Companies that adopt the HP approach are considered to encounter many opportunities afforded by I4.0 driven by emerging digital technologies. Therefore, this research *hypothesizes that:*

Companies highly-driven by the HP approach, i.e., companies characterized by high ASCOS and PDC, are also more aggressive when it comes to adopting the I4.0 approach, and implement I4.0 practices more than would otherwise be the case.

Although there are a number of practices involved in the I4.0 approach, in this research smart factory and smart product will be used as proxies for the *I4.0 approach* to test the above hypothesis. These are two typical concepts used by Kagermann et al. (2013) to introduce the I4.0 concept and will be described in greater detail below.

Kagermann et al. (2013) wrote (p. 19): “***Smart factories*** are capable of managing complexity, are less prone to disruption and are able to manufacture goods more efficiently. In the smart factory, human beings, machines and resources communicate with each other as naturally as in a social network” For their part, Burke et al. (2017) stated (p. 2): “A true smart factory can integrate data from system-wide physical, operational, and human assets to drive manufacturing, maintenance, inventory tracking, digitization of operations through the digital twin, and other types of activities across the entire manufacturing network. The result can be a more efficient and agile system, less production downtime, and a greater ability to predict and adjust to changes in the facility or broader network”. Porter and Hippelmann (2015) characterized the smart factory as networked machines which automate and optimize production bringing about efficiency and a reduction in malfunctions. Therefore, although there is still no single definition of smart factory (Strozzi, et al., 2017), taking into account the above-mentioned articles, the smart factory could be defined as having such characteristics as communicability between machines or facilities, self-controlled and autonomously optimized operation, and the

self-examining capability of working conditions. These are the commonly mentioned conditions that characterize smart factory (hereafter SF) operations.

Kagermann et al. (2013, p. 9) characterized ***smart products*** as those that are aware of the details of how they are manufactured and how they are intended to be used. Porter and Hippelmann (2014) defined smart products as those into which three types of components are embedded: Physical components, smart components and connectivity components. Physical components include mechanical and electrical parts. Smart components are operating systems such as sensors and microprocessors, which make the product function for its designed usage. Connectivity components give communicability to the product by wired or wireless connection. For their part, Mani and Chouk (2017) stated that smart products are distinguished by three functions: Sensor functions (to collect data about the environment), actuator functions (to actuate an action, controlled by some other entity) and network connectivity functions (including WiFi, Bluetooth or RFID). Therefore, in essence, from the above comments, it could be said that smart products (hereafter SP) have communication capabilities and are designed to optimally go through their life cycle stages from their manufacture to final usage thanks to their communication capabilities, with relevant external units such as machines and users such as customers.

Taking into account the characteristics of SF and SP, companies aggressively adopting the HP approach are expected to find the SF and SP concepts valuable for the construction of their value creation process, especially at all stages of the supply chain (Burke et al., 2017) and customer product usage processes. The latter is considered to contribute to the strength of product and demand predictability by enhancing the product's benefits and high utilization (Porter and Hippelmann, 2014). Therefore, in line with our research hypothesis, when companies adopt a high-level HP approach they will closely follow an I4.0 approach and will achieve a high level of I4.0 implementation (represented here by SP and SF levels).

Measurement and analysis results

This study's analyses are based on an international online joint survey on I4.0 involving 5 countries (Austria, Germany, Italy, Japan, and Spain) and three industries (Machinery, Electronics and Automotive) that compete globally with a high degree of competitiveness. An initial sample of 276 companies was obtained. However, it was decided for this research to use only data from companies with no missing values. This led to a final sample of 186 companies (Austria, 30; Germany, 36; Italy, 28; Japan 56, and Spain, 36. Machinery, 69; Electronics 59, and automotive, 55).

Questionnaire responses were measured on Likert Scales from 1 (lowest) to 5 (highest). This research assumes that such high levels of competition drive companies to strengthen their value creation processes with a heavy reliance on manufacturing and supply chain process I4.0 targets (Kagermann et al., 2013), and to take a more aggressive I4.0 stance than they would do otherwise.

The constructs used for this analysis are: a) the concepts representing the HP approach, which were explained above: ASCOS, PDC and Integrated Capability of ASCOS and PDC (as a second-order construct); and b) those that represent the I4.0 concept: SP and SF and Comprehensive I4.0 (second-order SP and SF construct). The responses in the questionnaires related to ASCOS and PDC are respondents' perceived levels of the corresponding items compared to their strongest competitors. The responses to the questionnaires related to SP and SF are the perceived levels of implementation of their corresponding aspects.

The *Smart Product* construct was developed by five questionnaires. As stated above, a Smart Product is designed to optimally go through its life cycle stages from manufacturing to final usage by reason of its communication capabilities. The analyses for the development of this construct advised us to divide the above-mentioned characteristics into two stages: Work-in-process and finished product. Although the definition of *Smart Product* implies that products know how to be manufactured (Kagermann et al., 2013), nonetheless it was decided for this research to include the "smart" features of work-in-process parts in the Smart Factory construct (see below) as these parts' smart features can be considered to be part of smart manufacturing operations (Zhong et al., 2017). Although this may be considered controversial and further analyses need to be conducted, for this study, "Smart Product" will only be defined by its finished product-related features.

So, the *Smart Factory* construct is measured by a) five questionnaires referring to production facilities, which reflect communicability, self-control, autonomous optimized operation and the self-examining capability of working conditions; and b) six questionnaires related to work-in-process parts with "smart" features that enable the production facilities to operate as expected in "smart" ways.

As shown below, the reliability and validity tests for these constructs, with data normalized by country, show very satisfactory values for the corresponding loading factors of their components, average variance extracted (AVE), composite reliability (ρ_C) and ρ_T-Cronbach's alpha:

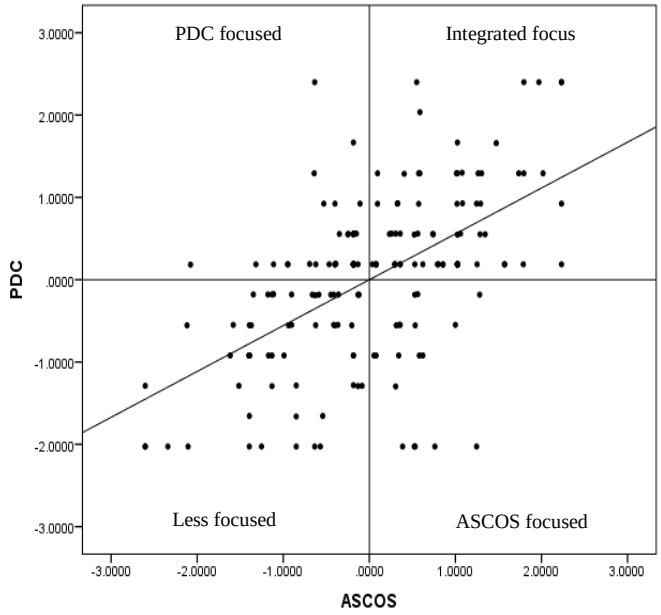
a) ASCOS: Loading factors above .779; AVE= .694; ρ_C =.919; ρ_T =.883
b) PDC: Loading factors above .915; AVE= .838; ρ_C =.903; ρ_T =905
c) Integrated capability of ASCOS and PDC: Loading factors above .862; AVE= .593; ρ_C .921; ρ_T =.83
d) SP: Loading factors above .771 ; AVE= .646; ρ_C =.901; ρ_T =.864
e) SF: Loading factors above .710 (except one with .611) ; AVE= .550; ρ_C = .930; ρ_T =.917
f) Comprehensive I4.0 (smart factory and smart product): Loading factors above .765 ;AVE= .705; ρ_C .826; ρ_T =.601

With respect to the discriminant validity of the constructs, the Heterotrait-Monotrait Ratio (HTMT) is 0.758 (somewhat lower than the 0.9 limit) between the second-order constructs (Integrated capability of ASCOS and PDC, comprehensive I4.0) and below 0.622 for the first-order construct comparisons.

Figure 1 shows where the sampled companies are located on the ASCOS (X-axis) - PDC (Y-axis) graph. The two capabilities are positively correlated (.557). Four groups were defined using the ASCOS and PDC averages: High performer (HP)/Integrated focus (68 companies) (this means that both ASCOS and PDC are above the average); ASCOS focused (19), (ASCOS is above the average and PDC is equal to or below the average); PDC focused (44) (PDC is above the average and ASCOS is equal to or below the average) and Less focused (55) (both ASCOS and PDC are equal to or below the average).

Next, the mean difference between the HP group and the other three groups for the Comprehensive I4.0 construct are analyzed with ANOVA. *Table 1* summarizes the results: The columns show the mean values of the comprehensive I4.0 implementation variables for each of the plant groups (HP, ASCOS focused, PDC focused and Less focused). The High Performer/Integrated focus group values are seen to be significantly higher in all cases than the other groups'.

Figure 1 – Group classification by PDC and ASCOS



Note: the vertical and horizontal lines are the average ASCOS and PDC values. The diagonal line is the line regressing PDC on ASCOS.

Table 1 – Between-group comparison of I4.0 Implementation Levels

	Integrated focus (n=68)	ASCOS focused (19)	PDC focused (44)	Less focused (55)
Comprehensive I4.0	.516	-0.127*	-0.0915**	-0.521***

Note: significant between-group comparison with Integrated focus group: *** at p<.000, ** at p<.001, * at p<.01. ANOVA analysis with Tukey's Post Hoc Multiple between-group comparisons.

Finally, *Table 2* shows the stepwise regression results for Smart Factory and Smart Product with PDC and ASCOS as independent variables and their integrated capability.

Table 2 – Stepwise Regression Results

	PDC	ASCOS	Integrated capability	R^2
Comprehensive I4.0	ns	ns	.514 (8.123)	.260

Note: R^2 is the degree of freedom adjusted coefficient of determination. The figures in parentheses are t-values. Significant at p<0.000

All these results confirm the research hypothesis. Most significantly, the integrated capability of ASCOS and PDC present in HP group companies is more influential for I4.0 implementation than either ASCOS or PDC alone. If the focus of I4.0 is to be on the total value creation process as Kagermann et al (2013) stated, this result is understandable.

Discussion and conclusions

I4.0 is expected to provide a great number of opportunities for strengthening the value creation process. A distinction between I4.0 and traditional automation is that I4.0 focuses

on value creation process renovation through the "smart" concept characterized by connectivity involving all physical component units such as machines and products, company people, partners and customers. (Kagermann et al., 2013; Porter and Hippelmann, 2014, 2015). So, the capability most needed to take advantage of I4.0 concepts is the capability to understand how to enhance the effectiveness of value creation by aligning connectivity. This study shows that the two capabilities, ASCOS and PDC, can be drivers that effectively enhance connectivity to strengthen the value creation process. These capabilities may represent the competencies needed to understand which patterns of connectivity are essential from the viewpoint of the whole value creation process and to implement them quickly and steadily in interactive ways. As implications for materializing two key concepts of I4.0, Smart Product and Smart Factory, these are fruit that mature thanks to both ASCOS and PDC. In other words, and as a major managerial implication, companies should strengthen both their market and supply chain process focuses to develop Smart Product and Smart Factory—key components of I4.0—as they embody the driving forces of the whole value creation process, as shown in the equation (1).

In this study, many research points have not been addressed due to length restrictions. These include, for example: The adoption patterns of I4.0 technologies for Smart Factory and Smart Product, an explanation of the cross relationships between (ASCOS, PDC) and (SF, SP), an analysis of country and industry differences and the determinants of the contributions made by the effects of I4.0 implementation on performance, all of which are on our ongoing research agenda.

Acknowledgments

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Action research in operations management: an analysis of its contribution to research and managerial practice

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Abstract

This paper analyses the theoretical and managerial contributions of action research (AR) studies in the field of Operations Management. First, it develops two corresponding frameworks to classify the different types of both research and managerial contributions produced by AR studies. Secondly, the paper then analyzes and classifies accordingly these different types of contributions from 54 AR studies found in Operations Management journals. Thirdly, the paper then proposes key avenues for improvement of the contributions of future AR studies, as well as ways to overcome the main challenges that such studies typically face.

Keywords: Action research, Research contributions, Managerial contributions

Introduction

The analysis of the contribution of operations management (OM) research to managerial practice has been a key concern for researchers for years. Already in the early 1980s, Buffa (1980) highlighted that OM was in the process of becoming a "functional field of management". Craighead and Meredith (2008) stressed that while OM research had actually evolved towards a more direct observation of the phenomenon being studied, it was necessary to reinforce those efforts through such research methods as case and field-based studies, experiments and action research (AR).

The focus of our analysis in fact is AR, which according to Shani and Pasmore (1985, p. 439) may be defined as "an emergent inquiry process in which applied behavioural science knowledge is integrated with existing organisational knowledge and applied to solve real organisational problems. It is simultaneously concerned with bringing about

change in organisations, and developing self-help competencies in organisational members and adding to scientific knowledge. Finally, it is an evolving process that is undertaken in a spirit of collaboration and co-inquiry". Therefore, its dual contribution in terms of both the academic and managerial dimensions as well as the collaboration between researchers and practitioners are two of the main features of AR.

In the OM field, in particular, Coughlan and Coghlan (2002) analysed the relevance of AR as a methodology that permits, at the same time, solving a problem for a firm and making a relevant contribution to theory as it represents the application of the scientific research method to practical problems and implies active collaboration between researchers and firms.

The aim of this paper is to analyse the research contribution of identified AR studies as well as the types of benefits that practitioners gain from these studies. Consequently, we want to answer the following research questions.

RQ1: What kinds of research approaches are used in AR studies carried out in OM research?

RQ2: What kinds of practitioners' benefits predominate in AR studies carried out in OM research?

To answer these questions, we first review to what extent AR has been used in OM research. This allows building a database of articles using AR that can serve as the source to answer both RQ1 and RQ2. These results allow us to analyze the main challenges for AR to become more relevant in the OM field. Then, we develop a framework in order to analyse the contributions of these papers in both terms: research and managerial contributions.

Therefore, the goal of our study is to understand the dual contributions of AR studies in OM (to date), and to identify the main challenges for the use of AR in OM research going forward.

The structure of the paper is as follows: in section 2, it is described the dual purpose of AR and a framework is developed in order to answer the research questions. In section 3 we describe the methodology which resulted in a database of 54 AR studies in OM during the time period of 2000-2015. Section 4 presents our findings and in section 5 we discuss opportunities and challenges for the use of AR in the OM field.

Theoretical background

In this section we first describe the main requirements of AR in term of its dual purpose and collaborative aspects, and second, we introduce the typology used to classify the AR papers in terms of both research approach and practitioners' benefits.

Dual purpose in AR studies

Several definitions of AR exist (e.g. Shani and Pasmore (1985) mentioned). To some extent these definitions reflect the evolution as well as the different approaches to AR. This can perhaps also explain why the meaning of AR, and the way it is applied, differs somewhat across disciplines. For this reason, AR is sometimes labelled as an "umbrella term" describing a variety of approaches and styles of research (MacIntosh and Wilson, 2003).

The implementation of AR in the OM field differs from the one found in other areas where AR originally emerged (medicine, psychology, sociology). In these fields the role of the practitioner is to be a "patient", on which the researcher develops different experiments. In the case of OM, there is a relationship where both researchers and practitioners (firms), have the same hierarchical level and where there is a win-win relationship. The specific features of AR in OM studies, as compared to more traditional

AR studies, are important to emphasise as they highlight that the research objective should be of mutual interest to both the researcher and the practitioner.

A crucial aspect of a rigorous research design is a proper description of the unit of analysis. One aspect that differentiates AR based papers from case studies is that the unit of analysis is treated as an active object. The outcome is, therefore, both an action and research (Coughlan and Coghlan, 2002), where research is used to inform practice, and practice is used to inform research (Näslund, 2002).

AR projects are often characterised as cyclical in nature, corresponding to the cyclic loop of learning. AR projects go through a spiral of cycles (phases) of planning, action (implementing), observing (evaluating), and overall analysis and reflection as a basis for new planning and action (Ballantyne, 2004). In this spiral of cycles, each of these activities should be systematically and self-critically implemented and interrelated. The researcher is involved in the actual project, and then steps aside to meticulously reflect and analyse what happens in the organisation (Daudelin, 1996). Thorough understanding and analysis constitute a key requirement for taking new action.

The collaborative nature of AR is mentioned in the literature is another key aspect of AR and directly related to its dual purpose. In the research process, researchers and practitioners collaborate in all the AR cycles by sharing ideas and reflections the participation of the studied organisation in the cyclic research process will increase authenticity and trustworthiness of findings. Thus, research rigor is achieved in a collaborative manner. In this sense, Coughlan and Coghlan (2002, p. 233) write: "AR is a challenging approach to research because it requires confident and experienced researchers to cope with the uncertainty of the unfolding story and to be able to work as researchers exposed to the reality of organisational change in real time." Due to the requirements that derived from the collaboration between researchers and managers, a team-based approach is often recommended for AR studies.

As a corollary, figure 1 summarises the main features of AR in terms of assuring the dual contribution of those studies based on this methodology.

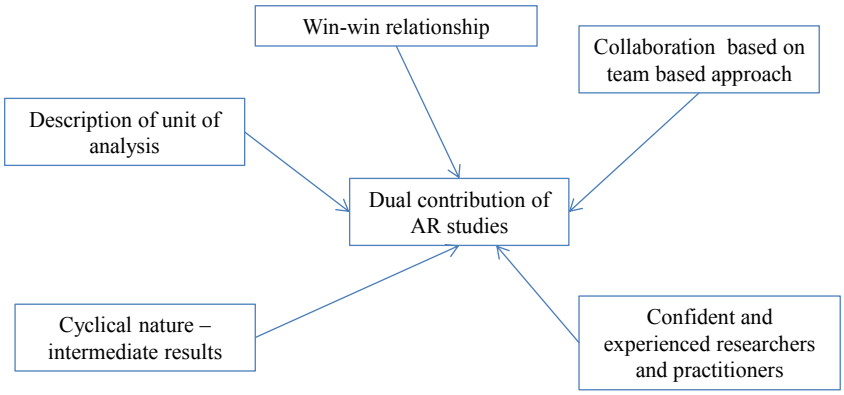

Figure 1 - Main features of AR that assures the dual contribution.

AR in OM: theoretical framework

For the analysis and classification of the dual contribution of AR studies in OM research (i.e., research contribution and practitioners' benefit), we develop a theoretical framework that covers both dimensions.

Analysis of research contribution

We base the classification of research contributions on three distinct research approaches, which determine the path of conscious scientific reasoning: deductive/theory testing,

inductive/theory building and abductive/theory elaboration. Figure 2 illustrates the three research approaches as described in Ketokivi and Choi (2014).

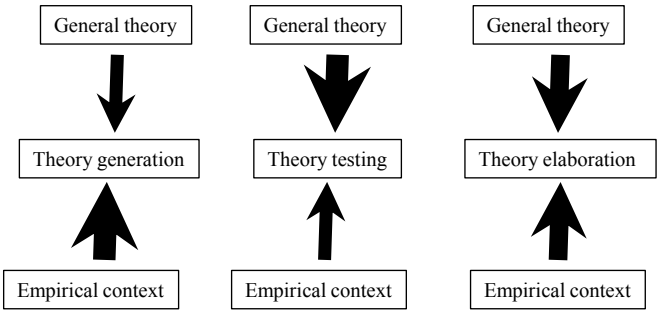

Figure 2 - Features of theory generation, testing, and elaboration approaches (Ketokivi and Choi, 2014).

- *Deductive research/Theory testing*: This approach starts by reviewing existing theory. Then, logical conclusions are derived from this theory in the form of general laws presented as ex-ante hypotheses/propositions (H/Ps). Finally, these H/Ps are then tested empirically (Spens and Kovács, 2006) and general conclusions are presented based on the corroboration or falsification of the H/Ps. The driving force in conventional theory testing is deduction, i.e., explicit derivation of hypotheses from a priori selected underlying theory (Ketokivi and Choi, 2014).
- *Inductive research/Theory generation*: The knowledge of a general framework is not necessarily needed as a starting point. H/Ps are developed on the basis of empirical studies instead of previous observations (Spens and Kovács, 2006). In terms of theory generation, Ketokivi and Choi (2014, p. 234) state that "the premise is that in the context of the specific research question and empirical setting, explanation (theory) derives from exploration (analysis)".
- *Abductive research/Theory elaboratio*n: It starts with the observation of a real-life phenomenon. The researchers initiate a creative, iterative process of "theory matching" and "systematic theory combinations" in an attempt to develop a possible theoretical framework or to extend the existing theory used prior to this specific observation (Spens and Kovács, 2006). Ketokivi and Choi (2014, p. 236) explain that "abductive reasoning involves modifying the logic of the general theory in order to reconcile it with contextual idiosyncrasies."

Practitioners' benefit

In order to classify practitioner benefits, we define three types/levels of contributions that the firms can get from an AR study: diagnosis, proposal and implementation.

AR studies contribute a *diagnosis* to practitioners when they describe and analyse a particular issue, but neither recommendation on how to improve the situation, nor specific proposals are then described in the paper. In this sense, the researchers primarily aim to identify (root) causes for the problems at hand

Contributing a *proposal* implies that the researcher recommends some specific actions to the practitioner to be carried out in order to improve the situation. These recommendations can come in very different forms (e.g., a strategic plan or a change program). The recommendations, however, are not described as a specific manner and no actual implementation is reported in the paper.

We classify a contribution as *implementation* when the organisation dealt with in the AR study has already realised a proposed solution and the results achieved are reported as well. In AR studies classified in this category, researchers usually develop and describe a specific tool or model for the issues the practitioners face, and the benefits for the practitioners are quantified and there is an explanation of the implementation stages that have been carried out.

Methodology

Selection of journals and articles

In order to select the AR studies to be analysed for our research questions, we searched for corresponding articles in the following 15 OM journals: *Decision Science* (DS), *International Journal of Operations & Production Management* (IJOPM), *International Journal of Physical Distribution & Logistics Management* (IJPDLM), *International Journal of Production Economics* (IJPE), *International Journal of Production Research* (IJPR), *Interfaces*, *Journal of Business Logistics* (JBL), *Journal of Operations Management* (JOM), *Journal of Purchasing and Supply Management* (JPSM), *Management Science* (MS), *Manufacturing & Services Operations Management Journal* (MSOM), *Omega*, *Production and Operations Management* (POM), *Production and Planning Control* (PPC), and *Supply Chain Management International Journa*l (SCMIJ).

We selected these journals as they are known to (1) publish empirical papers that use case study and other similar (AR kind of) methodologies (Barratt et al., 2001; Näslund, et al. 2010) and (2) they are cited for their scientific quality in studies that have analysed this for OM journals (Olson, 2005; Zsidisin et al., 2007).

The time period analysed goes from 2000 to 2015. Our initial search in the journals selected was for articles that included the word "action research" in the title, abstract or keywords. Then we removed from the initial database those papers that were purely theoretical or descriptive in nature and those that actually did not develop the AR methodology. In the end this resulted in a set of 54 papers for our analysis.

Coding and analysis

The analysis of the 54 AR studies identified was carried out as follows: first, each author analysed the same five articles to determine their theoretical and practical contributions. The results were then compared. Wherever there were disagreements in the classification, there was a joint discussion to refine the criteria for classification. As a result, we created a template with detailed criteria that permitted the authors to classify the papers in a distributed manner (one paper – one "reviewer"). When there were conflicts or doubts about the classification of an article, the rest of co-authors were consulted to find agreement about the best assignment for it.

Findings and discussion

Descriptive analysis of action research studies

Figure 3 shows the chronological evolution of the analysed papers. The low number of studies found illustrates the residual importance of AR in OM journals.

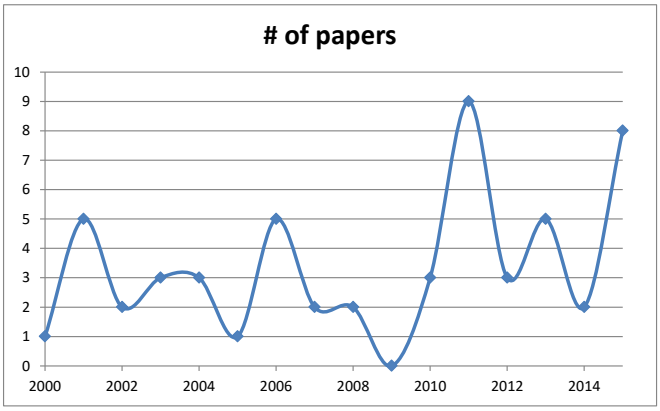

Figure 3 - Chronological evolution of the analysed papers (2000-2015).

In terms of journals, IJOPM papers represent almost 40% of AR studies found, and IJPE, IJPDLM and PPC cover another 30%. So, it seems that there are few OM journals that publish most of the AR papers, and therefore the degree of dissemination of AR in OM research appears to be very low according to our data set.

Analysis of research questions

RQ1: What kinds of research approaches are used in AR studies carried out in OM research?

We analysed the number of papers classified according to the three types of research approaches during the period of analysis (2000-2015). The distribution is not homogenous in terms of publications per years. In the category "theory generation or inductive approach", 13 studies were published in the first 8 years and another 12 in the 5 years from 2010-15. Every single year in the period analysed at least one paper has been published, with the exception of 2009.

With regard to the 15 papers classified as "theory testing or deductive approach", four of them were published in 2015, and six were published in the period 2010-2014. Although the majority of the AR studies in OM research have taken the "inductive or theory building approach", our data set shows a slight trend to publish increasingly AR studies following the deductive approach. Finally, we found fewer papers corresponding to a "theory elaboration or abductive approach" and they appear to be spread randomly over the period analysed.

The analysis of our data set reveals a pattern similar to the one reported in Barratt et al. (2011), where they found as well as predominance of inductive papers (82%) over deductive ones (18%). As a research methodology, AR has proven to be valuable not only for inductive studies, but also for deductive or abductive ones. Appendix 2 provides a detailed description of the research contribution for each paper.

RQ2: What kinds of practitioners' benefits predominate in AR studies carried out in OM research?

The number of studies classified according to the three types of practitioner's contributions during the period of analysis (2000-2015) was also analysed.

In the period analysed, "implementation" is clearly the predominant approach in our data set. This dominance has even increased in the last few years. In this category, there is significant reporting in detail projects that have achieved very specific benefits for the companies collaborating. For example, Baker and Jayamaran (2012) reported a 27%

inventory reduction thanks to the AR project carried out. In some other cases, for example, Adebanjo et al. (2013), the description of the implementation is of more general nature, like the reorganisation of the supplier selection process, and no specific results are reported.

In the "proposal" category, the main contribution for practitioners in the three papers identified, consisted in recommendations about specific improvements to be carried out in the company. In Neely et al. (2000), for example, the recommendations were specified in the form of a workbook that provides guidelines for a process-based design of a performance measurement system. Shaw et al. (2001) developed a framework that aims to become a model of good practices for new product (or process) development (NPD) in the fine chemicals industry. Finally, Braz et al. (2011) focused on presenting a proposal to improve the performance measure system of the company at hand.

Many of the papers assigned to the category of "diagnosis" appear to follow a similar conceptual approach. Based on the analysis of one or more specific case-studies, the articles then developed a more general methodology. A representative example of this is Dey et al (2015). They developed a method for the strategic evaluation of suppliers based on seven case studies. Appendix 2 provides a detailed description of the practitioners' benefits for each analysed paper.

How to advance one step further: opportunities and reflections

In order to identify the main challenges related to the dual contribution of AR within OM research, it is necessary to first analyse the combination of both research and practitioner contributions. This is presented in Table 2.

Table 1 - Distribution of papers in terms of the dual analysis

	Diagnosis	**Proposal**	**Implementation**	**TOTAL**
Theory generation/ Inductive	4	2	24	30
Theory testing/ Deductive	3	1	11	15
Theory elaboration/ Abductive	0	0	9	9
TOTAL	7	3	44	54

The analysis of the different combinations reveals that the "inductive-implementation" is the most common one in our data set. This seems to be in line with van Aken et al. (2016, p. 2), where they explain that "most action research projects aim for case-specific improvements". Though, we consider that the scope of AR should not be limited to an "implementation" approach, as we see a significant opportunity to leverage the main advantage of the AR methodology (i.e., its dual contribution), by pursuing more of the other possible combinations of dual contributions of AR studies (cf. left hand side of Figure 6).

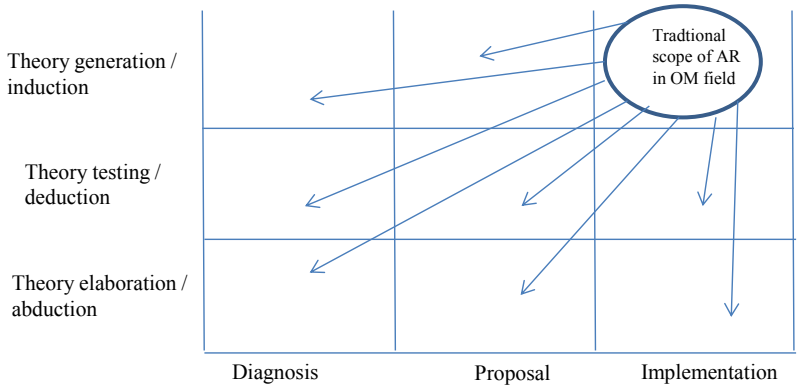

Figure 6. Challenge to overcome: moving one step ahead in the dual contribution of AR studies.

The resolute use of multiple AR methodologies may allow researchers to carry out not only papers based on inductive approaches but produce also studies based on deductive and abductive ones. In this sense, Spens and Kovács (2006) highlighted that AR has specific features that favor the development of abductive studies. Specifically, one way to further develop AR contributions in OM research could consist on reinforcing the "breadth" of AR scope. So, AR should not be limited to implementation approach but to emphasise also the dual benefits offered by the categories of diagnosis and proposals. Moreover, doing so may allow developing AR studies based on abductive and deductive papers. This challenge is emphasised in Figure 6. Then, we identify and describe three main challenges that may help to reinforce the role of AR in OM.

Developing the full potential of AR for practitioners

The thorough review of the 54 papers with regard to their dual contribution revealed a very relevant finding: in general, authors do not report the managerial contributions with the same level of detail than the theoretical ones. It seems that due to the fact that journals are written for academics (and reviewed by academics), authors are only requested to work out the academic contributions. This is also the case when researchers use AR methodology, even if in this case managerial contributions are considered to be a distinctive feature of the research.

This has two main implications for our study. First, as already mentioned (cf. methodology section 3), we had to "remove" papers from our database where the authors reported the use of AR (in the title, abstract or keywords), but then we could actually not find any description at all of practitioners' contributions in the paper. Secondly, sometimes we had to classify papers with regard to their managerial contribution based on a few single sentences, in which the authors summarised their contribution to practice, as there were no specific sections in the papers reporting this in a more detailed manner.

Given the characteristics of AR, a rigorous article should include a discussion of why AR was an appropriate form of research for the particular study. This is linked with the fact that AR studies do not have to be limited to "implementation" but may also be useful for the cases of "diagnosis" and "proposals". Eden and Huxham (1996) stated that theory building in AR is incremental in nature. Similarly, Perry and Gummesson (2004) claimed that theory building in AR is conducted in small steps from the particular case to the general.

Consequently, the development of AR articles that highlight (and detail) the different contributions made to practitioners should be encouraged both in journals and conferences.

AR projects versus AR studies

In order to further enlarge the "breadth" of AR studies, we may rely on the concept of an AR project. McNiff (2016) emphasises in some way the concept of AR projects and the need of ensuring that action research projects are conducted with a high quality in both action and research and the need to be linked with a firm philosophical base.

As a consequence, we consider that the development of AR projects allows to move away from the traditional view of AR as "extended case studies". This view of projects versus case study allows a higher intense collaboration between academic and practitioners and generates learning in the different stages of the AR.

In order to enhance AR projects, it is very helpful that they are implemented using a specific support infrastructure that allows the researcher to be involved in the practitioner's organisation, which implies to establish a collaborative framework that permits the researcher to develop the project from inside the firm. Two examples of support infrastructure can be a research/business chair at a university sponsored by a company and a doctoral thesis. Regarding the first one, Avella and Alfaro (2014) explained how such a chair can be a useful tool for developing OM research projects based on AR methodology (e.g. Zuber-Skerritt and Fletcher (2007)).

Action research as an open innovation practice

A way to impel AR is to link it with open innovation and to show why it can be considered as an open innovation practice that combines the outside-in process with the inside-out process and co-operate with other companies in strategic networks. The analysis of AR studies in OM journals determines that dual contribution is a differential aspect of this methodology that has to serve to promote its use in both academic and business environment.

Conclusions

First, it has been found that AR studies in OM are usually based on inductive approaches that focus on problem solving. We consider that this view has to be overcome and we show that there are OM papers based on AR methodology that develop both deductive and abductive approaches and that, at the same time, the main contribution to the practitioner does not consist on giving a specific solution to a specific problem.

It is necessary to make both OM researchers and practitioners perceive AR as a tool that permits them a win-win relationship. To do so, it is recommendable to build an infrastructure that facilitate this kind of studies. More specifically, the development of specific tracks in academic and professional conferences devoted to enhance university-firm relationships or to encourage in PhD programs thesis based on AR would encourage researchers to carry out AR studies. The renaissance of AR as a methodology in the OM field will permit to reinforce the impact of academic research for firms, one of the most relevant challenges for any business research.

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Supply chain and quality management: an inter-relationship towards sustainability performance

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Abstract

This study aims to examine the inter-relationship between supply chain and quality management systems to find out possible integration or mutual support of these two systems towards sustainability performance, based on survey-based empirical methodology. Analysis results find positive mediating effects of quality management practices on the relationship between supply chain management practices and sustainability performance, while they illustrate insignificant mediating effects of supply chain management practices on the relationship between quality management practices and sustainability performance. Furthermore, a significant offsetting effect from simultaneous implementation of supply chain and quality management practices is suggested in the relationship with economic returns.
Keywords: supply chain management, quality management, sustainability performance

Introduction

"Sustainability management" by "adoption of best management principles, models and practices" is an approach to simultaneously achieve economic growth, social equity, and environmental performance (Kuei and Lu, 2013). Quality management (QM) and Supply chain management (SCM) are operations management initiatives that would be adopted for the sustainability management purposes. QM seeks to gain competitive advantages over a long period of time. QM practices contribute to elimination of wastes, defects, and poor-quality outputs to provide superior values to customers. However, QM is criticised for too much internal focus (Foster, 2008). Resource dependence theory suggests that a single organisation cannot be self-sufficient with their internal resources; instead, resource acquisition is necessary to create complementary resources (Flynn and Flynn, 2005). In the global market, lack of self-sufficiency forces organisations to shift from internal practices alone into the supply chain (Flynn and Flynn, 2005; Kaynak and Hartley, 2008). SCM, therefore, has attracted huge research interest. However, SCM is still somehow criticised for its narrow orientation with over-emphasis on cost and efficiency

(Huo *et al.*, 2016). In this context, the integration of QM principles and SCM is suggested to expectedly achieve cumulative competitive capabilities (Flynn and Flynn, 2005).

The concept of supply chain quality management (SCQM) has attracted research interest since the 2000s. SCQM is suggested as a fruitful research field for the future (Foster, 2008). Several studies made efforts to conceptualise and provide better understand about SCQM such as Robinson and Malhotra (2005) and Foster (2008). Some studies compared principles of QM and SCM as well as identified common practices of QM and SCM and proposed them as SCQM practices (Fernandes *et al.*, 2017; Foster, 2011). Some scholars empirically studied the contribution of SCQM on organisational performance (Zeng *et al.,* 2013; Azar *et al.,* 2009; Kaynak and Hartley, 2008). Various research methodologies are adopted including literature review and prescriptive suggestions (Foster, 2008), case studies (Robinson and Malhotra, 2005; Zu and Kaynak, 2012; Kuei *et al.,* 2011), and survey-based empirical method (Zeng *et al.,* 2013; Kaynak and Hartley, 2008). Although there are pioneer works in this field, more empirical evidence in the setting of emerging economies is needed.

This paper aims to test the underlying relationship between supply chain – quality management practices and sustainability performance in Vietnam-based enterprises. The study would not only enrich the literature of supply chain quality management and sustainability by offering new empirical evidence of the underlying relationship, but also provide managerial insights into how operations management practices should be utilized to achieve sustainability goals in a emerging economy. The remaining of this paper presents literature review to propose a research model and develop research hypotheses, followed by research methodology and results from data analysis. The last two sections provide discussions on important findings and final conclusions.

Literature review

Understanding about Supply chain - quality management

Quality management is used to one of prioritized approaches for manufacturing and service organisations to build-up their competitive advantages. Much of academic work has investigated the effectiveness of QM principles and practices. The impact of QM practices has proven significant on operational performance but not always on business performance (Sousa and Voss, 2002; Robinson and Malhotra, 2005). This would due to the fact that principles and practices of QM have been much internall focused (Foster, 2008; Zhang *et al.,* 2011; Zeng, Phan and Matsui, 2013). Internal capabilities from excellent quality management of an organisation are no longer sufficient for the globally competitive market nowadays (Robinson and Malhotra, 2005; Vanichchinchai and Igel, 2011). An organisation could not exist alone and perform well without cooperation from its partners.

Suggested by Resource Dependence Theory, resource acquisition is increasingly important with any organisation in the globally competitive market (Flynn and Flynn, 2005). This process is strongly supported by the inter-organisational relationship (Oliver and Ebers, 1998; Flynn and Flynn, 2005). As such, the topic of inter-organisational relationship management or supply chain management has generated considerable interest. Moreover, with the globalization, organisations have no longer competed within the national boundary but in the global market (Vanichchinchai 2011; Flynn and Flynn, 2005; Kuei *et al*, 2001). In this context, SCM has been increasingly concerned as a weapon to respond correctly, rapidly, and profitably to market demand (Zeng *et al.*, 2013; Kuei *et al.,* 2011).

QM and SCM are originally different initiatives but have evolved to merge towards a common goal of customer satisfaction (Li *et al.,* 2006; Zhang *et al.,* 2011). Toyota

Production System or JIT production initiated in the 1960s emphasised the importance of perfect quality and supplier relationship. The integration of QM and SCM is suggested by many scholars as a critical factor to the success of organisations (Gustin, 2001; Narasimhan and Das, 2001; Hutchins, 2002; Pagell, 2004; Miller, 2002). From the middle of the 2000s, supply chain quality management has become a fruitful research direction (Flynn and Flynn, 2005; Robinson and Malhotra, 2005; Foster, 2008; Kaynak and Hartley, 2008). Several studies made efforts to provide better understandings about SCQM and proposed SCQM as an emergent research field for the future (Robinson and Malhotra, 2005; Foster, 2008).

Robinson and Malhotra (2005) defined "supply chain quality management is the formal coordination and integration of business processes involving all partner organisations in the supply channel to measure, analyse and continually improve products, services, and processes in order to create value and achieve satisfaction of intermediate and final customers in the marketplace". Foster (2008) defined SCQM as "a systems-based approach to performance improvement that leverages opportunities created by upstream and downstream linkages with suppliers and customers". In this study, supply chain – quality management is defined as a mutual supportive mechanism of quality improvement practices and supply chain management practices to ensure the quality of intra- and inter- organisational activities and smoothly manage resource flows between a focal firm and supply chain partners.

Research on supply chain – quality management

Although there is much attention on quality management and supply chain management in recent decades, the studies on these two fields tended to be separate (Vanichchinchai and Igel, 2011; Fernandes *et al.*, 2017). From the middle of the 2000s, supply chain quality management has been viewed from a more integrated perspective. *Some studies identified common practices of QM and SCM in the literature :*

- Fernandes *et al.* (2017) conducted a study on the integration of SCM and QM by identifying their common key practices from the literature. The five common practices of SCM and QM are leadership, management and strategic planning, stakeholders involvement and commitment, information, and continuous improvement and innovation. The study proposes a conceptual model to present key areas of SCM and QM and the relationship between them. The model suggests that integration and sustainability are important for both fields.
- Quang *et al.* (2016) proposed a conceptual framework to test the effect of SCQM practices on firm performance. The proposed structural model describes multi-level linkages among SCQM practices and between SCQM and performance. The study emphasises a research gap on the interactions among SCQM practices and the consideration of information and supply chain integration as SCQM practices.
- Mellat-Parast (2013) using a relational view of inter-organisational competitive advantage, developed a theoretical background for SCQM. The study reviewed the literature and proposed key practices of QM and SCM from a learning perspective. Quality practices at the firm level include top management support, information systems, employee involvement, process improvement, product/service design, and customer satisfaction. Quality practices at the supply chain level comprise trust, governance, information integration, process integration, and cooperative learning.
- Foster *et al.* (2011) aims to offer a better understanding of SCQM practices by comparing the management tools and methods of operations managers and supply chain managers. The results pointed out that more collaborative is management approach of supply chain managers whereas operations managers are likely to manage the supply

chain through procedural methods. The study found that on-the-job training, data analysis, supply chain management, customer relationship management, project management, and surveys are common practices adopted by both types of managers.

Some scholars empirically studied the impacts of SCQM on organisational performance:

- Zeng *et al.* (2013) empirically study the relationships among internal QM, upstream QM, downstream QM and their effect on quality conformance and customer satisfaction and loyalty. The results demonstrate dominant role of internal QM in the SCQM which imply a necessity to effectively implement QM internally before moving towards SCQM. Downstream QM mediates the impact of internal QM on customer satisfaction while upstream QM appears to be lack of influence on performance.
- Vanichchinchai and Igel (2011) studies the linkages among total quality management practices, SCM practices, and firm's supply performance in Thailand's automotive industry. The study develops and validates measurement instruments. Analysis results using structural equation modelling indicate that the impact of total quality management practices on firm's supply performance is significantly positive not only directly but also indirectly through SCM practices.
- Han *et al*. (2007) examines the relationships among QM practices, supply chain integration, and firm performance in 229 Chinese organisations. By structural equation modelling, the results show that QM practices directly and positively impact on firm performance. Supply chain integration does not directly affect firm performance but indirectly affect it through QM practices.
- Lin *et al*. (2005) studies the relationship between SCQM and organisational performance in Taiwan and Hong Kong. Using structural equation modelling technique, analysis results show that QM practices are positively correlated with supplier participation and supplier selection. Supplier participation mediates the impact of QM practices on business results and customer satisfaction.
- Flynn and Flynn (2005), under the perspective of resource dependence theory (Pfeffer and Salancik, 1978), figured out feasible themes on the dependence between buyers and suppliers to create synergies. The study provides empirical evidence supporting for an integrated relationship between quality management and supply chain management.

As can be seen from the extensive literature review, the existing body of work on supply chain quality management could be classified into three categories. The first category is to understand an integrated concept of supply chain quality management (Foster, 2008; Robinson and Malhotra, 2005). The second one is to identify common practices of supply chain management and quality management and consider them as supply chain quality management practices (Fernandes *et al.*, 2017; Foster *et al.,* 2011; Quang *et al.,* 2016). These studies mainly confined themselves at the conceptual level. The third category is to empirically study the relationship between supply chain quality management practices and organisational performance. These studies, however, mostly focus on evaluating QM issues in the context of internal and external supply chain (Quang *et al.,* 2016). The constructs to measure supply chain quality management are extension of quality management constructs into supplier relationship and customer relationship (Kaynak, 2008; Zeng *et al.,* 2013; Lin *et al.,* 2005). There is a lack of consideration in critical supply chain management practices such as information management and/or process integration.

Moreover, performance measurements in the existing literature are primarily related to economic aspect (such as operational performance, quality performance, customer satisfaction, and so on). Little work has considered how supply chain – quality

management practices affect three dimensions of sustainability performance (economic, environmental, and social dimensions). To fill this research gap, this study seeks to answer a research question *"How would the integration of QM practices and SCM practices affect sustainability performance?*" by considering sets of critical QM practices and SCM practices and three dimensions of sustainability performance.

Analytical framework and hypothesis development

In the literature review, SCQM has been defined and studied from different perspectives. The first point of view considers SCQM as an extension of quality management into supplier management and customer management (Kaynak, 2008; Zeng *et al.,* 2013). The second point of view regards SCQM as applying systems-based approach of quality management into the whole supply chain network (Foster, 2008). The third point of view demonstrates the synergy effect when SCM and QM systems are implemented simultaneously (Flynn and Flynn, 2005).

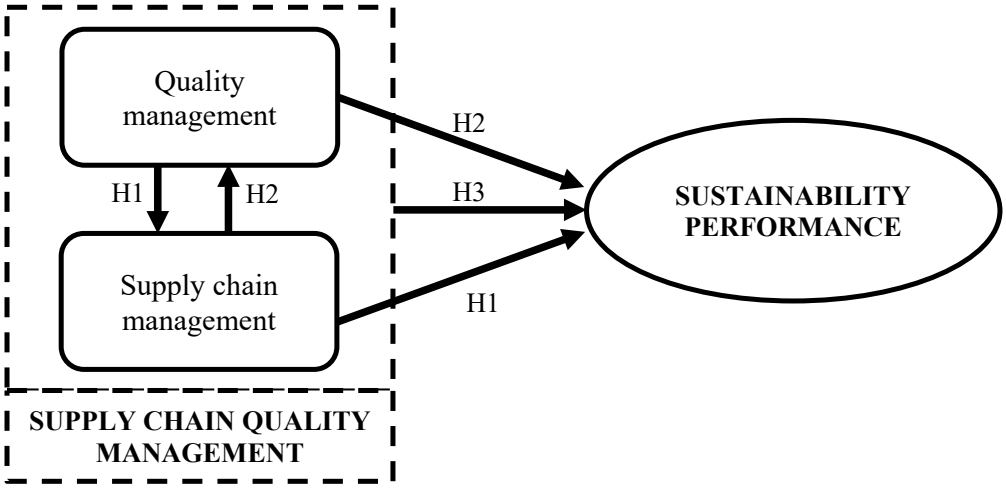

Figure 1 – Research model

QM initiatives have been used to be a weapon to gain competitive advantages since the 1950s. The birth of SCM is considered as a response to the movement of competition from single firms to the supply chain. SCQM, from this point of view, refers to an extension of QM into upstream and downstream supply chain (Kaynak and Hartley, 2008) in which SCM practices would strongly support and complement for QM system to achieve performance goals of the organisation. Supporting for this argument, Vanichchinchai and Igel (2011) found significant indirect and positive impact of QM practices on performance through SCM practices. Moreover, Lin *et al*. (2005) also found that QM practices significantly impact on organisational performance through the mediation of supplier participation. The literature discussed above leads to following hypothesis:

Hypothesis H1: SCM practices positively mediate the relationship between QM practices and sustainability performance

From SCM standpoint, SCM is a broad management picture in which QM plays a critical role. The principle of QM, the system-based approach, would be applied into SCM to create an efficient SCQM system (Foster, 2008). High quality internal coordination and activities must strongly support for external partnerships in supply chain management (Lambert and Cooper 2000; Vanichchinchai and Igel 2011). As such, QM practices are

expected to facilitate SCM practices (Vanichchinchai and Igel, 2011) towards performance objectives. Supporting for this argument, Han *et al.* (2007) found that supply chain integration does not directly affect firm performance but indirectly affect it through QM practices. Additionally, Zhu and Sarkis (2004) found empirical evidence that the higher QM adoption level facilitates the stronger impact of green SCM on performance. From the literature, hypothesis H2 is stated as followed:

Hypothesis H2: QM practices positively mediate the relationship between SCM practices and sustainability performance

The third perspective considers SCQM as an integrated result from simultaneous implementation of QM and SCM. Both QM and SCM pursue a final goal of customer satisfaction and loyalty, but they target different functional objectives of quality performance and delivery performance respectively (Vanichchinchai and Igel, 2009). Therefore, simultaneous implementation of QM and SCM would result in a synergy or a conflict (Vanichchinchai and Igel, 2011). Flynn and Flynn (2005) figured out the potential to pursuit quality goal and supply chain goal at the same time to create cumulative capabilities and demonstrated this argument by providing empirical evidence. Kannan and Tan (2007) investigated the effect of operational QM practices in the supply chain context and found some significant synergy of internal and external practices. Hypothesis H3, therefore, is stated as followed:

Hypothesis H3: Simultaneous implementation of QM practices and SCM practices yields positive synergy effect on sustainability performance

Research methodology

The methodology adopted in this study is a survey-based empirical method. A questionnaire was designed to collect data from Vietnam-based enterprises. Quality management practices are measured by the following eight constructs: top management support for quality management, training, product/service design, quality data and reporting, process management, continuous improvement, problem solving, and rewards. Supply chain management practices are measured by the following six constructs: top management support for supply chain management, information sharing, information technology, process integration, strategic supplier relationship, and customer relationship. Sustainability performance is evaluated in terms of economic performance (economic returns, cost reduction, market performance), environmental performance (emission reduction, resource consumption reduction), and social performance (internal social performance, external social performance).

The questionnaire was sent to a list of 992 Vietnam-based enterprises, followed by reminder emails and phone calls to non-respondents during a five-month period from November 2016 to March 2017. Finally, a total of 144 valid responses was used in the analysis of this study. The response rate was 14.5 percent.

Hypothesis testing and results

In this study, mediating effect is tested using PROCESS macro with bootstrap method that is suggested by Hayes and Rockwook (2017). Before testing the hypotheses, reliability and validity of the measurement scales are confirmed by reliability tests including Cronbach's alpha and confirmatory factor analysis.

The mediating effect of SCM practices on the relationship between QM practices and sustainability performance (SP)

To test hypothesis H1, total effect of QM on SP, direct effect of QM on SP when SCM holds a constant, and indirect effect of QM on SP through SCM are calculated. If direct

effect is insignificant while indirect effect is significant, then SCM can be deemed as a mediator of QM's impact on SP, and vice-versa. The analysis results show that there is no significant meditating effect (indirect effect) of SCM practices on the relationship between QM practices and sustainability performance. Significant total impacts are mainly derived from direct impact of QM practices on SP. As such, hypothesis H1 is rejected.

Table 1: Analysis results on mediating effect of SCM on the relationship between QM and SP

	Economic performance			Environmental performance		Social performance	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total effect	0.38***	0.14	0.46***	0.076	-0.35*	0.55***	0.53***
Direct effect	0.41**	0.003	0.53***	-0.055	-0.62*	0.37*	0.34**
Indirect effect	-0.03	0.13	-0.08	0.13	0.27	0.19	0.20

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level, by one-tailed test
(1) Economic returns, (2) Cost reduction, (3) Market performance, (4) Emission reduction,
(5) Resource consumption reduction, (6) Internal social performance, (7) External social performance

Mediating effect of QM practices on the relationship between SCM practices and SP

To test hypothesis H2, total effect of SCM on SP, direct effect of SCM on SP when QM holds a constant, and indirect effect of SCM on SP through QM are calculated. If direct effect is insignificant while indirect effect is significant, then QM can be deemed as a mediator of SCM's impact on SP, and vice-versa. The analysis results show that QM practices have complete and positive mediating effect (indirect effect) on the relationship between SCM practices and economic returns, market performance, internal social performance, and external social performance. Interestingly, QM practices show significantly indirect but negative effect on resource consumption reduction with coefficient of -0.50 (significant at the 5% level). In summary, the analysis results show some significantly positive mediating effect of QM practices on the relationship between SCM practices and economic return, market performance, internal and external social performance. As such, hypothesis H2 cannot be rejected.

Table 2: Analysis results on mediating effect of QM on the relationship between SCM and SP

	Economic performance			Environmental performance		Social performance	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total effect	0.30**	0.16	0.34***	0.11	-0.18	0.51***	0.50***
Direct effect	-0.03	0.16	-0.09	0.15	0.32	0.22	0.23
Indirect effect	0.33**	0.00	0.43***	-0.04	-0.50**	0.29*	0.27**

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level, by one-tailed test
(1) Economic returns, (2) Cost reduction, (3) Market performance, (4) Emission reduction,
(5) resource consumption reduction, (6) Internal social performance, (7) External social performance

Synergy effect from simultaneous implementation of QM practices and SCM practices

To test the synergy effect from simultaneous implementation of QM and SCM practices on sustainability performance, regression analysis was adopted where independent variables are QM practices, SCM practices, and QM practices multiplied by SCM practices (QM*SCM represents for synergy effect) and dependent variables are seven sub-scales of sustainability performance. From the analysis results, a significant offsetting effect was found in the relationship with economic returns (coefficient of -0.27,

significant at the 5% level). In the relationship with other dimensions of sustainability performance, simultaneous implementation of QM and SCM reveals insignificant either offsetting or synergy effect. It can be seen that no synergy effect is found by simultaneous implementation of QM practices and SCM practices. As such, hypothesis H3 is rejected.

Table 3: Analysis results on the effect of simultaneous implementation of QM practices and SCM practices on SP

	Economic performance			Environmental performance		Social performance	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
R^2	0.15	0.014	0.23	0.03	0.07	0.24	0.32
Significance	0.00	0.57	0.00	0.22	0.02	0.00	0.00
	Beta	Beta	Beta	Beta	Beta	Beta	Beta
Constant	-1.55	2.14	1.33	01.52	2.74	-0.76	1.00
QM	1.40***	0.07	0.73*	1.10	-0.26	0.97**	0.49
SCM	1.04**	0.23	0.12	1.51	0.70	0.87*	0.40
QM*SCM	-0.27**	-0.02	-0.05	-0.31	-0.10	-0.16	-0.04

Note: *** significant at 1% level, ** significant at 5% level, *significant at 10% level, by one-tailed test
(1) Economic returns, (2) Cost reduction, (3) Market performance, (4) Emission reduction,
(5) Resource consumption reduction, (6) Internal social performance, (7) External social performance

Discussions and implications

Based on the results using aggregate constructs of QM practices and SCM practices, it can be seen that simultaneous implementation of QM and SCM would result in an offsetting effect on economic returns. That means if an organisation invests a huge amount in developing comprehensive QM system and SCM system at the same time, it may have a negative influence on their economic performance. This may be because QM and SCM systems target different primary goals. QM drives towards high quality performance while SCM prioritises responsive delivery performance (Vanichchinchai and Igel, 2009). It seems to be difficult for most of the Vietnamese enterprises to pursue both goals simultaneously because they have to cope with severe resource constraints. Therefore, one suggestion is that the organisation should consider to adopt either QM system or SCM system first, and followed by the other system later.

QM practices have directly significant effect on SP which constitute significant total effect of SCQM on SP even with or without mediating role of SCM practices. Meanwhile, SCM practices represent insignificant direct impact on SP but significant indirect impact on SP through QM practices. It can be seen that the impact of SCQM practices on sustainability performance is strongly facilitated by QM practices. The reason would be because Vietnamese firms have longer implementation experience of QM compared to SCM. QM has been adopted and improved to achieve a certain performance level in Vietnamese enterprises. SCM, on the other hand, was introduced and diffused into Vietnamese enterprises more recently. Therefore, it would be understandable for the fact that QM practices seem to strongly support and facilitate the influence of SCM practices on various aspects of organizational performance including economic, environmental, and social performance. This finding is consistent with an argument that SCM broadens the management scope into external relationships, but it could not work well without the support from internal collaboration and high-quality performance of personnel within the organisation (Lambert and Cooper, 2000). In this situation, quality management, despite being criticised for too internal focus, has become an essential foundation for supply chain management (Vanichchinchai and Igel, 2011). This argument is support by Flynn *et al.*

(2010), where they emphasised the prerequisite role of internal integration to external integration, which in turn affects business performance. This finding implies a suggestion on how enterprises should allocate their limited resources to achieve their primary goals effectively. From the above findings, firms in Vietnam should better well implement QM system before implement SCM system.

Conclusions

This study seeks to examine the underlying mechanism of SCQM towards three aspects of SP or the triple bottom line. The finding of a supportive relationship between QM and SCM is considered as a response to the calls from Foster (2008), Flynn and Flynn (2005), Robinson and Malhotra (2005), and Li *et al.* (2005) for further investigation of possible integration between two disciplines. QM practices appear to play a more fundamental and antecedent role compared to SCM practices towards sustainability goals. This result is consistent with Zeng *et al.* (2013) and Vanichchinchai and Igel (2011), which found that QM implementation within an organisation is considered as foundation for SCM implementation and as a prerequisite for effective SCQM implementation.

Although the study has some contribution to the literature and practices, it is important to note its limitations. Methodologically, the subjective nature of the study entails some bias inherent in survey based work. The study collects cross-sectional data by self-reported questionnaire which comprises question items regarding both practices and performance evaluating based on a five-point Likert scale. Although the authors tried to address the issue of this bias by asking for multiple respondents from each organisation, perceptual and individual bias may still exist. This limitation could be somehow handled in future research by adding more objective question items. Another limitation is from the data source, that is, enterprises in one country, Vietnam. This research could be extended to more emerging economies and also more developed economies for a comparative study.

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The impact of CEO stock options on supply chain stability and the moderating role of a powerful COO

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Abstract

Supply chain disruptions (SCDs) remain one of the most significant threats to firms' performance. In this study we investigate chief executive officer (CEO) stock options as an antecedent of SCDs. Based on an eleven-year sample of more than 2,000 disruptions in U.S. S&P 500 firms we conceptually and empirically explain an inverted U-shaped relationship between CEO stock options and SCDs. We contribute to research the investigation of a previously neglected antecedent of SCDs, a more nuanced view on the strategic impact of CEO stock options, and insights on the moderating effect of relative chief operating officer (COO) power.

Keywords: Supply chain disruptions, CEO stock options, COO power

Full Paper

Introduction

Business interruption risks remain a significant threat to firms' performance. Despite the high importance of SCDs for academia and practice, their causes are neither conclusively identified nor empirically well understood. Moreover, even though their decisions directly influence the supply chain, the impact of decision makers in charge of operations management is also neglected in operations management research (Hendricks, Hora, & Singhal, 2014). In this context, stock options are supposed to evoke more aggressive risk-taking by otherwise rather risk-averse executives in alignment with the shareholders' interests. The concept of stock options allows executives to participate from the potential upsides of high-risk decisions with limited downside risks due to their optionality. This also comprises an increased willingness to take risks with regards to supply chain

management. Recent studies are ambiguous regarding the effectiveness of CEO options and call for further research on contingency factors impacting managerial risk taking (Benischke et al., 2019; Wowak, at al., 2015).

By contrasting agency and behavioral agency theory, we investigate the impact of CEO options on SCDs and the moderating effects of relative COO power and market uncertainty (see figure 1). We draw upon a unique, hand-collected sample of more than 2,100 firm-year observations over the years 2006 to 2016 with more than 2,000 SCDs in 223 S&P 500 firms. To support our manual sampling process, we used a machine learning algorithm to identify potentially relevant SCDs from more than 450,000 press announcements.

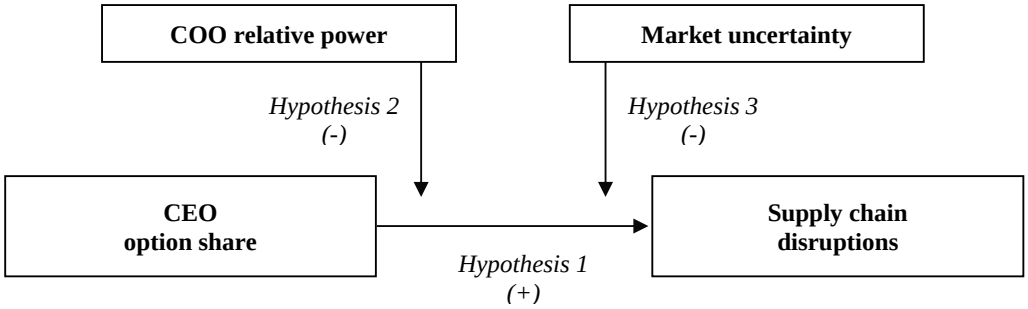

Figure 1 – Simplified research model

Our study contributes to operations management research in multiple ways. First, we identify and empirically investigate CEO options as a widely neglected organizational antecedent of SCDs. Second, we establish an inverted U-shaped relation between CEO options and SCDs enhancing research on CEO options with a more nuanced perspective on the effects of CEO options. Third, our study highlights the importance of having a powerful COO in the top management team with regards to supply chain stability. Fourth, we emphasize the necessity of adopting a contingency perspective when assessing CEO options and SCD risks. Finally, we introduce machine learning as a supporting technique to empirical secondary data research in operations management.

Theoretical background

SCDs

Prevailing research on SCDs emphasizes their harmful consequences: Hendricks & Singhal in several studies found, that SCDs diminish stock returns, market and shareholder value, and reduce sales over several years following a disruption (1997, 2003, 2005). In line with Hendricks & Singhal (2003) we define SCDs as unexpected events in the supply chain or its environment that threaten the normal business operations of a firm. Existing studies on SCDs vary strongly in the events being considered. Based on related supply chain risk literature, we use a dichotomous classification to cluster the SCDs used in our study. First, we separate micro- and macro-SCD-risks being in- and external to the organization (Wu et al., 2006). As we in this study investigate the effects of CEO stock options on SCDs, we exclusively focus on micro-disruptions which can directly be influenced by the firms. Loosely following the meta-analysis by Ho et al. (2015), we consider the following micro-disruptions in our study: demand and supply mismatches, delays, outages (of machinery or production), strikes, product quality issues, recalls, infrastructural problems, and issues of adverse business conduct. In line with Hendricks

& Singhal's understanding of supply chain management and its subsystems, we assume that executives either indirectly (through negligence of important operations processes) or directly (through active strategic decisions or conscious misconduct) effect SCDs (2014).

(Behavioral) Agency Theory and CEO Options

The basis of agency theory and research on CEO options is the separation of ownership and management in firms, leading to potentially diverging interests between shareholders (principals) and managers (agents) (Jensen & Meckling, 1976). Principals delegate the management of the business to the agent (i.e. the CEO), who is assumed to act in their best interest. In this context, agency theory assumes, that agents are risk-averse. Stock options are supposed to reduce the CEOs' risk-aversion by offering the CEO the opportunity to profit from firm success while not suffering from potential loss (Wiseman & Gomez-Mejia, 1998). Since CEO options are meant to influence a CEO's behavior, behavioral agency theorists pronounce the need to combine agency with behavioral decision theory to fully explain its effects (Martin et al., 2016). Behavioral agency theory enhances agency theory by prospect theory to explain managerial risk-taking (Wiseman & Gomez-Mejia, 1998). Prospect theory postulates that managerial decision behavior depends on individual valuation of potential gains and losses to the personal wealth (Kahneman & Tversky, 1979) with wealth being understood as current, just-received, and fully anticipated wealth. Accordingly, agents weigh anticipated future wealth against declines in current endowed wealth (Benischke et al., 2019).

Development of hypotheses

CEO options and SCDs

If not in charge of operations themselves, CEOs have a strong impact on strategic decision-making regarding initiatives that affect company operations, such as cost-reduction programs, process-oriented programs (e.g. quality management, working capital management), or budgeting (e.g. R&D spending) (Wowak et al., 2015). Overly risky decisions in pursuit of stock performance optimization, thus, have the potential to evoke SCDs. Whereas agency theorists postulate a linear relation between CEO options and managerial risk-taking, based on the behavioral agency theory we assume that the relation between stock options and risk-taking is more nuanced and driven by two latent interacting forces: the perceived benefits in case of success and the perceived costs in case of loss associated with higher risk-taking by the CEO. CEOs with a low stock option share have little incentive to take risky decisions, as they only limitedly benefit from increasing share prices if the high-risk initiative achieves anticipated results. However, they have much to lose in terms of non-financial wealth or imminent penalties. With an increasing but still moderate CEO option share, the financial incentive to take risks increases, as the fully anticipated wealth assigned to high-risk initiatives becomes more compelling. As risk-taking preferences of an agent vary depending on the executives' framing of the situation and anticipated effects on the personal wealth (Sitkin & Weingart, 1995), the CEO will constantly weigh benefits and costs of risky decisions against his current endowed wealth. Up to a certain point depending on the personal risk-taking preference, the incremental benefits of taking additional risks will overweigh the perceived incremental costs and will cause CEOs to ignore indications of project failure, to be negligent about risk mitigation, or to ignore downside risks of their decision (Wowak et al., 2015). As a consequence, we assume SCDs to increase. Following our logic of decreasing marginal benefits and increasing marginal cost of taking high-risk

decisions, we argue that with a high option share relative to the CEOs total compensation, risk-taking decreases as the CEO considers a large part of his prospect wealth at risk.

Hypothesis 1 (H1): CEO options exhibit an inverted U-shaped relationship to the frequency of SCDs, such that firms with low and high CEO option shares will experience fewer SCDs than those with medium CEO option shares

CEO options, market uncertainty, SCDs

When analyzing managerial risk-taking behavior, market uncertainty being defined as the extent to which a CEO faces an unpredictable and unstable environment (Finkelstein & Boyd, 1998) is arguably of special interest. Uncertain markets are characterized by constant variations in customers, preferences, and competition and increased supply chain risks per se (Trkman & McCormack, 2009). This will enhance the perceived costs of additional risk-taking by the CEO. Moreover, research suggests that with increasing market uncertainty firms face higher complexity in their task environment and an increased need to review and adjust strategies continuously (Miller & Friesen, 1983). This increases the alignment efforts within the top management team (TMT), which restricts the CEO in making high-risk decisions. Finally, with less predictability of the market and a growing amount of personal wealth being linked to firm performance, CEOs tend to become increasingly risk-averse and seek to preserve personal wealth (Wiseman & Gomez-Mejia, 1998). As the marginal costs increase as compared to the marginal benefit related to additional risk-taking, the U-shaped relationship between CEO options and SCDs is flattened, thus SCDs decrease.

Hypothesis 2 (H2): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter in markets where uncertainty is high and (b) steeper in markets where uncertainty is low.

CEO options, relative COO power, SCDs

Past research suggests that the increasing marginal cost curve counteracting the marginal benefits of CEO options might increase in the presence of a powerful COO. Power is defined as the extent to which the COO can influence the behavior of others and has the discretion to shape and implement strategic decisions in his interest (Finkelstein, 1992). The COO frequently is delegated responsibilities usually held by the CEO. He, thus, reduces power distance in the TMT and constrains the power otherwise centralized in the position of the CEO (Worrel et al., 1997). With increasing power of the COO, the CEO needs to more closely involve him when initiating strategic changes in a firm's operations. By creating a task-oriented conflict between CEO and COO, decisions are made in a process of social interactions that reveals differing assumptions and expectations (Marcel, 2009). This alignment process will arguably constrain the CEO's tendency to disproportionally focus on upside potential of high-risk decisions with regards to operations and, in turn, increase the CEOs perceived risk to be blamed with a negative outcome of a high-risk initiative if pursued against opposition. Second, power structures in TMTs can create conflicts among executives. By contending the power of the CEO, the COO takes a monitoring role towards the CEO. This is based on an inherent competition between the CEO and COO and the fact that a weak performance of the operations function being visible to the external labor market might harm future employment opportunities of the COO (Fama, 1980). Third, the functional backgrounds represented in the TMT influence the salience of certain organizational objectives and performance drivers (Marcel, 2009). While Hayward & Hambrick show that CEOs – a

role rather focused on output-oriented than internal processes – tend to be more risk-seeking with higher individual power (1997), COOs will presumably act in the foremost interest of their functional responsibility and, thus, will challenge overly risky decision based on a profound understanding of the operations function.

Hypothesis 3 (H3): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter, when the relative power of the COO is high and (b) steeper, when the relative power of the COO is low.

Data and methods

Sample

To empirically test our hypotheses, we gathered more than 2,000 SCDs from PR Newswire press announcements in the Factiva database from 223 publicly traded S&P 500 firms in the U.S. between 2006-2016. Based on the taxonomy developed above, we identified key search terms to identify first relevant disruption announcements per category, following the procedure of Hendricks & Singhal (2005). To handle the number of announcements and support our manual coding process, we developed a supervised machine learning algorithm, using python 3.6 & scikit-learn libraries, to automatically identify potentially relevant announcements based on both, title and body of the announcements. We re-read all announcements tagged as potentially relevant by the algorithm to judge the appropriateness, discussed unambiguous announcements. We, then, clustered the announcement into the SCD categories introduced above, using triple coding technique and regularly testing for intercoder reliability (Daniel & Harland, 2018). We then merged this SCD sample with TMT data from S&P Capital IQ's ExecuComp and firm characteristics from S&P Capital IQ's Compustat.

Measures

We operationalized our dependent variable (DV) *supply chain disruptions* as count variable (i.e. the number of recalls of firm i in year t), ranging from 0 to 8 in our sample. Our independent variable (IV) *CEO options* was operationalized as the share of stock options granted relative to the total compensation of the CEO as reported by ExecuComp. Following prior research, we calculated this variable as a two-year weighted average (Wowak et al., 2015).

With regards to our moderating variables, we put our focus on the presence of the COO role rather than on the title as such, following Hambrick & Canella (2004). We operationalized COO relative power as the COO's total compensation relative to the total compensation of the highest paid TMT member (the CEO). This definition implies that higher relative compensation ratios indicate higher power in the TMT (Daily & Johnson, 1997). We operationalized market uncertainty as the coefficient of variation of sales per industry on four-digit SIC code level in a given year (Tosi et al., 1973).

To increase robustness of our research model we included multiple control variables on firm-, industry- and TMT-level. On firm-level, we controlled for *firm size*, *financial slack*, *operating performance*, past financial performance using *Tobin'sQ*, *R&D intensity*, and *capital intensity*. On environmental-level, we controlled for *market uncertainty*, *technological turbulence*, and *technological sophistication*. On TMT-level we considered *TMT size*, *TMT ownership structure*, *CEO duality*, and *COO relative power*.

Since firms with a history of SCDs may be more likely to subsequently encounter problems, we included lagged DVs in all models. Finally, all research models contain *year* and *industry dummies*. We lagged all variables in our model (except for the DV) by

one year to account for the fact, that strategic decisions based on information in a given year, will take time to become effective (Souder & Bromiley, 2012). All continuous variables are winsorized at the 1.0% level to avoid bias from outliers.

Model

We use STATA's generalized estimating equation (GEE) model to analyze our unbalanced and pooled cross-sectional time-series data, following structurally similar studies based on longitudinal data (Wowak et al., 2015). GEE measures the effect on the DV "population-averaged" across all units in the data set, thus, considering both, within- and between-unit variation. Unlike alternative approaches (e.g. random- or fixed-effect models), GEE can deal with potential heteroscedasticity and serial correlation as it accounts for both inter- and intra-firm variations (Shah et al., 2016). Moreover, GEE does not (wrongfully) omit "zero SCD" firms (Sine et al., 2003).

Results

Table 1 provides descriptive statistics (unstandardized) and correlations (standardized) for all variables used in our models. The top right part of the matrix shows Spearman's rank-order correlations, the bottom left values show Pearson's product-moment correlations. The fact there is no significant correlation between CEO options and SCDs might be a first indication that the relationship might indeed not be linear rather curvilinear / U-shaped.

Table 1 – Descriptive Statistics and Correlations

Variables	M	SD	Min	Max	1.	2	3.	4	5	6	7.	8	9	10	11	12	13	14	15	16
1. Supply chain disruptions	0.77	1.52	0.00	8.00	1.00 (0.00)	0.49 (0.00)	0.00 (0.92)	0.00 (0.92)	0.29 (0.00)	0.20 (0.00)	0.29 (0.00)	-0.04 (0.08)	0.02 (0.33)	0.14 (0.00)	0.00 (0.68)	-0.02 (0.36)	0.02 (0.32)	0.05 (0.02)	0.08 (0.00)	0.05 (0.03)
2. Supply chain disruptions (lagged)	0.77	1.51	0.00	8.00	0.63 (0.00)	1.00 (0.00)	-0.03 (0.19)	-0.03 (0.19)	0.29 (0.00)	0.21 (0.00)	0.29 (0.00)	-0.04 (0.05)	0.03 (0.14)	0.14 (0.00)	0.01 (0.54)	-0.01 (0.63)	0.04 (0.08)	0.03 (0.10)	0.06 (0.01)	0.05 (0.02)
3. CEO options	0.22	0.19	0.00	0.84	-0.03 (0.16)	-0.05 (0.02)	1.00 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.02)
4. CEO options squared	0.08	0.12	0.00	0.71	-0.04 (0.02)	-0.05 (0.03)	0.91 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.01)
5. Firm Size	9.70	1.11	7.57	12.51	0.34 (0.00)	0.35 (0.00)	-0.08 (0.00)	-0.08 (0.00)	1.00 (0.00)	0.64 (0.00)	0.92 (0.00)	-0.35 (0.00)	-0.05 (0.03)	0.08 (0.00)	0.10 (0.00)	-0.01 (0.75)	0.05 (0.03)	0.03 (0.11)	0.18 (0.00)	0.19 (0.00)
6. Financial Slack	7.21	1.47	3.56	10.82	0.26 (0.00)	0.27 (0.00)	-0.04 (0.04	0.01 (0.65)	0.65 (0.00)	1.00 (0.00)	0.61 (0.00)	0.03 (0.18)	0.34 (0.00)	-0.18 (0.00)	0.24 (0.00)	0.33 (0.00)	0.35 (0.00)	0.02 (0.25)	0.17 (0.00)	0.05 (0.03)
7. Operating Performance	7.81	1.11	5.59	10.67	0.34 (0.00)	0.34 (0.00)	-0.07 (0.00)	-0.07 (0.00)	0.92 (0.00)	0.63 (0.00)	1.00 (0.00)	-0.11 (0.00)	-0.05 (0.03)	0.18 (0.00)	0.10 (0.00)	-0.03 (0.11)	0.03 (0.14)	0.02 (0.48)	0.16 (0.00)	0.22 (0.00)
8. Financial Performance	2.09	1.03	0.57	8.64	0.01 (0,73)	-0.02 (0.43)	0.07 (0.00)	0.12 (0.00)	-0.33 (0.00)	0.04 (0.09)	-0.12 (0.00)	1.00 (0.00)	0.30 (0.00)	-0.14 (0.00)	0.13 (0.00)	0.23 (0.00)	0.15 (0.00)	-0.04 (0.07)	-0.05 (0.03)	-0.06 (0.00)
9. R&D Intensity	0.03	0.05	0.00	0.68	0.03 (0.13)	0.05 (0.03)	0.09 (0.00)	0.16 (0.00)	-0.14 (0.00)	0.27 (0.00)	-0.12 (0.00)	0.33 (0.00)	1.00 (0.00)	-0,37 (0.00)	0.41 (0.00)	0.90 (0.00)	0.67 (0.00)	0.02 (0.22)	0.03 (0.09)	-0.06 (0.00)
10. Capital Intensity	0.49	0.36	0.03	1.61	0.12 (0.00)	0.13 (0.00)	-0.08 (0.00)	-0.11 (0.00)	0.14 (0.00)	-0.18 (0.00)	0.20 (0.00)	-0.17 (0.00)	-0.32 (0.00)	1.00 (0.00)	-0.09 (0.00)	-0.45 (0.00)	-0.42 (0.00)	0.00 (1.00)	0.07 (0.00)	0.19 (0.00)
11 Market uncertainty	2.60	1.74	0.32	8.21	0.03 (0.10)	0.04 (0.11)	0.04 (0.06)	0.10 (0.00)	0.10 (0.00)	0.23 (0.00)	0.13 (0.00)	0.16 (0.00)	0.36 (0.00)	0.01 (0.67)	1.00 (0.00)	0.50 (0.00)	0.40 (0.00)	0.06 (0.01)	0.14 (0.00)	-0.12 (0.00)
12 Technological turbulence	0.04	0.06	0.00	0.49	0.04 (0.07)	0.06 (0.01)	0.06 (0.00)	0.13 (0.00)	-0.00 (0.86)	0.36 (0.00)	0.10 (0.61)	0.26 (0.00)	0.74 (0.00)	-0.38 (0.00)	0.50 (0.00)	1.00 (0.00)	0.73 (0.00)	0.02 (0.49)	0.05 (0.01)	-0.10 (0.00)
13 Technological sophistication	0.31	0.46	0.00	1.00	0.00 (0.83)	0.02 (0.31)	0.11 (0.00)	0.15 (0.00)	0.03 (0.10)	0.34 (0.00)	0.02 (0.26)	0.12 (0.00)	0.58 (0.00)	-0.40 (0.00)	0.31 (0.00)	0.72 (0.00)	1.00 (0.00)	0.01 (0.80)	0.03 (0.16)	-0.08 (0.00)
14 TMT size	5.62	0.88	4.00	9.00	0.05 (0.03)	0.34 (0.11)	-0.02 (0.31)	0.00 (0.84)	0.04 (0.08)	0.02 (0.42)	0.01 (0.70)	-0.05 (0.02)	0.02 (0.31)	0.00 (0.91)	0.06 (0.01)	0.3 (0.19)	0.01 (0.66)	1.00 (0.00)	0.05 (0.01)	-0.07 (0.00)
15 TMT ownership structure	0.36	0.22	0.00	0.95	0.11 (0.00)	0.10 (0.00)	-0.49 (0.00)	-0.39 (0.00)	0.20 (0.00)	0.20 (0.00)	0.19 (0.00)	-0.04 (0.04)	0.05 (0.01)	0.09 (0.00)	0.18 (0.00)	0.11 (0.00)	0.04 (0.08)	0.06 (0.01)	1.00 (0.00)	-0.05 (0.03)
16 CEO duality	0.62	0.48	0.00	1.00	0.06 (0.00)	0.07 (0.00)	0.02 (0.26)	-0.02 (0.36)	0.19 (0.00)	0.03 (0.23)	0.21 (0.00)	-0.05 (0.01)	-0.15 (0.00)	0.15 (0.00)	-0.14 (0.00)	-0.16 (0.00)	-0.08 (0.00)	-0.07 (0.00)	-0.06 (0.00)	1.00 (0.00)

Notes: Table exhibits Spearman's rank-order correlations top right and Pearson's product-moment correlations bottom left with ρ values in parentheses; $N = 2{,}134$

As we have COO presence in only 53.6% of all firm-year observations we shrink our sample size by 990 observations with the inclusion of the COO power moderator and control variable. Accordingly, we tested hypotheses 1 and 2 ex ante in separate models without the COO power variables. We repeated the tests in a second group of models including the COO power moderator and variables to test hypothesis 3. This approach allowed us to test hypotheses 1 and 2 without a potential COO presence selection bias

(which we separately tested for as described below) and served as a first robustness test for the effects investigated in hypotheses 1 and 2. Table 2 exhibits the results of the regression analysis. Model 1-1 contains control variables only. Model 1-2 tests the main effect and model 1-3 includes the main and the first interaction effect without the COO power variables. Models 2-1 to 2-3 are identic in structure to models 1-1 to 1-but include the COO power variables. Model 2-4 additionally contains the second interaction term. Model 2-5 is the full model with the main and both interaction effects. All models are highly significant (p<0.01) and show increasing Wald χ^2 statistics with inclusion of the IV and additional moderators. Despite the drop of 990 firm-year observations between model 1 and 2 all results remain constant for both, the main and interaction effect, indicating a high robustness.

Table 2 – Regression Results: Effect of CEO options on Supply Chain Disruptions

	Model 1			Model 2					Robustness Tests					
Independent variables	**(1-1)**	**(1-2)**	**(1-3)**	**(2-1)**	**(2-2)**	**(2-3)**	**(2-4)**	**(2-5)**	**(3-1)**	**(3-2)**	**(3-3)**	**(3-4)**	**(3-5)**	**(3-6)**
CEO options		0.319**	0.423**		0.341*	0.504**	0.358**	0.507**	0.229**	0.227*	0.580**	0.402**	0.533**	0.502**
		(0.100)	(0.101)		(0.137)	(0.135)	(0.131)	(0.137)	(0.077)	(0.103)	(0.142)	(0.135)	(0.140)	(0.138)
CEO options squared		-0.270**	-0.401**		-0.349*	-0.555**	-0.371**	-0.556**	-0.240**	-0.238**	-0.751**	-0.380**	-0.577**	-0.554**
		(0.101)	(0.104)		(0.138)	(0.148)	(0.131)	(0.150)	(0.069)	(0.079)	(0.160)	(0.129)	(0.149)	(0.149)
Firm Size	0.347†	0.377†	0.356†	0.483*	0.501*	0.459*	0.493*	0.457*	0.298**	0.284**	0.498*	0.487*	0.524**	0.479*
	(0.196)	(0.193)	(0.192)	(0.221)	(0.222)	(0.214)	(0.219)	(0.213)	(0.298)	(0.055)	(0.209)	(0.216)	(0.201)	(0.202)
Financial Slack	-0.008	0.001	0.011	-0.046	-0.032	-0.015	-0.036	-0.023	-0.021	-0.020	-0.038	-0.034	-0.014	-0.027
	(0.084)	(0.083)	(0.083)	(0.109)	(0.110)	(0.109)	(0.109)	(0.109)	(0.054)	(0.057)	(0.106)	(0.107)	(0.107)	(0.110)
Operating Performance	0.159	0.127	0.134	0.061	0.032	0.042	0.019	0.027	0.030	0.044	-0.025	-0.003	0.017	0.007
	(0.194)	(0.195)	(0.191)	(0.223)	(0.224)	(0.216)	(0.219)	(0.212)	(0.107)	(0.041)	(0.209)	(0.215)	(0.203)	(0.200)
Financial Performance	0.030	0.043	0.231	0.068	0.084	0.052	0.060	0.034	0.066†	0.061*	0.048	0.034	0.012	0.027
	(0.059)	(0.062)	(0.061)	(0.077)	(0.095)	(0.075)	(0.066)	(0.064)	(0.035)	(0.031)	(0.072)	(0.074)	(0.067)	(0.070)
R&D Intensity	0.094	0.108†	0.107†	0.149†	0.173*	0.173*	0.183*	0.182*	0.058	0.058	0.193*	0.170*	0.227**	0.177*
	(0.064)	(0.032)	(0.627)	(0.077)	(0.074)	(0.076)	(0.073)	(0.074)	(0.053)	(0.040)	(0.079)	(0.076)	(0.072)	(0.081)
Capital Intensity	0.149*	0.150*	0.152*	0.116	0.113	0.109	0.113	0.111	0.046	0.045*	0.109	0.119	0.116	0.114
	(0.070)	(0.070)	(0.070)	(0.085)	(0.085)	(0.083)	(0.085)	(0.083)	(0.042)	(0.021)	(0.080)	(0.083)	(0.086)	(0.082)
Market uncertainty	0.089	0.100	0.103	0.051	0.075	0.069	0.087	0.081	-0.001	-0.002	0.040	0.048	0.066	0.097
	(0.098)	(0.094)	(0.966)	(0.113)	(0.111)	(0.108)	(0.113)	(0.110)	(0.053)	(0.033)	(0.100)	(0.103)	(0.111)	(0.109)
Technological turbulence	0.100	0.084	0.101	0.055	0.026	0.058	0.017	0.049	-0.006	-0.006	0.072	0.077	0.043	0.052
	(0.078)	(0.076)	(0.079)	(0.098)	(0.095)	(0.095)	(0.093)	(0.094)	(0.069)	(0.051)	(0.093)	(0.095)	(0.095)	(0.098)
Technological sophistication	-0.016	-0.008	-0.033	-0.153	-0.142	-0.151	-0.173	-0.178	-0.047	-0.048	-0.119	-0.184	-0.190	-0.174
	(0.206)	(0.199)	(0.199)	(0.217)	(0.214)	(0.212)	(0.212)	(0.211)	(0.118)	(0.067)	(0.200)	(0.208)	(0.215)	(0.212)
TMT size	0.060†	0.615†	0.602†	0.070	0.065	0.072†	0.073	0.079†	0.065	-0.063	0.076†	0.081†	0.106*	0.080†
	(0.034)	(0.034)	(0.034)	(0.045)	(0.045)	(0.044)	(0.045)	(0.044)	(0.035)	(0.031)	(0.042)	(0.044)	(0.485)	(0.044)
TMT ownership structure	0.013	0.518	0.054	0.067	0.099*	0.097†	0.073†	0.095†	0.084	0.086**	0.091†	0.107*	0.101†	0.092†
	(0.041)	(0.043)	(0.044)	(0.046)	(0.050)	(0.053)	(0.049)	(0.051)	(0.041)	(0.031)	(0.050)	(0.496)	(0.051)	(0.052)
CEO duality	-0.944	-0.892	-0.095	-0.097	-0.125	-0.122	-0.118	-0.115	-0.088	-0.086*	-0.081	-0.098	-0.117	-0.144
	(0.097)	(0.010)	(0.097)	(0.138)	(0.142)	(0.136)	(0.135)	(0.132)	(0.070)	(0.042)	(0.127)	(0.131)	(0.133)	(0.141)
Supply chain disruptions (lagged)	0.248**	0.246**	0.248**	0.252**	0.257**	0.273**	0.273**	(0.286**	0.606**	0.606**	0.282**	0.276**	0.274**	0.286**
	(0.043)	(0.044)	(0.044)	(0.053)	(0.053)	(0.528)	(0.049)	(0.049)	(0.061)	(0.032)	(0.047)	(0.047)	(0.050)	(0.049)
COO relative power				-0.059	-0.050	-0.059	-0.081	-0.087	-0.047	-0.047†	-0.105*	-0.106*	-0.107†	-0.087†
				(0.056)	(0.056)	(0.056)	(0.051)	(0.052)	(0.036)	(0.027)	(0.051)	(0.053)	(0.057)	(0.053)
Market uncertainty x CEO options			-0.205*			-0.347**		-0.327**	-1.44*	-0.140†	-0.5117**	-0.391**	-0.323**	-0.336**
			(0.090)			(0.125)		(0.123)	(0.072)	(0.082)	(0.127)	(0.132)	(0.121)	(0.127)
Market uncertainty x CEO options squared			0.204*			0.355**		0.338**	0.158*	0.153*	0.526**	0.356**	0.338**	0.347**
			(0.087)			(0.106)		(0.106)	(0.063)	(0.068)	(0.120)	(0.114)	(0.105)	(0.110)
COO relative power x CEO options							-0.340**	-0.316**	-0.197*	-0.198**	-0.267	-0.343	-0.314**	-0.310**
							(0.102)	(0.098)	(0.079)	(0.050)	(0.108)*	(0.117)**	(0.097)	(0.097)
COO relative power x CEO options squared							0.277**	0.243**	0.176**	0.179**	0.124	0.235*	0.243**	0.237**
							(0.097)	(0.082)	(0.062)	(0.036)	(0.103)	(0.104)	(0.081)	(0.082)
Inverse Mills ratio (IMR)													-0.106	
													(0.080)	
CEO options (predicted)														0.160
														(0.332)
CEO options squared (predicted)														-0.144
														(0.247)
Observations	2,134	2,134	2,134	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144
Number of firms	223	223	223	205	205	205	205	205	205	205	205	205	205	205
Wald χ^2 / R^2	1920.16***	2036.03***	2151.58***	467.69***	551.63***	630.06***	570.21***	654.27***	0.377**	0.377**	748.17**	572.10**	662.28**	710.75**

Notes: Robust standard errors in parentheses. Industry and year dummies included but not shown
† p<0.10; * p<0.05; ** p<0.01; two-tailed tests

Hypothesis 1 theorized an inverted U-shape relationship between CEO options and supply chain disruptions. Necessary condition for such a curvilinear relationship is a negative second-order effect of the IV in our regression model. In support of Hypothesis 1, model 1-2 shows that CEO options have a highly significant effect on supply chain disruptions and the second-order effect is significantly negative. In hypotheses 2 and 3 we theorized a flattening in the inverted U-shape relationship between CEO options and supply chain disruptions by our interaction effects. A flattening (or steeping) of a quadric relationship requires the regression coefficient between the interaction effect and the squared IV to be significant and positive (negative) (Haans et al., 2016). As depicted in our full model 2-5 the coefficients of both interaction terms are significant and negative, with their corresponding second-order effects being significantly positive. H1, H2, and H3, thus, are strongly supported.

Given the stable results of the main and the first interaction effect in both the model with the COO variables (N = 2,134) and the model without the COO variables (N = 1,144), our estimations show high robustness. Still, we conducted multiple additional checks to ensure a high robustness of our findings. Our main analysis was conducted using a

negative binominal distribution best fitting our count data DV. To ensure our results are not driven by model specifications, we reran the analysis with an ordinary least square (OLS) random effects model with robust standard errors (model 3-1) and with Driscoll-Kraay standard errors to rule out cross-sectional correlation (model 3-2) (Shah et al., 2016). Both models confirm the results presented above. Next, we reran our main model with two different specifications of our IV using an unweighted average in model 3-3 and annual values in model 3-4. Again, our estimations are confirmed.

Firms with COOs might be substantially different from firms without COOs. Unobserved factors (e.g. operations management experience of the CEO) might influence both, the decision to have a COO and supply chain related outcomes and bias the results of our study. To test for this potential sample selection bias, we applied a Heckman two-stage selection model (1979) in line with prior TMT research (Kim et al., 2016) and included an inverse Mills ratio (IMR) predicting COO presence in all our models 2-1 to 2-5. As the IMR is insignificant and all other results remain robust, our analysis does not suffer from a sample section bias. The results including the IMR are shown for the full model in model 3-5. Moreover, we drew on multiple means to lower the risk of potential endogeneity in our study. Among other measures, we created an endogeneity control by regressing CEO options in $t-1$ on eleven of its potential firm-, industry-, and TMT-level antecedents in $t-2$ and including this predicted IV as endogeneity controls in our models 2-1 to 2-5. Again, the results remained robust in all models. We show the results for the full model in model 3-6. Given the results of the tests above, reverse causality and endogeneity do not appear to be a problem in our study.

Discussion

Theoretical Implications

Our findings have important implications for research on SCDs and the extensive literature on the impact of CEO options on executive behavior. First, we extend operations management research by investigating CEO options as an organizational antecedent of SCDs. We empirically show, that CEO options – especially at medium levels – increase the frequency of SCDs. Second, we contribute to strategic management research which investigates the effects of executive stock options. While research on this topic has long been dominated by two schools of thought – agency theory expecting more risky decisions and behavioral agency theory expecting less risky decision as consequences of stock options – our research conceptually and empirically adds a more nuanced assessment of CEO options to prevailing literature. Third, this study identifies both organizational and environmental factors that have significant impact on CEO option-induced risk-taking. Both, market uncertainty and relative COO power have a flattening effect on the relationship between CEO options and SCDs, thus, diminishing the CEOs willingness to take disproportionate risks with regards to operations management. As of today, research on performance effects of COOs is ambiguous (Hambrick & Cannella, 2004; Hendricks et al., 2014). Our findings underline the importance of a COO at equal terms with regards to supply chain stability and further confirms research underlining the importance of operations capabilities in the TMT as a source of competitive advantage.

Finally, our study advances strategic and operations management research from a methodological standpoint. As the algorithm is not limited to a predefined dictionary of relevant terms but constantly evolves based on the growing training data set, this approach might be an interesting alternative to dictionary-based approaches. Especially in times of "big data" that can hardly be managed manually anymore and for relatively new areas of research where no established dictionaries exist, this approach can become increasingly relevant.

Practical Implications

Our findings bring about two important implications for decision makers. First, we advise decision makers to carefully select and combine different tools of executive compensation. Whereas CEO options might not be the best incentive used by itself, they still might be a valuable tool to induce additional risk-taking if required. However, this decision needs to be made very deliberately, keeping in mind potential risks. We, thus, recommend decision makers to balance CEO options with other means of executive compensation such as stock that also have a downside potential and reward sustainable decision making. Second, if using CEO options, we advise decision makers to embed their usage in an organizational setting that either does not facilitate strategic individual actions by the CEO or, as this study has proven, has a relatively low power distance in its TMT to enable mutual control among executives.

Limitations and Avenues for Further Research

Our study is subject to certain limitations that provide interesting avenues for further research. First, while our study focuses on the effects of CEO options, future research should investigate the interplay of CEO options with other prevailing means of executive compensation (e.g. stock ownership) in predicting supply chain stability. Second, whereas we focused on CEO compensation, it might be of interest to investigate effects of additional TMT characteristics on supply chain stability. Third, research has a strong focus on the CEO when investigating the effects of stock options. Future studies could expand this scope to other TMT members' roles and strategic outcomes in their areas of responsibility to better understand potentially diverging interests between different functional strategies.

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Nontoxic communication strategies for pharmaceutical product recall operations: Empirical evidence of Chinese social media data

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Abstract:

This study explored the public perceptions of pharmaceutical product recall operations based on over 100,000 Sina Weibo data of twenty-one drug recall events in China from 2011 to 2018. We found that: 1) the information agents of drug recall event are now mainly authoritative third-party media; 2) except for extremely serious product-harm crisis, public opinions of most events gradually degraded into non-toxic within two weeks, while pharma companies should take full advantages of the "transition time" to mitigate the explosion of negative public opinions; 3) the apology strategy is less effective and more proactive actions should be considered.

Keywords: Product recall, Public perceptions, Social media

Introduction

Till now pharmaceutical product recall events are prevalent due to mistakes in the pharma supply chain and the stringent regulations (Ball et al., 2018). In the connected world, a typical product-harm can spread fast through various social media platforms in the form of public opinions and sentiment of product recall (Spence et al., 2016). Companies recognizes social media as an irreplaceable platform to interactively communicate information to public during product recall advisory and for marketing (Lee et al., 2015). Especially for pharma products, due to the lack of technical knowledge, the public cannot fully understand the real consequences, and hence this may not similar to other products or mobile recall events (Chen et al., 2015). Hence, it is vital to understand how customers respond in the social media era context and to what

extent companies can leverage the information available in social media platform to develop an effective product recall communication strategy (Wowak & Boone, 2015). Even though social media is garnering importance its usage during crisis is embedded with several challenges (Ki & Nekmat, 2014; Li & Li, 2014). Therefore, the main purpose of this study is to answer: 1) who are the "information leaders" of Chinese pharmaceutical product recall events; 2) how publics respond to different clusters of recall events in China.

This article is organized as follows: the extent literature with regard to the applications of social media into recall management is discussed in Section 2. Text mining and social media data collection processes are explained in Section 3. The results based on the social media data are exhibited in Section 4. Subsequently, the managerial implications of this study are discussed in Section 5. Finally, the study concludes with the limitation and future trend of research.

Literature review

Recently, social media platforms have been gradually used as directly communicate approach to a large audience (Lee et al., 2015). Compared with traditional communication channels, social media is relative easy to reach individuals and to communicate effectively with wider community and to regain brand image (Long et al., 2010). However, there are also issues related to loss of message control. Other than a few limitations there are several benefits such as good communications with customers post-crisis to restore customer trust (Tse et al., 2018). Widely used analysis in the social media context is sentiment analysis or content analysis towards one specific recall event. For example, Chen et al. (2015) analysed the number of Weibo posts, Baidu Indices and mass media news before, during and post the "Kangtai hepatitis B vaccine crisis". It found that some false information and distorted media reports exacerbate public perceptions on the event, and timely response should be implemented within the short period before the high public attention arose. Besides, based on Twitter data of "Tesco Horsemeat recall scandal", Tse et al. (2016) use text mining method to analyse the sentiment of public, which explores the content of social media data during one-week period and reported the negative trends compared to the conventional channels. Likewise, Tse et al. (2018) carried out another study based on the Facebook data of "Tesco Horsemeat recall scandal", which compared the social media data of customer behaviours for the apology of Tesco. In pharma industry, Ledford and Anderson (2013) conducted a content analysis via a CAUSE model based on the Facebook data of a voluntary recall event. It states that customers will seek for information and support from social media platforms and the focal company that is incompetent to design and deliver clear and satisfied solutions. This information will impede the enactment behaviour of some customers. In addition, the relationship between social media and stock market performance has also been explored. Lee et al. (2015) stated that the high frequency of social media activities of focal firms will mitigate the negative effects on shareholder value, while Hsu & Lawrence (2016) found that the high-level engagement on social media has no significant impact on the stock price during recall. Besides, scholars also focused on post-crisis response strategy via social media platforms. Borah

& Tellis (2015) selected online chatter data from several automobile forums and indicated that the online chatter will aggravate significant negative effect on sales and apologizing advertisement also lead to negative effect on both focal and non-focal companies. Furthermore, there is a new trend that social media data have been used to identify potential safety hazards in a proactive way. Mummalaneni et al. (2018) analysed the review data of baby cribs from Amazon and indicate that some "smoke terms" that generated from sentiment analysis can be applied to explore potential safety hazards and thereby firms can conduct actions more proactively. In pharma industry, Hoang et al. (2018) studied the real-world Twitter data from over 10,000 users and found that social media data can be used to detect unknown adverse reactions, which support the research of Freifeld et al. (2014) in which they stated that Twitter data mentioning medical products and explaining their side-effects have concordance with the report from FDA.

Overall, there is extensive research covering product recall and the use of social media in product recall management. These researches focus more on an independent event (i.e. the Kangtai hepatitis B vaccine crisis), while the multiple-cases analysis of different recall events is not very clear. Besides, the study about non-toxic operations strategy is still scarce. In addition, as the second largest pharmaceutical market in the world, the research focus on China is rare, and hence the exploration on Chinese pharmaceutical recall management will be helpful.

Methodology

Data collection

This study chose Sina Weibo data as a research sample. We first collected the pharmaceutical recall data from Chinese CFDA official website. In total, there were eighty-five recall events were reported. Then the Sina Weibo posts and comments of each recall event were collected thorough Python 3.6. For each event the combination of "the name of company" and "recall" was set as searching key words and the time span of each event was defined as three weeks after recall announced. For each post, the information including the user name, content, number of likes, number of comments, number of reposts, time and URL were collected. Then, the top 10 hottest comments (that has top 10 highest number of likes) of each post were collected, which includes user name, content, number of likes, time and URL. In total, 20,592 Sina Weibo posts and 107,842 comments were collected. Because some recall events did not attract enough public attentions, hence the number of posts and comments were not adequate for our analysis. Finally, we decided to focus on twenty-one events which had more 60 posts. The details of the chosen events are shown in Table 1.

Table 1 The basic information of recall events

	Event	Time	Total Posts	Total Comments	Total Reposts
1	GSK China	2011.12	163	210	0
2	Shuzhong Pharma Co., Ltd	2012.4	340	685	0
3	Changchun Overseas Pharma Co.,Ltd	2012.4	270	275	1

4	Xiuzheng Pharmaceutical Group	2012.4	1537	3969	4
5	Jilin Huinantianyu Pharma Co., Ltd Case 1	2012.4	652	498	0
6	Jilin Huinantianyu Pharma Co., Ltd Case 2	2015.12	255	3170	3435
7	Xi'an Asilan Pharmacy Co., Ltd	2015.12	260	3169	3431
8	Jichun Pharma Co., Ltd	2015.12	547	3277	3529
9	Chongqing Quanxinshengxiang Co.,Ltd	2015.12	252	86	231
10	HuinanSanhe Pharma Co., Ltd	2015.12	322	3170	3435
11	Tonghua Limin Pharma Co., Ltd	2015.12	81	120	73
12	Guangxi Rongren Pharma Co., Ltd	2015.12	400	2065	2904
13	Changzhi Sanbao Bio Pharma Co., Ltd	2015.12	65	308	847
14	Guilin Xingda Pharma Co., Ltd	2015.5	247	172	238
15	Hainan Yier Pharma Co., Ltd	2016.1	495	5158	4980
16	Taiji Group	2016.11	400	2065	2904
17	Shenyang Xindi Pharma Co.,ltd	2017.12	958	2298	3661
18	Jilin Xinhui Pharma Co., Ltd	2017.7	176	129	353
19	Changchun Changsheng BioChem	2018.7	11118	498015	1003393
20	Wuhan Institute of Biological Products Co., Ltd	2018.7	1242	68286	82284
21	Zhejiang Huahai Pharma Co., Ltd	2018.7	812	10717	8575

Data analysis

Text Mining (TM) is a widely used data mining approach that focused on high volume of textual data, which is robust for analysing the sentiment polarity of publics expressed in social media context (Tse et al., 2018). Generally, Machine Learning and Lexicon-based approach are two widely used methods for sentiment analysis. The lexicon-based method can directly assign the polarity of text content without any training database (Taboada et al., 2011). In this research, we used three lexicon-based libraries for simplified Chinese text processing (Tsinghua University Sentiment Dictionary, CNKI Sentiment Dictionary and Taiwan University Sentiment Dictionary), to conduct sentiment analysis to achieve the *Polarity of public perceptions*. Each post and comment got a number to reflect the polarity of content. Finally the cluster of post and comment were determined by the value (positive, zero and negative) and classified as positive, neutral and negative.

Findings

The main social media users of pharmaceutical product recall events

It is noteworthy that the pharmaceutical product recall events are now attracting far more volume of public attentions than five years ago. As the prevalence of social media, the information of recall events are now disseminating faster and broader than previous instances, which thus forced pharma companies to concentrate more on effective communications via social media platforms. For each recall event, we selected the top 30 hottest social media users that have the highest comments and reposts volume. These users were classified as six clusters, which are the government-led social media users, famous third-party social media users, local social media users, Internet Celebrities, healthcare industry related social media users and other users. Figure 1 illustrated that

there were a few government-led official accounts and famous third-party mass media active accounts that was established before 2015. At this stage, the most common users are private Weibo accounts with relatively low followers. Given the low level of impact of these private users, the other Sina Weibo users did not put too much emphasis on these recall events. As shown on Table 1, the five recall events from 2011 to 2012 had low volume of comments and almost zero-level reposts. Afterwards, more locally media accounts (i.e. local newspaper account, local government account, etc.) were engaged in the post-recall period between 2015 and 2016, especially for some regional recall events without national impacts. Subsequently, an increasing number of more authoritative and famous third-party national media (i.e. Global Times, Financial Network, Southern Urban Daily, Sina Finance, etc.) Weibo accounts that have higher influence on the publics were becoming the major participants of recall events. In addition, the followers of government-led social media accounts grew significantly. For example, the CCTV News has over 83 million followers and the People's Daily has over 88 million followers. Once the pharmaceutical recall events have been commented by these accounts, the public attention picks up at the growth is exponential.

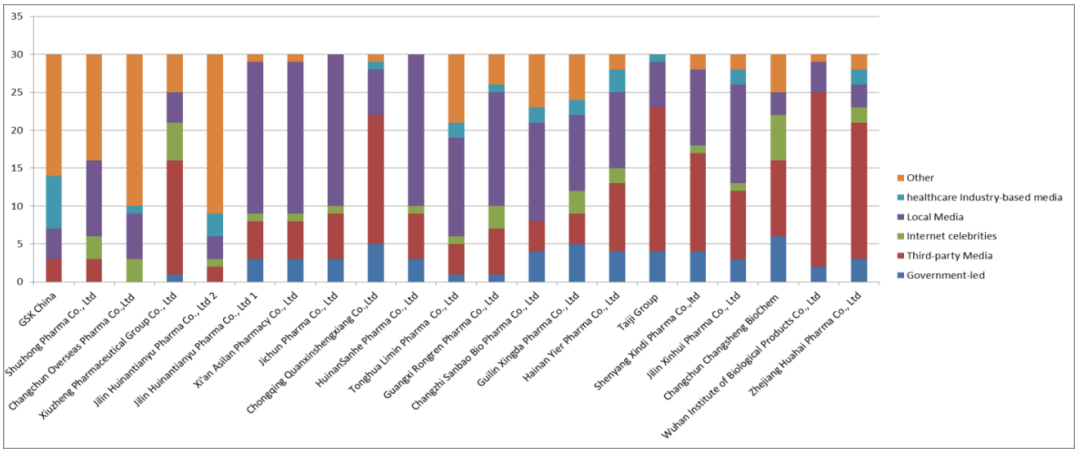

Figure1 The classification of Top 30 information leaders of typical recall events

To understand who the "trendy" was during post-recall period, this study analyzed the frequency of those 630 users whose Sina Weibo post had highest number of comments and reposts. Overall, the Top 20 information leaders were mainly government-led media and national-level third-party media accounts that have millions of followers and have significant impact on public perceptions. Although there were two healthcare professional accounts and four local media accounts, the audiences of them were relatively narrow.

Table 2 The Top 20 information leaders of Chinese pharma recall events

	User name	English Name	Frequency	Classification	Followers
1	*新京报*	Beijing News	10	Third-party	35.8 Million
	环球时报	Global Times	10	Third-party	20.8 Million
	人民网	People.com.cn	10	Government-led	63.9 Million

	央视新闻	CCTV News	10	Government-led	83.7 Million
5	*人民日报*	People's Daily	9	Government-led	88 Million
	财经网	Financial Network	9	Third-party	33.7 Million
7	*头条新闻*	Toutiao News	6	Third-party	64 Million
	央视财经	CCTV Finance	6	Government-led	31.7 Million
	法制晚报	Legal Evening News	6	Third-party	23.9 Million
	医药观察家网	Medical Observer	6	Healthcare	70,000
11	*羊城晚报*	Yangcheng Evening News	5	Local Media	11.1 Million
	南方都市报	Southern Urban Daily	5	Third-party	16.8 Million
	三峡日报	Three Gorges Daily	5	Local Media	1.07 Million
14	*新浪财经*	Sina Finance	4	Third-party	18 Million
	中国之声	The Voice of China	4	Third-party	25.4 Million
	丁香园	Clove Garden Pharma Newsletter	4	Healthcare	1.3 Million
	凤凰网视频	PhoenixNet Videos	4	Third-party	8.1 Million
	法制日报	Jurisprudence Daily	4	Third-party	2.9 Million
	新闻日日睇	News Eyes	4	Local Media	0.67 Million
	燕赵都市报	Yanzhao Metropolis Daily	4	Local Media	8.6 Million

The daily change of public attention

To explore how the public attention fluctuated during different recall events, this study analysed the number of daily comments for three weeks post-recall period. We classified all twenty-one recall events into four main categories, which are raw material related recall event, low public attention recall event, middle public attention recall event and high public attention recall event. In terms of the first cluster (shown as Figure 2)，despite with different attention-degree, both of the raw material recall events did not attract public attention for a long time. After first two or three days' heated discussion, the publics always shown their tolerance and blame less for the involved companies. After one week, the public attention level was almost back to zero.

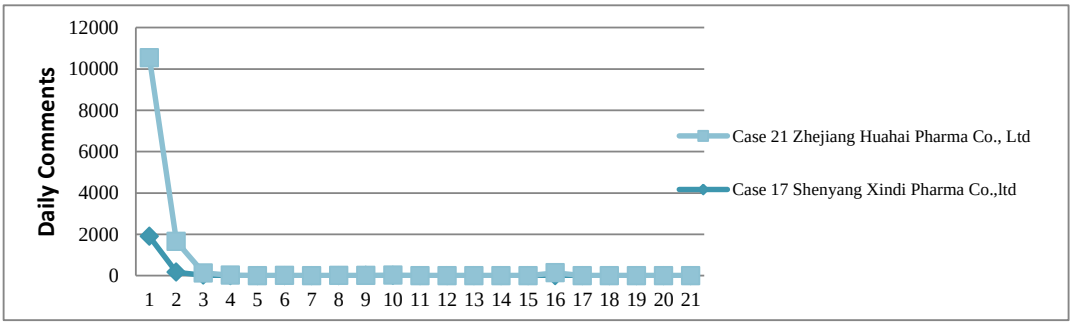

Figure 2 Daily Comments of Raw material related recall event

As for the low and medium public attention recall events, after recall announced there was always a two to four days "buffer period" for pharma companies to deal with the explosive public opinions from social media. In terms of some events without serious hazard (i.e. Case 1, Case 9, Case 13, Case 16), publics will not have further discussions on these topics afterwards. However, for those events with safety hazards and high public involvement, the follow-up

inspection reports from Chinese CFDA or punishment via other government sources would then generate a second peak (i.e. Case 2, Case 4) around one week after recall announcement. Afterwards, the public attentions will back to zero level after two weeks.

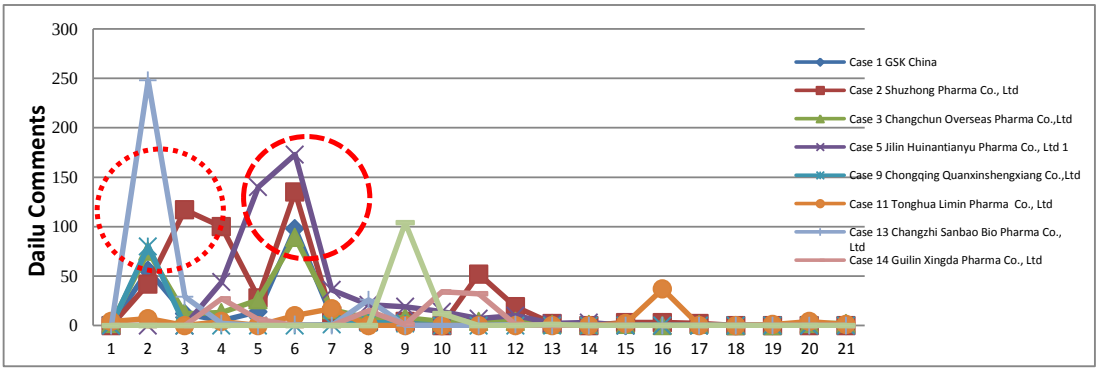

Figure 3 Daily Comments of low public attention recall events

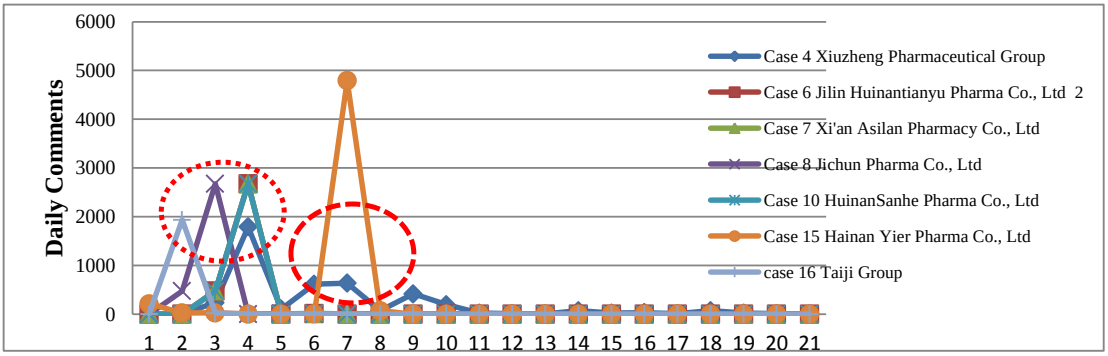

Figure 4 Daily Comments of medium public attention recall events

However, in terms of the events caused serious safety and high public concerns, the extension of the time period was much longer than other events. Even after three weeks, the daily average comments were still around 1,000. Although there may be two to three days buffer time for pharma companies to provide positive reactions, once involved in this kind of event, they have to spend substantial amount of time and resources to flee from the mire.

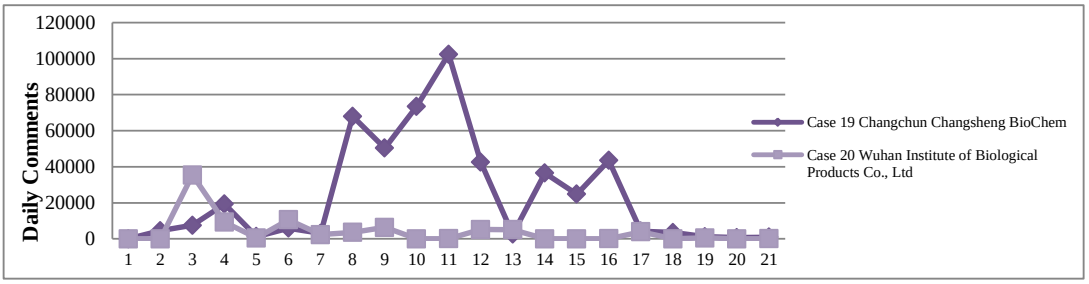

Figure 5 Daily Comments of medium public attention recall events

The time series analysis of public perceptions: the Changsheng BioChem Vaccine case

To explore the changes of public perceptions more in-depth, this study chose a latest case, Changchun Changsheng BioChem vaccine recall event, as an example to explain how the polarity of public perceptions changes during the post recall period. As shown on Figure 6, there were seven main events happened. After CFDA published the recall announcement on 15th July 2018, Changsheng started the recall on the second day and the public perceptions become extremely negative. On 17th July, Changsheng published a statement that confirmed the production of defective vaccine has been stopped and expressed the apology to the publics. However, the publics were not satisfied with their response, which is in line with the negative polarity data at point 2. Then on the fifth day, several famous media released news that the recall was reported by insider staff and further inside information was published, and hence the publics expressed more untrustworthy and anger on the company, then the polarity decreased again. Afterwards the President Xi and Prime Minister Li stated "the recall event must be seriously investigated and corrected" in succession on 23rd July and 25th July and the Chairman of Changsheng and other senior managers were arrested. Therefore, the public opinions were to some extent recovered during these days. Then as the investigation conducted, more news reported the staff of Changsheng meant to destroy the evidence of sixty hard disks that recorded the production information, thereby the public opinions back to extremely negative again. After two weeks, the investigation was finished and Changsheng got very serious punishment, and meanwhile Prime Minister Li stated the long-term vaccine regulation and traceability system must be established. Those reactions again regained the trust from publics.

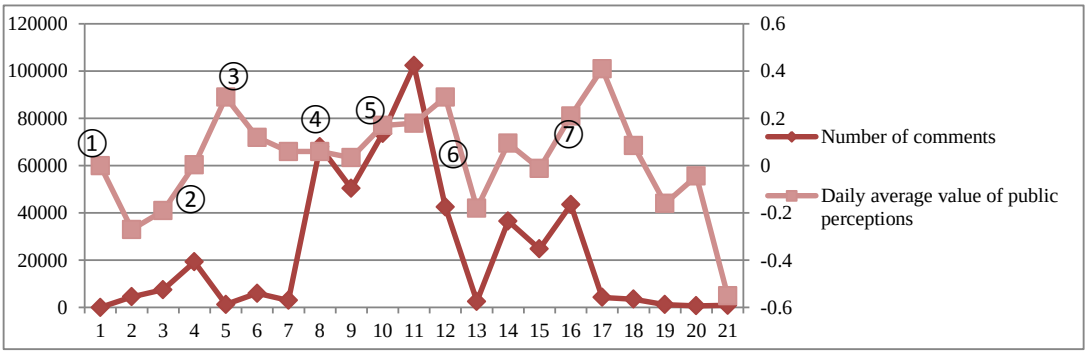

Figure 6 The daily average value of public perceptions

Discussion

First, for the social media users, as mentioned above, the major information leader are now becoming authoritative third-party media users. On one hand, the reliability of news is better than past and less irresponsible "toxic" small media can distort the public opinions. On the other hand, it means the fully control of information post recall is more unprocurable. For those pharma companies still tend to manage all information sources and try to delete relevant negative news as conventional way are now becoming more and more difficult. Therefore, Chinese pharma companies must rethink their media relationship strategy. A long term social media relationship should be established before the product-harm risks.

Second, time to recall is a crucial factor that directly influences the response of publics. According to current Chinese recall regulations, the time limit of recall is in accordance with the class of recall (Class I within 24 hours, Class II within 48 hours and Class III within 72 hours). However, this time limit in China is more like the time to stop the circulation of products from market. According to the results, most recall events had a two to four days "buffer time" for companies to conduct effective response activities before the public opinions become worse. However, few pharma companies have persuasive responses during this time. Another time point is around one week when the government always publishes follow-up report to explain the investigation and corrective actions, especially for serious events. If the pharma company could not achieve effective management before the first time limit, they must make full use of this one week to establish a responsible company image, otherwise they will be more passive and incur substantial number of negative comments afterwards.

Besides, as can be seen from Figure 6, the polarity of daily sentiment is able to reflect the changes of public perceptions caused by different key issues. It is noteworthy that simple apology to the publics may not as effective as previous time. Compared with other industries, pharma products are closely related to safety and health of all human beings. Therefore, the public concerns of potential hazards may weaken the effectiveness of apology. In addition, due to the extremely poor performance of Chinese pharma companies in the previous time, publics will not be satisfied with simply apology response strategy. Pharma companies should provide more details about how to collect defective drugs and how to compensate involved patients.

Overall, pharma operation managers can benefit from the evidence-based guidelines to integrate social media context into post-recall communication strategies. First, this study helps pharma companies to identify "toxic" information agents of recall events and thereby establishing close relationship with them on the long run. Meanwhile, pharma managers can understand the importance of non-toxic "buffer time" and conduct more effective actions during "non-toxic to toxic" transition time and hence mitigating potential impacts.

Conclusion

Through the analysis of Sina Weibo data of twenty-one pharmaceutical recall events, we found that: 1) the major social media information leaders of drug recall events are now mainly authoritative third-party media, which thus make pharma managers more difficult to fully control the negative information post-recall; 2) except for those extremely serious product harm-crisis, the social media public opinions of most recall events will gradually degrade within two weeks, while pharma companies still need to make full use of the "buffer time" to mitigate the explosion of social media attentions; 3) the apology strategy is becoming less effective in current years, and hence more proactive response actions should be considered.

The limitation of this study located on two aspects. First, all these companies are only based on Chinese background, the geographical differences should be considered to compare the other social media from different perspectives (i.e. Facebook, Twitter). Second, given this study is a retrospective study that collected historical social media

data, a part of data may be deleted by the users, which thus affect the accuracy of data analysis.

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Success factors for rapid roll-out of a lean method change: A pharmaceutical manufacturing case study

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Abstract

The ways of coping with the complexity of implementing lean production in Multinational Corporation diverge. Successful knowledge transfer within corporations' network of production plants is of major importance. One way to roll out programs with changes rapidly is through top management commitment. The paper reports from an industrial case study exploring the characteristics, as well as issues and success factors, of a roll-out program to implement a standard. Important factors were identified, such as early involvement of stakeholders, type of knowledge transferred, involvement at both group and individual level, and to secure external deliveries prior to initiation of the program.

Keywords: Operations/production management, lean management, lean production

Introduction

The last two decades, many multinational corporations (here, MNC) have expanded their manufacturing footprint by increasing their number of production plants worldwide. There are numerous benefits with MNC, such as market presence, the ability to invest and the diversity of knowledge within the corporation. However, new challenges may also come with an expanding manufacturing footprint. For example, transferring knowledge within a MNC could be challenging due to complexity caused by variation amongst the production plants (Jacquier-Roux and Paraponaris, 2012; Boscari, Danese and Romano, 2016).

High level decisions may affect the production system at several production plants in various ways, which increases the complexity to implement, for example, lean practices in MNC (Bellgran, 2018). Considering that the fundaments of implementing lean production may be a strategy of survival on the world market, large investments of

multi-plant improvement programs are of major importance to be successful. Moreover, unsuccessful programs could lead to reduced competitiveness. According to Netland *et al.* (2014), limited available research within the field of improvement programs makes it challenging for industry to get guidance to manage and design them successfully (Netland and Aspelund, 2014).

The research within the field of lean implementation as a concept and specific lean practices, both theoretical and empirical, is extensive. Despite this, few examples of successful implementation of the concept outside of Japan are presented due to the challenges faced in the deployment of lean (Jadhav, Mantha and Rane, 2014). Some papers suggest sequences in which lean practices should be implemented, with the intension to guide towards a successful implementation (Womack and Jones, 2003; Hines, Holweg and Rich, 2004; Anand and Kodali, 2010). But, lack of a consistent lean implementation framework with guidelines or a process is among the issues challenging lean implementation success (Bhamu and Sangwan, 2014). There is no well-known best way to implement lean production. Although examples of different conditions fostering success of lean transformation found in literature are; top management commitment, early employee involvement, employee autonomy and information transparency of achieved benefits while some issues being, for example, improperly planning prior and after the implementation (Achanga *et al.*, 2006; Scherrer-Rathje, Boyle and Deflorin, 2009; Bhamu and Sangwan, 2014).

In industry organizational systems are created for implementing lean where lean practitioners function at different hierarchy levels involved in different levels of business process management. There are various ways of implementing methods and standards in the organization. Often standards are developed globally and gets piloted at a production plant prior to a broad roll-out in the corporation. This can be beneficial in terms of efficiently targeting a wide range of production plants, but can also create resistance and decrease engagement when standards are not created locally at the production plant.

The way of achieving lean production consist of several attempts of implementations and rolling out new improvement programs to develop the current production system. Despite the vast literature on lean implementation, there is limited research of effective processes of rolling out changes of existing lean practices. One exploratory study presents seven roll-outs in production plants of different MNCs (Secchi, Raffaele; Camuffo, 2016). However, these roll-out processes were studied at case companies with no previous experience in lean production.

Successful knowledge transfer within corporations' network of production plants is of major importance. The knowledge transfer is considered as a process that is dependent on the nature of knowledge and the ways of communicating (De Luca and Rubio, 2019). There are two types of knowledge; explicit and tacit (Nonaka and Teece, 2001). Explicit knowledge can be expressed with words and numbers, thus can be shared through for example, manuals or standards. On the other hand, tacit knowledge is difficult to explain with words and is very subjective, which makes it hard to transfer to others. With the aim to reach a wide group of plants at a MNC in designing improvement programs there might be lack of understanding in type of knowledge to be addressed, and perhaps tacit knowledge is neglected in roll-out programs.

This research aims to describe the issues and success factors identified when rapidly rolling out an improvement program with the purpose of changing a lean method by adapting global standards of the MNC. More precisely, the research questions to be answered in this paper are:

RQ1: What characterises a rapid roll-out process when transferring a standard within a multinational corporation?

RQ2: What are the issues and success factors for a rapidly roll-out process when transferring a standard within a multinational corporation?

Methodology

The paper sets out to explore and describe characteristics of a rapid roll-out of a lean method change. A rapid roll-out is here interpreted to be a few months targeting an entire production plants consisting of several levels of management and business units. In the context of this paper, the term "lean method change" is defined as the objective of the improvement program aiming for transferring knowledge from global "best practice" of the MNC to one of the production plants. The change is considered to be minor and the lean method is already a part of the current lean practice. A minor change can be, for example a different approach in the method, or a template modification, hence the aim is to improve the use of the method. .

This study has the perspective of the process of transferring knowledge within multinational corporations, from global level of the corporation by adapting a global standard and transfer it further to one production plant. By following the roll-out program from the point of the decision by top management to the implementation at the shop floor, an in-depth case study approach was considered suitable for the purpose. It follows the preconditions of a case study, as presented in (Yin, 2009).

The roll-out program was initiated by top management at a multinational corporate production plant. A representation of all levels of the hierarchy within the production plant was part of the study. The roll-out program was followed at one of several business units (here called "Unit X"). The management consisted of four levels, included with top management. Involved lean practitioners were functioning at three levels: global, local-central and local-business unit. Data was collected through semi-structured interviews, on-site observations and documentation from different corporate functions. The interviews started with an initial protocol and were tailored to fit specific the interview setting; notes were taken both during the interviews and the observations.

The analysis was performed utilizing mixed method in two steps. At first, triangulation of data was made of the interview notes, field notes and documentation in order to verify the description of the roll-out program. Secondly, a comparative analysis was done of the planned roll-out and the actual execution of the program. The subjective views on the success of the roll-out was measured at the company by their achievement of set milestones and amount of individuals receiving training.

Theoretical framework

Lean production is a concept inspired by the Toyota Production System (TPS) where the fundamental purpose is to eliminate waste of the value stream of products, including the supply chain. With the main focus on bringing value to the customer the essential purpose of implementing lean is for some industrial corporations a way to stay competitive (Netland, 2016). There is comprehensive literature about the lean philosophy and principles, and the tools and methods supporting them (Womack and Jones, 2003; Hines, Holweg and Rich, 2004; Liker, 2004; Shah and Ward, 2007). Even though lean as a concept is easy to grasp, it is difficult to implement for various reasons. Previous research (e.g. Sherrer-Rathje *et al.* (2009)) describe these challenges by highlighting failed attempts to implement lean practices at companies with no previous experience of lean. The challenges with implementing lean production can also be reflected in the study of Netland (2013) describing the occurrence of tailored corporate specific production systems, by which a production corporate is adapting the production system based on

TPS. This may be result of issues to adapt and sustain the effects of lean practices to the corporations' unique contexts.

Based on the current challenges of implementing lean production in multinational corporations the capability of creating value depends partly on the transfer of internal and external knowledge to the local context. The process of rolling out improvement programs based on adapting knowledge from one part of the corporation to another can be compared to the knowledge transfer process. Moreover, when a production plant adapt a global standard and use the skills and capabilities of global practitioners in the MNC the knowledge needs to be transferred from one part of the organization to another. As described by Nonaka and Takeuchi (1995), the transfer of knowledge is in general a very challenging assignment because knowledge is not tangible and usually get defragmented across the organization. Also described in literature, lean transfer is a complicated process due to the combination of for example technical and analytical tools ("hard practices"), and teambuilding and employee training ("soft practices") (Shah and Ward, 2007; Danese, Romano and Boscari, 2017).

Findings

Context of the production plant

The roll-out case was initiated by the top management team at a production plant located in a western country, which is a part of a multination corporation. The corporation is active within the pharmaceutical field which includes development of new medicines as well as production. With more than 60.000 employees at 30 different production plants located in 18 different countries, the production plant in this study is one of the largest.

The organization has lean practitioners' positioned both on a global and local level. Locally the structure can differ between plants depending on the context. The global lean practitioners have responsibility to lead group-wide improvement programs targeting several production plants for example assessment programs or developed global standards. Some standards are considered mandatory and others optional for the production plants to adopt. At the production plant in this study there are lean practitioners at a central level supporting the entire plant ("central lean support" in Figure 1). Furthermore, other lean practitioners support the management group locally at the seven business units of the plant ("local lean support" in Figure 1).

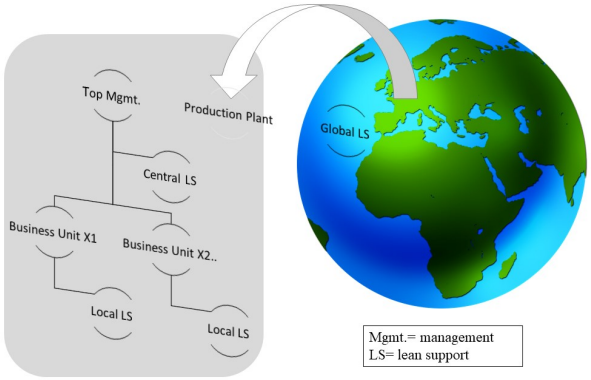

Figure 1: Overview of lean practitioners' organizational structure

The lean practitioners on local-central level has often responsibility in the development of business processes through global and local networks. In practical means that imply knowledge transfer between practitioners in binary directions. The aim of process networks is to constantly develop the process to the “best practice” of the corporation.

In this context, a group-wide assessment program identified gaps of desirable capability in a certain lean method. The assessment was partly based on adoption of global standards. There was a deviated view among lean practitioners whether the production plant complied with the mandatory global standard. This was one of the triggers for the top management to decide a rapid roll-out program aiming the entire plant.

Describing the planned roll-out

The roll-out program consisted of three components, see Table 1 and Figure 2. The first component, an e-learning targeting the entire site on individual level. Purpose of the e-learning was to create awareness, provide interactive training and enable follow up of the training. The second component was training by global lean practitioner to all lean practitioners at the production plant and the top management. The training was focused on both the purpose of the roll-out, and knowledge transfer of the global standard. The third component was the change from current template to the new global standard template.

All components were ought to be rolled out rapidly, within a few months, to the entire plant (see left in Figure 2). The roll-out program was planned and lead by top management starting with component 2, training of the highest level of management. Parallel to component 2 shortly thereafter component 1 should be available and target individuals. Early on at the decision stage some stakeholders where involved; global and local lean practitioners (both central and at business units).

The purpose of training (component 2) was to involve all managers with the starting point of top management, which in turn trained the next level of management with optional degree of support of lean practitioners at respectively business unit (see Figure 2).

Table 1: Overview of the components in the roll-out program

	COMPONENT 1	COMPONENT 2	COMPONENT 3
INTENSION BY TOP MANAGEMENT	e-learning: - targeting all individuals - awareness and support for component 2 and 3 - enable follow up	Training: - global lean practitioner - global training material - targeting groups of: a) lean practitioners b) management c) support functions d) shop floor	New template: -Adoption of a global standard (best practice) - Apply to mandatory global standard
ACTUAL ROLL-OUT	Delayed due to external part (translation to local language).	- Informational training to lean practitioners, with discussions - All managers trained on time - "Clinics" formed for lean practitioners - Roll-out at business units flexible but provided deadlines - Different approaches on respectively production line within business units	- No changes to template - Implemented on various times on different production lines. - Deadlines by top management
TYPE OF KNOWLEDGE TRANSFER	Explicit and tacit	Explicit and tacit	Explicit

The actual roll-out

The actual roll-out of the program, (see right in Figure 2), did not completely compile with the planned. The major deviation was a delay of e-learning (component 1). The e-learning could not be rolled out due to delays of translation of global learning material to the local language. Some frustration and confusion was noted due to challenges with scheduling training time for operators when the e-learning was not available on set time. Likewise, information of coming changes in template spread in the organization and entailed increased pressure of managing questions before received information and training. Moreover, compromised communication with external parties was the reason of the delay.

The training of all management levels were executed according to set deadlines. So, managers of all business unit were provided with information of the change and need of support by lean practitioners varied among them. At "Unit X" the management team firstly used provided information, and upon need for practical training adjusted information material to the local context. Prior to management meetings the lean practitioners at Unit X had a preparative training session with support of central lean practitioners. One of the local lean practitioner supported to a major part by training the lower management levels. In terms of optional design of the roll-out at the business unit's, only deadlines were decided by top management. In addition, a new component was developed (called "Clinics" see Figure 2). Whereas the purpose of hands-on training by all lean practitioners with new template. Held by the global lean practitioner at two occasions and was optional to attend.

Above all, despite clear definition by top management for successful implementation the actual roll- out program was considered as successful in the means of all managers being trained (component 2). Furthermore, after 20 weeks 57 % of all employees received training, which was considered acceptable.

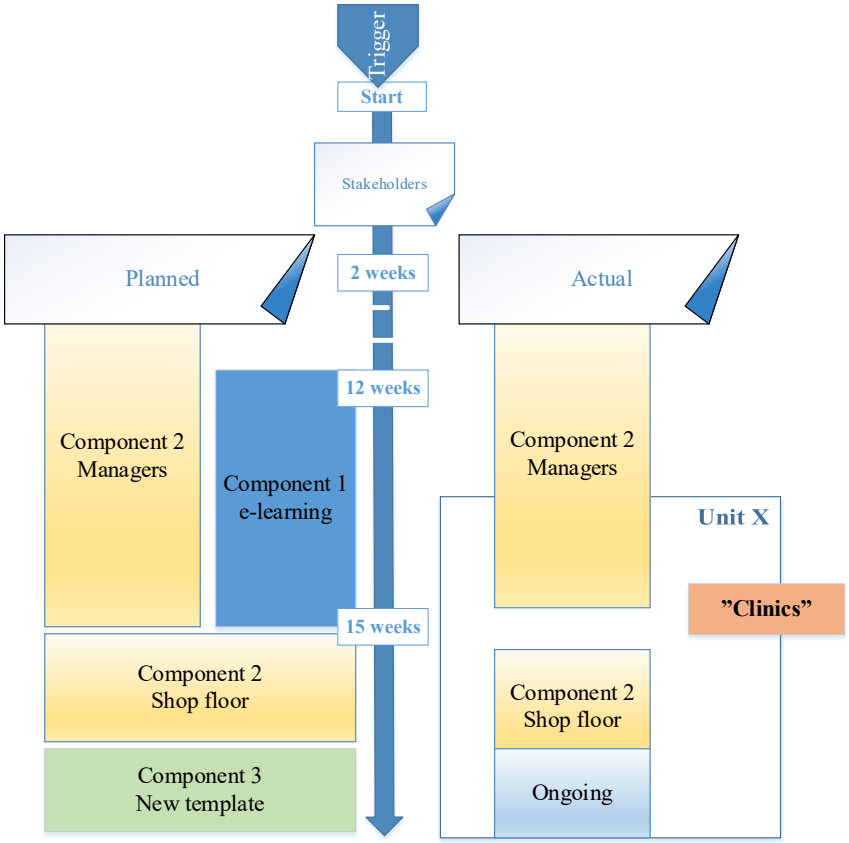

Figure 2: Scheme of planned (left) and actual (right) roll out program

During the training of the local lean practitioners, it came across that there were contradictions between the global and local views of current ways of managing the particular lean method at the production plant. It also came across that the purpose of the rapid nature of the roll-out was not well understood and there was some degree of lack of transparency in the communication from top management as to what the decision was based on, for example that early inclusion of stakeholders and comparisons of old template with the new template was done.

The emphasis on new template (component 3) was predominant in all levels of lean practitioners. During discussions regarding issues around the decisions of mandatory and optional standards on a global level the feeling of "loss of power" was expressed for example, one central lean practitioner commented:

"I have the feeling that the global people take over",

Then again, unexpected changes of opinions were also identified. Some individuals changed their view of global and local collaboration.

The new template was perceived as complicated and difficult by lean practitioners, managers and other support functions. A reaction to the rapid roll-out was by one lean practitioner exemplified in this quote:

"I do not understand what we put energy on. The good thing is that they [top management] took the decision and they are responsible for it... but the template is not going to solve the problem".

Yet, changes in the view regarding the template were noted over time, for example, several of the early involved persons from different functions could after approximately

3 months agree on that the new template is an improvement compared to the current template. One local lean practitioner said:

"At first, I thought 'No!' But I guess I am over that phase in my change curve and I think the new template is better".

This got confirmed by several other persons from other business of units. With this in mind, the reactions of operators were positive and realistic in the means of that they could see benefits at the initial training session of the new template and understanding that supplementary training is needed. Thus, responses to change of template were perceived as more positive in contrast to the ones of management level. Exemplified here after a training session of management at Unit X:

"I experienced that they over complicated it .. the new template is certainly messier, but they had the same reaction as I did in the beginning".

In combination with the frustration of the rapid roll-out program it was mentioned several times that top management being responsible for the decision was viewed as positive in the motivational aspect of transferring the knowledge to lower levels in the organization.

Discussion

The purpose of the roll-out program was to increase the capability concerning a specific lean method and adopting to a global standard seen as "best practice". The combination of components 1-3 (in Table 1) had the intentions to transfer knowledge to individual and group (lean practitioner and management) levels of the organization. This was performed through a global lean practitioner and global standard in writing as the transfer agent. Explicit knowledge was transferred in every component; global learning material in e-learning, global learning material in training of top management and lean practitioners and global standard in form of a new template (see Table 1). However, with major emphasis on adapting to a global standard (i.e. explicit knowledge), component 1 and 2 in the roll-out program was also dependent on tacit knowledge. Moreover, the tacit knowledge of the global practitioner was of use in sessions in form of discussions and interactive hands-on training created in form of "clinics" (see Figure 2). The flexibility of each business unit to design the roll-out further could be seen as a strength to create new formats of training if needed even though it is not predefined by top management. Suggested here is a new component "Group level- Tacit knowledge creation" to be considered (see Figure 3). Even though the lack of outspoken intention to transfer the tacit knowledge it is seen as a success factor to give the business units autonomy for a part of the roll-out program. However, the success of the program was not measured through gained capabilities but received training. It could be argued the roll-out program was based on management of information rather than knowledge.

The roll-out program is not considered successful in the perspective of accomplishing a transfer of all components to set deadlines. The major deviation was the delay of component 1, e-learning to all individuals of the production site. However, the intention was to create awareness and be support through the roll-out program, yet did not stop the progress of the other components. Despite the clear issue with the delay due to external parties, such as translation of documents to local language, it was a factor of success to design the program to not have dependent components in order to enable the intensity of the roll-out. Likewise, the e-learning was built to be interactive to train individuals by using explicit knowledge but information was needed to be typed in and therefore categorized as "tacit knowledge creation" and is proposed to be a later component of the program (see Figure 3).

One approach to the difficulties to roll-out programs broadly, and also quickly, can be to build the roll-out program addressing these different success factors: means of transferring the tacit knowledge (e.g. global practitioner in MNC), group level as well as individual level, understanding of the transferred explicit knowledge and creation of own tacit knowledge.

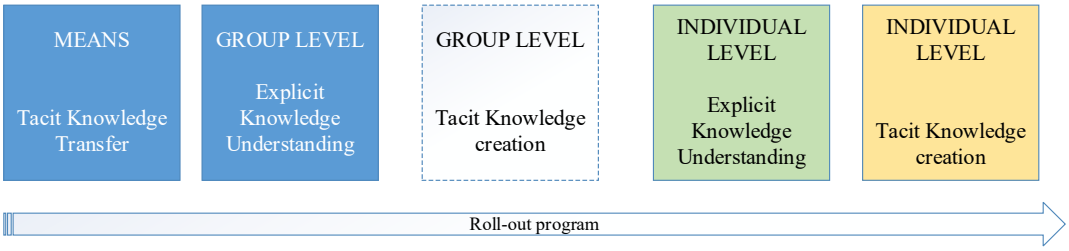

Figure 3: Suggestion of successful components of a rapid roll-out program

Several individuals of those involved early in the program stated an individual change after some time regarding the new template, thus could see benefits with the global standard. That is an indicator of the explicit knowledge in component 3 was not adequate and the other components was needed as a part of the program (see Table 1).

By rapidly rolling out a program widely at a production plant that leads to change may compete with other ongoing activities. If the time required for the program does not match with available time both frustration of involved actors, and decreased effectiveness of the program can occur. Thus, the frustration and resistance observed could reduce people's commitment (Senge *et al.*, 1999). Although the clear top management commitment in the roll-out program is seen as a success factor due to that it was a clear statement of importance of the specific capability, one should address the risk of organization inertia if multiple programs or activities are ongoing simultaneously.

Conclusion

Recommendations in case of future rapid roll-out programs is to involve stakeholders early, consider type of knowledge to be transferred when designing the program, involve at both group and individual level and secure external deliveries and communication prior to initiation of program. The findings contribute to knowledge of how to improve the design and planning of roll-out programs initiated by top management of production plants belonging to a MNC. This is of relevance to industry, because rapid roll-out programs locally at single production plants can be triggered as result of group-wide MNC improvement programs. The key success factors for a rapid roll-out process can be used prior the decision for more sustainable effects. Such support affects the quality of the roll-out process, for example by reduced resistance level and less frustration. Likewise, the method of rolling out programs rapidly should only be wisely considered dependent on type of knowledge that should be transferred. This in turn enables corporations to deliver better value to their society of end customers by the potential performance gains of successful rapid roll-out processes, in the field of production management in general and lean management in specific.

Limitations/implications

This study was not designed to follow all business units at the production plant. There were variety among the production units in the roll-out approach locally. Hence, this

study is only capturing a smaller context of the production plant. Also, due to that the roll-out program is still ongoing there is minor data from shop floor level which may weaken the operational point of view. Furthermore, effects on actual business results cannot be stated at this point and needs to be followed in a longitudinal study.

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How To Write and Publish a High-Quality [Systematic] Literature Review in the Domain of Operations and Supply Chain Management?

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Abstract

Whereas systematic literature reviews and systematic reviews have become common practice for the domain of operations management and supply chain management, guidelines have been confined to which steps and processes should be followed; the aim of this paper is to not only discuss some of the steps in more detail, but also to provide guidelines to what constitutes a high-quality literature review, whether systematic or not.

Keywords: Literature reviews; operations management; supply chain management; systematic reviews.

Introduction

Whereas literature reviews are part of any scholarly study into operations and supply chain management, guidance on how to conduct literature review is relatively scarce, except for what are called systematic reviews aka systematic literature reviews. There is some general guidance on how to conduct literature reviews, such as Green et al. (2006), and protocols for literature reviews (for example, Cronin et al., 2008; Tranfield et al., 2003), some of them directed at operations management, for instance, Thomé et al., (2016), albeit that the latter is a re-iteration of techniques for systematic reviews derived from practices in the domains of medicine and nursing. However, based on recent submissions to ranking journals (e.g. Journal of Manufacturing Technology Management) and practices found in published literature reviews, there are points that deserve attention by authors interested in publishing high-quality literature reviews.

Objectives of Paper

How to conduct an appropriate literature review is a contentious point of discussion. There are those that advocate systematic reviews and systematic literature reviews. For instance, Seuring and Gold (2010, p. 552) advocate the use of content analysis to this purpose, but also note that this often falls short of expected reporting standards in the case of supply chain management. Contrastingly to those favouring there are calls that systematic approaches to literature reviews are limiting useful outcomes. For example, Boell and Kecmanovic (2010; 2015) demonstrate the limitations of systematic approaches to literature reviews that have become more popular; instead they see literature reviews as a creative process where the state-of-the-art knowledge captured by literature is constantly

assessed on its value. However, both views indicate that literature reviews should be capturing extant knowledge in a meaningful way and appropriately reported, including the rationale for the approach.

Scope and Outline of Paper

To this purpose, this paper will offer guidelines for what is to be expected from high-quality literature reviews; these guidelines can be used by doctoral students, early career researchers, academics and members of editorial boards to conducts and to present these reviews. These guidelines should be read in addition to existing guidelines. The scope of the current paper does not include propositional papers, because these serve a different purpose.

This paper will start with how literature reviews contribute to the rationale and content of empirical studies. This leads to consideration of quality criteria for literature reviews. Afterwards different types of literature reviews are presented related to these quality criteria. This will be followed by how the contribution to knowledge can be identified. Some practical issues are also highlighted before the concluding section of the paper.

Positioning Literature Reviews

Literature reviews are not just a matter of doing them, but play a role in the research process and the design of research studies; however, particularly for operations management, much attention has paid to guidance for specific research methods, while somewhat neglecting the role of literature reviews contributing to research processes and enhancing the quality of studies. A case in point is Forza (2002, pp. 160, 187) who refers to literature to be consulted about content validity, constructs of surveys and theoretical underpinnings, albeit detailed guidance is missing. The same assertion, including the consultation of experts, already appears in Flynn et al. (1990, p. 266), when advocating empirical research for operations management in general, and Malhotra and Grover (1998, p. 412) specifically for surveys. In the same vein, McCutcheon and Meredith (1993, p. 250) indicate that postulates should be derived from literature for case study research. Stuart et al. (2002, p. 423) take it further by stating: 'the implication we draw is that better (i.e. publishable) research papers start from a broad literature base.' This all indicates that the use of literature should aim for achieving content validity ex ante empirical research methods and development of practical applications; therefore, the quality of literature review determines the suitability for this purpose.

However, literature does not only play a role for achieving content validity in empirical studies, but should also be used for assessing external validity. For instance, Voss et al. (2002, pp. 216–7) advise to compare emergent conceptualisations from case study research with existing scholarly knowledge. A case in point is Dekkers (2018, pp. 272–3) who compares methods used for designing organisational structures based on group technology in three cases with five reported cases in literature; this provides evidence for da Silveira's (1999, p. 470) propositional parameters that determine the choice of method for cell formation. This illustrates Voss et al.'s point about comparing conceptualisations from case studies with related ones found in literature, thus increasing external validity of findings from empirical research.

Furthermore, also for achieving rigour and reliability scholarly knowledge should be integrated in a study. A particular point is the design of a study, where beyond generic guidance for detailing a research method, specific points could be addressed. A case in point is the use of focus groups in empirical studies. In addition to generic guidance found in books, such as Cresswell (2014), specific publications have addressed how to

enhance this research method in order to achieve more reliable outcomes. For example, Kidd and Parshall (2000, p. 298–9) present recommendations for the recording of focus groups, the number of researchers per focus groups, their roles and the checking of any tentatively identified issues for confirmation or clarification. Such detailed guidance for a specific derived from a literature review will lead to increasing the rigour and reliability of a specific empirical study.

Assessing Quality of Literature Reviews

In addition to literature contributing to the construct validity, external validity, and design of research methods for empirical studies, quality criteria for research also apply to the literature review itself; an issue we intend to explore now. A starting point is that most commonly literature reviews can be viewed as qualitative research. There are many publications addressing different aspects of the quality of qualitative research, with Mays and Pope (2000), and Walsh and Downe (2006) being publications in point; note that many of these writings are set in different disciplines, because looking into the quality of qualitative research in operations and supply chain management is mostly limited to case studies (e.g. Seuring, 2008) and action research (for example, Näslund et al., 2010). If a literature review is considered akin to qualitative research, then there is abundant writing available ranging from discussing criteria (for instance, Tracy, 2010) to reporting standards (e.g. O'Brien et al., 2014; Tong et al., 2007). Setting aside the worthiness of the literature review in these publications for later, conventional criteria for qualitative research include internal validity, external validity, reliability and objectivity (Guba and Lincoln, 1989 cited in Halldórson and Aastrup, 2003, p. 323) and in similar vein, objectivity, internal validity, external validity and utilisation (Miles and Huberman, 1994, pp. 277–80). However, a literature review is different from qualitative research in terms of data collection and analysis. Therefore, some criteria or only aspects of criteria for may apply to literature reviews; these will be discussed next to provide guidance.

With regard to validity, the literature review needs not only to provide a close examination of retrieved publications, but also it self to provide a coherent skeleton from a critical perspective. In this respect, for qualitative research in logistics, Halldórson and Aastrup (2003, pp. 323–4) posit that craftsmanship and trustworthiness play a major role in creating validity. According to them, craftsmanship refers to checking, questioning and theorising (ibid., pp. 323, 328–9). Applied to a literature review this means that retrieved studies should be scrutinised on their factual contribution and placed in the wider context of a literature review. A case in point is Dekkers et al. (2013, p. 317), when they come across the study by Antonio et al. (2007) on the impact of product modularity on competitive capabilities and performance of manufacturing firms; they duly note the authors' circular reasoning for the origins of modularisation and the performance criteria used in the study. This also implies that research methods used in studies should be evaluated on their appropriateness. One way of doing so in a literature review is by triangulation, a common method for assessment in qualitative research (Mays and Pope, 2000, p. 51). By comparing two or more publications with different research methods or with different samples, an appraiser will look for patterns of convergence or divergence. The notion of trustworthiness adds further depth to a literature review, using Halldórson and Aastrup's (2003, p. 326–9) description. Credibility, one of its qualities, means that the context of relevance to the literature review is used explicitly to evaluate studies. Such is explicitly stated by Mazzocato et al. (2010, p. 376) in the rationale about lean thinking for health care presented in their introduction and later (ibid., pp. 377–8) for the context of specific health care provision when evaluating other studies. In this reasoning, also

Table 1: Overview of quality criteria for literature reviews

Criterion	Aspect	Qualitative Research	Literature Reviews
Craftsmanship	Checking	Control for researcher bias	• Two or more researchers conducting evaluation of publications independently. • Seeking advice from experts.
		Triangulation	• Comparing findings of a study with others: methods, samples and analysis. • Patterns of convergence or divergence.
		Considering deviants/ searching for extreme cases	• Explicitly searching for cases that do not fit with existing conceptualisations, theories, methods and data.
		Search for contradicting evidence	• Explicitly searching for falsification in literature. • Considering critical reviews of theories, conceptualisations and methods.
		Exploring competing explanations	• Abductive reasoning. • Considering different aspects, context and causal relationships.
		Feedback from others	• Supervision and mentoring. • Seminars, conferences, etc.
	Questioning	Searching for different interpretations	• Different viewpoints to be considered. • Different values and priorities.
		Using different questions for evaluating data	• Generating alternative questions for appraising studies.
	Theorising	Evaluating theoretical views	• Comparing theories, conceptualisations and methods. • Searching for limitations of theories, contingencies.
		Falsification of knowledge claims	• Searching for tautologies. • Detecting underlying assumptions. • Deductive and reductive reasoning.
Validity		Triangulation	• Comparing findings of a study with others: methods, samples and analysis. • Patterns of convergence or divergence. • Considering contingencies.
		Credibility	• Comparison of contexts. • Patterns of convergence or divergence. • Generalisation or instantiation through isomorphism, homomorphism and abstraction (classification, aggregation, generalisation).
Dependability		Tracked invariance	• How invariance is related to evidence and methods used.
Rigour			• Relatively delimited question(s) for review. • Review protocols. • Coding (if appropriate).

transferability as quality of trustworthiness is found in terms of whether findings from one context can be applied in other contexts. Such would require considering isomorphism (Dekkers, 2017, p. 64; Halldórson and Aastrup, 2003, p. 323) and levels of abstraction (Dekkers, 2017, pp. 43–52; Timpf, 1999). This means that the basis for high-quality literature reviews is found in craftsmanship (checking, questioning and theorising), searching for triangulation, consideration of context and abstraction from the perspective that a literature review is a critical work; see Table 1 for an overview and more detail.

Occuring as a second main criterion for literature reviews, derived from qualitative research, is reliability or dependability (the latter related to trustworthiness as quality of qualitative research). Reliability relates to the quest for invariance (Halldórson and

Aastrup, 2003, p. 328), which in the case of a literature review, principally tells that outcomes should be the same, no matter the evidence base that is accessed and the method for the appraisals; subtly different, dependability considers traceable invariance. This quest for invariance can be considered akin to the principle of theoretical saturation (Steenhuis, 2015, p. 356) for case studies; invariance for literature reviews occurs when no longer inferences and conclusions change when subsequently publications are added to the literature review. To avoid complacency, craftsmanship in literature reviews includes searching for publications with extreme and deviant findings, thus meeting the subcriterion for falsification for qualitative research (Halldórson and Aastrup, 2003, p. 328–9). Consequently, this indicates that a literature review should indicate whether outcomes of its appraisal would benefit from further studies applied to similar samples (confirmatory research), different samples (either generalisation or instantiation) or different research methods (triangulation).

Following another, fourth criterion – confirmability – Halldórson and Aastrup (2003, p. 328) suggest that data should be tracked back to their sources and an audit process. Normally, such should be made evident in empirical studies. However, for the case of literature reviews, this could be seen as not only accurately citing or paraphrasing sources, but also providing coherent reasoning. In addition, this criterion could also be asserted by external reviewing; in the case of literature reviews, this could be 'independent' academics reviewing a literature review, but also reviews and feedback from seminars and conferences. Evidencing how reviewing and feedback has shaped a literature review may be a point to be addressed in publications, but is hardly common practice, though worthwhile considering.

Particularly systematic approaches to literature reviews add rigour as an additional criterion for quality. In these approaches, called systematic qualitative literature reviews and systematic quantitative literature reviews by some (e.g. Green et al., 2006, pp. 145), the way publications are evaluated is driven by a protocol and the analysis follows also pre-set patterns. It should be noted that Boell and Kecmanovic (2010, p. 131; 2015, p. 169) advocate that systematic literature reviews are confined to clearly delimited topics about which sufficient publications are available; for the latter, it may be noted that this will most likely depend on how much robust evidence is available. This means that although rigour can be added by developing a protocol for a set review question, for generic literature reviews this may be too restrictive for developing research questions during process of the literature review.

Types of Literature Reviews

In addition to considering how criteria can be used to improve the quality of literature reviews, another question what different types of literature reviews are. It ranges from limited literature reviews, in terms of number of publications, to extensive literature reviews. The first can commonly be associated with statistical analysis and econometric modelling, in which authors get quickly to the point about the usefulness of their research and then go on with the empirical study. Typically, these include also assessment for the rationale of variables to be used. Examples of this category are Çankaya et al. (2019) and Green et al. (2019). More extensive literature reviews include both the pros and cons of theories, conceptualisations, methodologies and methods to arrive at an evidence-based position to what extent there is a gap in scholarly knowledge and how to advance research. Instances of extensive, informative literature reviews are Boer and Boer (2019), and Newman (2003). At the extreme end of the typology are the systematic literature reviews and systematic reviews; the former follows a systematic approach to a review

question, whereas the latter is aiming at the impact of an intervention, thus having a narrowly focused perspective. Cases in point of these systematich approaches for the operations and supply chain management are Colicchia and Strozzi (2012), and Stone (2012). The practice of limited literature reviews may be acceptable for some research, but our attention in this paper has gone and will go to what could be classified as extensive literature reviews that are not restricting the rationale to publications that favour a certain stance or specific study.

In this typology, the criteria for the quality of literature review should be applied in a different manner to each archetype. In a limited literature review the aim is identifying relevant variables for constructs and causal relationships that are of interest. Meeting the quality criteria for this type of literature review means investigating 'questioning' and 'theorising', searching for falsification, evaluating triangulation and looking at contexts of specific (empirical) studies. When undertaking an extensive literature review such includes also the consideration of abstraction mechanisms – classification, aggregation and generalisation –, and investigating for invariance.

Identifying the Contribution to Knowledge

Particularly, with the number of submissions of systematic literature reviews increasing, it is important that the contribution to academic knowledge is ensured. Some submissions in their search of literature find other existing reviews, sometimes published a few years before, which arrive at similar findings, and despite such claim their contribution as being original and novel. This implies that any literature review should start with positioning existing reviews on the topic or related to the topic: what will the literature review offer what others have not yet looked at. This also implies then that the review questions should be different from existing writings. Such should be assessed a priori, and, therefore, part of the introduction of a literature review.

Furthermore, a literature review should not be focused on a single outcome or single model. In general, outcomes of literature reviews should cover a wide range of topics and pinpoint implications for further studies. An example of this practice is found in Salgado and Dekkers (2018) providing a range of topics, and guidance for doctoral students, early career researchers and research programmes. This implies that the a priori contribution to knowledge should be evaluated and presented ex post.

Some Practical Points for Literature Reviews

In addition to the quality criteria for literature reviews, there are some practical points that emerged from reviews of submissions to a variety of journals. These points also reveal practices for writing literature reviews (and what should be avoided).

Understanding of Conceptualisations and Key Terminology

In addition to demonstrating knowledge about the state-of-the-art in a domain, conceptualisations and key terms (and their alternative formulations) should be understood. A recent example is a study that looked at the term 'supply chain management' only, but when the reviewers extended the search with 'supply chain' and 'supply network' it appeared that others already described the outcomes of the submission. Such examples show that the actual outcomes of a literature review are dependent on the formulation of keywords and knowledge about terminology in a domain.

Furthermore, key conceptualisations and key terms should be defined. A case in point is the term 'business competitive landscape' appearing as a key concept in a submission to a ranking journal; however, this term is hardly used by other publications and never in the

core of their argumentation. In the submission no definition or description is provided, this leaves open with is meant with this key term and also leads to questions about the empirical research that was undertaken.

Close and Critical Reading

Such extensive literature reviews consider evidence or reasoning presented in other papers rather than just lifting statements from publications. This should be reflected in adequate paraphrasing. Inadequate paraphrasing happens frequently. For example, Dekkers and Kühnle (2012) are paraphrased by de Moura and Botter (2017, p. 883) for the following three statements:

- *Factors such as financial sustainability, ways of relating to their supply chain and customers, reliability and recognised quality of products and service are key points that shall be taken into consideration when making strategic decision for a company to become globally competitive.*
- *Thus, it is essential that companies make investment as a way to stand out from competitors and gain recognition.*
- *It is also essential to integrate innovative business strategy of a company and its partners.*

However, none of these statements can be traced back to the actual text nor can they be considered interpretations of it. This shows that paraphrasing must meet a few criteria to be meaningful:

- The actual meaning of the fragment in the cited source should not be altered. However, it is not necessary to include all details from the original passage.
- In addition, one point made in the cited fragment should not be stressed more than others. If one point needs to be stressed more, because of the direction of the literature review, then such should be mentioned.

The same page of de Moura and Botter (2017, p. 883) shows that for the same sentences a considerable number of other publications are cited, some repeatedly for the same three statements. It is unlikely that may studies have similar findings or reasoning and indicates that literature has not been well consulted. Moreover, this practice of does little justice to the authors of the works cited. This means that close reading and understanding, sometimes subtle differences, of existing publications is a prerequisite for producing high-quality literature reviews.

In addition to close reading and appropriate paraphrasing, both favourable and critical publications should be considered. An example is the literature review by Dekkers (2011, pp. 937–40) when addressing three theories for outsourcing; not only does it present how transaction cost economics, the resource-based view and the notion of core competencies can be used, but it also includes arguments from other works that have addressed deficiencies and incorrect application to domains. Thus, a high-quality literature review does not only consider supporting arguments for points made, but also examines those works that have been critiquing canonical views.

Retrieval of Sources

From published reviews it has become apparent that search strategies have changed. Quite a number of authors tend to use a range of publisher-specific databases. A case in point is Akbari (2018, p. 1552), who uses six of these publisher-specific databases; however, no rationale is presented why the databases of the publishers Hindawi, Inderscience and Sage have not been consulted. Ultimately, the purpose of a search strategy is to find as many as possible relevant publications (it is almost impossible to find all). Therefore, it is more

efficient to use generic databases, such as ABI/INFORM, Google Scholar and Scopus; in this respect, Green et al. (2006) recommend using at least two databases. Note that knowing about specific databases is helpful; the retrieval of publications through ScienceDirect is a subset of those found through Scopus, both owned by Elsevier. Sometimes, this subtle different escapes authors, such as Grubic (2014, p. 102). Also, complementary search strategies, such as snowballing, could improve finding relevant publications (see Greenhalgh and Peacock, 2005; Wohlin and Prikladnicki, 2013). This implies that the base for a solid search strategy can be found in the use of appropriate generic databases and search engines in combination with complementary search strategies.

Some authors use specific journals for retrieving relevant publications. Such is the case for Swanson et al. (2017, p. 305) identify eight journals to look into theories used for research into logistics and supply chain management; the rationale for these journals is derived from a preceding study they seek to replicate partially. Note that in case specific journals are selected, the quality of a journal is not necessarily related to the quality of a publication.

Analysis of Sources

After finding relevant sources, the subsequent analysis should be sufficiently in-depth from the perspective of the review questions. This extends to looking into origins of concepts, for example value stream mapping (e.g. Nowak et al., 2017) originates in the ASME processing mapping standard. But it also covers breaking down theories or concepts; a case in point is the decomposition of the resource-based view found in Amit and Schoemaker (1993). This analysis should lead to novel conjectures, for a manuscript to be worthy to be published.

Reporting of [Systematic] Literature Reviews

In addition to some guidelines for reporting of literature reviews, all accounts in a literature review in an academic journal should lead to conjectures. A frequently used aspect of literature reviews is the journals in which publications have been found. However, seldom does this lead to conjectures. When writing authors should ask themselves what other academics can take away from reading a literature review beyond the research the authors have in mind. The danger here is that literature reviews remain to descriptive and in this manner do not contribute to advancing research into the domain.

Also, Seuring and Gold (2012, p. 552) draw attention to the reporting, while stating that literature reviews on supply chain management often use content analysis without denoting such explicitly, they lack a detailed description of data gathering, a rationale for the pattern of analytic categories, and quality criteria such as replicability, reliability and validity. In this sense, Schlosser (2007, p. 2) stresses the importance of reporting the protocol used in the case of systematic literature reviews. Thus, reporting is of profound importance to literature reviews, even though their criteria seem to apply in the first instance to systematic literature reviews. Even when reporting the latter, all elements of a publication should lead to conjectures that build towards the finding. A common element is the reporting of journals in which relevant publications are found; often these do not lead to any conjectures or arguments, and thus, it can be questioned what should overviews contribute to such publications. In the same spirit, Lin and Evans (2012) report in a more generic form that attention should be paid to writing adequate literature reviews.

Concluding Remarks

A word of caution may be in order. Hammersley (2007, pp. 300–1) points out that though generic criteria for qualitative research, in our case the literature review, may apply, each piece of work should be assessed on its own merits. Generic criteria are found in works like Poortman and Schildkamp (2012) in addition to some publications mentioned before in this article. These criteria tend to place emphasis on transparency and rigour. Such criteria gravitate researchers to more systematic approaches, however, these have a downside, which is that they require a more specific review question (or questions). This means that literature reviews should be adequate to their purpose rather than just following a protocol or sets of guidelines.

In this respect, it should not be forgotten that literature reviews serve three purposes. The first one is that they justify particular empirical research by exploring its necessity and how it builds on extant knowledge. A second purpose is that an overview of what has been accumulated as scholarly knowledge. A final purpose is that literature reviews provide pathways for research and agenda for researchers beyond specific studies. For all three purposes, literature reviews should be compelling and inspiring, above all!

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The patterns and productive efficiency of global firms' working capital management

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Abstract

Effectively managing working capital is a critical issue in corporate finance and recently in the operations/supply chain and finance interface area. Therefore, this paper intends to examine the patterns and productive efficiency of global firms' working capital management (WCM) during and after global financial crisis for the period of 2008-2015. To do so, we investigate the relationship between the elements of cash conversion cycle (CCC) and return on sales (ROS). The purpose is to discover the differences, trends, and productive efficiency of WCM by different groups of firms with different profitability patterns in different industries.

Keywords: Working Capital Management, Data Envelopment Analysis, Forbes Global 2000 Time Series Data

Introduction

Effectively managing working capital is an important issue in corporate finance. It is mainly composed of a major portion of a financial part (Weston and Brigham, 1979). It could affect the firm's profitability, risk, and value (Smith, 1980). Specifically, working capital management is an essential component of widely firms' strategy to create shareholder value. It is a result of the time lag between the expense for the purchase of raw materials and the collection for sales of finished goods (Shin and Soenen, 1998). It contains a tradeoff between risk and profitability. Increasing the profitability tends to increase risk, and reversely, focusing on risk reduction tends to decrease potential profitability (Teruel and Solano, 2007). Cash conversion cycle is a key element in working capital management. It could reflect how much to invest in inventory and how much credit to take from suppliers (Gitman, 1974). It is a performance measure for a company to manage working capital (Richards and Laughlin, 1980).

Previous studies have analysed whether shortening the cash conversion cycle has a positive or negative effect on the firm's profitability. Many studies found that efficiently managing cash conversion cycle tends to lead to higher profits, suggesting its importance in corporate finance management (Gentry et al., 1990; Jose et al., 1996; Shin and Soenen, 1998; Wang, 2002; Deloof, 2003; Lazaridis and Tryfonidis, 2006; Padachi, 2006; Teurel and Solano, 2007; Nobanee et al., 2011; Yazdanfar and Ohman, 2014; Linh and Mohanligam, 2018). Further, some studies have analysed the effect of the firms' cash conversion cycle in various industries in different countries (Raheman and Nasr, 2007;

Teruel and Solano, 2007; Uyar, 2009; Nobanee et al., 2011; Enqvist et al., 2014: Chang, 2018). However, our study provides the different profiles of cash conversion cycle and its elements among groups of firms with different patterns of ROS during and after crisis. It is supposed to empirically investigate the relationship between cash conversion cycle and profitability ratio (ROS) for 'Forbes Global 2000' firms in automobile industry during (2008-2011) and after (2012-2015) global financial crisis for the period of 2008-2015. Its purpose is to provide better understanding and management tool to deal with cash conversion cycle in different time periods with different characteristics among groups.

The rest of this paper is organized as follows. In section 2, literature review is presented. In section 3, data and variables are described. In section 4, the methodology is presented. In section 5, analysis results are presented. Finally, the conclusions are discussed.

Literature Review

Managing working capital is an important part for firms in corporate finance management. Cash conversion cycle is a critical component in working capital management. The cash conversion cycle is typically defined as days of inventory outstanding plus days of accounts receivable outstanding minus days of accounts payable outstanding. Firms effectively can increase or decrease cash conversion cycle components such as the days of inventory outstanding (DIO), the days of accounts receivable outstanding (DRO), and the days of accounts payable outstanding (DPO) according to their policies to improve profitability.

Prior studies reveal that there are a positive significant relationship and a negative relationship between cash conversion cycle and profitability. Hawawini et al. (1986) argued that firms could increase their profitability by managing the number of days of inventory outstanding to a reasonable minimum. Jose et al. (1996) asserted that active working capital management policies increase firms' profitability. Shin and Soenen (1998) argued that working capital management influences firms' profitability and liquidity. Reducing working capital management leads to higher profits. Wang (2002) analysed Japanese and Taiwanese firms during 1985-1996 and showed shorting cash conversion cycle could increase operating performance. Deloof (2003) analysed that large Belgian firms from 1992 to 1996 can increase profitability by reducing the number of days of accounts receivable outstanding and by reducing the number of days of inventory outstanding. Teruel and Solano (2007) found that minimizing working capital investment would have a positive effect on the profitability of the firms. Lue et al. (2009) showed that if firm's value increases, cash conversion cycle will be decreased. Gill et al. (2010) drew a conclusion that if cash conversion cycle is maintained at optimal level, firms could increase their profits. Oladipupu and Okafor (2013) argued that there is a positive relationship between firm's working capital management and profitability.

However, Afza and Nazir (2007) analysed that there is a negative relationship between cash conversion cycle and profitability. Raheman and Nasr (2007) demonstrated a negative relationship between cash conversion cycle and profitability. Uyar (2009) observed there is a negative relationship between working capital management and profitability. Linh and Mohanligam (2018) indicated that cash conversion cycle has a negative relationship with profitability. Based on these studies, we could infer that firms could have industry benchmarks to manage their working capital management policies.

Data and Variables

- *Data*

The data used in this study was acquired from the Datastream database. It contains financial data of firms. It is panel data collected from the top 42 firms in the 'Forbes Global 2000' ranking in automobile industry for the period of 2008-2015. This period was divided into two sub-periods, during (2008-2011) and after (2012-2015) global financial crisis to reduce the effect from global economic conditions and better manage the patterns and productive efficiency of global firms' working capital management in different situations (Habib et al., 2013).

- *Variables*

In order to investigate the patterns and productive efficiency between working capital management and profitability ratios during (2008-2011) and after (2012-2015) global financial crisis for the period of 2008-2015, the return on sales (ROS) was used as the dependent variables.

With regards to the independent variables, we used the cash conversion cycle (CCC) as a key element in working capital management. It is defined as days of inventory outstanding plus days of accounts receivable outstanding minus days of accounts payable outstanding. In this regard, the number of days of inventory outstanding (DIO) was calculated as 365 X (inventories/purchases). It can affect the average number of days of inventory. Longer storage days indicate an inventory investment for a specific level of operations. The number of days of accounts receivable outstanding (DRO) was calculated as 365 X (accounts receivable/sales). It is the average number of days that the firms can receive payments from customers. The number of accounts payable days (DPO) was calculated as 365 X (accounts payable/purchases). The firms can make their payment commitments to their suppliers (Teruel and Solano, 2007). Considering the cash conversion cycle (CCC), we used the cash conversion cycle (CCC) and each element such as days of inventory outstanding (DIO), days of accounts receivable outstanding (DRO) and accounts payable days (DPO) separately. And we used the the logarithm of sales (lnsales) as control variable.

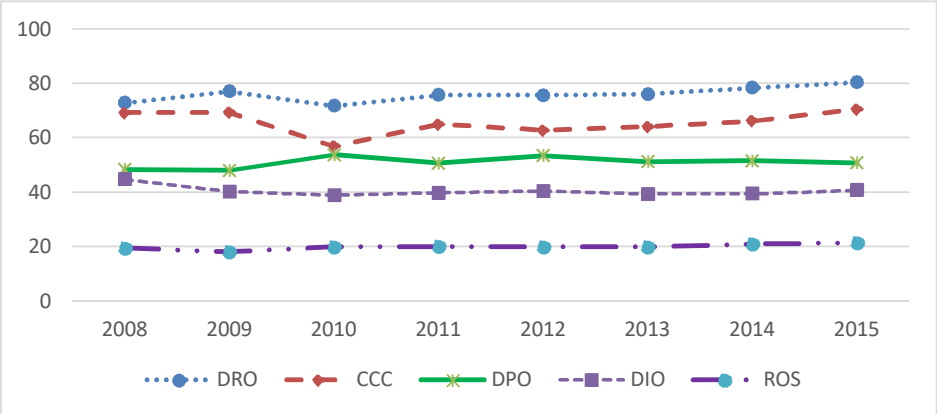
- *Descriptive Statistics*

Table 1 shows descriptive statistics about the variables used for the sample. These are means and standard deviations about variables during and after global crisis. Fig. 1 depicts patterns about descriptive statistics. As shown in Table 2, we divided ROS into four groups. Based on the firms' performance during and after global crisis, we found four patterns in the firms' performance, i.e., some firms show high performance pattern during global crisis while other firms indicate low performance pattern after global crisis.

Table 1 – Descriptive statistics

Global Crisis		During (2008-2011)				After (2012-2015)			
Year		2008	2009	2010	2011	2012	2013	2014	2015
DRO	Mean	72.9	77.1	71.8	75.8	75.7	76.1	78.5	80.4
	SD	39.8	43.8	38.4	43.3	42.8	44.1	49.9	52.0
CCC	Mean	69.3	69.4	56.9	65	62.8	64.2	66.3	70.6
	SD	49.6	50.9	47.4	49.1	49.2	48.3	51.0	52.9
DPO	Mean	48.3	48	53.7	50.6	53.4	51.2	51.5	50.7
	SD	22.0	25.7	22.7	23.7	24.2	22.5	24.4	21.0
DIO	Mean	44.7	40.2	38.9	39.8	40.4	39.3	39.4	40.8
	SD	21.5	14.8	14.6	17.0	16.0	15.3	15.7	15.8
ROS	Mean	19.5	18	19.9	20.1	19.8	19.9	21	21.3
	SD	7.2	7.9	7.7	7.0	7.6	7.9	7.7	7.6

Notes: DRO = days of accounts receivable outstanding; CCC = cash conversion cycle; DPO = days of accounts payable outstanding; DIO = days of inventory outstanding; ROS = return on sales



Notes: DRO = days of accounts receivable outstanding; CCC = cash conversion cycle; DPO = days of accounts payable outstanding; DIO = days of inventory outstanding; ROS = return on sales

Figure 1 – Descriptive statistics

Table 2 – Descriptive statistics of each group

Global Crisis		During (2008-2011)				After (2012-2015)			
Variables / ROS		DIO	DRO	DPO	CCC	DIO	DRO	DPO	CCC
High→High	Mean	44.3	80.3	49.4	75.2	41.6	76.9	45.7	72.9
	SD	3.6	7.4	5.8	8.8	2.8	5.0	4.5	7.8
High→Low	Mean	39.8	74.6	56.4	58.0	34.8	81.8	50.5	66.1
	SD	10.5	18.8	6.6	23.3	3.4	10.2	3.6	12.1
Low→High	Mean	37.1	72.3	51.7	57.7	37.9	79.9	60.1	57.7
	SD	5.4	6.1	9.5	12.9	3.1	10.3	4.0	12.7
Low→Low	Mean	46.1	68.4	37.5	77.0	49.9	66.8	41.8	74.9
	SD	4.8	4.2	7.0	9.2	2.4	4.5	4.8	6.1

Notes: DIO = days of inventory outstanding; DRO = days of accounts receivable outstanding; DPO = days of accounts payable outstanding; CCC = cash conversion cycle

Methodology

For the analysis, we conduct a paired t-test method and a panel data analysis method by using panel data (Baltagi, 2001; Beasley, 1996).

In detail, first, we employ paired t-tests on ROS for the differences in means to divide the firms in different groups with different ROS trend patterns during (2008-2011) and after (2012-2015) global financial crisis (Beasley, 1996). Then, we research firms' CCC and its elements in different groups in order to discover their ideal profiles and deviations.

Second, we apply a panel data analysis method to test the effects of CCC and its elements (DIO, DRO, DPO) on profitability ratios (ROS) (Baltagi, 2001). Estimates were acquired by the following equations:

$$ROS_{it} = \beta_0 + \beta_1 CCC_{it} + \beta_2 lnsales_{it} + \eta_i + \lambda_t + \varepsilon_{it}$$

$$ROS_{it} = \beta_0 + \beta_1 DIO_{it} + \beta_2 DRO_{it} + \beta_3 DPO_{it} + \beta_4 lnsales_{it} + \eta_i + \lambda_t + \varepsilon_{it}$$

where dependent variable ROS = return on sales; independent variables CCC = cash conversion cycle, DIO = days of inventory outstanding, DRO = days of accounts receivable outstanding, DPO = days of accounts payable outstanding; control variable lnsales = logarithm of sales, and ηi (unobservable heterogeneity) = measurement of each firm's characteristic, λt = time dummy variables, εit = error terms for subscripts i = firm and t = period (Teruel and Solano, 2007).

To conduct the panel data analysis, we first test whether there is correlation between unobservable heterogeneity of each firm and independent variables of the model. If the correlation is related to fixed effect, we could take the consistent estimation through the within-group estimator. Otherwise, we could use a more efficient estimator related to random effect (Teruel and Solano, 2007). After taking Hausman test (1978), we adopted the fixed effect.

Results

Table 3 shows the results obtained after t-test results of each group about ROS performance. The results indicate there are positive correlations between group 1 and group 3,4 about DIO during global crisis. Reversely, there are negative correlations between group 1 and 3 about DRO and DPO during global crisis. There is a negative correlation between group 1 and group 4 about DPO. After global crisis, similar results are obtained about DIO, DRO, and DPO expect CCC. Regarding CCC, group 1 is positively correlated to group 4. There are positive correlations between group 2 and group 3 about DIO, and between group 2 and group 4 about CCC during global crisis. Reversely, there are negative correlations between group 2 and group 3 about DRO, and between group 2 and group 4 about DPO during global crisis. There is only a positive correlation between group 3 and group 4 about CCC during and after global crisis.

Table 3 – T-test results of each group about ROS performance

Global Crisis	During (2008-2011)				After (2012-2015)			
Variables / ROS Performance Group	DIO	DRO	DPO	CCC	DIO	DRO	DPO	CCC
1	3*** 4**	3**(-)	3*(-) 4**(-)		3** 4**	3**(-)	3**(-) 4**(-)	4**
2	3**	3*(-)	4**(-)	4**	4*		3*(-) 4*(-)	4**
3				4*				4*

Notes: ROS = return on sales; DIO = days of inventory outstanding; DRO = days of accounts receivable outstanding; DPO = days of accounts payable outstanding; CCC = cash conversion cycle; ROS Performance Group Range 1-4 = (1 = High → High, 2 = High → Low, 3 = Low → High, 4 = Low → Low); (-) = Negative Correlation; $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Table 4 presents the results obtained after regressing the equations. During global crisis, ROS is reduced by lengthening CCC and DRO. It is increased by lengthening DPO. This result shows that firms increase their profitability by reducing CCC and DRO. Regarding control variable, it is positively correlated to log sales. After global crisis, ROS is reduced by lengthening DIO and DPO. This result provides that firms increase their profitability by reducing DIO and DPO. Maintaining days of inventory outstanding for less time improves profitability (Teurel and Solano, 2007).

Table 4 – Regression results for effects of WCM on ROS

Independent Variables	Dependent variable = ROS	
Global Crisis	During (2008-2011)	After (2012-2015)
CCC	-0.033(-2.90)***	-0.000(-0.01)
ln(sales)	3.631(4.27)***	-0.239(-0.58)
R^2	0.212	0.002
DIO	-0.030(-1.31)	-0.118(-2.04)**
DRO	-0.033(-2.29)**	-0.005(-0.44)
DPO	0.038(1.70)*	-0.077(-1.86)*
ln(sales)	3.673(4.20)***	-0.339(-0.24)
R^2	0.151	0.088
Observation	168	168

Notes: ROS = return on sales; CCC = cash conversion cycle; ln(sales) = logarithm of sales (control variable); DIO = days of inventory outstanding; DRO = days of accounts receivable outstanding; DPO = days of accounts payable outstanding; $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$

Conclusions

This study provides new theoretical and practical insights into the differences, ideal profiles and productive efficiency of global firms' WCM with different ROS patterns for automobile industry using the panel data for the period of 2008-2015. To the best of our knowledge, this study is the first attempt to investigate the crucial supply chain-finance interface issue, i.e., the relationship between WCM (CCC elements) and profitability ratio (ROS) for the period of economic crisis and recovery.

However, this study has limitations, which mean future research directions. Because the data for this study were obtained from large firms in Forbes Global 2000 rankings in automobile industry, future studies of investigating firm size effect must be considered. Furthermore, this study could be considered for firms in other industries with different product and process characteristics for the different periods and countries.

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Registrars or Firms? Exploring the ethical issues in third party certification schemes

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Abstract

This study examines the link between firms' motives in adopting ISO 9001 standard and their selection criteria for certification bodies (CBs) of ISO 9001. Using the dataset drawn from 597 ISO 9001 certified firms in Australia and New Zealand, the findings show that internal motives drive firm to prefer CBs that offer strict auditing of quality system while external motives lead firm to select CBs that offer market credibility. The findings further show that CBs with strict auditing has a stronger effect on operational benefits of the certification compared to CBs that offer market credibility.

Keywords: non-financial auditing, certification, motives

Introduction

Non-financial auditing of organizational performance is becoming increasingly prevalent around the world. Non-financial auditing takes many forms and focuses on many issues, such as an organization's quality, ethical, and sustainability practices. Like financial auditing, it focuses on comparing an organization's performance against a reference point, such as the ISO 9001 and ISO 14001 standards for quality and environmental management systems, respectively. In any case, audits must represent a genuine attempt to cover both the positive and negative aspects of an organization's performance (Dogui et al. 2014).

Ethical issues are inherent in all forms of auditing. Audits should be carried out by well-trained, competent auditors who are independent and free from conflicts of interest (see, for example, ISO 19011:2018). As an illustration, given the need to impartially assess an organization's compliance with a reference point, auditors should not provide consulting on the practices they are auditing (Heras-Saizarbitoria et al. 2013). This is critical given that auditors must make numerous judgements in any audit (Power & Terziovski, 2005), even in "filter" forms of auditing (Busch, 2011).

In non-financial auditing, successful audits are often (but not always) used for certification purposes. For example, organizations may have their compliance to a management system standard, like ISO 9001 and ISO 14001, formally certified. In fact,

well over 1,000,000 ISO 9001 and over 350,000 ISO 14001 certifications have been issued worldwide as of the end of 2017 (ISO, 2018). Organizations may seek certification for a variety of reasons, such as customer pressure and external image (Darnall & Edwards, 2006) or when their partners lack information or fear opportunism (King et al. 2005).

Certifications are typically issued by arms-length, third-party *certification bodies*, also known as "registrars", which employ auditors to verify compliance with a reference point's requirements (Pivka, 2004). Certification bodies are often expected to adhere to standards of conduct (e.g., ISO CASCO standards) and may be registered by accreditation bodies, such as national standards organizations, like the Joint Accreditation System of Australia and New Zealand (JAS-ANZ). Third-party certification offers the promise of an unbiased, independent evaluation of the organization's conformance to the standard's requirements.

Ethical issues, however, have the potential to compromise the auditing and certification process. For example, organizations typically have discretion in selecting a certification body, and frequently can choose among many options (Dogui et al. 2014). A further complication is that audits are usually "contracted and paid for by the company that wishes to become certified" (Heras-Saizarbitoria & Borial, 2013, p. 59). This can call into question the "independence and impartiality of the certification process" (Dogui et al. 2014, p. 14).

Ethical issues in non-financial auditing and certification processes are in need of further research (Heras-Saizarbitoria & Borial, 2013). Although third-party certification may provide an organization with increased credibility and legitimacy, there is no guarantee of honesty in the certification process (Heras-Saizarbitoria & Borial, 2013; King et al. 2005). The purpose of this paper is to investigate the role of certification body selection in the quality of third-party audits. We investigate whether organizations select certification bodies on the basis of audit strictness or market credibility. We also study the operational and market benefits that arise from the audit. Two key research questions guide our study:

- RQ1: How do organizational motives impact the selection of certification bodies?
- RQ2: How do certification bodies and organizational motives impact the benefits of certification?

To answer the research questions, we surveyed 597 companies in Australia and New Zealand registered to ISO 9001. We focus on ISO 9001 since it is the world's most popular non-financial management standard. Building on an earlier study (Castka et al. 2015), we find that organizations' motives define their preference of certification bodies' characteristics (i.e., whether they offer strict audits or market credibility), and that organizations' motives are also most important in driving the real benefits achieved.

The paper makes several contributions. First, it adds to the limited empirical research on how firms choose certification bodies (e.g., Castka et al. 2015; Poksinska et al. 2006). None of the earlier literature has studied this issue from an ethical perspective. Second, it is the first paper to study how organizational motives influence the selection of certification bodies, and how those collectively influence the audit benefits. Third, we build on legitimacy theory to articulate the ethical implications of organizations' auditing preferences. We explore the implications of the possibility of organizations to obtain benefits, even if this requires them to unethically avoid strict audits.

Theoretical Background

ISO 9001 was introduced in 1987 and has been updated four times, most recently in 2015. The standard includes an extensive set of requirements intended to help an organization

improve its product quality, but it does not specify required levels of performance or methods to meet the requirements. Certification mechanisms for ISO 9001 have also evolved over time, and have become "increasingly structured, professionalized, and codified" (Borial & Gendron, 2011, p. 335). Moreover, as the world's most popular non-financial management standard, ISO 9001 has helped shape the development of other non-financial management systems and their certification mechanisms (Boiral & Gendron, 2011).

Organizations have considerable discretion in terms of how they meet ISO 9001's requirements and research has shown there is considerable heterogeneity in its implementation (e.g., Heras-Saizarbitoria & Boiral, 2015; Storz, 2007; Walgenbach, 2001). Organizations can implement the standard differently, even when responding to similar pressures (Heras-Saizarbitoria & Boiral, 2015). The variety of methods organizations can use to implement ISO 9001 underlines the importance of auditors' judgement in certification audits. Auditor independence is particularly critical, since "the certification process is most often depicted as a rational, neutral, and unequivocal process" (Boiral, 2012, p. 633).

Certification audits are often regarded as "trust-providing" processes that provide social legitimacy through impartial verification (Boiral, 2012, p. 634). Trust in certification audits, however, can be undermined by the "customer-supplier" relationship between the organizations being audited and the contracted certifying bodies (Boiral & Gendron, 2011, p. 338). Conflicts of interest, for example, can lead to a superficial audit (Boiral & Gendron, 2011). Research has shown that different auditors and certification bodies can have vastly different expectations (Poksinska et al. 2006). To avoid issuing unworthy certifications, auditors (and, more broadly, certification bodies) must be particularly alert to "decoupling" between organizations' stated and real practices (Meyer & Rowen, 1977), a phenomenon that has been studied extensively in a management standards context (e.g., Boiral, 2007).

Unfortunately, there is evidence that organizations frequently adopt ISO standards symbolically (Boiral, 2003; Christmann & Taylor, 2006; Heras-Saizarbitoria & Boiral, 2015). This can perpetuate "rational myths", where practices are perceived as legitimate even though they have only ceremonially been implemented (Boiral, 2007 and 2012; Heras-Saizarbitoria & Boiral, 2015). Such differences between rhetoric and reality have long been recognized (e.g., Zbaracki, 1998). When organizations that have not internalized (Kostova & Roth, 2002) a standard's requirements receive certification, a "performance-portrayal" gap (Adams, 2002) can emerge (i.e., management systems lacking rigor are formally recognized). This can further encourage seeing certification as an end in itself, analogous to degree-purchasing syndrome in education, whereby organizations "acquire ISO certification as a sort of 'organizational degree' after passing a quite predictable exam" (Boiral, 2012, p. 633).

Legitimacy is, thus, one of the key drivers for organizations seeking to obtain ISO 9001 certification. As Boiral and Gendron (2001, p. 338) explain, ISO 9001 certification is "driven by a quest for institutional legitimacy through the adoption of internationally recognized practices that aim to demonstrate the organization's accountability with respect to quality." Legitimacy has been defined by many authors, but here we adopt Suchman's (1995, p. 574) widely-cited definition: "a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions".

Research shows that "ceremonial integrators" of ISO 9001 (i.e., organizations superficially adopting the standard) are especially motivated by external legitimacy (Boiral, 2003; Heras-Saizarbitoria & Boiral, 2015). A wide range of benefits have been

associated with increased legitimacy from certification, such as helping an organization improve its image, legitimate its activities, and satisfy stakeholders (Boiral, 2007, p. 129). However, as Boiral (2007) implies, when requirements have only ceremonially been implemented, organizations may leave themselves open to charges of "organizational hypocrisy" (Brunsson, 1989). These concerns could be particularly magnified due to certification bodies' potential conflicts of interest arising from, for example, the competition amongst themselves and their position as a certification supplier to an audit customer (Borial & Gendron, 2011).

All of these issues cast "doubt on the imagery of impartiality, rigor, and accountability projected by organizations through discourses of certification" (Boiral & Gendron, 2011, p. 331). A third-party audit, therefore, does not necessarily prevent the legitimation of poor performance. While strict audits, defined below, can prevent legitimizing poor performance, weak audits can be used for that very purpose. Certifying unworthy organizations goes against the interests of stakeholders, such as customers and the general public. Ethical certification bodies, more focused on strict auditing than market credibility, are critical to preventing this problem. There is a need to study how organizational motives impact the selection of certification bodies and how, in turn, certification bodies and those motives impact the operational and market benefits earned by standard certification.

Hypothesis Development

The purpose of certification is to differentiate between organizations that have met a standard's requirements and those that have not. Ethical issues, such as conflicts of interest, have the potential to blur that distinction. When organizations have a genuine desire for a *strict audit*, i.e., one that rigidly adheres to and fairly assesses compliance with a reference point's requirements, this purpose may still be achieved. However, when organizations are more interested in obtaining the *market benefits* of certification, and are willing to pursue those at any cost (including certifying undeserving practices), they could unethically use certification as a means to legitimate their behaviour. We term the desire for a strict audit vs. one focused on market benefits as an organization's *auditing preference*.

Organizational motives for pursuing ISO 9001 certification have been widely studied. They include improving products, enhancing productivity, gaining market access, growing market share, improving supply chain management, improving profitability, reducing information asymmetries, responding to customer pressure, or improving external image, among others (Boiral & Roy, 2007; Castka et al. 2015; Castka & Balzarova, 2010; Corbett, 2006; Darnall & Edwards, 2006; King et al. 2005). In this paper, we categorize organizational motives for pursuing certification as *internal* and *external* motives. We focus specifically on building a foundation for systematic business management and establishing a springboard for continuous improvement as internal motives. Our external motives of focus are meeting customer and market requirements and enhancing the organization's image and reputation.

The motives listed above demonstrate that organizations seeking certification to a standard, like ISO 9001, often pursue certification as a mechanism to legitimize their behaviour, and, ultimately, help shape social perceptions. Organizations genuinely meeting ISO 9001's requirements have earned the legitimacy conferred by certification. These organizations may select certification bodies on the basis of audit strictness. Organizations, however, may be interested in the benefits of being recognized as certified to a standard's requirements even in cases where they do not actually meet those

requirements. These organization's may select certification bodies on the basis of the market credibility they offer.

Organizational motives for selecting certification bodies have not been widely studied, though the limited research available supports the assumptions above. Castka et al. (2015) found that certifier selection is influenced by an organization's auditing preferences and that organizations interested in genuine improvement tend to choose reputable certification bodies. We build on Castka et al.'s (2015) study to investigate the effect of an organization's audit motives on its auditing preferences. Based on the above, our first two hypotheses directly address RQ1 and lay the foundation for addressing RQ2.

- Hypotheses 1 (H_1): Internal motives have a stronger association with CBs offering strict auditing than with CBs offering market credibility
- Hypothesis 2 (H_2): External motives have a stronger association with CBs offering market credibility than with CBs offering strict auditing

The benefits of ISO 9001 certification are closely tied to the motivations listed above. In this paper, we consider that operational benefits (i.e. quality of products / services and efficiency of the processes) as reflecting the true intent of the ISO 9001 standard. Whether these benefits are realized in practice, however, depends on how the standard is actually implemented, to respond to many studies which have questioned the effectiveness of ISO 9001 and its real impact (see, for example, Boiral & Roy, 2007). In this regard, CBs will play an important role to ensure that firms have demonstrated their serious commitment in implementing the requirements of ISO 9001 standard by focusing on substantive (e.g., actual practices) rather than ceremonial (e.g., overreliance on documentation) aspects of the audit process (Boiral & Gendron, 2011).

We argue that organizations that have genuinely implemented the standard's requirements and have sought a strict audit, are more likely to obtain stronger operational benefits than organizations that have not. They are also likely to obtain market benefits. Organizations that seek certification purely for market credibility purposes, however, are more likely to try to legitimate poor practices. Although they are less likely to obtain operational benefits than organizations that have substantively implemented the standard, they may still be able to obtain the market benefits conveyed by the third-party certification and use it as a "rubberstamp". The certification which is focused on ceremonial aspect of ISO 9001 results in a performance-portrayal gap that helps explain the unethical distortions that arise when companies are able to legitimate unworthy performance. Based on the above, our next hypothesis focus on the effect of CBs preferences on the benefits of ISO 9001 adoption, which aims to address RQ2.

- Hypothesis 3 (H_3): CBs offering strict auditing have a stronger association with operational benefits than do CBs offering market credibility

Method

Sampling and procedures

The participants were selected for participation in this study from a JAS-ANZ database that lists all Australian and New Zealand companies that are certified to ISO 9001. From a total of over 10,000 companies listed in this database, 4,000 Australian and 1,000 New Zealand companies were randomly selected and received our survey. Targeted respondents to the questionnaire were managers within each organisation who had knowledge and responsibility for the implementation and maintenance of the company's quality management system. In total, 597 usable responses were received from Australian firms and New Zealand firms.

Measures

The content of the scales for internal motives, external motives, and operational benefits are derived from the study by Nair and Prajogo (2009). The two characteristics of CBs are measured by a single item that reflects firms' reason for selecting the CB, namely "Our CBs offering strict quality auditing" and "CBs offering market credibility", taken from Castka (2013).

Results

Scale validity and reliability

All five scales were subjected to validity and reliability test. The results show acceptable fit as indicated by several key fit indices (RMSEA = 0.056, NFI = 0.984, CFI = 0.989, and GFI = 0.990). However, the output also suggested the covariance between the errors of two items (i.e. "To build a foundation for systematic business management" and "To meet customer and market requirements"). We consider that the covariance (ψ = -0.07 at $p < 0.01$) deemed plausible as it shows the contrast (negative correlation) between internal motives and external motives. Adding the covariance has improved the measurement model significantly as indicated by the significant drop of the chi-square value from 17.51 down to 8.90. All other fit indices are also improved (RMSEA = 0.036, NFI = 0.992, CFI = 0.996, and GFI = 0.995. The complete results of the CFA are presented in Table 1 below.

Table 1 Construct validity and reliability

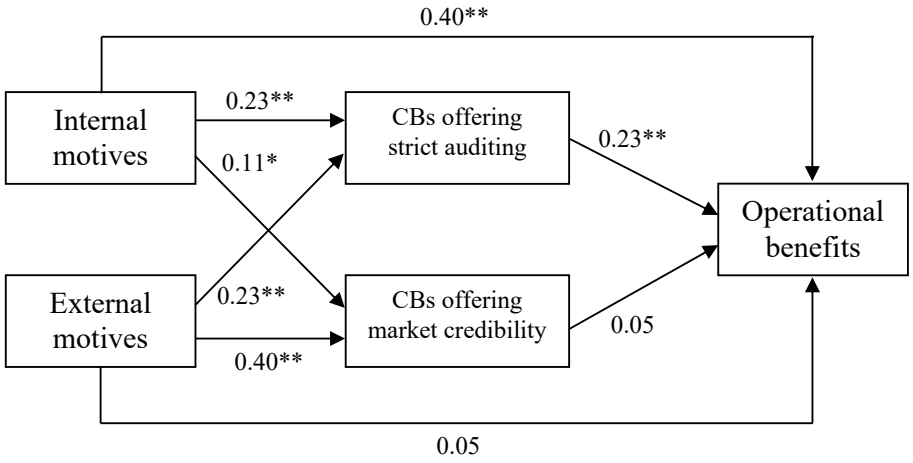
Scales	Items	Loading path	Cronbach's alpha
Internal motives	To build a foundation for systematic business management	0.88	0.79 [a]
	To have better control of operations of the business	0.89	
External motives	To meet customer and market requirements	0.45	0.41 [a]
	To enhance company's image and reputation	0.92	
Operational benefits	Improved level of quality of our products and/or services	0.82	0.52 [a]
	Reduced our operating costs	0.63	

[a] Pearson *r* correlation (significant at $p < 0.01$) is used instead of Cronbach's alpha for measuring reliability since the scale only has two items. Pearson *r* values above 0.2 suggests good reliability

Structural relationship

The hypotheses are tested simultaneously using Structural Equation Modelling (SEM) technique using latent variables. However, since constructs "CBs offering strict quality auditing" and "CBs offering market credibility" are measured by one observed variable, we need to convert them into latent variables by setting the loading path of the observed variable to the latent variable to be 1 and the error variance of the observed variable to be 0. The similar processes are also applied for the two control variables (firms' size and the year of certification) in the research model. In addition, we also believe that selecting auditor is not the only essential strategy that firms take in realizing their motives in adopting ISO 9001 and achieving the outcomes of the adoption. Studies have shown that the implementation of the ISO 9001 standard, such as training employees and developing and maintaining procedures), for example, is also driven by motives and has significant effect on the outcomes (firms' performance). In other words, CBs selection does not fully mediate the relationship between motives and outcomes of ISO 9001 adoption, hence, we need to set the direct path between the two motives to operational performance.

The research model presented in Figure 1 shows a good fit as reflected by the key fit indices (χ^2 = 27.84 with degree of freedom (df) = 21, RMSEA = 0.023, NFI = 0.984, CFI = 0.996, and GFI = 0.991). Looking at the path coefficients, there are indications for supporting our comparative hypotheses. Internal motives show relatively stronger effects on CBs offering strict auditing compared to CBs offering market credibility (γ = 0.23 at p < 0.01 versus γ = 0.11 at p < 0.05 respectively), supporting H_1. Similarly, external motives show relatively stronger effects on CBs offering market credibility compared to CBs offering strict auditing (γ = 0.40 at p < 0.01 versus γ = 0.23 at p < 0.05 respectively), supporting H_2. Finally, CBs offering strict auditing shows a relatively strong effect on operational benefits than do CBs offering market credibility (γ = 0.23 at p < 0.01 versus γ = 0.05 at p > 0.05 respectively); hence, H_3 is supported.



*p < 0.05 **p < 0.01

Figure 1 Research model

However, in order to test the three comparative hypotheses, we need to test of the two paths that we compare are significantly different by creating a competing model where the two paths are set to be equal. In testing H1, we created a competing model by setting the two paths from internal motives to CBs offering strict auditing and to CBs offering market credibility to be equal. This results in an increase of χ^2 to be 34.72 at df = 22, hence, producing $\Delta\chi^2$ of 6.88 with df = 1 to the original model. The value of $\Delta\chi^2$ is greater than 6.63 to support that the two models are significantly different at p < 0.01. Therefore, the result suggests that setting the two paths to be equal decreases the model's fit; hence, we can conclude that the two paths are different and since the path from internal motives to CBs offering strict auditing is stronger than that to CBs offering market credibility, we can conclude that H_1 is supported. Similar procedure is applied for testing the other two hypotheses. In testing H2, the competing model which sets the path from external motives to CBs offering market credibility to be equal to the one to CBs offering strict auditing produces χ^2 = 38.31 at df = 22, hence, resulting in $\Delta\chi^2$ of 10.47 with df = 1 to the original model. The value of $\Delta\chi^2$ is greater than 6.63 to support that the two models are different at p < 0.01; hence, supporting H_2. In testing H_3, the competing model which sets the path between CBs offering strict auditing and operational benefits and the path between CBs offering market credibility and operational benefits to be equal produces χ^2 = 31.57 at df = 22, hence, resulting in $\Delta\chi^2$ of 3.73 with df = 1 to the original model. The value of $\Delta\chi^2$ is very close to 3.84 to support that the two models are different at p < 0.05 (or at least at p < 0.1); hence, supporting H_3. Indeed, the effect of CBs offering market credibility to

operational benefits is non-significant (as shown earlier), providing further support for H_3.

Finally, the model shows that internal motives also show a significant path on operational benefits ($\gamma = 0.40$ at $p < 0.01$) while external motives do not ($\gamma = 0.05$ at $p > 0.05$). This result is compelling in two ways. First, it shows that firms will have other strategies or mechanisms to realise their internal motives in adopting ISO 9001 standard and achieve the intended outcomes (i.e. operational benefits) over and above selecting appropriate CBs. At the same time, the result also shows that external motives have no direct effect on operational benefits, and even their indirect effect on operational benefits is fully mediated by CBs with strict auditing. This finding, therefore, provides evidence on the importance of having the right motives in adopting the ISO 9001 standard.

Discussion and Conclusion

The findings have shown the implications of two contrasting motives for selecting CBs in adopting the ISO 9001 standard. If a firm's internal motives reflect a desire to build a solid quality management system in its business operations, this will likely lead it to show a serious commitment to implementing the standard, which also impacts how they choose CBs. Our findings clearly show that, in selecting the CB, firms driven primarily by internal motives will focus more on a CB that shows uncompromising quality in the auditing process (i.e., a strict audit) instead of offering primarily market benefits (as per H_1). This is because these firms are focused on the substantive aspect of ISO 9001 (i.e., a solid quality management system) rather than the ceremonial aspect (i.e., certification). While they still seek ISO 9001 certification, firms driven by internal motives consider it as a secondary outcome of adopting the standard. As demonstrated by our findings, their primary focus is on high quality products and an efficient process.

External motives, on the other hand, reflect institutional pressures to attain ISO 9001 certification. Firms driven by these motives are more focused on seeking the legitimacy conferred by certification (i.e., a ceremonial aspect) rather than building a quality system (i.e., a substantive aspect) as prescribed by the standard. In seeking legitimacy, external motives would lead firms to mainly focus on obtaining certification from a CB that is well recognized in the market. This motive leads firms to base their selection on CBs with high market credibility rather than those with high audit strictness (as per H_2). In other words, institutionally-driven motives lead firms to seek an enhanced, institutionally-driven image. However, as the findings show, increased market credibility does not necessarily reflect the true value intended by ISO 9001 standard. Our results suggest that it does not have a positive effect on operational benefits, hence, delivering significantly lower value for ISO 9001 adopters (as per H_3).

From an ethical perspective, we can draw several insights from the findings. First, our findings show that CBs offering market credibility have a significantly weaker effect on operational benefits than CBs offering strict audits; indeed, they have no significant effect. This finding draws a sharp distinction between the substantive and ceremonial aspects of obtaining certification. The failure (non-significant effect) of CBs offering high market credibility, but low audit strictness, in delivering operational benefits for their clients indicates the potential for an ethical problem where firms expect to receive operational benefits arising from certification, but do not. Engaging the wrong CBs, which deliver low (or no) real operational benefits from ISO 9001 adoption (other than the certification) could explain the growing disillusion many companies are experiencing in standards adoption (e.g., Castka and Corbett, 2015; Lal (2004)).

Second, in conjunction with the first ethical issue, the failure of CBs to adequately distinguish between companies that have substantively and symbolically implemented

the standard is creating market distortions that can lead to customer manipulation. ISO 9001 is a widely-recognized management system standard and its certification is intended to offer customers assurance of the certified firm's ability to deliver products meeting specified requirements. Being certified by recognized CBs could increase the level of customer confidence, yet, as the findings show, even certified companies may not be capable of delivering on customer expectations. This problem is paramount given that most customers cannot themselves check the quality of their suppliers' processes, and, therefore, must rely on the certification for gaining this assurance. The certification of undeserving ceremonial integrators of ISO 9001 can also adversely impact the reputation of the standard and, more broadly, non-financial auditing, resulting in a cynical view on standards adoption (Boiral, 2003).

Third, formally recognizing firms that have only symbolically implemented ISO 9001 can have a number of cost implications. Firms are responsible for covering the costs of audits provided by certification bodies, which can often be substantial, particularly when the costs of surveillance and renewal are also considered. Customers expecting products meeting their requirements due to their production in a certified system, may also incur costs associated with, for example, unanticipated low product quality or paying a premium for products produced under certified conditions. Although we do not specifically address the issue of costing in this study, the high cost for engaging CBs or paying for products produced by certified firms may not deliver value commensurate to the cost.

Fourth, the findings shed light on the perils of certification bodies finding themselves in a customer-supplier relationship with the organizations they are contracted to audit (Boiral and Gendron, 2011). The increasing commercialism and competition amongst the certification bodies themselves (Boiral and Gendron, 2011), combined with limited enforcement power of national standards organizations (i.e., the accreditors of certification bodies) is fostering an expectation that organizations (i.e., customers) will get what they want and pay for (i.e., a "lenient" audit result), rather than what they deserve (i.e., a fair audit). The findings show that, if they are motivated to do so, organizations will be able to obtain certification even if they are not genuinely committed to the standard. These issues create ethical dilemmas for organizations, auditors, and certification bodies. For example, certification bodies and their auditors face dilemmas arising from their conflicts of interest, such as their need for impartiality from, while being financially dependent on, their customers.

In conclusion, our study has demonstrated the ethical issues pertaining to the auditing and certification process of the ISO 9001 standard. This study is one of the first to explicitly adopt an ethical perspective on the role of certification bodies in implementing ISO 9001, and, more generally, in the auditing field. One recommendation we propose is the need for better regulating CBs, through strengthened enforcement powers of national standards organizations, to ensure that they operate according to the basic principles intended by ISO 9001 standard. Such regulation would reduce unethical behaviours not only from the CBs who do not perform strict audits, but also from clients who seek to legitimate poor performance, thus capturing the benefits of legitimation without actually doing the things for which they have been certified.

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An Empirical Analysis on Factors Influencing Smart Product Development from Industry 4.0 in Indian Context

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Abstract

Smart product development (SPD) in industry 4.0 facilitates decision making during different activities involved in development process. Contextual evidence shows such activities are influenced by several factors; however there remains little understanding on factors influencing SPD from industry 4.0 in Indian context. Present study aims to identify and develop perception based prediction model to investigate critical factors influencing SPD. Two dimensions extracted viz. “technological” and “strategic” factors have significant positive impact while out of five identified critical factors three have significant positive impact i.e., technology & innovation, system integration and collaborative engineering. Thus, increasing quality of industry 4.0 can be accomplished with proper integration of technologies.

Keywords: Critical factors, India, Industry 4.0, Smart product development

Introduction

With the advancement of digital technologies and a paradigm shift to industry 4.0 manufacturing industries have been found to be in major transformation towards adopting smart manufacturing (Feeney et al., 2015). This new industrial trend affects organizational structure and customer’s demand (Gilchrist, 2016) which resulted into development of complex and smart products with new capabilities thus influence product life cycle that is somewhat different from conventional product development approach (Nunes et al., 2017; Ahmed et al., 2019). Industry 4.0 is an integration of “intelligent systems, machines, production and processes to form a well-defined network” (Kagermann et al., 2013, cited in Ahmed et al., 2019). It is a concept that involves combined components of “cyber physical systems (CPS)”, “internet of things

(IoT)" with cloud based models as disruptive technologies (Wang et al., 2015; Dalenogarea et al., 2018). It produces new types of products with intelligent systems embed in it. Despite the recognition of the term "smart" as extensively used by many organizations and researchers, still today there is no consensus of consistent definition. The concept of "smart product" is a network based integrated approach that spans entire manufacturing process and control production stages/processes autonomously (Nunes et al., 2017). It is characterized by its computation and data-storage facilities and its way of interaction with other objects. From developing economy like India manufacturing industry resembles high priority sector in terms of wealth creation and employment generation. However, such development initiative is still in its concept phase and has got immense potential to bring positive effects in terms of cost, quality, productivity, time, flexibility and innovation. Traditional product development approach consisting of multiple processes and sub-processes that interferes decision making information and knowledge capture (Ahmed et al., 2019) and hence real time decisions cannot be taken (Wasim et al., 2013). This becomes an imperative for development of frameworks for smart products so as to offer unprecedented customer insights. In-spite of several advantages in combining industry 4.0 and SPD, majority of the Indian industries are in state of dilemma with respect to its adoption and implementation. Contextual evidence indicates that factors that influence traditional product development approach may not be same as in case of smart product development. Thus the purpose of this paper is to identify the critical factor dimensions that affect smart product development from Indian industry 4.0 perspective. Accordingly the following objectives have been considered.

Objectives: (i) To identify and predict the influence of critical attributes or indicators on SPD; (ii) To identify critical factor dimensions and its influence on SPD.

Hypotheses Development

Technology and Innovation

With high-technology development influenced by innovation facilitates product design and development process. Such innovation led technological development engenders substantial changes in existing market that leads to successful product development. Quality of the product can be improved with technology intervention as organizations are moving towards digitalization in context of industry 4.0. Development process of smart product entails diffusion of advanced technologies and equipment, advanced production procedures with upgraded software and databases. Thus it is expected that 'technology and innovation' would increase the process flow by focusing on process innovation. Accordingly the following hypothesis is proposed.

H1: Technology innovation has positive influence on smart product development

Collaborative Engineering

Collaboration, in terms of human interface perspective, aids towards execution of series of activities which provides channel for team. Collaborative product development from

engineering perspective is a technology oriented process that is used to design innovative and improved products by exploring new markets so as to gain competitive advantage (Büyüközkan and Arsenyan, 2012). From the literature it is evident that collaborative process is followed in many industries those are involved in complex product and service development including research and development (Feller et al., 2005). Collaborative engineering also focuses in handling problems in relation to partner selection and evaluation which is critical for product development success. Thus following hypothesis is proposed.

H2: Collaborative Engineering has positive influence on smart product development

System Integration

Pertaining to SPD from Industry 4.0 perspective, SI refers to cyber physical systems that interconnect physical systems and communication infrastructure (Baheti et al., 2011). Integration of cyber technologies make products internet enabled that generates lots of data and communicates with other interconnected products. These facilitate product development process which can be achieved in cost effective and effectual manner. With system integration approach flexible operations could be performed by adjusting combination of standardized modules that speed up the product development process and reduces time to market. Thus following hypothesis is proposed.

H3: System integration has positive influence on smart product development

Sustainability

Sustainability is considered to be a critical attribute that strategically addresses the risk management in product development. With reference to environmental perspective issues pertaining to sustainability related to smart products focuses on reducing wastes, resources and energy thus moving towards green products. Reducing series of activities pertaining to traditional product development approach would eventually make the process efficient and eliminate any special causes of defects which ultimately lead to product development success. Moreover, economic sustainability facilitates agility and smooth flow in smart product development with objective to maximize profit and minimize costs. Thus the following hypothesis has been proposed.

H4: Sustainability issues have positive influence on smart product development.

Lean Operating System

Lean implementation is initiated by cyber physical system (CPS) which results in elimination of wastes by maximizing productivity. Such implementation produces products at low production costs, with good quality, better accessibility to market and customer satisfaction. Lean aspects of product development include knowledge based engineering focusing on smart technology, mistake proofing, and continuous improvement as core enablers for process development (Khan et al., 2013). Knowledge based platform proposed in work of Ahmed et al. (2019) demonstrates the influence of

advanced lean technology in product development process using knowledge-based engineering. Thus the following hypothesis is proposed.

H5: Lean Operating System issues have positive influence on smart product development.

Methodology

In order to address the research objective the present study adopts qualitative and quantitative approaches. A comprehensive search on related literature has been conducted to identify critical attributes of SPD in context of industry 4.0. To carry out qualitative based approach a semi-structured questionnaire was prepared in understanding the contextual attributes and accordingly an in-depth interview is carried out from ten manufacturing organizations where respondents were from top management and managers who have got experiences of working in domain of product development. Criteria for selecting respondents were such that they should have atleast served for minimum of eight to ten years as senior manager category with respect to design, R&D, marketing aspects of product development. Organizations involved in manufacturing products that includes consumer based household appliances and intelligent medical devices are considered in this study. Overall five critical attributes have been finalized to be taken into consideration from industry 4.0 perspectives. With identification of critical attributes of SPD attributes a structured questionnaire is developed and respondents were asked to give their opinion for each attributes on 5 point Likert scale ranging from “5= strongly agree” to “1= strongly disagree”. A structured questionnaire was sent to around 250 organizations, out of which 200 organizations responded. Out of 200 questionnaires received 35 found to be with missing data thus total 165 questionnaires were taken into consideration for further data analysis. Overall 165 respondents’ opinion is finally captured for data analysis. SPD is taken as dependent variable in terms of product development success considering operational performance measures. To establish link between predictor and dependent variables proposition have been drawn considering literature and contextual understanding (Büyüközkan and Arsenyan, 2012; Hermann et al., 2014; Kiel et al., 2016; Jianfan et al., 2017; Mrugalska and Wyrwicka, 2017; Kamble et al., 2018). Thereafter, a step-wise multiple linear regression modelling is performed to study the influence of all the five models on SPD. Secondly, factor analysis with PCA (principal component analysis) is done on five attributes to extract and identify the critical dimensions. Third, the extracted critical dimension is further subjected to regression analysis to predict and understand the relationships between extracted factor dimensions and dependent variable (SPD success). In this study SPD is taken as dependent variable which is measured by both operational and quality performance.

Data Analysis and Results

This research is exploratory in nature. From quantitative perspective firstly a step wise multiple linear regression modelling is executed which shows all five models are statistically significant with positive and significant impact on SPD. The data being

captured were further subjected for corroboration to see whether it could be analyzed through factor analysis or not. Accordingly, we performed the following analysis: (i) Correlation Analysis: Correlations were high among the practices; (ii) stepwise regression model of critical attributes on SPD (iii) Bartlett's Test of Sphericity: Found to be significant ($p < 0.05$), this shows the acceptability of data; (iv) Kaiser Meyer Olkin Test (KMO): KMO test has been found to be 0.752, which is well above cut-off range; (iv) cronbach alpha: overall is 0.791, F1 is 0.823 and F2 is 0.696. Therefore based on analysis it can be concluded it is appropriate to conduct factor analysis (Meyers, 2006; Pallant, 2007). Before conducting factor analysis we performed univariate and multivariate statistics of the variables and discovered no apparent outliers (Jun et al., 2006). To further confirm the existence of normality we conducted two tests i.e. Kolmogorov-Smirnov and Shapiro- Wilks tests, which shows p value to be greater than 0.05 and therefore revealed normal distribution.

Table 1. Correlation Matrix

	SPD	TI	SI	CE	LOS	SUST
SPD	1.000					
TI	0.686	1.000				
SI	0.639	0.651	1.000			
CE	0.537	0.554	0.619	1.000		
LOS	0.334	0.321	0.370	0.224	1.000	
SUST	0.333	0.365	0.370	0.253	0.554	1.000

Table 2. Stepwise Multiple Linear Regression Model

Models	Predictors	β Coefficients	Std. Error	t statistics	Adjusted R^2	R^2 Change	Std. Error	F value	VIF
1	Constant	1.207	0.214	5.646***	0.468	0.471	0.769	145.064***	
	TI	0.676	0.056	12.044***					1.000
2	Constant	0.732	0.225	3.259***	0.530	0.065	0.722	93.352***	
	TI	0.462	0.070	6.645***					1.734
	SI	0.343	0.072	4.744***					1.734
3	Constant	0.582	0.239	2.435**	0.535	0.009	0.718	64.017***	
	TI	0.430	0.071	6.030***					1.852
	SI	0.287	0.079	3.642***					2.084
	CE	0.133	0.076	1.738*					1.733
4	Constant	0.311	0.317	0.981	0.537	0.005	0.716	48.641***	
	TI	0.419	0.072	5.845***					1.879
	SI	0.264	0.081	3.275***					2.189
	CE	0.136	0.076	1.788*					1.736
	LOS	0.104	0.080	1.300					1.175
5	Constant	0.300	0.322	0.933	0.535	0.000	0.719	38.691***	
	TI	0.417	0.073	5.746***					1.913
	SI	0.263	0.081	3.237***					2.204
	CE	0.136	0.077	1.782*					1.736
	LOS	0.094	0.091	1.039					1.514
	SUST	0.015	0.070	0.219					1.541

Note: *Dependent Variable is Smart Product Development (SPD); TI: Technology and Innovation; SI: System Integration: CE: Collaborative Engineering; LOS: Lean Operating System; SUST: Sustainability*

Durbin Watson value: 1.987 ; ***p value < 0.001; **p value < 0.05; *p value < 0.10

Factor analysis is performed on five critical indicators as identified from review of literature and contextual understanding based on qualitative study. We conducted factor analysis on explanatory variables/indicators with objective to determine minimum number of factors that accounts for maximum variance in data. The factors were extracted using principal component analysis (PCA with varimax rotation). The objective of deploying PCA is to reduce the number of variables (Jolliffe, 2002). PCA is used to "extract maximum variance from the data set with each component thus reducing large number of variables into smaller number of components" (Tabachnick and Fidell, 2007), which facilitate easier interpretations. Table 3 exhibits rotated component matrix which shows all the five variables having factor loading of more than 0.5 and further could be reconfigured into two factor dimensions as being extracted. Factor dimensions extracted are labeled as "Technological" (F1) and "Strategic" (F2).

Table 4. Factor Analysis

Variables	Factor Loadings		Total Variance	KMO
	F1	F2		
TI	0.811		75.80	0.752
SI	0.837			
CE	0.864			
LOS		0.869		
SUST		0.850		

Note: Rotation Method: Varimax with Kaiser Normalization

The overall reliability analysis shows Cronbach's alpha to be 0.791 which validates the reliability of the study. Further reliability analyses show Cronbach's alpha values for factor dimensions F1 and F2 to be 0.823 and 0.696 respectively, which validates the reliability of the factors being extracted. Regression analysis is performed on two extracted factors. The model explains the variance ranging between 46.8% to 53.5% i.e. the predictors explains the variance in the dependent variable well which is more than the standard 40%. Durbin- Watson index suggests that there is no problem of autocorrelation in data. F-value and VIF indicates that overall model has no multicollinearity problem.

Table 3. Coefficients Target: SPD

Model Term	**Coefficient**	**Sig.**	**Importance**
Intercept	3.678	.000	
FAC_1_transformed	0.717	.000	0.883
FAC_2_transformed	0.273	.000	0.117

Note: F value: FAC1_1 is 141.5 and FAC2_1 is 20.557

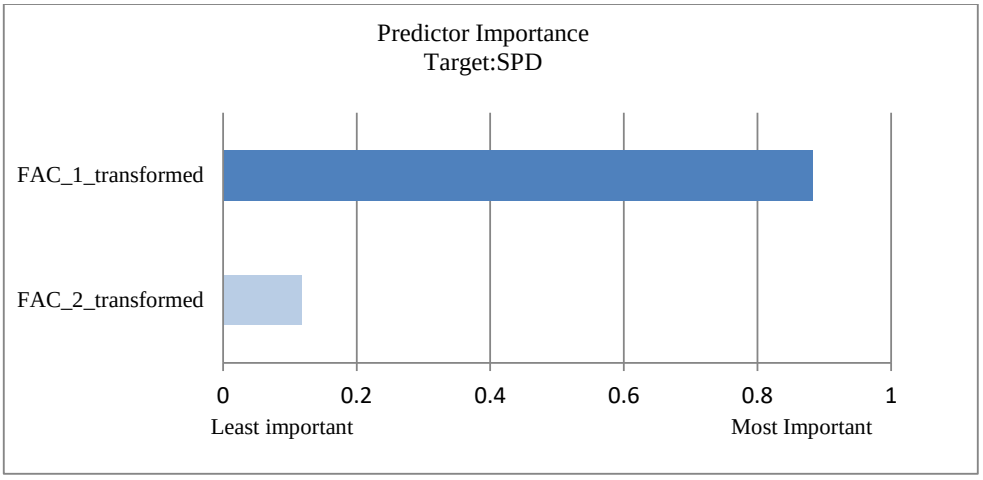

Figure 1. Predictor Importance

Overall, analysis (Figure 1) indicates the importance of technological factors which can be regarded as critical dimension for SPD. It is expected that from industry 4.0 perspective, IoT could have capability to offer transformational solutions for solving the complex digital issues in complex digital environment. In our opinion smart India in future would add value to realisation of industry 4.0 by deploying cloud manufacturing / manufacturing-as –a- service (Maas) which is gaining importance in manufacturing industry. Cyber-physical systems resemble a significant technological enabler for smart product development.

Findings and Discussions

The stepwise regression analysis reveals that attributes like technology and innovation (TI), system integration (SI) and collaborative engineering (CE) have significant positive impact on SPD whereas attributes like lean systems (LS) and sustainability (SUS) have insignificant impact on SPD. The impact analysis of technological innovation indicates that Indian industries are moving towards digital manufacturing where product development process will be executed through organised application of scientific knowledge and is consistent with Hecker (2005). With intervention of advanced technologies it is also likely that developmental process is driven by innovations that add value to the products which facilitates market demand. Here, SI resembles critical significance of cyber physical systems (CPS) where organizations would be able to generate large chunks of production data for real time analysis and decision making. Perception of respondent's towards SI also confirms the rapid move of manufacturing organizations to adopt IoT (internet of things) based approach where objects/ entities are virtually interconnected with lots of data being generated. CE approach also shows the significance of concurrent engineering management on the developmental process of SPD. As SPD from industry 4.0 perspectives is in its stage of infancy thus it would take some time to apply lean systems management and to develop a sustainable framework. Although TI, SI and CE models have been found to be statistically significant however impact of TI, SI found to be strong and CE to be moderate. This shows the lack of prominence in teamwork and human resource

practices. Exploratory factor analysis extracted two factor dimensions which are referred to as constructs namely“technological” and “strategic” factors respectively. Based on analysis performed, automatic linear modelling shows that both technological and strategic factors have significant impact on SPD which is interesting and thus exhibits paradox. The paradox itself gives an impression that strategic factor alone could not significantly impact SPD when acting alone but can significantly influence when combined effect of each technological attributes (TI, SI and CE) is deployed which shows complementarity effect with other resources. The results indicate that Indian industries with respect to Industry 4.0 anticipate better digital adoption with reduced operational costs and productivity improvement. The significant influence of strategic factor indicates the importance of triple bottom line (3BL) with lean initiatives as critical strategic components towards successful SPD initiatives. The perceptual measures from technological perspective expected to exhibit digital automation with integrated sensor systems as one of the most implemented technologies. The results obtained based on analysis gives an overall impression that increasing quality of industry 4.0 can be accomplished with proper integration of technologies and strategy. The integrated application of technological and strategic factor dimensions indicates that when products embed with advanced technology it increase intelligence and play strategic role. From lean initiatives the results indicate the possible dominance of design engineers to hide unwanted and irrelevant features and reduce environmental impact of product. Findings exhibit an overall impression that strategic/ intelligent product information is likely to be utilized as part of user-centered design process, where industrial designers can take advantage of smart product’s life cycle management. Overall the perception based findings show that advances in semantic and sensing technology can change approach of user interaction with products which eventually leads to product development success.

Contribution of the Study

In this study attempt has been made to analyze the perception of Indian organizations which are involved in product development in order to measure the impact of factor dimensions on SPD in terms of expected implementation benefits. Since the concept of smart product development from industry 4.0 in Indian context is in its stage of infancy and the scarcity of literature available in the said context clearly shows the prominence of the present study and its contribution. Results demonstrate the emergence of two constructs (technological and strategic) which are positively associated to expected benefits in terms of SPD success. The main contribution of this paper is identification of emerging constructs (herein referred to as factor dimensions) of SPD and how these factor dimensions are seen in emerging economy context like India, since most of the studies have been done from developed nations perspective. In this regard the present study showed how technological and strategic factor dimensions are associated with projected benefits of SPD. The designated approach using quantitative model for industries 4.0 gives industries the opportunity to learn regarding solutions from techno-strategic aspect which may be deemed to be a novel contribution from Indian context since Industry 4.0 is still in concept development phase.

Conclusions

In this paper the current industrial development on smart products from industry 4.0 in Indian context has been represented. The attributes and factor dimensions influencing SPD gives a preliminary overview regarding developmental process based approach for smart products. SPD from industry 4.0 perspective in Indian context being relatively new thus there is always a possibility of high degree of uncertainty and technological know-how for real time implementation. Hence, present study would be beneficial for its application based findings which could be taken up by the industries as partial guidelines to undertake implementation procedures from both technology and strategic perspectives.

Practical Implications

Results derived from this study can be beneficial to operations manager and industry policy makers to execute decisions at all levels from strategic, tactical and operational aspects. From operational perspective the results exhibit which attributes are critical for successful implementation of SPD. Considering the present industrial scenario the results would provide partial guidelines to the industries who wish to adopt the strategy of industry 4.0 and think which attributes should be considered. Accordingly based on competitive priorities industries can develop and design their implementation strategies. On other hand industrial policy makers can use the findings of this study to initiate policy level decisions as to what technology and strategic dimensions need to be considered during developmental phases of smart products in order to achieve competitive advantage. For example technological attributes like TI, SI and CE could be strong trending patterns followed by strategic attributes like lean systems and sustainability. Results and findings derived from this study can be beneficial to operations manager and decision makers to design their implementation strategies.

Limitations and Future Scope

In this study five critical attributes of SPD have been considered and there is a scope to explore more number of attributes from industry 4.0 perspective. From statistical perspective the study has some limitations since we considered perceptual measures based on respondent's opinion from industry 4.0 context, thus there may be possibility of respondent's bias. Secondly, there is a scope to increase number of respondents to generalise the findings. Future research can incorporate multiple variables and attributes along with control variables for advanced statistical learning. Furthermore, advanced prediction modelling could be initiated in future to investigate the role of contextual variables. Researchers can even think of bringing design management aspects into the entire process flow methodology to make smart products highly flexible and quality oriented.

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How Many Cases Do You Need for Studies into Operations Management? Guidance Based on Saturation

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Abstract

The case study methodology is a well-established method in operations management; however, clarity lacks on how to determine the number of cases required in multiple cases studies designs. This paper considers how the principle of saturation can help with this important aspect of research design. Saturation is considered at different aggregation strata and leads to rules that can be followed to help ensure both internal and external validity. This paper offers recommendations to identify when empirical data are incomplete from the perspective of saturation. These guidelines will help both novice researchers and more experienced ones, albeit in different ways.

Keywords: Case study methodology; operations management; saturation

1. Introduction

The case study methodology has been widely adopted in operations management. Early advocates included McCutcheon and Meredith (1993), Westbrook (1995), Meredith (1998), Voss et al. (2002), Voss et al. (2002) and Westbrook (1995), because of insight that can be generated and its potential to identify possible further research. There are number of seminal work that explain the works and provide guidance including Yin (1984) [and later editions], Barratt et al. (2011), Fox-Wolfgramm (1997), McCutcheon and Meredith (1993) and Stuart et al. (2002). However, the number of cases it still something researchers ponder about when adopting the case study strategy for a particular project.

1.1. Background and Objectives of Paper

Despite its widespread use, within and beyond operations management, guidance about how to set the number of case studies is scarce and the advice varies. For example, Rowley (2002, p. 20) posits that 'the greater the number of case studies that show replication, the greater the rigour with which a theory has been established'. This statement leaves the number of case studies open, but it suggests at least two. Eisenhardt (1989, p. 545) claimed that four to ten cases usually work well and states that with less than four cases it is often more difficult to generate theory in complex situations. Miles (1984) suggested 15 cases, whereas Levy (2008) indicated that the number of case studies depends upon the purpose of the study, but did not specify any particular number. These incongruent suggestions provide only a limited answer to the question of how to determine the number of case studies required.

However, a common theme is that the justification for the number of case studies required has been based upon the principle of saturation. Cruzes et al. (2015, p. 1657) suggested that new studies should add to knowledge relating to the prevailing research question, and Eisenhardt (1989, p. 545) referred to theoretical saturation for setting the number of cases, based on the work of Glaser and Strauss (1967). Steenhuis (2015) uses the principle of saturation to show that adding case studies until a high degree of saturation is achieved is the way forward; this is called the iterative-progressive case study method. However, this may result in the need to add case studies, which may exceed the resources available in funded or doctoral research projects. Thus, the following two questions remain that we seek to address in this paper:

- What is the minimum number of case studies that should be examined based upon the principle of saturation?
- What are methods to enhance the saturation for findings of case studies beyond adding additional cases?

1.2. Scope and Outline of Paper

The purpose of this paper is to set out further guidance about the number of case studies based on the principle of saturation for the domain of operations management. Some studies refer to saturation when providing a rationale for the number of case studies. For example, Pagell and Wu (2009, p. 40) claimed that they limited their study to ten case studies, because they reached the saturation point in their opinion; however, they did not provide any evidence for this assertion. Note that they also ambiguously stated that they could not process more cases in one study; hence, it cannot be established whether their decision to limit the study to ten supply chains was instigated by saturation or feasibility, two very distinct and seemlingly incompatible reasons. Similarly, Choudhari et al. (2013, p. 463) referred to saturation as justification for adding two more cases, but they did not provide any further detail. Also, in other instances saturation is referred to, but without any clear rationale or evidence. The only exception to this lack of more precise guidance is Steenhuis (2015), but this work does not help research determine how many case studies are needed in advance. To generate this guidance, research in other domains was consulted. Taber (2000) describes an example of the use grounded theory and the concepts of 'theoretical sensitivity', 'theoretical sampling' and 'theoretical saturation'. Fusch and Ness (2015) critiqued two qualitative studies for data saturation and concluded that failure to reach data saturation has a negative impact on validity. However, these authors did not provide detail on how to apply the principle of saturation when determining the number of case studies in a research design.

The paper is organised as follows. The next section will elaborate briefly on the case study methodology. This will be followed by a section on the principle of saturation for case studies. The fourth section elaborates how this principle will assist in determining the minimum number of case studies, while a final section concludes with implications for research.

2. Case Study Methodology

Before going into more detail about the case study methodology, the question arises what this approach to research constitutes. In this respect, Yin (1984, p.23), seen as one of the originators of the case study approach, defined the case study research strategy 'as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used'. This implies that the influence of context

is seen as playing a pivotal role in the understanding of phenomenon. Corroboration of the emerging interpretation is sought by using multiple sources of evidence; this could be obtained to applying a single method to multiple cases, or alternatively applying multiple methods in one instance (Yin, 1981, pp. 58–59). However, because the way the case study methodology is defined, it is often associated with qualitative research methods; for example, Eistenhardt and Graebner (2007, p. 25) referred to it from this perspective. However, looking at Yin's definition (Yin, 1984, p. 23) the type of research method is not specified, leading to one wondering how this orientation towards qualitative methods came about. Indeed, it has been noted that case studies may adopt quantitative, qualitative or mixed research methods (Rowley, 2002).

2.1. Brief History

The case study method as a methodology for research appeared at the end of the 1970s and the early 1980s. In one of the earliest publications on case studies, Yin and Heald (1975, p. 372) stated that 'the case survey method is mainly concerned with the analysis of qualitative evidence in a reliable manner.' However, in this work the explanation and the example position the case study survey method as a systematic review (see Green et al. [2006, pp. 104-5] for a description of such reviews) rather than an individual study, because Yin and Heald (1975) aggregated findings across studies. Stake (1978, p. 7) advocated case studies as a useful method for exploring theory development and commented that this method would be likely to remain popular amongst social scientists. A further development of the case study method can be found in Miles (1979, p. 591 ff.), which described the development of a framework for innovative public schools based on the investigation of six cases. However, it was Yin (1981) that sets out the case study methodology and more detail was provided in the his book (Yin, 1984). From this point forward, case studies become a widely accepted research strategy across disciplines. Examples include: Eisenhardt (1989) for business and management, Houghton et al. (2013) for nursing, Westbrook (1995) for operations management, Gerring (2004) for political sciences, and Runeson and Höst (2009) for software engineering. The case study approach has been defined as a research strategy Yin (1981, p. 58).

Whilst case studies have gained traction across disciplines, some confusion remains about its meaning and its underpinnings throughout. First, different labels are used that appear to be interchangeable (Hamel et al., 1993): 'case study', 'case study method' and 'case method'. Sometimes, these terms hide subtle differences. Is the onus on a single case or limited cases being available or is it seen as a specific approach to the research design? Second, the case study methodology is principally without a specific research method. In this respect, the use of Delphi studies, focus groups, interviews and quantitative data has been reported. Third, the term case study is used for a range of different approaches. For example, Gerring (2004, p.342) attested to action research, field studies, etc., when referring to five different interpretations of the case study methodology, of which two can be found in Yin (1994). Though these points should be kept in mind, these three matters do not impact really on the question of how many case studies are necessary to achieve reliability and external validity.

2.2. Traditions for Case Studies

Early writings gravitated towards propositions. For example, Miles (1979, p. 592) used propositions, partially based on the reduction of variables in a project about processes involved in the creation of three elementary and three secondary public schools, as examples of innovative organisations. This point has been reiterated in more recent

publications, such as Gimenez (2005, p. 318), Starman (2013, p. 40) and Tight (2010, p. 334). However, the latter two tightly were linked to Flyvbjerg's (2006) rebuttal of critiques. This means that existing or tentative theories can be used for generating propositions, and thus, the case study methodology can also be used for hypothesis testing, as noted by Schurink and Auriacombe (2010, p. 452). A case in point for the latter is Dekkers (2010, 2011) who generated propositions for the impact of outsourcing decision on operational control based on three theories – transaction costs economics, resource-based view and core competencies – and two more propositions derived from reasoning about the impact of the decision. Thus, a first strand of cases studies has focused on hypotheses, either by generating or testing theories.

A second stream sees case studies as a means to generate theory. For example, Andrade (2009, p. 52) referred to this approach when stating that 'theory must emerge from data, and not from any preconceived hypothesis along a conceptualisation progression'. This grounded-theory approach, in the tradition of Glaser and Strauss (1967), which is based on pure inductive logic, where the new theory is derived strictly from the collected data. In this respect, Eisenhardt (1989, p. 536) intimated that this 'clean slate' approach is an ideal, and that in research practice the method is informed by the extant literature and existing theories in the theory-building process. Starting from scratch, as implied by the grounded theory approach, is impractical, because the study's research objectives, the selection of subjects (or objects), and data gathering require some rationale or preconceived ideas; even Glaser and Strauss (1967, p. 169) encouraged researchers to 'use any material bearing in the area.' Subsequently, a number of articles (for example, Bourgeois and Eisenhardt, 1988; McCutcheon and Meredith, 1993; Voss et al., 2002) have suggested the use of a priori constructs to help shape the initial design of theory building research. However, such a priori constructs are only to be considered as tentative, akin Popper's thinking, and may not be in the resultant theory (Eisenhardt, 1989; McCutcheon and Meredith, 1993). In the end, the higher the level of consistency between the emergent theory and existing theory, the higher the external validity achieved.

2.3. Replication Logic at Heart of Methodology

In the case of multiple case studies, the core of the case study methodology is replication logic to achieve such external validity. This is captured by Gerring (2004, p. 344) who stated that 'a single unit observed at a single point in time without the addition of within-unit cases offers no evidence whatsoever of a causal proposition.' Consequently, research using the case study methodology must include the temporal dimension for a single case, or otherwise, compare similar instances of phenomena. A single case study is possible, when it concerns an extreme case, a critical case or a paradigmatic case (Flyvbjerg, 2006, p. 230); in none of these three types will saturation be achieved if studies are restricted to one case. Additional case studies will be necessary to achieve generalisation. If the objective is producing similar results, then this is called literal replication, or when producing predictable results, then it is labelled theoretical replication; note the subtle difference between our statement and Rowley's (2002, p. 21). In this context, Levy (2008, p. 14) remarks that the latter is particularly evident in the criteria for case selection and logic of interpretation in extreme cases, deviant case strategies and comparative studies (using Flyvbjerg's [2006, p. 230] wording for consistency throughout our paper). Both literal and theoretical replication aim at extending findings to other groups or settings, not to augment the number of data points to increase the confidence of within-group findings (McCutcheon and Meredith, 1993, p. 246). Thus, replication logic aims at

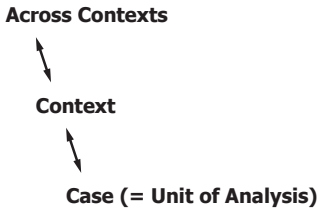

Figure 1: Levels of analysis for case studies

the generalisation of results, findings and theory, whether through literal or theoretical replication by purposefully adding cases.

Ideally, whereas the number of case studies is determined by replication logic, there is also a trade-off between external validity across cases and in-depth observations for each case. The sufficiency of in-depth observations for each case refers to achieving reliable outcomes. In this respect, Voss et al. (2002, p. 202) note that multiple case studies could reduce the depth of a study when the resources are constrained; for example, this may be the case for doctoral studies. However, multiple case studies may enhance generalisability of conclusions, models or theory, and reduce observer bias as long as each case demonstrates that it meets criteria for quality of research design.

2.4. Analysis of Case Studies

In general, four criteria are used for assessing the quality and the generalisation of conclusions, models or theory derived from case studies: construct validity, internal validity, external validity and reliability (Rowley, 2002). These constructs are not limited to case studies, but are seen as generic criteria for the quality of investigations, for example, by Drost (2011) and (Fitzner, 2007). However, in the context of case studies, external validity can be seen as the generalisation of findings to other settings or systems. The evidence and analysis in multiple case studies supports this generalisation by identifying aspects or features of settings that may influence a phenomena or contingencies within cases with the same purpose. It should be noted that the generalisation of a contextual setting or contingencies across contexts is not known on beforehand when designing the methodology. Cepeda and Martin (2005, p. 855) remarked that external validity also concerns whether conjectures, findings and conclusions are connected to existing scholarly knowledge which implicitly calls for an adequate literature review.

As the case study methodology not just investigates cases, but also analyse the impact of a context on a phenomena related to a case, the analysis should consider different levels. Fox-Wolfgramm (1997, p. 446) mentioned the interplay between contexts in this respect and later (ibid.) indicated multiple levels of analysis. We have called these units of analysis and labelled the levels as context, case and embedded unit of analysis. Figure 1 shows the two units of analysis for holistic case studies. For example, these holistic case studies look at firms as a single unit. When considering parts of a firm, but not the

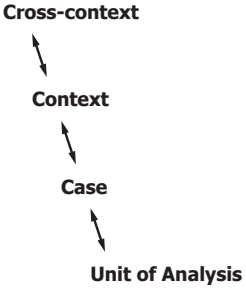

Figure 1: Levels of analysis for embedded case studies

total, an additional unit of analysis emerges, which is called an embedded unit of analysis; see Figure 2.

Nothwithstanding rigour in analysis at different levels, the limited number of objects or subjects implies abductive reasoning. Because case studies are characterised by more variables than the number of instances, this seems unavoidable. Therefore, the variables considered and their causal links imply abductive reasoning, which starts with an incomplete set of observations and proceeds to find the likeliest possible explanations (Dekkers, 2017, pp. 61–3).

3. Principle of Saturation for Case Studies

Whether further efforts for data collection or additional cases are needed could be determined by saturation. This can be defined as the point at which incremental learning becomes marginal to achieve a predetermined research outcome, which Glaser and Strauss (1967, p. 61) called theoretical saturation. Operations management research that has adopted the case study methodology or provided insight into the methodology has mimicked this stance. For example, when discussing theoretical saturation, Ravenswood (2011, pp. 681–2) cited Eisenhardt (1989, pp. 533, 545–6), however Eisenhardt explicitly referred to Glaser and Strauss (1967). In the same vein as Glaser and Strauss, Lincoln and Guba (1985, p. 204) recommended sampling 'to the point of redundancy.' Fox-Wolfgramm (1997, p. 447) exemplified this by stating that in her study, codes, themes and patterns began to stabilise two-thirds of the way through data collection in research relating to strategic processes in banks. According to Fusch and Ness (2015, p. 1408) data saturation is reached based on three criteria: (1) when no new information will be obtained through further data collection; (2) when further coding is no longer feasible; and (3) when there is sufficient information to replicate the study. However, it is not clear from their writing whether all these criteria should be met, or that at least one should be satisfied. Andrade (2009, p.48) referred to 'theoretical saturation' as 'theoretical sufficiency'. This was derived from Dey (1999, pp. 116-7), who claimed that theoretical saturation 'has connotations of completion [and] seems to imply that the process of generating categories (and their properties and relations) has been exhaustive'; note the use of the wording 'exhaustive' rather than 'exhausted'. In this respect, theoretical sufficiency is preferred because, theoretical saturation turns out to be an inflexible expression, while both indicate that the data have been properly analysed.

Saturations is mentioned in articles about the quality of case studies as a prominent criterion, e.g. Cepeda and Martin (2005, p. 862), however, the concept is often not operationalised. Van Aken et al. (2016, p. 6) argue that 'saturation' is an instance of the law of diminishing returns and that 'field tests are intended to produce a 'saturated body of evidence' on the pragmatic validity of a generic design'. Morse (1995) indicates that saturation is inconsistently assessed and reported. This means that reporting of saturation should be a prominent feature of publications using the case study methodology

In this respect, Brod et al. (2009, p. 1268) proposed a saturation grid 'whereby major domains (topics or themes) are listed along the vertical and each group/interview is listed along the horizontal … Saturation is reached when the grid column for the current group is empty, suggesting that new themes or concepts have emerged. However, the final determination that saturation has been reached is made during data analysis (coding) and documented with a refined saturation grid'. This approach could be applied to case studies and units of analysis, too. Data triangulation can improve construct validity (Rowley, 2002). Data tri-angulation helps ensure data saturation, particularly when triangulation

is based on the use of different research methods which creates rich in-depth data (Fusch and Ness, 2015, pp. 1411–2).

Data saturation for case studies happens at two levels and in the case of an embedded unit of analysis even at three levels, though not necessarily in one study. At the level of the case of the embedded unit of analysis, saturation will be achieved once new empirical data does not yield anymore new coding, or when the case study can be replicated. Saturation at higher levels can be identified when there are no new relevant characteristics that influence phenomena or properties of the studies subsystem or aspectsystem.

4. Determining Number of Case Studies

Setting aside how the principles for saturation may influence the research design using the case study methodology, some authors have already provided guidance about the number of case studies. For example, Eisenhardt (1989, p. 545) indicated four to ten cases. However, the choice is context dependant and it is recommended to use the principle of saturation; see Figure 3 for the resultant overview.

4.1. Replication Logic

Gerring (2004, p. 343) indicated that at least two cases are needed to make a comparison. However, this means that differences between cases cannot necessarily be replicated. This may concern causal relationships when considering theoretical and literal replication. Thus, at least another case, a third one is needed, to compare findings.

4.2. Purpose of Study

In terms of systems theories a case study always concerns a subsystem and a limited number of aspects (Dekkers, 2017). This means that abstraction needs to take place. Timpf (1999) identified three types of abstraction: classification, where properties of the system call for grouping to decrease the number of variables; aggregation, which involved putting together different entities to form a coherent whole; and generalisation, is the application of behaviour derived from one set of entities to another set of entities based upon the existence of similar relationships and elements, but not necessarily all.

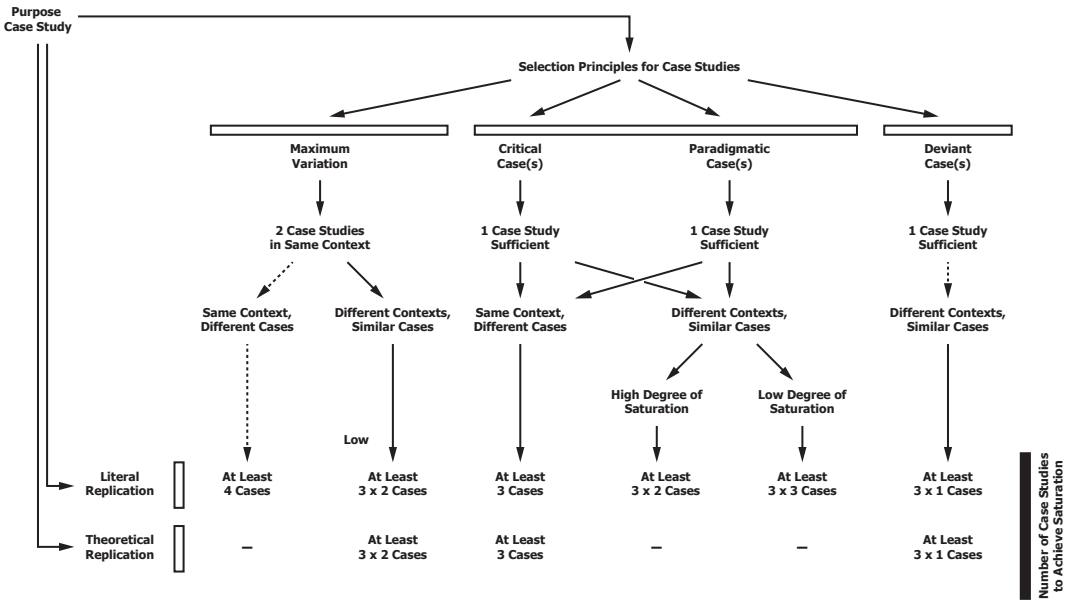

Figure 3: Pathways for determining the number of case studies in the case of the holistic approach

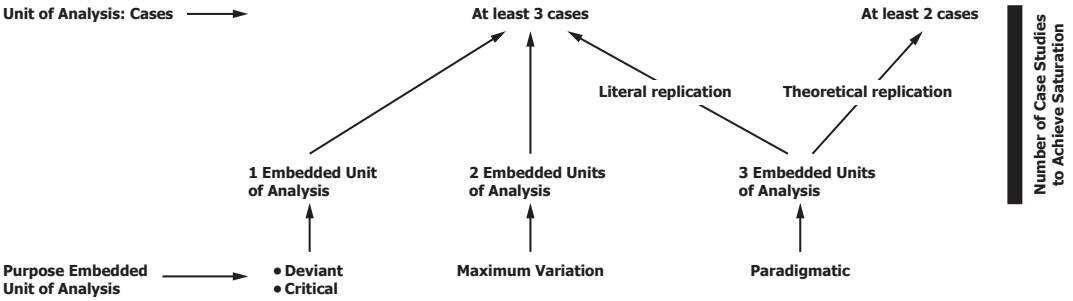

Figure 4: Minimum number of case studies when studying embedded units of analysis

4.3. Unit of Analysis

Case studies can involve either single or multiple cases; and may be holistic (single unit of analysis or embedded (multiple units of analysis) (Yin, 1994). There are thus four types of case study design: single case/holistic (type 1); single case/embedded (type 2); multiple case/holistic (type 3); and multiple case/embedded (type 4). Single cases are akin to a single experiment and are appropriate when the case is special, for example to test a well-established theory where the case is extreme or unique. They may also be used as a pilot in multiple case studies (Rowley, 2002, p. 21). Multiple case studies are preferable as the research outcomes become more robust with more cases. Cases can be selected so that they produce similar results (literal replication) or produce contrasting results for predictable reasons (theoretical replication) (Rowley, 2002, p. 21). There is a distinction between holistic case studies and embedded units of analysis. Figure 3 only looks at holistic case studies. Figure 4 adds considerations for embedded units of analysis.

4.4. Snowball Sampling

Snowball sampling occurs 'when the researcher accesses informants through contact information that is provided by other informants. The process is, by necessity, repetitive: 'informants refer the researcher to other informants, who are contacted by the researcher and then refer her or him to yet other informants, and so on' (Noy, 2008, p. 330). Snowball sampling can be used for identifying cases. Subsequent adding of cases provides two purposes to a study. First, it allows the further development of concepts and new insights. This is particularly aimed at achieving saturation. The work of Steenhuis (2015) points in the same direction, though viewing it as the iterative-pragmatic case study method. Second, additional cases allow the replication of earlier findings. However, this strategy could lead to (unintended) bias in the selection of cases and not necessarily the most suitable cases are selected. This means that snowball sampling can be an effective strategy, but requires studies to carefully consider how recommended cases will contribute to the rationale of the research.

4.5. Other Complementary Strategies

In addition to snowball sampling, other complementary strategies for achieving saturation could be used:

- One alternative strategy is the use of focus groups after findings from the case studies have been inferred. Such is suggested by Fusch and Ness (2015, p. 1410) from the perspective of qualitative research; however, this strategy seems to be less favoured by studies in operations and supply chain management.
- A second alternative strategy is indicated by Eistenhardt and Graebner (2007, p. 27); after examining replicated findings further cases can be explored at a higher level

of abstraction. Dekkers (2009) adopted this approach when examining innovation practices in a Chinese manufacturer of professional printing equipment; the performance of other Chinese firms in the same sector was used to reason that findings may not be restricted to the original company studied.

- A third strategy is to complement the empirical case studies with published studies. Such will result in fragmented data, because these previously published works may have differing research objectives and reporting. An example is found in Dekkers (2018), when comparing three empirical case studies with five reported case studies on group technology; this allowed drawing more robust inferences for specific themes.
- Finally, studies using the case study methodology for a particular purpose can be pooled. Although technically this should be considered a systematic literature review.

5. Discussion and Conclusions

Qualitative research is not concerned with statistical generalisability and uses nonprobabilistic sampling. The most commonly used samples are purposive (Guest et al., 2006). It is often recommended that the size of purposive samples should be established inductively and sampling should be continued until theoretical saturation occurs (Guest et al., 2006). Data saturation is reached when there is enough information to replicate the study. A failure to reach data saturation has an impact on the quality of the research and hampers content validity (Fusch and Ness, 2015).

In research practice, data saturation and the number of case studies will be often a balancing act. As Fusch and Ness (2015, p. 1413) remarked: 'there is no one-size- fits-all method to reach data saturation; moreover, more is not necessarily better than less and vice versa.' So in the case of limited resources, which is a common constraint with funded research and doctoral studies, it may be necessary to limit the number of cases. It is often better to think of data as being 'rich' (quality) and 'thick' (quantity) rather than think in terms of sample size (Dibley, 2011). The quality of the research can also be improved by obtaining data from multiple sources and applying mixed methods. A saturation grid can help identify the marginal benefit of adding each case. Inevitably, in such studies the principle of saturation implies that one case needs to be added beyond those directly required: one case too far!

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Digital process innovation and financial performance: An event study

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Abstract

Digital process innovation—defined as the use of digital technology for process innovation—has recently become a new orientation of manufacturing companies to solve operational problems; however, the actual impact of digital process innovation is still unclear. In this research, we study the actual effect of digital process innovation on organizational performance. We further examine whether the impact of digital process innovation is strengthened if manufacturing firms increase their absorptive capability and their slack resource. This research provides valuable insights into how to effectively implement the strategy of digital process innovation.

Keywords: Digital process innovation, Absorptive capacity, Slack resource

Introduction

Operational problems, such as high-volume inventory, continuously increasing operational cost, operational inefficiency, are usually the concerns of the conventional manufacturing process (e.g., Boston Consulting Group, 2014; Kearney, 2016). Recently, digital process innovation—defined as the use of digital technology for process innovation—has become a new orientation of manufacturing companies to solve such kind of operational problems and has demonstrated its effectiveness. Taking GE Company (d'Aveni, 2015) as an example, it adopted digital technology in the production mode transformation of an engine from the assembly of twenty separate cast parts into direct production of one piece. This saves 75% of the operational cost. Nevertheless, there are some other concerns towards the effect of digitized operational processes. For instance, more energy is required in three-dimensional printing than in the traditional injection molding (Chen et al., 2015). Thus, the actual impact of digital process innovation is still unclear.

In this research, we study the actual impact of digital process innovation on organizational performance. We further investigate operational factors that may exert significant bearing on digital process innovation to enhance a firm's performance. Specifically, we examine that the impact of digital process innovation is strengthened if manufacturing firms increase their knowledge absorptive capability and their slack resource.

Theoretical Background and Hypothesis Development

Digital process innovation enables firms to promptly and accurately identify customer requirements and preferences and to offer customized even new products that, in turn, better meet customer individual requirements (Armenakis and Harris, 2009; Ye et al., 2007; Judge et al., 2009). This may result in increasing firms' performance. Hence, we hypothesize that the adoption of digital process innovation can improve a firm's performance, as shown below.

Hypothesis 1: Digital process innovation enhances organizational performance.

Operational absorptive capacity is referred to the capability of an organization's operational units to obtain, assimilate and exploit knowledge from external source (Patel et al., 2012). In a company, when its operating unit has absorptive capacity, the unit is more likely to have the ability and flexibility to obtain, assimilate and exploit the information provided by external parties and required for the implementation of digital process innovation, leading to higher organizational performance. Therefore, we hypothesize:

Hypothesis 2: Absorptive capacity of a firm positively moderates the relationship between digital process innovation and organizational performance.

Slack resource is defined as the buffer resource, in excess of the minimum necessary resources for a firm's daily operation, for coping with environmental uncertainty (Nohria and Gulati 1996). Companies with slack resource are likely to have buffer resource as safeguard to present the risk imposed while implementing digital process innovation, leading to enhanced organizational performance. Thus, we have the following hypothesis.

Hypothesis 3: Slack resource of a firm positively moderates the relationship between digital process innovation and organizational performance.

Methodology

We conducted a longitudinal event study to test the effect of digital process innovation on organizational performance. We focus on manufacturing companies that are publicly listed firms in the Mainland China. Driven by the recent China's policies such as Made in China 2025 and internet plus manufacturing action (China Daily, 2016), many manufacturing companies have gradually adopted and even have fully implemented the strategy of digital process innovation. Hence, manufacturing companies in the Mainland China are the most proper setting to conduct this study.

We consider digital process innovation as a firm's official launch of digital innovation initiative for its manufacturing process. Accordingly, we collected the

announcements about the adoption of digital process innovation from Factiva and Wisenews using keywords, for example digital platform, digital channel, digital manufacturing, intelligent manufacturing, additive manufacturing, and three-dimensional or 3D printing. Return on asset is regarded as the performance outcome of the firm. R&D intensity as a proxy for absorptive capability while slack resource is based on inventory level.

Finally, we obtained the relevant announcements from a sample of 168 firms. For these sampled firms, we collected data on return on asset, absorptive capacity and slack resource from the China Stock Market and Accounting Research databases.

Data Analysis and Results

We employed the approach of longitudinal event study to test the causal relationship between digital process innovation strategy and organizational performance. The results show that digital process innovation has a long-term effect on the performance of manufacturing companies. Subsequently, we conducted the ordinary least squares regression to examine the potential moderating effects of absorptive capacity and slack resource on the association among digital process innovation strategy and firm performance. The findings demonstrate that absorptive capacity and slack resource strengthen the effect of digital process innovation on firm's performance.

Discussion and Conclusion

This research reveals the real impact of digital process innovation on organizational performance in the manufacturing domain and explores the factors to enhance such impact. Specifically, it fills up the gap how to effectively implement the strategy of digital process innovation. This research also provides useful guideline for effective implementation of digital process innovation by considering a firm's internal absorptive capacity and slack resource.

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The impact of supply networks and their collocation with firm's subsidiaries on firm performance

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Abstract

Buying firms belong to two separate networks: the internal network consisting of their subsidiaries, and the supply network consisting of their suppliers. Incorporating three theoretical perspectives: knowledge based view, social network theory and dual embeddedness, this study proposes a model explaining the link between geographic dispersion of those networks, their collocation and performance. We argue that the relationship between geographic dispersion and performance is moderated by collocation of both internal and supply networks. Using a large scale study based on secondary data, this paper offers an understanding of the interplay of internal and supply networks and the effect on performance.

Keywords: Geographic dispersion, supply network, internal network

Introduction

Multinational companies (MNCs) operate through globally dispersed networks of plants in which knowledge is developed and exploited at multiple units. The reason for the existence of multinational companies is their ability to transfer, recombine, and exploit resources through several contexts and between countries (Meyer et al., 2011). Gupta and Govindarajan (2000) argue that a multinational company can be considered "a network of capital, product, and knowledge transactions among units operating in different countries". MNCs are in a powerful position to access resources and capabilities from several local contexts and assimilate them to create competitive advantages. The broader the dispersion of MNC knowledge activities infers that these companies undertake knowledge related activities in diverse locations. This multiplicity of contexts allows the MNC to tap into knowledge from various knowledge clusters and hotspots (Meyer et al., 2011). Many scholars argued that companies should expand to a foreign country gradually as they accumulate resources and international experience (Zeng et al, 2013).

Global supply chains include MNCs that integrate geographically dispersed processes to gain advantage of diverse location benefits. In fact, supply chains are not just a combination of buyers-suppliers' relationships but they consist of networks that are spreading globally. Yet, the supply network coordinates not only with the firm as one entity but with its several subsidiaries as well as its headquarters. In fact, Demeter et al (2016) have suggested that, in practice, subsidiaries of buying firms operate as members of two distinct networks: internal network composed of several subsidiaries belonging to the same company, and external supply network identified through information and material flows between different companies that cooperate with each other in a supply chain.

The need to look at supply chains as a network of firms that can collectively achieve better performance, operational effectiveness and sustainable competitive advantage has long been recognized (Choi and Hong, 2002). Yet, empirical research has only recently moved beyond the investigation of the dyadic relationship between the buyer and supplier to that of supply networks (Borgatti and Li, 2009; Kim, 2014; Kim et al., 2011).

Therefore, this study aims at establishing whether there is a relationship with the firm's both internal (such as plants and subsidiaries) and external (such as suppliers and customers) network as sources of knowledge. This study is concerned with how firms achieve better performance by integrating both their internal and supply networks simultaneously, therefore, a dual view of embeddedness is adopted from the international business literature and transferred into a supply chain management context. To pursue this objective, the paper also draws on the knowledge based view and social network theory to explain how the geographical dispersion of the firm's networks can be beneficial to firm performance and whether collocation of these networks has any effect on this relationship. In fact, a large number of papers have been devoted to study this relationship (Lu and Shang, 2017) without considering collocation. However, results are still far from being conclusive.

Literature Review and theoretical standpoints

Dual embeddedness

Embeddedness refers to the extent to which a firm depends on its suppliers and buyers in a specific supply network structure (Nahapiet and Ghoshal, 1998). Embeddedness implies that the firms' competitive performance can be achieved more easily by the social ties they build with different actors in their social environment (Granovetter, 1985; Uzzi, 1997). The concept of embeddedness indicates the contextualisation of an economic action in ongoing arrangements of social relationships and seizes the contingent nature of the activities of an economic actor taking advantage of being embedded in a bigger social structure.

Embeddedness can be defined in terms of structural, relational, and cognitive aspects (Nahapiet and Ghoshal, 1998). Structural embeddedness stresses on the configuration of an entity's network of relationships, while relational embeddedness emphasises the role of quality of those relationships (Rowley et al. 2000). It has been claimed that only structural and relational dimensions of embeddedness are meaningful dimensions to examine the advantages of embeddedness because it is hard to operationally distinguish the cognitive aspect from other aspects (Granovetter, 1985).

Previous studies have focused completely on one view, missing a comprehensive view of the role of network embeddedness. Past research proposed several levels of structural embeddedness, containing company level, dyad level, and network level. Kim (2014)'s study showed that the understanding of structural embeddedness and relational

embeddedness must be taken into consideration in the efforts to improve firms' performance. In fact, the study found that the greater understanding of the supplier positional advantage is critical in the development of the operational performance and the structural position helps to improve the dyadic relationship and exchange between a buying firm and its supplier. Most research focus on the positive effects of embedded relationships (Bellamy et al, 2014); however, some researchers have found many negative effects on firm performance such as opportunism, redundant information, relationship inertia that leads to higher relationship costs and maintenance cost and, therefore reducing the positive impact of relational embeddedness (Uzzi, 1997; Villena et al., 2011; Rowley et al., 2000).

In the international business literature, the term "dual embeddedness" refers to the simultaneous integration of a subsidiary into its internal and external network (Figueiredo, 2011; Meyer et al., 2011). Dual embeddedness studies examine mainly how local market knowledge can be obtained from external networks, and dispersed within the MNC through the internal network of subsidiaries (Andersson et al., 2002; Meyer et al., 2011). Dual embeddedness is also defined as the dual linkages used by the firm to create capabilities to achieve better performance (Ciabuschi et al., 2014). It indicates that subsidiaries simultaneously sustain a positive relationship and efficient communication with both headquarters and local companies in host locations. In this way, the subsidiaries are able to tap into this network of local companies in order to learn about expertise and customers and thus seize local knowledge (Figueiredo, 2011). Then, they use their connectivity within the MNC's network to convey this knowledge. Subsidiaries have to be sufficiently close to the supply network within the local environment to generate knowledge access and inflows, and simultaneously be sufficiently close to the MNC's internal network for the knowledge to be successfully transferred and exploited through the MNC (Meyer et al., 2011). This may require proximity and collocation between the units.

Dual embeddedness was also used in studies on either internal or external embeddedness and their effect on subsidiaries' knowledge (Andersson et al., 2002).

Meyer et al, (2011) has noted that there has been rarely any empirical research studying the simultaneous impact of internal and external network. Most studies has either examined the effect of external or internal network and it is, hence, unclear how geographic dispersion and collocation relate to firm performance. In addition, supply chain management studies rarely consider both internal and supply networks simultaneously and when they do, the context has been primarily limited to manufacturing.

Despite the recognised importance of knowledge sharing in networks, the level of embeddedness of subsidiaries and its outcomes have not received much attention in the operations management literature. In contrast, the international business literature discusses internal integration and notes that greater internal integration creates opportunities for subsidiaries to learn from each other (Ghoshal and Bartlett, 1990; Gupta and Govindarajan, 2000) and thus creates potential further development (Ghoshal and Bartlett, 1990).

This study, therefore, answers to the call for research on dual embeddedness (Demeter et al., 2016) and does so by investigating the relationship between geographic dispersion and performance and the moderating effect of collocation in a set of firms and subsidiaries from the electronics industry.

Knowledge based view

This paper is also grounded on the knowledge based view (KBV) (Grant, 1996; Kogut & Zander, 1993). The KBV places knowledge as the firm's most important strategic resource (Kogut and Zander, 1993). It suggests that because knowledge is embedded within firms and is usually hard to imitate, access to heterogeneous knowledge bases is a major determinant of sustained performance. In addition, the KBV uses the logic of the resource based view (RBV) to suggest that knowledge is a major determinant of competiveness (Kogut and Zander, 1993; Grant, 1996).

Scholars also propose that knowledge sharing between alliance partners is a major contributor to enhanced competitiveness (Grant and Baden-Fuller 1995). Organizations are repositories of knowledge, the ability to access knowledge and to integrate it effectively is truly a source of competitive advantage.

In line with this, the knowledge-based view of the firm would suggest that collaboration provides access to strategic knowledge (Grant and Baden-Fuller 1995; Grant 1996), and that firm performance is directly linked to building capabilities through interacting with heterogeneous sources of knowledge (Kogut and Zander 1993). Therefore, not surprisingly, knowledge management practices among supply chain partners have attracted much attention (Sangari et al., 2015). The literature suggests that partnerships between buyer and supplier firms are a conduit for knowledge sharing that can result in improved performance along the entire supply chain (Dyer and Nobeoka, 2000; Krause et al., 2007). For example, the literature on supply chain collaboration shows that knowledge from upstream suppliers enhances buyer performance (Flynn et al., 2010). Also, according to Ghoshal and Bartlett (1990), specialized suppliers often possess unique knowledge that enables them to provide good quality products at low prices.

The KBV has been developed as an extension of the RBV and it suggests that in addition to its role in firms, knowledge can contribute substantially to an intangible strategic resource in supply chains as well, so that it can be a source of competitive advantages in supply chain and improved supply chain outcomes (Sangari, 2015).

In addition, the International Business literature has often considered that the rationale behind the existence and foreign expansion of multinationals lies in their knowledge and learning abilities (Kogut & Zander, 1993).

In this paper, geographical dispersion of supply networks and of internal networks are related to knowledge based resources in two ways. First, they affect the conduits through which knowledge based resources can be obtained and shared. Links among the buyer, its suppliers, its customers and its subsidiaries influence the access to knowledge. Second, they affect the heterogeneity of knowledge. This is mainly related to geographical dispersion because knowledge asymmetries highly likely exist among geographically dispersed firms (Lu and Shang, 2017).

Furthermore, research on the KBV of the firm has suggested that social networks facilitate the creation of new knowledge within organizations (Kogut & Zander, 1993; Tsai, 2001). Through the development of network ties, transfer of knowledge develops organizational learning. When different units are connected to each other, a network arrangement provides a flexible knowledge transfer structure that substitutes traditional hierarchical structures.

Social network theory

Social network theory (SNT) also adds insights to this paper. The supply chain management research is increasingly examining supply chain relationships beyond the traditional buyer supplier dyad, looking instead on the supply network (Wagner and

Neshat, 2010; Giannoccaro et al., 2017). Supply chain management is not just dyadic; it actually considers paths through a network of firms. Indeed, previously, the focus has been on paths between just two nodes: supplier to focal firm, and focal firm to buyer. Yet, the concept of suppliers of suppliers and buyers of buyers and so on has at all times been there, and recently, the notion of a supply network is starting to replace that of a simple path. Given that a supply chain is a network of companies and thus comprises several interrelated parties, Choi et al. (2001) stated that social network perspective could be an appropriate approach to study supply networks. Also, many studies in the supply chain management literature have shown the salience of social network analysis to study supply networks (Borgatti and Li, 2009; Kim et al., 2011; Kim, 2014). This stream examines supply chains as complex social networks and uses methods from social network analysis to understand relational ties and their effect on social capital, knowledge transfer, resource access, convergence, and contagion in supply chains.

SNT supports the idea that firms occupying a central network position are likely to achieve better performance due to their access to more information and resources. The more the in-degree and out-degree links a firm has with other units in the network, the higher its node centrality, which in turn leads to a higher access to heterogeneous knowledge. This concept indicates that the more ties a node has the more it is considered as central, thus, when a node is linked to a high number of other nodes, this node has high degree centrality.

More importantly, SNT highlights the effect of lack of connection which is structural holes on buyer performance (Burt, 1992). A buyer who connects disconnected units (i.e. who holds the position of a structural hole) enjoys brokerage opportunities. A hole implies that firms on each side have access to discrete knowledge and information (Burt, 1992). Hence, a structural hole maximizes resource-sharing and knowledge transfer advantages for the buyer. In addition, such benefits to the buyer vary distinctly with the level of connection between its suppliers, customers and subsidiaries. In other words, when the buyer holds a structural hole position, its subsidiary is connected to the buyer's suppliers and customers, and they, consequently, will allow the connection to their subsidiaries. Therefore, subsidiaries will have the potential to embed themselves within heterogeneous and different types of knowledge networks, in order to accumulate their capabilities required to strengthen their performance and competitive position (Cantwell and Mudambi, 2005).

The relationships between geographical dispersion, collocation and performance are derived from incorporating these three theoretical perspectives, and are more developed in the following arguments.

Conceptual Model and Hypothesis Development

In order to access the established and emerging supply markets around the world, firms need to be geographically dispersed. Bode and Wagner (2015) have associated geographical dispersion with the spatial complexity of companies' supply bases and defined spatial complexity as the extent of the dispersion among members within the network. The geographic dispersion of the supply network has proven to be one interesting avenue on the study of supply networks. Studies that have investigated supply networks' geographic reach have shown that it has an impact on a number of operational and supply chain goals (Lorentz et al., 2012).

Geographic dispersion in business management studies has been defined in many ways. Miroshnik (2002) describes geographic dispersion as the propagation of companies

over vast international distances. O'Leary and Cummings (2007) suggest that geographic dispersion has generally been defined in spatial terms, drawing on measures that take into consideration physical distances, number of countries, sites or locations.

In fact, when MNCs are widely dispersed geographically, each subsidiary builds up its own unique pattern of embedded network ties in the host country, therefore, the MNC headquarters encounters a bigger diversity as well as more opportunities to gain advantages from multinationality (Cantwell and Mudambi, 2005).

Narasimhan and Kim (2002) contribute to the above discussion from the supply chain management perspective, by finding evidence on an inverse U-shaped relationship between international market diversification and firm performance whereas Lorentz et al. (2012) suggest a negative relationship between intra-firm supply chain performance and geographic dispersion of sales and purchasing.

In addition, Manuj and Mentzer (2008) suggest that the internationalisation of supply adds complexity, and that ''greater supply chain complexity lessens the relationship between supply chain risk strategies and risk-related outcomes'', making management more challenging. Bode and Wagner (2015) studied a sample dominated by large firms and have found a positive relationship between the spatial complexity of the supply chain and the frequency of supply chain disruptions. However, organizations that have a high degree of geographic dispersion are, therefore, able to access and transfer knowledge more effectively from one unit to another, hence, they are more productive than organizations that are less capable of knowledge transfer.

The literature offers two opposite views on the effect of geographic dispersion and performance and the concept of geographic dispersion seems to have trade-offs. However, the KBV of the firm proposes that the benefits of access to knowledge outweigh the potential for opportunism in the collaborations between firms. As a result, we propose the following:

Hypothesis 1: The geographic dispersion of internal and supply networks of firms has a positive impact on firm performance.

On the other hand, collocation has been widely regarded as an effective way to improve performance (Narasimhan and Nair, 2005). Mechanisms like frequent team meetings, supplier conferences, cross functional teams and collocation are suggested to managers as ways of improving business outcomes (Cousins et al., 2008). In addition, Narasimhan and Nair (2005) define supply chain proximity as "the physical closeness of the buying and supplying firm". They found that supply chain proximity is positively associated with the formation of strategic alliance program as well as with performance. In fact, buyers who locate close to their customers and who require their suppliers to locate close to them implicitly value the physical proximity because it might enhance their ability to provide superior customer service, better control the flow of materials, better coordinate production schedules or be very responsive to changes in manufacturing demands. Therefore, if this flow of resources and knowledge is enabled through collocation of entities, greater effects on performance can be expected. In other words, with effective knowledge transfer processes in place, suitable knowledge can be channelled most effectually to the proper recipient, enabling a supply chain with a better performance.

Therefore, we hypothesize that:

Hypothesis 2: Collocation of internal and supply networks moderates positively the relationship between geographic dispersion and firm performance.

Design/methodology/approach

The geographic breadth and depth of a firm's multinational network are used as indicators of geographic dispersion. The breadth is measured by the number of foreign countries in which the buyer has at least one subsidiary whereas the depth is captured by the number of subsidiaries per foreign country. Collocation is captured by the number of suppliers and customers being collocated with buyers and their subsidiaries in the foreign countries. Firm performance is captured by return on assets, return on equity, and return on sales.

The hypotheses will be tested using a sample of firms in the electronics industry. The focus is on electronics because this industry has moved from being controlled by large companies like IBM, HP and Toshiba into an industry where companies have significantly developed global networks (Bellamy et al., 2014). Further, an industry such as electronics embodies aspects such as high market unpredictability, short product lifespans, and globalization (Sodhi and Lee, 2007). Secondary data for this paper is being collected from Bloomberg and Orbis, a financial database that includes information about more than 250 million companies around the world.

Conclusion

In this paper, a research model is derived from incorporating three theoretical perspectives: dual embeddedness, knowledge based theory and social network theory. Although, a big portion of supply chain studies has focused on geographical dispersion of supply network, but the question "What is the impact of collocation on the relationship between geographical dispersion and performance?" did not receive any consideration in the empirical literature. Driven by this question, this proposal aims to extend the literature in three main ways. First, empirical metrics will be used to measure the geographical dispersion, collocation of networks and performance and, an empirical investigation will explain the direct and moderating effect of the hypotheses. Second, this study will answer the call for research on dual embeddedness of a buying firm in its supply and internal network. Finally, this research is one of the first studies that considers collocation of dual network and its effect on performance which is an under-researched subject in the supply chain literature.

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Impact of Regional Contingencies on the Implementation of Lean Production: Two Romanian Case Studies

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Abstract
Whereas lean production is widely adopted in industry, there is a gap in the current literature regarding studies that consider implementation of lean production from a regional context. Hence, this study addresses the impact and contingencies of regional context on the implementation of lean production. More specifically, the results of two case studies in Romania are presented and discussed. Data collection included in-depth semi-structured interviews as well as observations of processes. The results show that using four dimensions of regional context does influence the implementation of lean production and the operational performance of the company.

Keywords: Lean production, regional dimensions, case study

Introduction
Lean production has been widely implemented by companies in different regions with the aim to improve performance. However, the impact of regional context when implementing lean production remains a gap in the literature (e.g. Bortolotti et al. 2015, Bhasin 2013). Few studies (e.g., Hines et al. 2004) that have looked into this issue lack sufficient in-depth analysis. Therefore, this study sets out to investigate in detail the impact that regional context may have on the implementation of lean production.

Research Objectives
Thus, this study aims at asserting the influence of the regional context on the implementation of lean production. It has become apparent that a few number of firms that adopted lean production, which relates to organisation culture (Bhasin 2013). In this

respect, regional context covers what members of society share and what leads to behaviour of the people, i.e. employees, suppliers and managerial mind (Wiengarten et al. 2015). More generically, some (e.g. Yadav et al. 2010) assert that firms struggle with implementing the concept of lean production, thinking that Toyota's success lies in their cultural roots and, hence, the concept is not transferable. However, Toyota has been successful in multiple countries, and not only Japan. Moreover, some (e.g. Kull et al., 2014; Wangwacharakul et al., 2014; Wang, 2008) have noted that the implementation of the concept of lean production varies for different regions, albeit without going into much detail. This study will address the gap about the adoption of lean production in regional contexts. Hence, the study addresses three research review questions:

1- To what extent the regional context contingencies affect the implementation of lean production as set of practices.
2- Are regional contexts a contingency for the design of lean production system?
3- How the regional context differs from a company to another?

To answer these questions, two case studies have been investigated in Romania, including an in-depth interviews and observation.

Outline of Paper

This paper is structured as follows. First, the literature review, which includes lean production and the regional context, is presented. Next, the methodology section, followed by an analysis of the papers. After that, there is a discussion of the findings. Then at last, conclusion of the study.

Literature Review

Before looking at the regional context, is necessary to look at what the concept of lean production constitutes. Although Womack et al. (1990) were the first researchers to propagate the conceptualisation of lean production, they never gave a specific definition for 'lean thinking'. This lack of definition in literature about lean production has reverberated until today, as Petterson (2009) notes. The only ones that have given a more specific description (rather than definition) of lean are Shah and Ward (2007), who have mentioned that lean production is about socio-technical system. However, even lean production practices and principles vary; some researchers list as few as five principles (Womack & Jones 1996), whereas others list over twenty practices or principles with more details for every aspect (e.g. Kull et al. 2014; Shah & Ward 2003; Shah & Ward 2007; Yadav et al. 2010). This implies that the concept of lean production is relatively undefined.

Hence, this lack of definition for lean production offers a unique opportunity to evaluate literature; the distinction of two strands of research into lean production serves as base for the further analysis. Therefore, this section of the paper will look with more detail into two different lenses: (i) lean production as a set of practices, (ii) lean production as design of production systems and to the regional context.

Two Lenses for Lean Production

The first lens, lean production as a set of practices, considers the process that a firm follows for implementing lean production, its methods, and tools, and practices. The practices can be defined as 'an activity or action which is performed to a standard which is better or equal to the standard achieved by other companies' (Davies and Kochhar 2002, p. 290). The tools that can be applied on Just-In-Time, total quality management, kanban, total preventive maintenance (e.g. Flynn et al. 1995; Shah & Ward 2003; Shah & Ward

2007). Lean practices lens is what most studies are addressing, what are those practices, what should be considered fundamental practices for implementing the lean production.

More specifically, some studies categories practices for lean production (e.g. people, process, tools). Shah and Ward (2003) grouped the practices into four categories: Just-In-Time (JIT), total quality management (TQM), total preventive maintenance (TPM), and human resource management (HRM), while this has 22 lean practices. Rahman et al. (2010) enumerate 13 practices out of the practices identified by Shah and Ward (2003) and they have grouped them in four categories. Moreover, Shah and Ward (2007) divide 10 factors into supplier-related, customer-related and internally-related (the process inside a firm). Chavez et al. (2013) descripting the internal lean practices that is mostly used on a shop floor of a firm, in another word hard practices and its effect on other dimensions such as quality and flexibility. Several studies have addressed lean practices in a different way by dividing them into two: soft practices and hard practices, such as (Kochan & Lansbury (1997); Rahman & Bullock (2005); Shah & Ward (2003); Yang et al. (2011)). Whereas, soft practices are focusing on people, for example, managerial practices and relationships (i.e. continuous improvement, top management leadership, and customer and supplier involvement), hard practices are concerned with technical and analytical tools, for instance, statistical process control and Kanban (Bortolotti et al. 2015). The latter also noted that the reason that most companies struggle with adopting lean production or getting the success they are looking for, resides mostly in ignoring soft practices and applying only the hard practices. Some practices may not be suitable for other region's employees; in this respond, Oudhuis and Olsson (2015) noted that regional differences should be taking in to account before implementing a production system. This all indicates that contingencies related to regional context may have a noticeable impact on the implementation of lean practices.

The second lens concerns the application of lean production principles (Bhasin 2012) to the design of production systems. For example, Low et al. (2015) study how to apply the lean principles to the design of a factory. In this strand of research, some studies use the principles for designing the firm, whereas (Black 2007 and Sobek II et al. 1999) fall back on the 'pure' Toyota production system. In addition, there are studies mentioning the lean principles for production as key to the design of production system (Black 2007; Mund et al. 2015; Low et al. 2015; Sobek II et al. 1999; Yadav et al. 2010). According to Yadav et al. (2010), the Toyota production system can be captured by four basic rules: (i) activities (how people work); (ii) connections (how the people connect); (iii) how the production line is constructed (pathways); and (iv) continuous improvement. According to Low et al. (2015), there are 11 key principles for lean production and the core is reducing the non-value-adding activities.

Some studies addressed applying the different principles on different regions without generalisation of the regional contexts such as Low et al. (2015) and Yadav et al. (2010). On the other hand, Sobek II et al. (1999) believed that applying the design principles of the Toyota production system is not related to the regional contexts. This all points to the necessity for evaluation whether contingencies related to the regional context have an impact on the design of production system.

Regional Context

For both lenses - lean production as a set of practices and lean as design of production system – contingencies related to the regional context need to be further specified, four dimensions could serve as initial classification (Aldossary et al., 2016). More specifically, the distance between a supplier and a manufacturing company to expand the most benefits from JIT (Cook 2001); also Arkader (2001) mentioned the location as barrier to JIT.

Culture differences between two nations (Wangwacharakul et al. 2014) or different cultural perspectives in an organisation, which includes the employees' relations and issues; which leads to cultural dimension. Another dimension concerns that get in the way of doing the business or smoothing the flowing of goods from a location to another or from a supplier to a company, as few studies described it as regulation and certificates (see Maleyeff et al. 2012; Rodgers & Wong 1996), which can be named as legislative dimension. Finally, considering the different ways that an organisation can look at its financial performance that may be a challenge in the implementation, as well as not having the right investment to help with the implementation change (Ketokivi & Schoeder, 2004), which can be linked to a financial affect. The geographical, cultural, legislative, and financial-economic dimensions can serve as classification of contingencies within regional context.

Research Methodology

Given the limited literature on this topic, and with the aim to achieve a deeper understanding of the effects related to regional context on the implementation of lean production, the study applied an exploratory multiple-case study methodology (Creswell 2003; Yin 2009). According to Eisenhardt (1989), case studies are useful when the phenomenon has not yet received appropriate ascertainment within the literature and when theoretical knowledge lacks clearness with respect to underlying issue. Moreover, multiple cases may help to understand the meaning and nature of real-life events, such as processes, relations and changes on organisational and individual levels (Yin, 2009).

In this respect, and for the explorative purpose aimed towards understanding, the empirical data for the case studies was collected through multiple methods and sources (Miles & Huberman, 1994; Yin, 2009). These included mainly semi-structured interviews and observations. Multiple interviews with top management and shop floor employees were conducted which lasted between 60 and 75 minutes. The interview data were supplemented with data collected through secondary sources, such as, project documentation, company guidelines, and web sites, and observations during the guided tours in the companies.

Case Study R1

The first empirical case (R1) concerns a manufacturing company in the aerospace industry. The company is in the medium size range with number of employees between 200 to 300 employees. R1 was founded in 2010 and the design of lean production was implemented from the beginning, adopted since they are a subsidiary of a conglomerate. Company R1 a full-service company includes extrusion, machining, and assembly into a single facility. Which serve customers all over the world from the far west as the United states to the far east Japan and China.

The value chain process followed by the company involves five main steps: (i) billet casting, (ii) extrusion, (iii) machining, (vi) surface treatment, and (v) assembly. In those steps for the analysis of the case study, they were assessed and investigated based on the dimensions mentioned before. Taking in perspective the plant size of the company, which almost includes three plants in one, which are the main three extrusion, machining and assembly. The delivery time of the company if the external suppliers are not involved the time is 8 days, however, when external suppliers get involved the time varies with no certainty.

Case Study R2

The second empirical case study (R2) is also a company in the aerospace industry, they focused on overhaul. Also, the company is a medium-sized company with the number of

employees being between 200 and 300. The company started implementing lean production with aim to cut waste, identification of internal benchmarks and giving ideas and concepts for specific problems.
Therefore, they are using five steps of the product line; starting with (i) the product comes in to the plant, (ii) the company assessed the product, (iii) orders placed for needed parts, (vi) components get reassembled, and finally (v) components are shipped back to the customer. The delivery time varies in between minor to major remanufacturing on the unit. The delivery time from the unit register to the plant to the time of leaving the facility ranges between 3 months to 18 months.

Results and Findings
The analysis followed the general thematic analysis approach indicated by Braun and Clarke (2006): i) familiarisation with data, ii) coding, iii) searching for themes, vi) reviewing themes, and v) defining and naming themes. Interview and focus group transcriptions were coded, checked and rechecked throughout the coding process for consistency. Whereas some themes were already latently found in literature discussed at the previous section, the analysis of the data gave rise to additional themes. The themes were reviewed and re-categorised resulting in to four main themes (Table 1), also can see Aldossary et al. (2016). The following sections will discuss in detail the findings of each dimension. The themes also

Geographical Dimension

The geographical dimension, is concerned with the location of companies, location of suppliers being in a cluster (Porter 1998), the relationship between the company and their supplier, and any geographical barriers related to the implementation of lean production. Whereas company R1 can manufacture all the necessary parts in site, there are cases when it is required to order these from external suppliers. More specifically, there are certain customers who may require from R1 to use specific external suppliers. These suppliers can be based in different places either in the U.S. or in Europe, consequently, R1 faces constant challenge with time deliveries. For example, a delivery to the US may take up to six weeks, which exceeds standards of R1of time deliveries to customers. Similarly, is the situation when a shipment goes to the far East (e.g. China).

Company R2 manufactures some parts, meaning that their inventory level has certain parts that are used commonly. However, when it comes to certain parts related to the core of engines, these are all supplied from two external suppliers based in central-west Europe. These two suppliers, based in different countries, will have to be involved for the remanufacturing of one component. As a result, depending on the condition of the unit received, the delivery time from the external suppliers can take 2-3 months for minor remanufacturing and up to 18 months for major remanufacturing. As a senior manager of R2 explained, that makes it very hard to meet the delivery time; mainly because most of the times the suppliers will take longer time in delivering the parts.

Hence, due to geographical proximities, both companies R1 and R2 are facing challenge with the delivery of parts. In company R1 the main issue appears to be the distance, and for company R2 distance as well as uncertain delivery coming from suppliers' contingent on the state of parts. Finally, both companies are also affected by the poor infrastructure of the region they are based in; which can significantly increase the lead-time for logistics.

Cultural Dimension

The second theme concerns the cultural dimension which is focusing on the employees' behaviour towards lean implementation. In the case of R1, from the beginning

of the company's found the company was designed to implement lean production system; and therefore, the employees did not go through any transformation period. Irrespectively, it is important to note that R1 operates in the north of Romania. Specifically, in this part of the country, people have a high level of education, and at the same time, they are very family-oriented meaning that employees prefer to work close to their hometown with most of them willing to do so, even if it means there will be less pay. This is clear in the case of R1 where more than 90% of the employees come from the same region. But the company is having very skilled and well-educated employees, due to the strong family oriented mind-set in this part of the country, businesses do not operate during the weekends. That means that R1 is not able to receive or send deliveries of parts during the weekends, which reduces the flexibility to respond to logistic perturbations.

Opposite to first case, R2 did not have a lean production system from the beginning, and therefore, when the management decided to implement lean production practises and lean design of production system, all the employees had to go through a transformation period. As a result, management faced challenges with employees accepting the change. As a senior manager explained, it has taken a lot of time and effort to smoothly transit to lean production and even now (at the time of the interview), they are still dealing with some negative attitudes from employees who find this system more demanding.

Legislative Dimension

The third theme, legal dimension, is mainly related to certification of some aerospace parts and the intellectual property agreements that the companies must obey. This means that without the necessary agreements, the company cannot produce certain parts they need. The legal dimension also concerns with the legal agreement that links each company with suppliers overseas. These legal issues contribute on the factors that affect the implementation of lean production. Whereas, companies R1 and R2, have this dimension as a contingency on the implementation of lean production, the legal factors are recognised as a way for controlling in this industry. For instance, in R1 there are fixed contracts with certain customers indicating that the customer's suppliers must be used on producing a product to that customer. Furthermore, they are certifying the products and some parts the companies R1 and R2 produced by the top customers in the industry.

Financial Dimension

The fourth and final theme, financial dimension, concerns the investment of implementing lean production and the plants' layout. In this regard, company R1 has invested heavily on the plant, and they are expanding the volume of production for the plant to reach its full capacity. Moreover, R1 is planning strategically to have another plant ready when the capacity of the first plant hits the maximum. At the same time, also tries to have duel source of producing all the parts needed to cut their costs and save time. However, the extrusion part of the company is in full capacity, and it causes delays to the other parts of the plant such as assembly line.

In Company R2, the case is slightly different. The budget for investing on the design of the production system is very limited, and the company tries to develop year by year. The flow of the units is not as smooth as it should be, but the company is making the most of the resources they have. Despite all the shortages in budget regarding the design, R2 is functioning is high-quality outputs.

The results of the two case studies confirm that the regional context does have an impact on the implementation of lean production. For instance, the cultural dimension within company and country shows a variety of aspects that have an impact on the implementation, such as; the employees' acceptance of change. Moreover, from the

geographical perspective, it is shown that the location of suppliers plays a considerable role in the implementation of lean production since both companies had first-tier suppliers abroad. Also, looking at the financial dimension of the companies, the support for the transformation of the production system varied from one company to another. Finally, the analysis of the legislative dimension in this study revealed challenges regarding intellectual property rights; more specifically, exclusive suppliers that were holding these rights for certain parts impeded on the flow of the production line, as the parts are only allowed to be produced from certain company.

In comparing the two cases, cross-case analysis was used to identify similarities and differences. Table 1 shows the findings of each case as well as the cross-case analysis of the two cases conducted.

Table 1 cross-cases analysis of contengencies related to regional contex

Theme	Case R1	Case R2	Cross-case
Geographical dimension	• Difficulty in connecting with customer and suppliers outside of EU, 6 weeks' shipment • Ideally one week is delivery time out of the plant • Delivery time sometimes gets delayed if external suppliers involved • Unpredicted the external suppliers with deliveries • Some customers prefer to be in reach with them location wise (not possible)	• The company deals with customers all over the world • Delivery time is not that accurate as dealing with multiple local and external suppliers • Using mainly external suppliers in EU • Issues in delivery with customers in outside of EU • Overall, quality wise is top in EU few times	• Delivery time goes beyond expected if shipping outside of EU • Using external suppliers that slows JIT
Cultural dimension	• In this region '*up north'* workers prefer to work at the same place as where their family (parents) live • Workers are family oriented • All workers here 'north' are educated • Minimum with a bachelor's degree, no less • Weekends are out of business for the company as well as delivery • Sometimes teamwork between plants are difficult, '*they would give each other hard time to help out'* • 12% is the workers turnover (*avg. in region*)	• Employees not happy with the change • Took time and effort to get into the change • Supportive top management but lower level workers nor cooperative with the change • Employees wanted to free times they had with the previous system • Number of training to be added • Knowledge of lean in not quite high between the workers	• Employees prefer living where the family lives (hometown) • Highly educated in the North • For old workers accepting the change to lean was not very successful • Shipments are limited to mid-week
Legislative dimension	• Fixed contracts to have customers' parts to be used in product they ordered. • Having the company dealing with the customer's suppliers • Some parts have to be delivered by externals suppliers in IP rights • Produced any parts they need if no IP restrictions • Big customers to visit plant and check quality themselves	• Certifying parts by big companies • All crucial mechanical parts from external certified suppliers outside of Romania • Company R2 authorise local suppliers	• Having main certified suppliers in EU – close in distance • Customers to certifies new products, as well as top companies in the industry • Contracts to link companies with certain suppliers of customers
Financial dimension	• Fully supported financially • Manufactured what they need to cut off costs and relatability on suppliers • Intended to improve the production line by cutting off extra 'check points' • Having dual source of getting parts • Intention of extended the plant To improve capacity	• Budget and investment of change is limited • Developing slowly • Using the plant layout as best for the budget • Layout is semi flow smoothly • Needs more development	• Design of plant is sufficient; it is developing to the best standard • Cut on costs as possible with local suppliers or manufacturing parts

Discussion of Findings

The first finding of this study is related to the financial investment of R1 and R2 on the design of the lean production operation system and the layout of the plant. In R1 the philosophy of was introduced when the company was founded; therefore, the company is accustomed to the system from the beginning, as well as having the footprint set for the production system. In the case of R2, the company started implementing lean production in 2012, and due to poor financial support they had a limited design developed to have the best design of the production system. The R1 has very slight disruption in the flow of the products, where the reason relates to the full capacity reached of the extrusion part of the plant and the unadjusted machines in the machinery side of the plant. However, in R2, the disruption in the flow of the units is caused due to the design structure not being on the highest standard, and not having considered and included all the necessary aspects as discussed by Black (2007) and Sobek II et al. (1999). Hence, the financial dimension plays a crucial role and more specifically, the limited investment affects in a high degree the design of the lean production system and therefore the operational performance of the companies.

The second finding concerns the effect of the geographical dimension has on the implementation of lean production. The location of the suppliers and ease of the supplier access play huge role in the success of applying the lean production. It was found that JIT is the practice mostly affected by the supplier access and location. For instance, company R2 is dealing mainly with two main external suppliers outside of Romania, which proves to be as one of their biggest challenges causing shortages in delivery time and delays. The situation is slightly different in company R1, it goes mostly the other way around which is the delivery to the customers. In both cases, once the supplier is located outside of the country and with the weekend work restrictions, that makes the impact on this dimension more tangible on the implementation. Therefore, the geographical dimension is found to be a barrier for successful implementation of lean production practices such as JIT, Kanban and Kaizen. This finding of the role of geographical dimension on the lean production practices supports the findings in literature of Cook (2001, p. 967) and Arkader (2001, pp. 91-2). Moreover, according to the analysis of the data gathered from both case R1 and case R2, it is evident that the role of the geographical dimension is the most challenging one for successful implementation of lean production.

The third finding is related to the organisational and regional culture. Our findings agree with the suggestions of Bortolotti et al. (2015) and Semeds (1994) that the organisational culture of a company may have significant effect on the successful implementation of lean production. More specifically, in case R2 the management faced the challenge of having the change to the lean production system. The acceptance is not easy from the employees' side. The company had to face some issues they have dealt with in some ways as they explained. Moreover, regarding the cultural dimension, the people who live in the north part of the country tend to be more educated and family oriented, who does not prefer to be working away from their hometown. As a cultural background of Romania with some ties of the religious beliefs, the weekends in the country is blocked, the compananies R1 and R2 are affected by this, as they are unable to make deleveries during the weekends.

The fourth and final finding in this study is about the legal dimension and how it may affect the implementation of lean production. The two companies mainly dealing with companies for the parts needed. Some of the companies are involved in certifying a product to be sold to top customers. Furthermore, some of the top customers relate their suppliers to be in link with Company R1. For example, if R1 want to have business with one of the leader in the industry, that customer requires R1 to deal with all materials

needed from the same supplier they deal with. Company R2 on the other hand, the suppliers they deal with are externals, and they are the ones who certify the R2 products based on legal ties. The reasons for having the connection only with these external suppliers is the intellectual property (IP) holders for certain parts; and therefore, the parts must come from them. Hence, whereas it is acknowledged that this dimension may affect in some degree the implementation of lean production, the companies have little to no control on most of the legal issues.

The four findings of this study show how regional dimensions can have different effects on the successful implementation of lean production. It is concluded that the most dominant regional dimension with the highest degree of effects is found to be the geographical dimension and the one with the least important effects is the legal dimension; it has effect but it could be mitigated.

Conclusion

The results of the case studies show that successful implementation of lean production is affected by dimensions related to the regional context they operate in. Therefore, this investigation study overcomes shortcomings of previous studies that have not considered this in sufficient detail. Hence, the conjectures and findings add new insight to the current literature. These findings are expected to give direction to managers about the successful implementation of lean production using the four dimensions.

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The impact of co-opetition on operational performance: the mediating roles of absorptive capacity and value chain agility

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Abstract

This paper aims to explain mechanisms that enable firms to manage the contradictory forces of co-opetition (i.e. simultaneous cooperation and competition) to achieve superior operational performance in business ecosystems. Since the benefits of co-opetition are not always straightforward, we intend to prove empirically the effects of co-opetition on operational performance through two mediators: absorptive capacity and supply chain agility. Data from 214 international firms in Tech-Cities were collected to test the hypotheses through regression analysis with bootstrapping. Results show that co-opetition is associated with higher levels of absorptive capacity and supply chain agility, which relate to superior operational performance.

Keywords: Co-opetition, supply chain agility, absorptive capacity.

Introduction

Co-opetition, defined as the simultaneous pursuit of cooperation and competition (Bengtsson and Kock, 2000; Brandenburger & Nalebuff, 1996; Luo, 2007), has received growing interest among scholars and managers over the past few years. Indeed, Luo (2007) posits that firms enhance performance through the advantages of both cooperation and competition. For instance, co-opetition has become a popular practice within the automobile industry where many traditional competitors such as Toyota, BMW, Peugeot, and Citroën have collaborated to share resources, develop new technologies or grow the market to obtain superior results compared to solely competing with each other (Ritala et al., 2014). However, the benefits of co-opetition are not always straightforward. Co-opetitive relationships are complex and they involve many risks since this practice literally means "sleeping with the enemy" (Bengtsson and Raza-Ullah, 2016). In fact, the paradoxical nature of co-opetition, which involves two co-existing and contradictory forces, generates co-opetitive tensions (Bengtsson, Raza-Ullah, et al., 2016). Due to the relative difficulty of balancing the dual forces of cooperation and competition, scholars suggest examining the dynamics underlying co-opetitive relationships (Wu, 2014) in

order to guarantee a firm's superior performance. Nevertheless, empirical evidence on the effects of co-opetition on performance are scarce (Quintana-García and Benavides-Velasco, 2004). Most studies have largely focused on innovation, financial or market performance, showing mixed results: both negative and positive (Park et al., 2014; Le Roy and Czakon, 2016). Regarding operations management research, although literature agrees that co-opetition has positive effects on cost reduction, quality standards, product efficiency or flexibility (Luo, 2007), the impact of co-opetition on operational performance has not been tested thus far.

Consistently, we question whether there is a mechanism through which firms can manage the contradictory forces of co-opetition to achieve superior operational performance. According to the literature, firms require certain capabilities to effectively manage a co-opetitive relationship (Gnyawali et al., 2016). Among these capabilities, scholars suggest that absorptive capacity is beneficial in co-opetitive relationships (Bengtsson and Raza-Ullah, 2016; Dorn et al., 2016; Wu, 2014) since knowledge can be obtained, assimilated, transformed, and exploited effectively (Zahra and George, 2002) to gain competitive positions in inter-firm networks. According to Ritala et al. (2013), absorptive capacity determines the extent to which firms can create value from co-opetitive relationships. Yet, empirical evidence on the effectiveness of co-opetition is needed (Dorn et al., 2016). Similarly, agility has been identified through exploratory case studies as a key capability to deal with the challenges of co-opetition (see e.g. Bengtsson and Johansson, 2014). Specifically, supply chain agility is crucial to managing inter-organizational relationships and improving competitiveness in operations (Swafford et al., 2006). However, the effects of co-opetition on supply chain agility for improving operational outcomes have not been empirically demonstrated.

This study utilises a relatively recent perspective based on collaborative management capabilities (Dorn et al., 2016) to examine the effect of co-opetition on operational performance. Specifically, it proposes absorptive capacity and supply chain agility as mediators in the relationship. Both capabilities are viewed by the literature as critical sources of competitive advantage and superior performance (Christopher, 2000; Liu et al., 2013; Zahra and George, 2002) when firms collaborate with other partners. To test different hypotheses, data were collected from 214 international firms hosted in two Tech-Cities and regression analysis with bootstrapping was used.

Our research enriches the co-opetition literature in several ways. Firstly, it is one of the first papers to introduce the concept of co-opetition within the operations management field. Secondly, it examines the "black box" or mechanisms by which firms can simultaneously compete and collaborate to obtain superior operational performance. Finally, it shows that co-opetition is a suitable collaboration strategy in order to build and increase a firm's absorptive capacity, which in turn transforms other operational capabilities such as supply chain agility to achieve superior results in operations.

The remainder of the paper is organized as follows. First, we present the theoretical background and hypotheses. Second, we explain the methodology employed, followed by the results and the discussion of these results. Finally, we address managerial implications, the limitations of the study and directions for future research.

Literature review and hypotheses

Co-opetition was coined in the 1980s by Ray Noorda, founder of Novell, to describe a paradoxical relationship that involves two contradictory forces: cooperation and competition (Bengtsson et al., 2016). Recently, co-opetition has gained attention for its positive effects on cost reduction, quality standards, product efficiency and flexibility, among other benefits (Luo, 2007; Morris et al., 2007; Ritala and Hurmelinna-Laukkanen,

2009). Many real-life examples and case studies of companies have recently proven that collaboration with competitors is, in fact, a successful collaborative strategy for relevant areas of a firm's operations. For instance, the collaboration between Sony and Samsung to create joint technology and manufacturing facilities in South Korea enabled them to become market leaders in the LCD TV segment (Gnyawali and Park, 2011). The result ended up with the development of high quality products, reduced development time, cost sharing and risk reduction. However, in the operations management literature, the impact of co-opetition on performance has not been tested so far. In an attempt to measure these effects we examine operational performance in terms of quality conformance to specifications, delivery speed, delivery dependability, cost, volume flexibility, and product mix flexibility (Hallgren and Olhager, 2009).

Through cooperative relationships, firms are able to share costs, information, knowledge and access to complementary resources (Bengtsson et al., 2010; Dussauge et al., 2000), while competition improves efficiency, increases innovativeness and forces firms to remain active in order to gain a competitive position (Bengtsson and Kock, 2000; Porter, 1990). Therefore, firms collaborate to jointly improve performance in some areas, and then compete in other areas to enhance their own performance (Luo, 2004). If, according to theory and some case examples, co-opetition enhances areas of firms' operations such as reduced costs, shorter lead times, product efficiency, flexibility or quality standards (Gnyawali and Park, 2011; Luo, 2007), then it may translate into positive effects for firms' operational performance. As a result, a firm that is capable of leveraging the dual benefits of co-opetition might exhibit higher operational outcomes. Thus, we propose the following hypothesis:

H1. *Co-opetition is positively related to operational performance*.

Moreover, absorptive capacity can help to explain how co-opetition efforts are translated into superior operational performance. First, partnerships with competitors improve learning and capability acquisition, especially from partners with complementary resources (Dussauge et al., 2000). Particularly, collaboration with competitors becomes more valuable since rivals operate in common contexts, confront analogous problems, satisfy similar needs, possess related knowledge and use similar technologies (Dussauge et al., 2000; Ritala and Hurmelinna-Laukkanen, 2009). Second, firms do not only maintain collaborative relationships with competitors to acquire new knowledge and skills from partners (Luo, 2007), but also to create and develop other capabilities through the intensive exploitation of existing ones (Quintana-García and Benavides-Velasco, 2004). Although there is a risk since the same knowledge used in cooperation could be used for competitive purposes (Gnyawali and Park, 2009), Cohen and Levinthal (1990) indicated that the negative appropriability incentive associated with spill-overs might be counterbalanced by a positive absorption incentive. Firms must ensure that the benefits of co-opetition exceed the costs associated with knowledge spill-overs. Therefore, firms maintaining co-opetitive relationships are involved in a race in which those achieving higher absorptive capacity remain on the winning side (Wu, 2014). As a result, through co-opetition firms enhance their knowledge base and skills, and they learn how to increase their current level of absorptive capacity (Gnyawali and Park, 2009). Finally, firms with high levels of absorptive capacity are better able to apply renewed knowledge in order to identify business opportunities (Liu et al., 2013). By leveraging new knowledge with existing knowledge, and then incorporating it into operations, firms may exhibit higher performance results. Therefore, we suggest the following hypothesis:

H2. *Absorptive capacity mediates the relationship between co-opetition and operational performance.*

Despite the above, additional variables may further explain the relationship between coopetition and operational performance. Specifically, through exploratory cases studies, Bengtsson and Johansson (2014) identified agility as one of the three interrelated capabilities to deal with the challenges of co-opetition in SMEs. In today's challenging global markets and unpredictable environments, agility is a capability that must be understood beyond the reach of the individual company. According to Hoek et al. (2001) firms should work together within the supply chain to achieve the desired level of agility. Consistently, we focus on the role of supply chain agility, which refers to a firm's ability to effectively collaborate with partners to respond to market changes in a speedy manner (Liu et al., 2013; Swafford et al., 2006), and this may also include competitors.

On the one hand, the literature has identified various benefits of co-opetition, such as the reduction of costs, uncertainties, and risks, superior quality standards, shorter lead times, greater speed in product development, improvements in product efficiency and product innovation, the achievement of scale economies, stronger market positions, and access to complementary resources (Gnyawali and Park, 2009; Luo, 2007; Morris et al., 2007). These advantages are closely related to the three critical processes of the supply chain—procurement/sourcing, manufacturing, and distribution/logistics— described by Swafford et al. (2006). Moreover, firms that implement co-opetitive strategies improve flexibility (Quintana-García and Benavides-Velasco, 2004), which is broadly considered by the literature as an antecedent or prerequisite for agility (Bernardes and Hanna, 2009; Swafford et al., 2006). On the other hand, supply chain agility may help to ensure superior operational performance when firms collaborate with competitors. First, supply chain agility can be seen as a critical mechanism for dealing with co-opetitive costs—technological risks, management challenges, and the loss of control (Gnyawali and Park, 2009). Second, it enables the firm to mitigate disruption risks, to react in a speedy manner to marketplace changes and other uncertainties, and to achieve superior competitive position (Braunscheidel and Suresh, 2009; Swafford et al., 2006). Finally, when firms collaborate with competitors, agility becomes essential in building and reconfiguring their relationships over time (Bengtsson and Johansson, 2014). Consequently, supply chain agility is a critical factor in responding effectively and efficiently to operational changes, and improving performance outcomes (Liu et al., 2013). As a result, we posit the following hypothesis:

H3. *Supply chain agility mediates the relationship between co-opetition and operational performance.*

In addition, absorptive capacity may also be effective for increasing a firm's levels of supply chain agility. Particularly, knowledge is one of the main ingredients for building a firm's agility. Agile firms continually marshal the necessary knowledge and assets for seizing market opportunities (Bernardes and Hanna, 2009). Moreover, according to Dove (1999), having the right knowledge in the right place at the right time through knowledge management is a key enabler for agility. In that sense, high levels of absorptive capacity ensure external knowledge acquisition to reengineer firms' processes and exploit new opportunities that are present in the environment (Cohen and Levinthal, 1990). As a result, firms can adapt and respond rapidly to marketplace changes to ensure supply chain agility. When firms collaborate with competitors, agility allows them to build and reconfigure relationships over time in order to sustain their opportunities (Bengtsson and

Johansson, 2014). Eventually, firms achieve superior competitive positions through supply chain agility (Swafford et al., 2006), leading to enhanced performance (Chen and Chiang, 2011). Therefore, we propose that absorptive capacity has an indirect effect on operational performance by shaping supply chain agility. In this sense, absorptive capacity and supply chain agility sequentially mediate the effect of coopetition on operational performance (i.e. serial mediation):

H4. *The relationship between co-opetition and operational performance is serially mediated by absorptive capacity and supply chain agility*.

Method

We tested the effects of co-opetition on the dependent variable, operational performance, with two serial mediators —absorptive capacity and supply chain agility— through a three-path mediation model depicted in Figure 1. The model is assessed using regression analysis with bootstrapping. Specifically, hypotheses were tested using the PROCESS macro for SPSS, which is widely used (Hayes, 2013) in the social and business sciences for estimating direct and indirect effects in single and multiple mediator models.

Data were collected from 214 firms hosted in two Tech-Cities located in Spain. Altogether, these Tech Cities account for more than 1,100 member organisations, which therein defines our target population. We developed a survey questionnaire with a seven-point Likert scale for each construct and some specific questions to measure control variables. The measurement scales for the variables were adapted from earlier studies to fit the specific context of this research. Only the scale for co-opetition was developed specifically for this study since Bengtsson and Raza-Ullah (2016) called for the development of new measurements that capture both the intensity and the similarity dimensions of cooperation and competition. Our final scale has six items based on a literature review on co-opetition. CFA analyses performed with EQS 6.1 guaranteed the psychometric properties of all of the measures.

Results and discussion

The present study develops an integrated model to explain how co-opetitive relationships in business ecosystems work within the field of operations management. Specifically, we empirically examine the operational performance implications of both absorptive capacity and supply chain agility for co-opetitive relationships in business ecosystems. We used the approach developed by Hayes (2013) to test the hypothesized relationships in a three-path mediated model. The model with all the estimates of the path coefficients is illustrated in Figure 1.

On the one hand, we analysed the direct effect of co-opetition on operational performance through H1, which stated that co-opetition is positively related to operational performance. However, the results of the regression analysis showed no significant effect for the direct relationship ($\beta = 0.003$, SE = 0.036, n.s), thereby rejecting H1. This result is consistent with a previous study that found that horizontal collaboration had a non-significant effect on firm performance (Robson and Bennett, 2000). Therefore, although co-opetition seeks to obtain the positive-sum effects of simultaneous cooperation and competition, there are several costs associated with this specific type of collaborative strategy that may impact the achievement of significant outcomes. According to Gnyawali and Park (2009), these costs are with regards to the risks of technological leakage, loss of control and exceptional management challenges. Similarly, Bouncken and Fredrich (2012) claimed that co-opetition has two faces: it can foster performance but at the same time it is associated with opportunism risks and misunderstanding among

parties, which in turn can undermine performance. In that sense, although co-opetition is considered an opportunity to increase operational outcomes through improved products and services, cost savings or shared resources, it simultaneously offers these same opportunities to competitors (Le Roy and Czakon, 2016). Thus, firms may not develop or sustain a competitive advantage over their competitors. Consequently, the direct effects of co-opetition on operational performance are unclear and its positive effects can be counterbalanced by the costs associated with co-opetition. Therefore, we might be missing the underlying mechanism through which co-opetition effectively influences operational performance.

On the other hand, we examined the indirect effects through the three-path mediation model with regard to H2, H3, and H4. H2 stated that absorptive capacity mediates the relationship between co-opetition and operational performance. The significance test required the prediction of an indirect effect of co-opetition on operational performance through absorptive capacity. According to the results, the effect is significant ($\beta = 0.021$, SE = 0.011, $p<0.001$), thereby supporting H2. Moreover, co-opetition predicted absorptive capacity ($\beta = 0.140$, SE = 0.057, $p<0.014$) and that absorptive capacity predicted operational performance ($\beta = .148$, SE = 0.067, $p<0.029$). Therefore, our findings suggest that only when firms develop strong absorptive capacity can they realize the dual benefits of cooperation and competition to obtain superior operational performance. First, collaboration with competitors eases external knowledge acquisition due to a common language and similar processes amongst competing firms (Wu, 2014). A rival's knowledge is more relevant for the firm since it is the basis of differentiation among competitors (Ritala and Hurmelinna-Laukkanen, 2009; Wu, 2014). Even if opportunistic behaviour is a concern, the competitive pressure means firms remain alert to knowledge spill-over. Moreover, the negative appropriability incentive may be counterbalanced by a positive absorption incentive (Cohen and Levinthal, 1990). Therefore, absorptive capacity is essential to guarantee a balanced situation among the strategic resources and capabilities that firms acquire from rivals and those that they provide. Second, co-opetition allows the firm to develop its current levels of absorptive capacity by integrating new knowledge from competitors. High levels of absorptive capacity ensure relevant knowledge is acquired and utilized effectively and probably faster than by competitors, which in turn provides a superior competitive position for the firm within its business ecosystems. Finally, having the right knowledge at the right time allows for making better operational decisions. In addition, by utilizing knowledge, firms can improve previous processes or develop new skills to enhance operational outcomes. As a result, firms collaborating with competitors obtain superior operational outcomes through the development of absorptive capacity.

H3 established that supply chain agility mediates the relationship between co-opetition and operational performance. On the contrary, the significance test that requires the estimation of an indirect effect of co-opetition through supply chain agility on operational performance was non-significant for that relationship ($\beta = 0.010$, SE = 0.026, n.s). As a result, co-opetition is shown to have no significant effect on supply chain agility, and therefore we reject H3. Although many benefits of co-opetition are related to the three critical processes of the supply chain—procurement/sourcing, manufacturing, and distribution/logistics— described by Swafford et al. (2006), co-opetition offers the same or similar opportunities to competitors. Moreover, since competitors operate at the same horizontal level they might share common suppliers. Thus, although suppliers may support firms with information regarding new technologies, products or services, or by giving advice on cost reduction (Robson and Bennett, 2000), improving agility through the supply chain, etc. competitors can also easily access the same benefits. All of this

provides no competitive advantage over competitors within the same business ecosystem networks. As a result, our findings suggest that the development of supply chain agility is not sufficient and does not guarantee superior operational performance when firms maintain collaborative relationships with competitors.

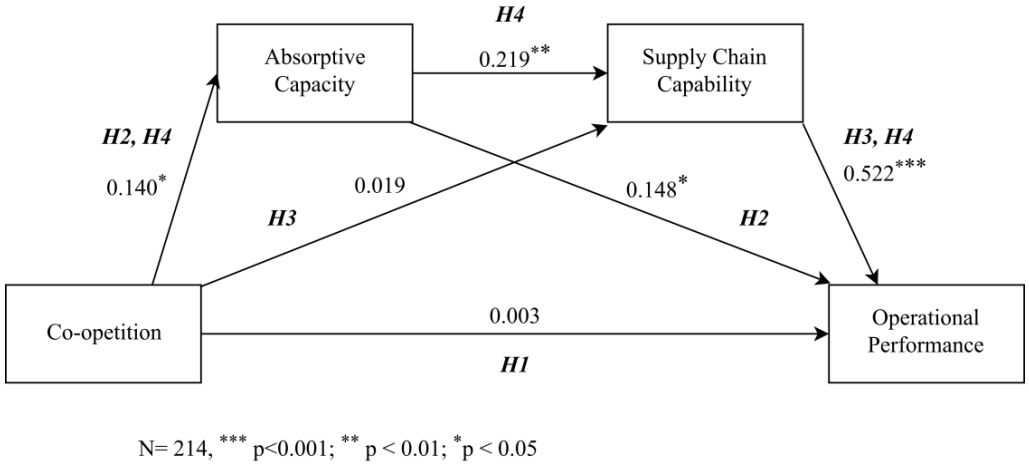

Figure 1 – Three-path mediation model.

Finally, H4 stated that the relationship between co-opetition and operational performance is serially mediated by absorptive capacity and supply chain agility. The indirect effects of co-opetition on operational performance through the mediation of absorptive capacity and supply chain capability were shown to be statistically significant (β = 0.016, SE = 0.008, p<0.001). Moreover, co-opetition is associated with both higher absorptive capacity (β = 0.140, SE = 0.057, p<0.014) and supply chain agility (β = 0.219, SE = 0.072, p<0.003), which relate to higher levels of operational performance (β = 0.522, SE = 0.103, p<0.000); therefore, H4 is supported. When a firm collaborates with competitors, it can acquire valuable knowledge since competitors pursue similar goals and interests. Moreover, similar knowledge bases with competitors facilitate the rapid acquisition and exploitation of knowledge in specific applications (Ritala and Hurmelinna-Laukkanen, 2013; Wu, 2014). This fact allows the firm to better understand how competitors operate and improves its ability to absorb knowledge. Furthermore, due to the competitive pressure, firms seek to improve their existing level of absorptive capacity in order to successfully integrate knowledge and exploit it faster than competitors. According to Ritala and Hurmelinna-Laukkanen (2013), firms with capabilities to manage knowledge exchanges effectively will be able to create a better basis on which to build on further technologies, concepts or capabilities. Specifically, absorptive capacity ensures appropriate knowledge to create a shared understanding with other partners in business ecosystems. As a result, firms can synchronize and better understand the market and other partners' activities in order to improve the overall agility of the supply chain (Liu et al., 2013). In this way, firms achieve superior competitive positions within business ecosystems since agility allows them to build and reconfigure relationships over time in order to sustain their opportunities (Bengtsson and Johansson, 2014). By improving agility in the critical processes of the supply chain (i.e. procurement/sourcing, manufacturing, and distribution/logistics: Swafford et al., 2006), firms can experience higher operational results. Therefore, collaboration with competitors has positive effects on operations through supply chain agility, but only when it is

indirectly affected by absorptive capacity. Previous studies are consistent with our results proving a positive effect of absorptive capacity on supply chain agility (see, e.g. Liu et al., 2013). In summary, absorptive capacity ensures renewed knowledge to better understand the market, which in turn promotes sufficient agility to effectively face up to the contradictory forces of co-opetition and obtain superior operational results.

Conclusions

The theoretical implications of the research are threefold. First, it enriches the co-opetition literature by extending its influence into a firm's operations. In particular, it is the first paper that empirically proves the impact of co-opetition on operational performance through the indirect effects of two serial mediators (i.e. absorptive capacity and supply chain agility). Second, our research examines some of the mechanisms or the "black box" by which firms can simultaneously compete and collaborate to obtain superior operational performance within a business ecosystem context. Specifically, the research shows that co-opetition is a suitable collaboration strategy in order to enhance a firm's absorptive capacity, which in turn transforms other operational capabilities such as supply chain agility to achieve superior results in operations. Finally, we have provided and validated a new scale for measuring co-opetition. Overall, our research leads to a better understanding of the mechanisms that enable operational outcomes to be realized when firms maintain collaborative relationships with competitors in business ecosystems.

Our results are also significant for managers whose firms belong to business ecosystems. First, managers who are reluctant to collaborate with competitors should consider the potential value of co-opetition beyond the risks associated with this practice. In complex and uncertain environments, such as business ecosystems, firms cannot stand alone to meet up to the challenges they face; thus they seek out co-opetitive partnerships (Bengtsson and Kock, 2000; Bengtsson and Raza-Ullah, 2016). Particularly, since competitors pursue the same goals and face similar problems, through co-opetition firms can achieve performance levels that no single firm could create alone (Peng et al., 2012). Second, in these large networks, co-opetition is a common practice. Thus, managers should be aware of the possible effects that this strategy implies for the firm's outcomes. As collaborating with competitors generates different sorts of tensions (Bengtsson et al., 2016) compared, for example, to supplier collaboration, managers should lead a firm's efforts towards the development of organizational processes and routines related to external knowledge identification, acquisition, integration and exploitation. This will give them an advantage over competitors to utilize a rival's knowledge faster than them. By using external knowledge, firms can make better decisions and gain a better understanding of the market and of other relevant partners. As a result, firms are better able to effectively collaborate with partners to respond to market changes in a speedy manner (Braunscheidel and Suresh, 2009; Liu et al., 2013; Swafford et al., 2006). This in turn will allow the firm to increase supply chain agility. Lastly, co-opetition can help the firm to improve operational performance by obtaining several benefits, such as cost reductions, superior quality standards or shorter lead times. However, managers should consider that without the development of capabilities for knowledge absorption, the benefits of co-opetition for supply chain agility and for firm operational performance will not be realized.

Finally, when interpreting the results of our study, some limitations must be taken into account. First, the use of cross-sectional data limits the cause–effect relationships that can be inferred from the results. Since business ecosystems are constantly evolving, future research could examine the relationships analysed using longitudinal data to understand more aspects of co-opetition in these complex networks. Second, the questionnaire is

limited to two Spanish tech cities. Thus, the generalizability of the findings to other international tech cities may be limited. Future research should consider carrying out similar studies in tech cities located in other countries. Finally, we investigated the possible benefits of co-opetition for a firm's operational outcomes. However, we did not compare this collaborative strategy against other types of collaboration that do not include competitors (i.e. collaboration with suppliers, customers, etc.). Although the literature agrees that firms obtain higher benefits through balanced-strong co-opetition than pure cooperation or competition (Quintana-García, Benavides-Velasco, 2004), an empirical comparison of co-opetition with other collaborative strategies for firms' operational performance has not been undertaken to date.

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Global Operations and Strategic Sourcing

Cost driven production outplacement among medium-sized manufacturers: The influence of Industry 4.0

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Abstract

Empirical investigations of how Industry 4.0 technologies affect outplacement patterns are sparse for medium-sized enterprises. This paper contains an empirical analysis of how industry 4.0 technologies affect cost driven outplacement of production based on 191 full and useable answers to a questionnaire-survey distributed in 2018. The paper builds on data revealing that companies' pursuit of cost-focused competitive strategy positively associates with moving production abroad. However, data also shows that the more Industry 4.0 ready decision-makers are, the less do cost-focused strategy drive production outplacement. Furthermore, perceived barriers towards Industry 4.0 technologies promote cost-driven outplacement whereas perceived drivers decrease cost-driven outplacement.

Keywords: Location of production, drivers, barriers, readiness, Industry 4.0

Introduction

The globalization of trade has led to increased pressure on Western-based manufacturers to be competitive. According to Porter (1985), firms pursue competitive strategies based on either cost leadership or differentiation. From a production perspective, manufacturing strategies must be aligned with the corporate strategy and thus also the competitive strategy (Skinner, 1969; Wheelwright, 1984). Western companies have experienced increased competition for companies manufacturing in low-salary countries like Asia and Eastern Europe. This development has pushed to development to outplace production in low-cost countries to remain competitive. Drivers for outplacing production have been much researched and cost considerations has been identified among the most prevalent motives (Contractor et al., 2010; Jahns et al., 2006; Mihalache and Mihalache, 2016).

This paper has its main focus on the cost motive for outplacing production since this is the most common. However, it should be emphasized well that other motives exist, such as proximity to markets and customers, access to knowledge and access to new technology

(Ferdows, 1997; Kinkel, 2012). In literature, there is a demand for focusing on firm size in the location of production issues, especially small and medium-sized enterprises (Arlbjørn and Mikkelsen, 2014). According to the EU Commission (2015), a medium-sized enterprise has between 50 and 250 employees, a turnover between 10 and 50 million Euro and a balance sheet total between 10 and 43 million Euro. Compared with large enterprises, medium-sized (as well as smaller) enterprises typically have fewer resources and experience in managing new technologies, CEO involvement in daily operations and having a dominating operation focus at the expense of strategic and development-oriented activities (Zach et al., 2014).

Recently, the literature on using advanced technologies often referred to as Industry 4.0, has increased intact with industrial diffusion. The discussion of such technologies is both applied in connection with avoiding production to move abroad and to be used as a driver for moving production back to original high-cost home destinations (e.g. Arlbjørn and Mikkelsen, 2014; Fratocchi et al., 2016; Tate, 2014). However, a recent literature review reveals a lack of empirical founded research on the application of Industry 4.0 technologies (Liao et al., 2017). This is supported by Castelo-Branco et al. (2019) who demands more research on the adopting of the various Industry 4.0 technologies in production processes. Furthermore, there seems to be a biased view on these technologies towards multinational enterprises (MNEs) (Liao et al., 2017; Mittal et al. 2018; Moeuf et al., 2018). SMEs often display a lower IT and Industry 4.0 readiness compared with MNEs due to e.g. lesser resource availability (Haug et al., 2011; Schumacher et al., 2016). The apparent lack of SME based studies towards smart manufacturing/Industry 4.0 indicates a research gap within the current scientific body of knowledge (Mittal et al., 2018).

Based on the discussion above, the purpose of this paper is to advance the understanding of the relationship between SMEs degree of strategic cost focus and the location of production as moderated by managers' perceptions of drivers, barriers, and readiness for Industry 4.0 technologies. More specific the paper pertains to the discussion of whether Industry 4.0 technologies may affect decisions on the relocation of production.

Conceptual frame of reference

Industry 4.0

The term Industry 4.0 originates from the German "Industrie 4.0" invented in 2011 in Germany as a Federal Government initiative to strengthen the competitiveness of the German manufacturing industry (Hermann et al., 2015). Industry 4.0 is an umbrella term for a number of different technologies that function in a cyber-physical system such as 1) big data and analytics, 2) autonomous robots, 3) simulation, 4) horizontal and vertical system integration, 5) internet of things (IoT) (including sensors), 6) cyber-security, 7) the cloud, 8) additive manufacturing, 9) augmented reality, 10) artificial intelligence, 11) mobile technologies and 12) RFID and RTLS technologies (Ruessmann et al., 2015; Sauncedo-Martínez et al., 2018).

Academic literature on the relocation of manufacturing with an emphasis on Industry 4.0 technologies has grown in interest during the last years. Fratocchi et al. (2016) and Tate (2014), for example, refers to the reduced cost of robotics as a driver for moving manufacturing back to high-salary cost countries where labor extensive jobs could be automated. Tate and Bals (2017) point out that the rise of automation and robotization with little or without human intervention is driving companies to re-evaluate their shoring decisions. Benstead et al. (2017) discuss automated machinery as a reshoring driver. Thus, Industry 4.0 technologies may be viewed as a driver for relocating production.

Readiness for Industry 4.0

According to Lokuge et al. (2019) readiness theory is concerned with the "readiness for

change" as a precursor to a successful implementation. It describes a state of being fully ready to engage in a specific activity. In other words, readiness is a state that is attained prior to the commencement of specific activity in relation to psychological, behavioral, and structural preparedness of the organizations (Lokuge et al., 2019). Haug et al. (2011) and Stentoft et al. (2019) suggest that Industry 4.0 readiness consist of the following dimensions: 1) pressures to change existing processes; 2) willing to take risks with the technologies; 3) having sufficient knowledge about the technologies, 4) having support from top management, 5) having employees with the right competencies, 6) having employees with the right motivation to work with the technologies and 7) having economic freedom to work with Industry 4.0.

New technology and the location of production

Extant literature on location of production have included the use of new technologies and automation of production as a potential lever for location decisions (Arlbjørn and Mikkelsen, 2014; Stentoft et al, 2016a; Tate, 2014). Investments in new technologies might prevent companies to outplace production and/or bring production back to home-destinations after previously have been moved abroad. However, research has shown that the readiness for such technologies still needs to be developed and especially for SMEs (Castelo-Branco et al., 2019; Stentoft et al., 2017, 2019).

Accordingly, we hypothesize that:

H1: Strategic cost-focus in SMEs associate positively with moving production abroad

H2: SME managers' perception of strong readiness for Industry 4.0 weakens the relationship between strategic cost focus and moving abroad

H3: SME managers' perception of og strong barriers for Industry 4.0 strengthens the relationship between strategic cost focus and moving abroad

H4: SME managers' perception of strong drivers for Industry 4.0 weakens the relationship between strategic cost focus and moving production abroad

Method

To test the hypotheses, we use questionnaire-survey on Danish SME manufacturers with between 50 and 250 employees. The survey was distributed in April and May 2018. Using the Danish company database "Bisnode", an initial list of 3.400 manufacturing SMEs was identified. Cleaning the list for companies without contact information, and companies that appeared on the list by error, the net list of companies was reduced to 2.632. Each company was first approached by phone, asking for the person responsible for business development, and asking for an agreement that the respondent would attend to a link to the questionnaire-survey, which was sent beforehand by e-mail to the respondent. Reminder e-mails were sent several times during April and May 2018. 736 companies agreed to attend the questionnaire-survey. Out of these, 191 provided full and useable answers on survey items concerning production out-placement, giving a response rate at 26.0%.

Measures

Dependent variable

With an interest in how industry 4.0 may have changed firms' dispositions to outplace production, our interest is in firms' recent as opposed to historical outplacement activities. As Industry 4.0 technologies are at a rapid pace of development, we decided to focus on outplacement activities over the recent three years only. The outplacement variable was assessed from the questionnaire item: "Has your company in the past 3 years taken production abroad?" [No=0; Yes=1].

Independent and moderating variables

Low-cost strategy orientation was measured on a five-point Likert scale questionnaire item: "To what extent is your competitive strategy cost-oriented (competing by cheaper prices)?" [1: very little; 5: very much]. Perceived readiness for industry 4.0 was measured using a scale developed by Haug et al. (2011). Seven 5-point Likert scale questionnaire items here combine into a one-factor solution (Appendix A), which explains 53.95 % variance, and with a Cronbach's alpha value of .852. We construct the Industry 4.0 readiness index as the average score of the seven items. Perceived barriers for industry 4.0 was assessed using eleven 5-point Likert scale questionnaire items (see Appendix A) (Stentoft et al., 2019). Factor analysis confirms a one-factor solution, which explains 48.88 % variance, having a Cronbach's alpha value of .890. The industry 4.0 barriers index was constructed as the average score of the eleven items. Perceived drivers for industry 4.0 was assessed using eight 5-point Likert scale questionnaire items (see Appendix A) (Stentoft et al., 2019). Results from the factor analysis show a one-factor solution, which explains 45.46 % variance, and reliability analysis shows a Cronbach's alpha value of .826. The industry 4.0 drivers index was calculated as the average score of the eight items. Interaction terms between low-cost strategy and the three Industry 4.0 indices are calculated based on standardized values.

Control variables

Several controls were employed. First, we controlled for *firm size* using the number of employees, and we control for *firm age* measured by numbers of years since the firm was founded. Firm size as well as firm age has previously been associated with decisions to outplace, as well as take back production (Arlbjørn and Mikkelsen, 2014; Roza et al., 2011). Also, we control for the firm's international engagement in terms exporting, measured by the firm's exporting as a percentage of turnover. Previous studies have shown a positive relationship between firms exporting and their propensity to outplace production. We also control for firms' innovation strategy, asking of the extent to which the firm pursues a *proactive innovation strategy* (single item, 5-point Likert scale). This is from the recognition that both low-cost and innovation strategies may provide a motive for outplacement of production (Fratocchi et al., 2016; Johansson et al., 2019; Stentoft et al., 2016b) – as well as for taking production home (Di Mauro et al., 2018; Srai and Ané, 2016; Stentoft et al., 2016b). In the interaction models specified below, we further include controls for the interaction between the three industry 4.0 variables (readiness, barriers, and drivers), and the proactiveness of firms' innovation strategy, thereby considering that the industry 4.0 context may similarly affect the association between firms' innovation strategy and production location decisions.

Analyses

To analyze how production outplacement associate with firms' low-cost strategy and perceptions of industry 4.0 readiness, barriers, and drivers, we used logistic regression. The self-report nature of the survey data raises the potential concern for common method bias (Podsakoff and Organ, 1986). Harman's single-factor test using all perceptual variables from the regression model produces a one-factor solution explaining 27.2 % of the variance, which indicates that common method bias is not a problem. Moreover, common method bias is generally considered less of a worry when interested in individuals' subjective perceptions, such as in the case of the industry 4.0 barrier and industry 4.0 driver variables. The concern is more prominent when perceptions are used as indices for more objective measures, such as if had the industry 4.0 readiness construct been used to indicate firms'

actual capacities to engage in industry 4.0 technologies and business models. Similarly, because common method variance can severely deflate interaction effects making them more difficult to detect (Siemsen et al., 2010), we contend that common method bias is likely to be small and not likely to affect the results.

Results

Table 1 shows the means, standard deviations and the correlations for the variables included in the study. Outplacement of production associate positively with low cost strategy, firm size, exporting, and proactive innovation strategy, as expected. There are no significant correlations between outplacement and any of the industry 4.0 variables. The correlation table is the low correlations among the independent variables, which signifies that the risk of multi-collinearity is low.

Table 1- Descriptive statistics

			Pearson correlations							
	Mean	Std.dv.	1	2	3	4	5	6	7	8
1.Outplace production	0,10	0,30								
2.Low Cost Strat	3	1,14	.19**							
3.I4.0 Drivers	2,63	0,68	.12	.12						
4.I4.0 Barriers	2,59	0,69	.09	-.01	.38**					
5.I4.0 Readiness	3,02	0,70	.13	.07	.54**	-.09				
6.Firm size	23,36	29,51	.23**	.17*	.08	.03	.12			
7.Firm age	11,80	5,60	-.02	.00	-.05	-.04	.07	.18*		
8.Exporting	33,61	35,11	.18*	.03	.07	-.01	.18*	.08	.11	
9.Proactive inn strategy	3,77	1,05	.25**	-.03	.32**	-.16*	.46**	.11	-.11	.22

Table 2 presents the results from the logistic regressions on outplacement of production. Model 1 presents the results from the main-effects model without the industry 4.0 variables included. The result support hypothesis 1 that low-cost strategy associates positively with outplacement of production. Results also suggest that proactiveness in firms' innovation strategies relates positively with production outplacement decisions – and that this association is somewhat stronger than the association between low-cost strategies and production outplacement. These direct effects remain significant as the industry 4.0 variables are included in model 2.

Table 2 - Logistic regression on moving production abroad

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Standardized regression coefficients (Standard.errors)					
Firm size	.318*	.479*	.411+	.484*	.368+	.362
	(.145)	(.213)	(.233)	(.220)	(.226)	(.238)
Firm age	-.258	-.165	-.080	-.163	-.176	-.079
	(.213)	(.261)	(.279)	(.262)	(.287)	(.293)
Exporting	.509**	.454#	.502*	.439#	.514#	.512#
	(.184)	(.259)	(.270)	(.264)	(.269)	(.277)
Proactive inn strategy (PIS)	.790**	1.188**	1.425**	1.193**	1.344**	1.667**
	(.239)	(.397)	(.459)	(.436)	(.442)	(.509)
Low cost strategy (LCS)	.410*	.655*	1.105**	.610*	1.056**	1.307**
	(.189)	(.262)	(.376)	(.269)	(.265)	(.412)
I4.0 Readiness		.096	.226	-.002	.265	.234
		(.415)	(.568)	(.436)	(.429)	(.486)
I4.0 Barriers		.750*	.868*	.506	.836*	.541
		(.368)	(.396)	(.468)	(.390)	(.455)

I4.0 Drivers		-.182	.021	-.123	.021	.468
		(.411)	(.448)	(.421)	(.544)	(.531)
LCS * I4.0 Readiness			-.839*			-.418
			(.386)			(.447)
PIS * Readiness			.236			.900
			(.400)			(.626)
LCS * I4.0 Barriers				.315		.813#
				(.310)		(.461)
PIS * I4.0 Barriers				136		.840
				(.397)		(.524)
LCS * I4.0 Drivers					-.792*	-1.131*
					(.360)	(.561)
PIS * I4.0 Drivers					.172	-.848
					(.420)	(.691)
Intercept	-2.65***	-3.16***	-3.79***	-3.09***	-3.57***	-4.14***
	(.264)	(.459)	(.630)	(.476)	(.568)	(.754)
LR chi2	38.03***	34.79***	42.53***	35.88***	41.21***	49.41***
Pseudo R2	17.16	25.50	31.17	26.29	30.20	36.21

*** p < .001; **p < .01; * p < :05; # p < .10

For low-cost strategy, the odds ratio is 1.925 (p=.012), signifying that the odds of outplacing production become almost two times higher with a one standard deviation increase in the strategic low-cost focus. Similarly, the odds ratio 2,117 for Industry 4.0 barriers, implies that the odds of outplacing production slightly more than doubles with a one standard deviation increase in perceptions of industry 4.0 barriers. The coefficient for Industry 4.0 drivers is negative but insignificant. The sign of the Industry 4.0 readiness coefficient is positive, but here again, the effect is insignificant.

Including the industry 4.0 variables in model 2 significantly increases the explanatory power of the model with Pseudo R2 increasing from 17.16 % to 25.50 %. This confirms our expectation that the industry 4.0 context has a bearing on production outplacement decisions. Nonetheless, of the three Industry 4.0 variables, only the negative effect from Industry 4.0 barriers is significant, signifying that SME managers' perceptions of high barriers to engaging with industry 4.0 technologies seem to encourage production outplacement decisions. In Hypothesis 3, we specified this relationship specifically for firms pursuing low-cost strategies. The results here indicate that perceptions of high industry 4.0 barriers also have a general effect in promoting production outplacement decisions.

Model 3 shows a significant negative interaction effect between low-cost strategy and industry 4.0 readiness. This result supports Hypothesis 2 that firms who pursue a low-cost strategy will be less inclined to outplace production when they perceive high readiness for industry 4.0. In turn, this is an indication that industry 4.0 technologies have the potential to strengthen firms' cost structure for their domestic operations. In model 4, the coefficient for Industry 4.0 barriers is positive as expected from hypothesis 3. Yet, the coefficient is insignificant, and hence leave no support for the expectation that firms pursuing low-cost strategies will be more inclined to outplace production when they perceive high barriers to engage with industry 4.0 technologies. In model 5, the negative and significant interaction term between low-cost strategy and industry 4.0 drivers supports hypothesis 4. The higher the low-cost focus of a firm, the more perceptions of high industry 4.0 drivers will tend to decrease the propensity of the firm to outplace production. In model 6 (the full model), the positively moderating effect from industry 4.0 readiness on the relationships between low-cost strategy and production outplacement remains significant turns insignificant. Opposite, we here see a moderately significant positive moderating effect from Industry 4.0 barriers.

The negative moderating effect from industry drivers on the relationships between low-cost strategy and production outplacement remains significant. Hence, results in model 6 support hypothesis 4, moderately supports hypothesis 3, yet do not support Hypothesis 2.

The marginal effect plot (see Figure 1) shows that the marginal effect of Industry 4.0 drivers on the effect from low-cost strategy is significant for the lowest 69 % perceptions of industry 4.0 barriers (i.e. up until half a standard deviation below the mean) and decreasing with lower perceptions of drivers. At the mean perception of industry 4.0 barriers, the marginal effect is a 9.3 %, increasing to 12,6 % at the 16 percentiles (1 standard deviation below the mean), and further increasing to 14.6 % at the 2,3 percentiles (2 standard deviations below the mean).

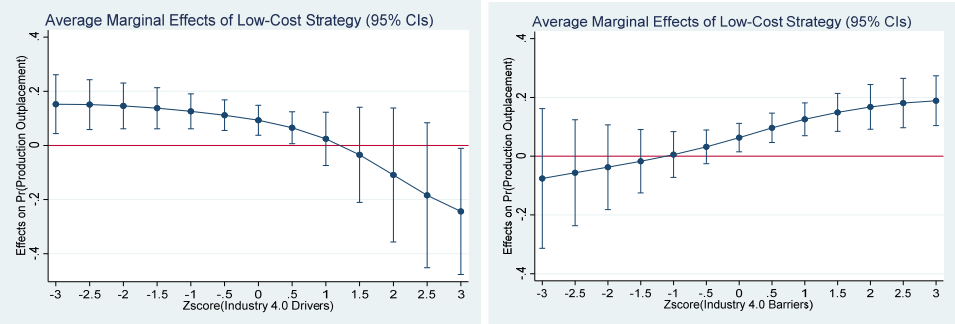

Figure 1 - Marginal effects of Industry 4.0 drivers and barriers

Figure 2 shows that marginal of Industry 4.0 barriers on the effect from low-cost strategy on production outplacement is significant from the mean score, and upwards. At lowest 16 percentile, there is a 4.2 percentage marginal change in the probability of outplacement. At the mean perception of industry 4.0 drives the marginal effect is 6.3 %, increasing to 12,6 % at the top 84 percentile (1 standard deviation above the mean), and further increasing to 16.8 % at the top 2.5 perceptions of industry 4.0 barriers (2 standard deviations above the mean). These results show that how managers perceive industry 4.0 drivers and barriers have quite considerable effects on how SMEs weight decisions of whether to pursue low-cost strategies by producing abroad or at home.

Discussion

The analyses in this paper reveal several interesting results. First, data support the relationship with a company's strong strategic cost focus and the outplacement of production to low-cost countries. Thus, in times where reshoring has received more awareness, a cost pressure still exists, which may put pressure to move production abroad to low-cost countries. However, operating with a cost competitive strategy may continuously stimulate a cost reduction focus in the supply chain and thus also for the manufacturing part. Such strategies can explain the reshoring activities where production is not moved back to home destinations but to other destinations from e.g. China to other Asian countries due to increased salary and welfare costs or to Eastern Europe due to lower total costs in terms of e.g. shorter transport distances, improved quality, and reduced management costs. Thus, costs are a major decision factor in location decisions of production which supports past research.

Another interesting result is that SME managers' readiness for Industry 4.0 dampens the effect of a strategic cost-focus on the outplacement of production. This result provides empirical evidence for past research contributions that on a theoretical level have mentioned the use of Industry 4.0 technologies as a mean to hinder some production to move abroad or

might be a driver for reshoring to home-destinations (Arlbjørn and Mikkelsen, 2014; Fratocchi et al., 2016; Tate, 2014; Tate and Bals, 2017). The result also supports the findings from the questionnaire-survey by Stentoft et al. (2016a), which showed that companies working with a higher level of technological supply chain innovation (in terms of digitalization, new process technologies such as additive manufacturing and automation and robotization) to a higher degree keep production domestic or backshores to domestic facilities. However, the industry 4.0 umbrella is wide why there still need research to be carried out that investigate which technologies that might be most appropriate under which circumstances. Manufacturing companies are different along a number of parameters why potential benefit and the antecedents for applying the technologies might be different.

This paper's analysis contains also the SME's perception of the drivers as well as the barriers relationship with a strategic cost focus and outplacement of production. The analysis shows some support that the more perceived barriers there exists towards Industry 4.0 technology, the more a cost focus drives outplacement. In contrast, data reveal with strong support that the higher the perception of Industry 4.0 drivers, the lesser the degree by which a cost-focused strategy will lead to outplacement of production. As the present utilization of Industry 4.0 technologies in general still is modest (Stentoft et al., 2017, 2019), one can find inspiration in Industry 4.0 maturity models to increase the knowledge level and thus reduce the barriers (Mittal et al., 2018). From a policy perspective, the lack of standards, the shortage of experts with the necessary skills and public policies could also areas to improve to reduce the barriers for SMEs (Castelo-Branco et al., 2019).

As a contribution to previous studies, the results from this study suggest that the identified industry 4.0 effects on production outplacement pertain to cost-driven motives. Analyses of how an innovation motive to outplace production associate with Industry 4.0 finds that companies that moves abroad based on an innovation perspective is not affected by Industry 4.0 technologies.

Conclusion

This paper has set out to analyze how cost driven outplacement of production is affected by SME managers' readiness and perception of drivers and barriers of Industry 4.0 technologies. The paper provides empirical data from Danish medium-sized manufacturers and reveals that companies that pursue a high degree of a cost competitive strategy are more dispositioned to outplace production to obtain low manufacturing costs. Overall, findings suggest that cost-driven outplacement of production are dampened by firms' Industry 4.0 readiness and perceived drivers of Industry 4.0, while promoted by perceived barriers to Industry 4.0.

These results have both theoretical and practical implications. For theory, this study indicates that Industry 4.0 technologies may affect decisions on the location of production. However, Industry 4.0 is a wide umbrella term, where there is a need to make detailed analyses for the single technologies. For practice, in terms of the companies and governments, these results indicate a need to invest resources to obtain a better knowledge level of industry 4.0 technologies in order make conscious and competitive decisions for where to locate production. Investing in Industry 4.0 technologies may hinder further manufacturing jobs to move out and may provide the basis for bringing jobs previously moved out back again.

Finally, the paper is not without limitations. First, data has only been collected by a quantitative method, why future research can explore this phenomenon further by a number of data-rich case studies. Second, data has been collected by using a single respondent at each company, why future research may include multiple respondents in each company. Finally, data is analyzed among Danish firms who are amongst the forefront OECD countries

concerning digital adaption (OECD, 2017) and among the most Industry 4.0 ready countries in EU (Castelo-Branco et al., 2019). Thus, future research can expand this study to other nations in order to make such comparisons.

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Appendix A: Industry 4.0 indexes

Questionnaire items	Factor loadings
Industry 4.0 readiness (Scale adapted from Haug et al., 2011). *To which degree do you agree to the following statements? (on a five-point Likert-Scale: 1 = to a very low degree and 5 = to a very high degree)*	
We experience a pressure to work with Industry 4.0 (e.g. from customers, suppliers, authorities etc.)	.509
We have the willingness to take risks to experiment with Industry 4.0	.747
We have the necessary knowledge about Industry 4.0 to judge its importance for our company	.764
We have necessary support from top management to judge and work with Industry 4.0	.781
Our employees have the right competencies to work with Industry 4.0	.798
Our employees have the right motivation to judge and work with Industry 4.0	.853
We have economic freedom to work with Industry 4.0	.635
Drivers for using Industry 4.0 technologies (Scale developed from Stentoft et al., 2019) *Please evaluate the following drivers for your company to use Industry 4.0 technologies? (on a five-point Likert-scale: 1 = to a very low degree and 5 = to a very high degree)*	
Customer requirements	.660
Competitors practice Industry 4.0	.713
To reduce costs	.794
To improve time-to-market	.771
Due to legal requirements/changed legislation	.589
Lack of qualified workforce	.670
Work initiated with input from the public advisor system (incubators, local business support)	.456
Conscious strategy on Industry 4.0	.683
Barriers for using Industry 4.0 technologies (Scale developed from Stentoft et al., 2019) *Please evaluate the following barriers for your company to use Industry 4.0 technologies? (on a five-point Likert-scale: 1 = to a very low degree and 5 = to a very high degree)*	
Lack of knowledge about Industry 4.0	.699
Lack of standards	.669
More focus on operation at the expense of developing the company	.490
Lack of data protection (cyber security)	.503
Lack of employee readiness	.723
Requires continued education of employees	.723
Lack of understanding of the strategic importance of Industry 4.0	.784
Lack of understanding the interplay between technology and human	.818
Too few financial resources	.811
Too few human resources (man power)	.624
Uncertainty about data security	.758

Localisation within the global supply chain: Evidence from the sporting goods industry

Keywords: Localization, Sustainability, Cricket bats

Topics: Global Operations and Strategic Sourcing, Operations Strategy, Sustainability in Operations and Logistics

Wordcount: 5033

Abstract:
The following paper explores issues of localisation, from both an international and local perspective. Initially the paper draws from literature discussing localisation within the context of the global supply chain, showing awareness to change focusing of development purely focused upon the company receiving and selling the finished good. The review identified that attention of the work is primarily focused on the food supply chain and the development of heavy industries. Using case data collected from both India and England form the cricket bat supply chain, the paper shows the different approaches and focus given to development across the locations. Interestingly, craft manufacturing skills are sustained in both locations, as a necessity in India but as a competitive priority for the English manufacturers.

Purpose:
The prevalence of operating within a global network of suppliers and customers has become so embedded within operations management research that is the accepted approach to operating. Even new, small organisations are able to tap into global networks of suppliers to source not only low cost generic components but complex, highly specialised finished goods (Mangan et al. 2010). This has created a whole field of research looking at factors affecting how global supply chains can be designed to enable focal firms (even small ones) to be able to compete in terms of price and functionality on a global stage. However, this perspective had tended to focus upon the global supply chain from the perspective of the focal firm, and how the global supply chain allows such firms to compete. The work has unfortunately paid less attention to organisations within the supply chain, or not until they start creating problems for the focal firm (Frankental 2004). In such situations, a lack of attention, combined with unscrupulous activities can lead to significant reputational risk (BBC 2014).

This raises the need to reframe perspectives on global supply chains in terms of their sustainability (Cerchione and Esposito 2016). However, in their review of sustainable supply chains, Seuring and Müller (2008) still overlooked the role of local manufacturing completely. Within their more recent review of sustainable supply chain management, Koberg and Longoni (2019) also overlooked the impact of localising production on sustainability issues. Conversely, broader research suggests there are significant gains to be made from focusing developments at a local level (Baines 2014, Lee et al. 1993), in terms of local employment and performance improvements, respectively. To address this oversight in the literature, the following paper provides an assessment of selected literature focusing on localisation within a global supply chain context. This is used to direct the analysis of a unique global supply chain (Cricket bats), where manufacturing is both located locally (in the UK) and globally (focusing on India) with products sold in a single market.

The following section reviews a selection of literature on global supply chains, that also gives attention to localisation in order to motivate the research question. This is following by a summary of the research methods, before presenting data on the companies involved in the research. The paper ends with discussions and conclusions of the research, in terms of how the different firms focus development to create competitive advantages that build upon their operating context and choices they have made related to manufacturing.

Literature Review:

While the idea of sourcing cheap, high quality raw material or components from around the globe has considerable appeal to a firm, Svensson (2001, p.15) suggested this was more of a "*managerial utopia*" that an operational reality. Global supply chains can create considerable issues in terms of control over disperse manufacturers, introducing considerable supply chain risk of disruption into the process of meeting customer demand (Tse et al. 2016). The following literature review provides an overview of a selection of supply chain literature, giving particular attention on localisation. The most influential topic was the role of food supply and security, as supply chains became progressive more globalised. One of the most influential pieces was by Lang (1999), who posed a number of important questions related to the impact of the global food supply chain and global levels of nutrition. While focusing upon a dramatically different context to cricket bats, his insight shows how changes to supply chain design could influence global demand.

In addition to the benefits of global production, the context of the food supply chain also provided insight on the benefits of localisation food productions closer to the market. Atallah et al. (2014) and Rothwell et al. (2016) employed simulation based research techniques to explore the impact of localising local productions of vegetables (lettuce and broccoli respectively). Each found that localising vegetable production reduced costs to the end users and environmental impact of supply chains, although there were limitations associated with assumptions in how the systems needed to be modelled. Exploring the impact of localisation on a more complex supply chain context (dairy), Nicholson et al. (2011) identified issues when localising that can increase costs more than the reduction of transport reduces them. Due to the need to process aspects of the milk supply chain, if production and assembly activities were localised as well as raw material production, costs tended to increase.

Research exploring non-food supply chains provided additional insight for the context of cricket bat supply chains. Kouvelis and Tang (2012) identify some risks associated with this situation, in terms of variations in product quality and delivery uncertainties arising from disperse production locales, reflecting issues discussing in the supply chain risk literature (Tse et al. 2016). Although risks may be present, and transport distances may increase significantly in global supply chains, these supply chain can also benefit from being views form a localisation perspective. Usui et al. (2017) showed the need for a strategic orientation, with establishing the supply chain being only the first stage of building a globally competitive supply network. Through focused development, Usui et al. (2017) showed supply chains with localised suppliers could be established with the potential for future improvement in performance.

Interesting, within the localisation literature, performance was focused around sustainability, giving attention to social and environmental measures, reflecting the triple bottom line perspective on business performance (Elkington 1999). Jaeglar and Burlat

(2014) considered that the social impact of supply chain decisions also need including, so their impact on supply chain design could be understood. Koberg and Longoni (2019) found that firms could choose between open (selecting suppliers) or closed (developing suppliers) orientations to achieve their aims of sustainability. This short review of selected literature provides key factors for consideration within the cricket bat supply chain, with attention on both the benefits, costs and the need to support developing within localisation discussions. Unfortunately, the literature discussing issues of localisation focused upon specific contexts, in the form of nearshore or offshore localisation. In comparison to this, the cricket bat supply chain manufactures both locally (in England) and globally (in India, amongst other locations), providing a unique opportunity to determine how the different manufacturers compete under different constraints. This leads to the presentation of the research question that we will work towards addressing within the current research.

RQ: How do small scale, local manufacturers compete with large, global manufacturers within a global market context?

The following section provides a summary of the research methods that were employed within the research.

Design/methodology/approach:
The research takes a theory building, qualitative approach (Meredith 1998), with the case data taking the form of a multi case study (Yin 2009) situated within single market. While multiple firms contribute to the research, due to the interconnectedness of the firms within the sample, each case can be directly compared with the other companies, due to selling the same product to largely the same customer (high quality, English Willow Bats). To explore the relevance of localisation practices to the global supply chain, observational and interview data were collected from site visits, supported by secondary company and sport related websites from four UK based manufacturers and three India based manufacturers. The four British firms were selected due to their reputation, access and their distinct approach to manufacturing bats, which was considered to provide a broad selection of approaches to operating. The three India firms were also selected due to reputation and access, who fortunately also chose distinct approaches to operating and manufactured at different volumes, although this was not an a priori selection criteria. Within both groups of firms, both the largest Indian and English manufacturer were included, providing a rich selection of firms operating with the cricket bat manufacturing market.

Data was used to produce firm specific case studies that covered a range of aspects of the manufacturing process, relationships with suppliers and the role of craft skills. These were returned to each case company to verify their accuracy and ensure each company was happy with the information that was included, helping ensure internal validity (Yin 2009). The case reports with the other data sources were then used as the foundation for analysis, which included within and cross case analysis (Eisenhardt 1989), both within groups of firms (English or Indian) and across the two groups. The findings of the analysis were then considered against a triple bottom line framework (Elkington 1999), to explore the relative local or global focus firms give to different benefits realised through development and how localisation affects this. Table 1 provides a summary of the companies involved in the research and data collected from and on them.

Company/Brand	Established	Size	Output	Business model	Data Collection	Notes
British Small 1 (BS1)	1992	Small – 6-7 bat makers	2500	Craft based manufacture	Site tour and interview with head batmaker	Established by Owner (ex-apprentice to a well known bat maker)
British Small 2 (BS2)	1996 established by an international and county level player	Small – 3 makers and 2 admin.	<5000pa (confirmed)	Craft based manufacture	1.5 hour interview and site tour with owner	Now run by Non Cricketing owner – notable for nuclear/engineering background
British Large (BL)	1885	Medium (30)	40,000 bats pa (30,000)	Automated mass manufacturer using CAD/CNC, supported by craft skills	Site tour and 1 hour interview with manager	Large Willow Supplier Account, supported by sourced willow.
British Small 3 (BS3)	2012	Small (10)	<3000pa (machine capacity of 6000 (2500 a year, machine capacity is 7500)	CAD/CNC bespoke manufacture, direct sales	2 hour interview and site tour	Hostile spin-off from from larger firm
Indian Small (IS)	1950 moved to Jalandar	Medium (for India) 100	100k English willow, 100k kashmiri willow	Considerable investment in professional player support	Site tour and interview with director	Very little mechanisation other than sanding and band saw
Indian Medium (IM)	1967	Medium Large (for india) 350	60,000 english willow, plus additional 140,000 kashmiri willow	Primarily sold under the New Balance Brand, with smaller Protos domestic brand	Site tour and interview with managing director and general manager	Mechanisation to facilitate consistent manufacturing and support worker wellbeing
Indian Large (IL)	Founded in 1931 but started making cricket bats in 1981	Large	100,000 English Willow, 250,000 Kashmiri Willow	Sold under their own major brand as well as under the labels of major "all sported" brands	Site tour and interview with two directors	Balanced approach between machines and craft skills

Table1: Case Database

Findings:

Across the 7 companies there was considerable variation in their approach to manufacturing, how they engaged with clients (both commercial and end user), how they marketed their products and even business models. This was considered a real strength of the research to develop broad and in depth understanding of multiple parties involved in the global cricket bat supply chain. For brevity, the following section reports on how the approaches of the different firms affected how they performed against the triple bottom line framework, rather than discussing within-case issues in detail. By using this framework and reflecting the attention of the literature on issues of sustainability to address the research questions, understanding can be developed of how each firm develops an advantage based on the aspects of the framework.

Economic:

The nature of the raw material supply chain placed a considerable constraint on each manufacturer, effectively determining how many and what grade of willow clefts they received, that determined how much bats could be sold for. Interestingly, due to the control the major supplier had over the raw material, they implemented some interesting policies that supported the maintenance of the smaller suppliers. Within the Indian companies, less was discussed about the access to willow, although the smaller firm did mention that access to the best willow clefts did limit further expansion. While this firm

commented that the quality of willow had reduced, all firms received a range of willow quality based on the overall population of willow that had been harvested in a given year. The role of the supplier within the industry was further highlighted by them not offering the larger contracts with reduced unit prices. While this did not provide the Indian firms with a price-based advantage, this policy did increase the value of the larger contracts to the suppliers.

As a result of this, each of the British manufacturers gave considerable attention to the maintenance and protection of the willow allocation, as without this, they stated they would not be able to operate. Even those with alternate sources were still heavily reliant on the major supplier, in terms of both volume and the quality of the willow. Following this constraint, the next issue was whether each company was able to sell the products they manufactured. For the larger manufacturers, primary approach to marketing was through the sponsorship of international players. For the most traditional Indian manufacturer, this appeared to be a considerable business expense, dedicating areas of manufacturing to the production of products for a single player. This also appeared to represent a significant part of the marketing budgets for the larger UK firm, who saw the promotion of their products and brand through sponsorship as a key way to sell more products. For the smaller UK firms, marketing took the form of sponsoring or supporting mid-level players, with the aim of establishing and developing the reputation of their products at a level of player likely to invest in top quality equipment. This form of marketing could also be combined with direct involvement with retailers, so that when retailers were approached, they would be able to discuss the benefits of particular products over others.

For the larger two Indian firms, they chose alternate avenues for selling what they manufactured. By manufacturing products that would be marketed under different brands, focus could be given to the manufacture of the best quality products, both bats and soft goods that could be sold without the need to invest in marketing. This situation was exemplified by the medium-sized Indian firm, who only marketed their own brand to the domestic market on a small scale. For the larger firm, who had a significant presence within the global market in their own right, had the expense of marketing their own products, that were in competition with their own bats, simply labelled differently. For the smaller UK brands, due to the limited availability of willow, combined with capacity limitation in some cases, there were limited opportunities to manufacture for other brands. Notwithstanding this, there were opportunities for the smaller, boutique brands to manufacture tailored, customer bats for professionals, who may be sponsored by brands without the capability to meet specific player requirements that sponsors could not deliver.

Addressing these issues provided each firm with means of manufacturing a sufficient number of products to sustain their business, so demonstrating economic sustainability. Interestingly, the retail prices of each bat (depending on the grade) was similar across the brands, suggesting that those companies supplying to retailers were likely to be selling products for a similar price. Those larger brands would then be required to purchase from a third party, maintain a margin before selling to a retailer. This would suggest that overseas manufacturers would need to offer a similar discount as the difference between manufacturing for direct sale and manufacturing for a retailer. While the benefits associated with manufacturing in India in terms of lower wages can be appreciated, the

nature and multiple tiers of the supply chain (to a degree) appeared to balance cost-based issues for the UK and Indian firms.

Social

For the Indian companies, a critical factor they (and the brands they were supplying for) had to consider was the nature of the production environment. While it was possible for the international brands to purchase low cost, high quality products from a number of overseas manufacturers, this created supply chain risks if the suppliers had poor working conditions. Through both open and closed supply chain structures, purchasers either selected suppliers with good worker conditions, or supported firms to develop them, respectively. For the two larger Indian firms, great attention was given to developing manufacturing processes and environments, in addition to giving attention to separate non-work areas for staff. While these resulted in a trade-off of increased costs, they stated this increased process efficiency, so offsetting some of the additional investment, but were a requirement of working with the international brands.

The smaller, more traditional Indian manufacturer provided a useful counterpoint to the other two. With attention given to making the best bats, accessories and other sporting equipment, the processes were primarily manual, apart from basic saws and sanding equipment, operating out of cramped working areas. While there was a stark difference between these manufacturers and the other Indian manufacturers, the owner stated that all workers were supported and had been working for the company for a number of years. Interestingly, maintaining these traditional ways of making bats was highlighted as important for the company, as further mechanisation or automation may improve aspect of the process, but may ultimately result in job losses. With attention on maintaining employment and supporting those workers who have been with the company a long time, this route for improvement was not being considered.

The British manufacturers had different issues to consider within their manufacturing facility, focusing primarily on managing costs. Within the context of UK manufacturing, there are a range of rules and regulations that ensure certain criteria are met and working conditions are at a satisfactory level. Due to the accessibility of the manufacturing facilities, there were more opportunities for facilities to be visited by potential customers and audited to confirm suitability of conditions. With these requirements set, for the two more traditional manufacturers (BS1 and BS2), attention was given to selecting premises that did not increase overheads, with processes that were able to deliver products at the necessary cost, quality and quantity. For the other two companies (BS3 and BL), the direct sales and scale allowed the technological small firm and the size of the largest UK firm, respectively, to invest in dedicate facilities with separate show rooms. In the technological small firm, they were also able to invest in an in-door cricketing area, to allow prospective customers to try a number of products or even hire the area to third parties, increasing their service offering.

An interesting additional factor for the British manufacturers was the availability of wood-based craft skills. While craft skills were also difficult to source in India, makers stated there were people with the necessary woodworking skills that could be trained. As a consequence, a further factor the British manufacturers have to consider was how to develop craft skills or overcome the need for them. Although overcoming the need for craft skills removed this constraint, in terms of access to labour, reducing the amount of craft

skills created an unintended consequence. With cricket bats representing traditional products, produced through traditional craft-based processes. From discussions with manufacturers and players about the different brands involved in the research, while some customers may focus upon branding, others value the process and skills of the manufacturer more. As a result, while attempting to remove time consuming and expensive processes through process improvements, maintaining keys activities represents an important competitive criterion that needed maintaining. Without this, while products could be marketed as English willow made in the England, they could not be marketed as being hand crafted.

Environmental

Apart from some fumes emanating from a bubbling pot in the corners of one of the Indian manufacturers, the issue of environmental impact was not covered explicitly within any of the interviews. Notwithstanding this, the impact of the global supply chain on the environment needs to be considered. While the size and volume of the products being moved is small compared to other industries (such as the automotive), there are also interesting factors to consider for the willow processed in India, due to the need for it to be transported to India and (in some cases) back to the UK. While other bat related material (e.g. handles) and soft goods raw material do not have to be imported from the UK, the movement of the willow did add costs (economic and environmental) to the Indian finished good. For the UK based manufacturers, these are costs they do not have to bare. In addition to transportation costs, UK manufacturers also had the opportunity to source their own Willow from other wood merchants, directly from growers in the UK or grow their own (BS2). This could be considered as a way of providing the UK manufacturers a means of bypassing the main supplier and controlling the quality of their primary raw material that the Indian manufacturers do not have available to them.

Discussions

The relative lack of literature exploring issues of localisation allows this research to open an interesting area of study, which is further emphasised by the unique nature of the cricket bat supply chain. In comparison to previous reviews, by focusing attention upon a specific supply chain does not attempt to present generalisable findings relevant across domains. However, this research allows more focused insight compared to previous work, specifically literature reviews, whose work tends to result in rather general frameworks (see Seuring and Müller 2008, and Koberg and Longoni 2019). The work also allows a direct comparison between overseas brands, manufacturers and suppliers, with those companies operating out of the UK. This highlights the benefits and drawbacks of both approaches to manufacturing that cricketing brands are able to choose between. The final novel aspects of the supply chain are that not only are all the firms operating in the same final market (English Willow Cricket Bats), they are also part of a single supply chain, using a single raw material and for the majority, a single supplier.

Overall, this investigation of cricket bat making within the UK and India identifies some interesting factors at play within a unique supply chain context. The use of the triple bottom-line to organise and summarise the analysis of the 7 case companies has been critical to more clearly understand the issues the firms experience and how they relate to one another. While there are issues and problems identified and documented about the triple bottom-line (see Norman and MacDonald 2004), it does give attention to social aspects of the process that are at times overlooked (Jaegler and Burlat 2014). By exploring

the operational contexts, at a detailed, operational level, it was possible to consider how changes in operational processes lead to improvements across a range of performance measures (Despeisse et al. 2012), including social. The comparison also allowed insight on how social benefits can be different depending on the context that is being explored.

To begin addressing the research question, the findings show the firms operating from within the UK are afforded two important advantages over their Indian competitors. Firstly, while contact with their raw material supplier needed to be carefully managed, they were able to develop direct relationships, and alternative sources of material. In comparison, although the contracts may be on a different scale, so representing more important customers for the supplier, the Indian companies appeared wholly reliant and dependant on a single supplier. They were also dependent on the condition of the wood, following storage and transport over the course of a number of months. In comparison the British companies were able to receive their products (if requested) in a rawer form (unseasoned or uncut) to condition how they saw fit. As this was wholly controlled by the suppliers, this created a risk for the Indian suppliers, that the condition and processes related to the raw material were more out of their control and it was difficult for them to be monitored (Kouvelis and Tang 2012).

Conclusion:

Although the work has been focused upon cricket bat manufacturing that represents a unique supply chain, due to a single source and almost single supplier of raw material, it has unearthed some interesting related findings. The single supply chain provides a useful foundation for the research with each company operating within the supply chain with broadly the same raw material cost (withstanding transport costs). By also producing largely the same products, while there are a wide range of sub markets for Cricket bats, each 'grade' of bat competes against similarly graded bats (the standard of the raw material determines that standard/price of the finished good). Within such situations, particularly within a retail environment, or indeed for major sports brands, those suppliers able to provide products at lower costs, provide opportunities for shops and brands to increase their own profit margins. This situation was what led to the off-shoring of manufacturing, when it was possible to procure similar quality products at less cost than to manufacturing them locally. In particular for the sports brand selling a wide range of products, cricket bat design and manufacturing may not be a priority, compared to overall profitability of a portfolio of sports goods.

With this consistent background, it is possible to clearly compare how the different firms' approaches to manufacturing bats impact their competitive position and the benefits they realise from their choices. This leads to an ability to compare how the processes present within these different manufacturing facilities impact both the end product and how they are marketed. For those companies producing for another brand, processes and facilities had to be designed and improved to meet the requirements, and in some cases, be marketed, by global sporting brands. This involved investing in aspects of the manufacturing facility away from the production process, allowing the brands to partially offset their decision to offshore manufacturing away from wholly being focused upon cost savings. This was exemplified by the firm with the long-term relationship with a supplier, who worked with the supplier on product design and marketed the standard of their production facility. This example demonstrates how a closed supply chain structure can

facilitate improvements that meet the needs of international companies across a range of TBL measures (Koberg and Longoni 2019).

For the UK based manufacturers, instead of needing to promote particular types of manufacturing facilities and conditions, as they were “English Willow”, “made in Britain”, working conditions were assured. As a consequence of this, the facilities focused upon the processes that were taking place and the products that were being produced. While the majority of the large brands had off-shored production, the companies that remained still needed to overcome the factors that had led to the off-shoring, higher operating costs and skilled labour shortages. As a consequence, the primary aim of the UK manufacturers was to design and develop processes that helped them reduce cost, which was further supported by reduced transport costs (Atallah, Gómez, and Björkman 2014), allowing them to remain competitive. However, it may not be possible to localise the production of other cricket products, such as soft goods, reflecting Nicholson et al. (2011), unless production costs can be manage, localising production could increase costs. It was then necessary for each firm to be able to demonstrate how their products and also services offered differentiated them from other local and international products that were available.

The maintenance of craft-based, traditional, bat-making skills in the UK could thus be seen as an important social benefit, adding value to the manufacturing land scape of the UK, that could provide these firms with a competitive advantage that was valued by customers. Closeness to the end user also provides opportunities to engage service oriented and development activities, supporting a direct sales model that was already being utilised by one of the UK manufacturers. Overall, the initial exploration into the context of cricket bat manufacturing provides both hope for the future of the industry, but also opportunities for developing. These may include coordinating developing activities across small manufacturers, such as growing will, that drawing from Usui et al. (2017) could provide benefits in the longer term.

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Scalable and flexible production ramp-up in global production networks – a strategic network approach

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Abstract

Strategic management of global production networks (GPN) is getting increasingly complex and continuously more relevant for the long-term success of producing companies. Each plant in the GPN needs to accomplish goals coming from strategic management to stay competitive by adjusting their plant capabilities. In tactical management, production ramp-up processes are a great chance to be used for adjusting plant capabilities due to the high investment and cost determination character. This paper faces the possibility to integrate production ramp-up processes in the strategic management of GPN. The approach identifies relevant ramp-up dimensions and processes for an early strategy achievement.

Keywords: Global production networks, production ramp-up, production strategy

Introduction

Companies of various sizes and industries structure their production in the form of global production networks (GPN) (Váncza, 2016; Bhinge *et al.*, 2015). These networks correlate with different strategy levels of a company (Holweg and Helo, 2014). In order to achieve the particular strategy levels, each plant meets its strategic goals by aligning its plant capabilities. These individual contributions form the basis of the global production strategy. (Friedli *et al.*, 2014)

When planning production ramp-ups for the future configuration in GPN, this has to be aligned with the strategy of the company. Individual processes during production ramp-up influence the plant. While there are approaches that only focus on specific fields of a production ramp-up, there is a need to operationalize production ramp-ups in a GPN (Nyhuis and Wiendahl, 2010). Other approaches focus on the systematization of change processes for increased changeability of factory structures, but do not take into account

the network character and comprehensive ramp-up processes (Löffler, 2011). The need for further research in this field focusing on performance measurement in GPN was identified by Cheng *et al.* and can be matched with strategic implications (Cheng *et al.*, 2015). These strategic implications correspond to the theory of an integrated manufacturing strategy decision-making structure proposed by (Olhager and Feldmann, 2018).

To tackle this lack in research and industry, the purpose of this approach is to identify processes during production ramp-up with strategic implications. In a first step, the strategy contents of a global production strategy are analysed. Furthermore, the importance of the individual strategy contents is specified using the established "Market Qualifier/Order Winner" method from (Hill, 1993). In addition, a creativity study analyses and selects relevant influencing factors for the interpretation of the global production strategy in a time horizon of five years (Linstone and Turoff, 1975). These are called key influencing factors and they are analysed in greater detail for their future development. In the second step, plant capabilities, or performance measures of a plant, based on the work of (Reuter *et al.*, 2016) and (Hallgren and Olhager, 2009) are expanded in the present paper and contrasted with the strategy contents in order to work out the influence of individual plants on the global production strategy in the GPN. Furthermore, industry and project characteristics are used to extend the developed model. In the following step, a modular production ramp-up process is developed which correlates to the action plan for a time horizon of approximately one to two years. Here, individual processes are worked out which influence the long-term global production strategy and therefore require special attention.

The remainder of this paper is structured as follows. First, an overview of relevant literature in the field of research is given, which emphasizes the introduced research gap. Thereafter, the developed procedure for the flexible and scalable design of a production ramp-up in GPN is presented. Afterwards, this approach will be validated through case studies with experts from the German automotive supplier industry, which will show the relevance in practice. The paper concludes with a discussion and an outlook on further research.

Related work

In the course of this paper, the topics of ramp-up management in GPN, strategy layers in GPN, changeability in GPN and plant capabilities need to be analysed in greater detail.

The production ramp-up in GPN has already been discussed several times in the literature. Becker *et al.* address the strategic production ramp-up in production networks of the automotive industry. They provide a mixed integer programming model, which calculates the optimal curve of a production ramp-up at different locations in the network. This optimization is assigned to operational management and has few strategic implications. Nevertheless, the authors position the strategic ramp-up planning between the strategic network planning and the operative planning of the production ramp-up, whereby only a conceptual classification takes place. (Becker *et al.*, 2017)

Fitzek's contribution also focuses on ramp-up management in networks. He analyses relevant influencing factors of the production ramp-up, their interaction and gives design recommendations for ramp-up organisations, communication and other particularities. Neither individual phases of the production ramp-up are analysed in detail nor are strategic aspects for a long-term design of the GPN taken into consideration. (Fitzek, 2006)

Fischer also discusses influencing factors of the production ramp-up at different locations without devoting himself to network effects. He conceives a methodology to

evaluate different site conditions in the preparation phase of production ramp-ups. This evaluation serves as a starting point for various recommendations for action to design a production ramp-up. For example, the flexibility of a factory and expansion possibilities on the shop floor are put in the foreground in order to react to changing framework conditions. Despite this, the author does not take plant capabilities into account. (Fischer, 2015)

With regard to the anchoring of different strategy levels in a GPN, Friedli *et al.* are regarded as a pioneer and state of the art. In their work, they describe the global production strategy, which consists of the production strategy and the network strategy. These form the foundation of strategic decisions in the GPN. However, their work does not focus on the possibility of integrating the production ramp-up and external influencing factors into the strategic management of GPN. (Friedli *et al.*, 2014) Other works like (Olhager and Feldmann, 2018) focus on the distribution of manufacturing strategy decision-making in GPN. They differentiate between network and plant level and find out that there are three types of decision-making. It is centralised by the network level or integrated between plant and network level or decentralised by the plant. The integrated perspective can be related to the integration of a single plant production ramp-up into the strategic decision making which is one of the focuses of the present paper. Löffler focuses on change management processes and the integration into strategic management, but does not exclusively include ramp-up processes. The author develops a system that allows to integrate transformation processes into the permanent adaptation of factories. (Löffler, 2011)

In the context of changeability, there are numerous approaches on how to handle changeability on plant level. In their approach, Lanza and Moser deal with an uncertain environment, which has to be regarded as the initial starting point for the concept of changeability. The authors analyse uncertain environmental factors to calculate the optimal design of GPN. Thus, the optimal configuration of the plants in the GPN is considered in detail. No focus is placed on the transformation of individual plants regarding the aspect of changeability. (Lanza and Moser, 2014)

Other researches like e.g. Haag focuses on the identification of changeability drivers in GPN. In doing so, he focuses on early-evaluation activities for an early knowledge of the transformation needs of the future. However, he does not focus on how to deal with this change and how to prepare one's own company for the change. (Haag, 2012)

Further approaches take the combination of strategic decisions and an external analysis into account. Moser et al. regard changeability in GPN as an important success factor for the future strategic orientation. Here, they consider external influencing factors and the degree of changeability that a GPN should have in order to act at minimum cost. However, ramp-up processes are not considered in detail and only a focus is placed on cost aspects. (Moser *et al.*, 2017)

In the area of plant capabilities, there are several approaches describing different dimensions of plant capabilities. The most common is the site capability approach of Friedli. He introduced the site capabilities Costs, Specification Quality, Conformance Quality, Delivery Speed, Delivery Reliability, Design Flexibility, Delivery Flexibility, Service and Sustainability. Nonetheless, an integration of relevant ramp-up processes to develop these plant capabilities is not considered. (Friedli *et al.*, 2014)

In summary, there are many approaches which focus on selected areas of ramp-up, strategic layers, changeability and plant capabilities in GPN. However, none of these approaches combines all aspects, which is necessary for the strategic management of future competitive GPN.

Approach of integrating ramp-up into strategic management of GPN

A framework based on the aforementioned topics of ramp-up management, strategic network planning and plant capabilities is proposerd. These topics combine important aspects for a sustainable management of GPN.

In the strategic alignment of GPN, the interaction of individual plants is of importance. It is substantial to find a way to quantify strategic contents of a company with the capabilities of plants (Mengel, 2017). These strategic contents must follow the external developments of a company and have to be designed accordingly (Gausemeier *et al.*, 2018). A GPN also achieves a higher performance than the mere aggregation of the performance of individual locations (Shi and Gregory, 1998). Here, the plant capabilities serve to relate the network performance based on individual plants. In order to adapt these capabilities purposefully, ramp-up processes in short-terms are used. Furthermore, depending on the external development of influencing factors and the firm's strategy, not all plant capabilities and therefore not all ramp-up processes are relevant. Accordingly, the paper proposes a three-step approach that supports the company in integrating ramp-up processes into GPN's strategic management (see Figure 1). First, the company's strategy and the relevant environment is analysed. Second, on plant level, capabilities are regarded and matched with the strategy level. Third, actions in form of ramp-up activities are chosen to flexibly react to strategic decisions.

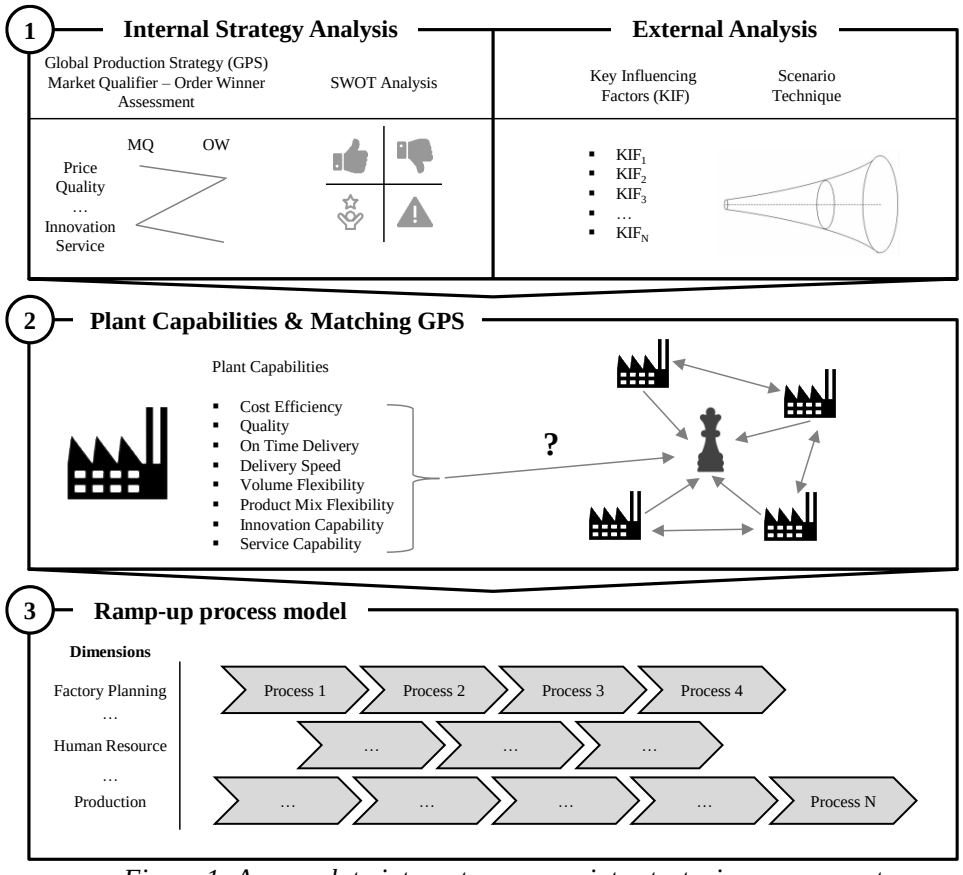

Figure 1: Approach to integrate ramp-up into strategic management

In a first step, the strategy contents of the global production strategy are analysed. These contents are divided into the nine dimensions: price, specification accuracy,

product quality, delivery reliability, delivery quality, product range, design flexibility, order quantity flexibility, innovation and service. (Friedli *et al.*, 2014) They particularize the areas of specialization a company can undergo. Furthermore, the importance of the individual strategy contents is specified using the established "Market Qualifier/Order Winner" method from (Hill, 1993). Where each strategy contents is weighted regarding its importance for the future strategy of the firm. Market Qualifier symbolize aspects which are necessary for a firm to be competitive in a business area. Order Winner symbolize the factor which is the reason for purchasing a product from a firm. Moreover, a SWOT (strengths, weaknesses, opportunities, threads) analysis is performed for the GPN to validate the identified strategy contents of the global production strategy (Wheelen and Hunger, 2011). In addition, a creativity study analyses and selects relevant influencing factors for the interpretation of the global production strategy in a time horizon of five years (Linstone and Turoff, 1975). These are called key influencing factors and they are analysed in greater detail for their future development. Possible relevant influencing factors are market development, labour cost, culture, fluctuation and so on. The assessment of these key influencing factors is done via the widely known approach of (Gausemeier *et al.*, 2018).

The second step of the approach is dedicated to the measurement of the capability of production plants. These individual capabilities are matched with the strategy contents of the global production strategy in order to make the influence of individual locations on the overall strategy achievement tangible. The detailed matching of the plant capabilities can be found in Table 1 and is derived through industry input via different workshops between researches and industry experts, as well as through an extensive literature review of relevant areas.

Table 1: Matching of Global Production Strategy and Plant Capability

Global Production Strategy - Strategy Contents	Plant Capabilities							
	Cost Efficiency	Quality	On Time Delivery	Delivery Speed	Volume Flexiblity	Product Mix Flexibility	Innovation Capability	Service Capability
Price	x							
Specification Accuracy						x		
Product Quality	x	x						
Delivery Reliability		x	x	x				x
Delivery Quality	x	x						
Product Range						x		
Design Flexibility						x	x	
Order Quantity					x			
Innovation							x	
Service			x					x

The product mix flexibility is now used as a describing example. Here, this capability has a connection to design flexibility, product range and specification accuracy. This influence stems from the fact that the product mix flexibility is very broadly diversified and thus influences diverse strategic content. The product mix naturally influences the product range, since the mix is a subset of the range. In addition, design flexibility is influenced, as each mix can also produce different designs. High specification accuracy also correlates with product mix flexibility, as a higher product mix enables a lower specification accuracy. Therefore, a negative influence is also possible here. It should be noted that the influence of the plant capabilities on the strategy contents of the global production strategy is only of a qualitative nature. The operationalization of the relationships is another core field in this area of research.

In the third and last step of the approach, the ramp-up process model is presented. This has a large number of processes that can occur during ramp-up. It supports the network manager in selecting elementary processes to build up identified strategic plant capabilities. In Figure 2 an exemplary process, the layout planning in the dimension factory planning is shown.

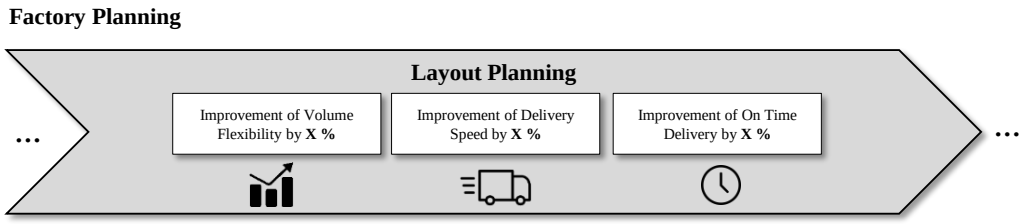

Figure 2: Exemplary Process of the Ramp-Up Process Model

Based on an extensive literature analysis and several workshops with industry experts from the field of automotive industry, a process model for the production ramp-up in GPN was developed. This consists of seven elementary plant dimensions. These are Human Resources, Research & Development, Factory Planning, Production, Logistics, Procurement & Purchasing as well as Marketing & Sales. During the implementation of the approach, the relevant processes for flexible ramp-up planning and thus the development of plant capabilities are disclosed to the network manager. Each process in the ramp-up process model is detailed via the influence of the specific process to the plant capabilities. Specifically, the dimension "factory planning" is important for the strategic development of plant capabilities in GPN (Heinen *et al.*, 2010). The degree plant capability improvement for each process is done via expert interviews and workshops. An intensive research and detailed planning of this process during a production ramp-up can help to easily follow strategic guidelines for the future of a plant. Thus, after completing the first two steps of the presented approach, a guideline of processes for ramp-up is delivered to the user for each dimension of the model, if relevant.

The application and usage of the framework helps strategic network managers to make valuable decisions in the management of GPN due to the holistic approach and widely applicable nature. It can be used as a guideline for the strategic management process and gives guidelines on how to integrate ramp-up into this topic.

Exemplary application of scalable and flexible ramp-up in automotive industry

The case study method according to (Yin, 2014) is suitable for the validation of an approach or a framework. Case studies are particularly suitable for answering and exploring explanatory questions. Since the focus is on supporting the strategic management in GPN, a qualitative case study is applied (Eisenhardt, 1989).

In a case study, at best several companies are interviewed in order to obtain the largest possible range of solutions. For well-founded results, however, the number of companies surveyed can also be kept low (Dyer and Wilkins, 1991). Therefore, eight workshops with automotive suppliers headquartered in Germany were conducted. All these suppliers operate their production in GPN.

The first step in the design of the case study was to get an insight into the GPN of the companies in order to understand and grasp the problems as well as the challenges of the industry. Accordingly, a team of two scientists conducted various workshops with the industry. At these workshops different functions of the respective companies were

present. The participants were ramp-up managers, global operational excellence managers as well as COOs and CEOs. This was helpful and needed to get a broad overview about the structure and the strategic guidelines of the GPN. Following (Eisenhardt, 1989), detailed minutes of the workshops were collected within 24 hours of each workshop, including workshop data, conclusions and overall impressions.

When aggregating the results from the workshops, many similarities were noticed. This speaks for the similar challenges currently faced by German automotive suppliers. In the following the aggregated results of the workshops are presented.

In the first step of the approach, the strategic contents of service, innovation, delivery reliability and order quantity were regarded as particularly relevant for the future design of GPN. These are seen as order winners.

Service and innovation are very important for the strategy, especially for technology leaders. This is largely due to the disruption caused by electro mobility. In addition, the degree of servitization is increasing, with more and more suppliers offering a product-service-bundle (Colledani *et al.*, 2016). Delivery reliability is also very important as the competition in the supply industry becomes stronger. Therefore, the reliability of the own company needs to be high. The order quantity flexibility is also an order winner. The project business with Overall Equipment Manufacturers (OEMs) is increasingly decisive for success. In this context, suppliers are often faced with very different quantities by the OEMs and it must be possible to react flexibly to these.

A SWOT analysis was carried out to substantiate these important strategic contents. This filters the relevant internal and external influences for the future design of the GPN and the production strategy. The elements of the SWOT analysis were developed by the company experts through brainstorming.

In summary, the quintessence of the analysis is that in the area of strengths, versatile production resources and a high depth of added value characterize all participating companies. In the area of weaknesses, it came out that customers sometimes have very high requirements with regard to delivery times. These may be hard to fulfill. In addition, the fluctuation of qualified personnel is a weak point. Opportunities lie in the area of market development in emerging markets, which means that new sales markets can be supplied. Threats are seen in the areas of an intensified competitive situation and the increasing demand for services. Companies must first act on this increased demand with a high quality to maintain their image sustainably.

For an in-depth analysis of the identified strengths and weaknesses, an external analysis was carried out with each of the companies in the respective workshops. On this basis, various scenarios were developed for the companies. Commonalities in the external analysis lay in the area of the elementary important influencing factors, which will be described in detail. Of great importance were the influencing factors market development, project business and competitive intensity.

Market development is elementary for the future design of the GPN of companies, since e.g. the business of the conventional combustion engine is shrinking and this loss can be counteracted by growth, especially in electro mobility.

The project business correlates strongly with the order strategy of the OEMs. These determine the production pace of the suppliers and the future strategic orientation of the GPN. Projects on many different continents mean for the suppliers also locations on these continents due to the strict delivery time requirements.

The competitive intensity is reflected in the delivery time, but also in the necessity to focus on the core competencies of the suppliers. Due to an increased competitive intensity, unique selling points must be inevitably anchored in the production strategy.

After analyzing the external influencing factors and having clear the strategy for the next years, one has to focus a specific plant in the GPN to start the development. This is necessary to have a good first step regarding the fulfillment of the firm's strategy. In this plant, there is a ramp-up process planned for the future in each considered company, which has to be used for an early strategy alignment.

In step two, the plant capabilities and did the linking of the relevant strategy contents from the workshops were focused. There, the five most relevant plant capabilities for the future in the supplier industry were identified. These are on time delivery, delivery speed, volume flexibility, innovation capability and service capability. Through the connection to the strategy contents, the identification was straight forward. The experts from industry emphasized the simple connection and valuated it. It is an easy way to make a fuzzy strategy transparent on plant level in a GPN.

After the clarification of the important plant capabilities, the next step was dedicated to the strategically important ramp-up processes. In the individual workshops, the ramp-up process model was introduced and fundamentally explained. Through the clear allocation of influences of the individual processes to the plant capabilities, the need for action and the focus for the design of the ramp-up became transparent.

In particular, it became clear through the workshops that processes in the areas of factory planning and human resources are very important for the identified plant capabilities. The processes location check, location planning, building planning and realization as well as layout planning are located in the factory planning area. All these processes contribute strategic importance to the plant capabilities volume flexibility, delivery speed and on time delivery. By a concentrated consideration of this area, a decision support for the ramp-up process is delivered to the participating companies. Thus, they can focus their activities more specifically and adjust their efforts accordingly.

For an improvement of the plant capabilities innovation capability and service capability, the area human resource is particularly suitable. In this area the processes personnel requirement planning, personnel recruitment and personnel development are considered. These processes can be focused to the extent that creative employees are hired to strengthen innovations. Furthermore, an atmosphere or corporate culture can be created in the personnel development process to promote innovation. This also strengthens service capability, since new product service bundles, for example, can be developed and marketed through innovations.

Consequently, the approach serves as a valid tool to make the connection between the production strategy, plant capabilities and ramp-up processes clear. The approach was validated successfully within industry through several workshops.

Discussion

The overriding goal of this research was to identify relevant ramp-up processes that can contribute to the early achievement of strategic goals. In order to achieve this, an approach driven by literature, which links the mentioned topics and transfers them into a procedural model, was developed. The developed approach takes up standardized aspects from common literature. In addition, the missing link to operational ramp-up management is explained and introduced.

The developed approach is validated by a case study. The case study consists of eight workshops with different companies from the automotive supplier industry. Due to the manageable number of workshops, a deep insight into the industry of automotive suppliers is delivered. The case study demonstrates how the approach can be used to steer day-to-day business during a ramp-up and to coordinate efforts.

The exact influence of individual ramp-up processes on plant capabilities remains unclear and requires an in-depth analysis. Different KPIs can be used for the influence. It requires an operationalization of the plant capabilities and the ramp-up processes for this impact direction. In addition, limitations are seen in a workshop number of eight. Further workshops in this topic area, in order to obtain a well-founded database, are recommended. Other industries can also be considered, but comparability between companies must be ensured. The contribution of this research is that it helps to clarify the relationship between the design of a ramp-up process and the strategic implications of the respective decisions. Also, it helps to scale and adapt identified processes in order to react to external disturbances and future developments. In addition, companies that are in the need of adapting their production strategy are supported by this research as important processes in the cause of the adaption are clearly stated out. The achieved results make it clear to planners in ramp-up management that certain processes are important in order to force the strategic importance of the plant in the GPN at an early stage of time.

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Exploring the Implications of M&A for Global Production Networks

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Abstract

This conceptual paper applies and extends the factory role model to provide a production network view on mergers and acquisitions. We map the production networks of an exemplary buyer and target company to explore the framework's potential implications for M&A. We find that a production network view is able to give useful guidance in post-merger integration, restructuring and divestment decisions. It also allows to highlight potential strategic gains for the global manufacturing activity of the post-merger company. Moreover, it mitigates the risk of trading off strategic manufacturing capabilities against purported cost-synergies and might therefore aid the long-term performance of manufacturers.

Keywords: Global Operations, International Manufacturing, Mergers and Acquisitions

Introduction

Mergers and acquisitions (M&A) have a profound impact on the production networks of multinational companies as well as the manufacturing industry as a whole. As data of the UN Conference on Trade and Development reveals, the value of realised cross-border M&A in manufacturing has surpassed the value of announced greenfield projects by nearly 84 billion US dollar (approx. 10%) between 2015 and 2017 (UNCTAD, 2018). As of now, the literature on production networks appears to not fully mirror the practical importance of M&A for manufacturing companies. Usually, the literature does not discuss whether changes to the network are due to greenfield projects or brownfield acquisitions (cf. Olhager et al., 2015). Instead, researchers appear to imply a greenfield approach. Overall, the topic of M&A is mostly neglected in operations management (Ferdows, 2018; Zhang et al., 2010). As a consequence, the production network perspective does not realise its full potential in influencing M&A decisions despite their major implications for manufacturing companies. In this paper, we suggest an application

of a core theory of production network management, the factory role model, and explore its implications for M&A in the manufacturing industry.

M&A allows companies to access new markets, join forces with or against their competitors, realise scale and scope economies and acquire new technologies and knowledge (Graebner et al., 2017). One of the dominant factors driving M&A activity is companies' potential to leverage their value creation by capitalising on synergies existing between companies. To establish which value the target company in question has, M&A practitioners draw on discounted cash flow analyses and past M&A transactions. However, as Gupta and Gerchak (2002) note, corporate finance methods focus on valuing the target firm, without factoring in important production characteristics of the acquiring firm. Hence, Gupta and Gerchak show how production flexibility and market demand of the acquiring company affect operational synergies. In a similar vein, we argue that important cues for the strategic implications of M&A deals in the manufacturing industry can be obtained from analysing the overall structure of the production networks of the buyer and target firm.

Providing a practitioner roadmap to achieving synergies, the popular Harvard *M&A Playbook* by Christensen et al. (2011) suggests, companies can leverage their business by "extracting [elements] from an acquired company and plugg[ing them] into the [parent company]". In the realm of manufacturing, these elements could also be factories or networks of factories. This notion gives rise to our first research question (RQ1): *How can manufacturing companies identify merger targets whose production network strategically complements their own network?*

The advice of plugging in resources from the target company into the parent company, also puts a question mark over the fate of the remainder of the target company. As Meyer and Estrin (2001) and Estrin and Meyer (2011) show, post-merger restructuring measures might, in extreme cases, lead to a complete abandonment of the target company's resources and organisational structures. Post-merger divestures of so-called "non-core assets" are not uncommon (Capron et al., 2001) and might have positive implications for firm performance (Moschieri and Mair, 2008). This leads to our second research question (RQ2)*: Which parts of the post-merger manufacturing network could potentially be divested to realise cost-synergies and which cannot?*

Literature and background on M&A

The collective term M&A encompasses both, the fusion of two previously separate companies to a new firm ("merger"), as well as the transfer of assets, such as factories or business units, between companies ("acquisition") (cf. Ghauri and Buckley, 2003). Some argue, that about 97% of all M&As are acquisitions and only 3% are mergers (Peng, 2009). Yet, the terminological distinction between the two is fuzzy, also considering the variously termed deal structures that exist (e.g. Emott, 2011). As the main body of the literature, we will summarise both phenomena under the term M&A or 'merger'.

The literature has identified various motivations for M&A. The underlying literature is multidisciplinary and different social science disciplines focus on different aspects of M&A performance. The three predominant disciplines in the M&A literature are strategic management, economics and corporate finance. Angwin (2007) identifies the latter to mainly focus on one-time gains, such as decreasing tax liabilities, reducing cost of capital, systematic risk, or improving companies' share price. In turn, classical considerations of economics in M&A would include the often quoted economies of scale and scope (e.g. Given, 1996) or aspects relating to bargaining power. The strategic management field

belaboured various aspects driving M&A such as the access to technological capability (e.g. Sears and Hoetker, 2014) or limiting competition (e.g. Porter, 1985).

Factors like these are often grouped and framed as operational and financial synergies existing between the involved companies (cf. Trautwein, 1990). In theory, the estimated level of synergies determines the maximum premium that is paid, exceeding the market value of the acquired company. However, one robust finding of the M&A literature is that only a small number of M&As are able to realise the aspired synergies. For instance, in a sample of McKinsey & Co encompassing 160 mergers, 70% of companies fail to realise the expected revenue synergies and 40% are unable to deliver the previously estimated cost synergies (Christofferson et al., 2004). As regards shareholder wealth, others find that "three out of four acquisitions fail" and shareholders might be off worse than before the merger (Selden and Colvin, 2003).

Key to the concept of operational synergies is the existence of overlap. The figure below from Payne (1987) illustrates how overlap in the value chain of buyer and target firm engenders potential synergy in the respective activities of the firm. Various contributions flash out this notion. For instance, Houston et al. (2001) consider the geographical overlap of operations to drive potential for cost savings from consolidation and divesture of redundant structures and operations. Related to this, Capron et al. (2001) show how merging companies in the same industry (i.e. in a horizontal merger) can gain economies of scale by selling off, shutting down or reducing, that is, divesting, excess capacities.

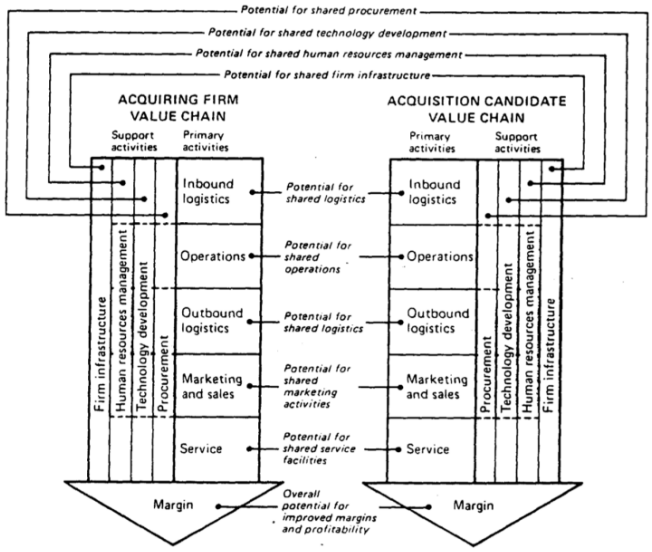

Figure 1: Potential synergy from overlapping firm activities (Payne, 1987)

Consolidation efforts such as these are embedded in the overall efforts of companies' post-merger integration (e.g. Graebner et al., 2017). Some authors, go as far as arguing that all value creation happens in this phase (Jemison and Haspeslagh, 1991). In line with this, a growing literature focusses on various aspects of post-merger integration of different firm activities (e.g. Homburg and Bucerius, 2005; Wijnhoven et al., 2006), restructuring and divestment (Capron et al., 2001; Estrin and Meyer, 2011; Vidal and Mitchell, 2015).

Consolidation measures such as these have a potentially profound impact on the operations in question, and manufacturing in particular. The literature suggests that a well-designed and managed production network can be a source of competitive advantage

(e.g. Gulati et al., 2000; Miltenburg, 2009; Shi and Gregory, 1998). The ensuing question of how can cost-based synergies as discussed above be realised without endangering the competitive advantage derived from a company's strategic manufacturing set-up remains unaddressed. As of now, no frameworks exist which guide companies in their decision on which elements of a manufacturing network are particularly valuable in a M&A and should be sought-after. Neither does the literature offer guidance on the divestment decision of which parts of the production network are of lesser strategic importance and can be divested to realise cost-synergies. This amounts to a gap in the literature which appears especially concerning considering the "mantra" of rapid post-merger action and the industries' focus on the first 100 post-merger days (e.g. Angwin, 2004). This way, the strategic long-term contribution of manufacturing in the company might be threatened by financial short-termism.

M&A and production networks – Insights and cues

Generally, it appears that, despite the impact of M&A on production sites and their operations, the operations management literature has, by and large, left the topic unattended (Ferdows, 2018). Hence, the questions addressed above appear to remain, by and large, unanswered. The purpose of this paper is to address these questions from a production network perspective, drawing on the existing literature in global operations management. Only a handful of pioneer works exist that approach the topic of M&A from a productions and operations management perspective, notably Srai et al. (2010) and Zhang et al. (2010). Yet, the literature has addressed a range of directly and indirectly related topics from various perspectives (cf. Cheng et al., 2015). Firstly, we will review the two above mentioned contributions of operations management on the topic of M&A. Afterwards, we review core contributions to the literature on manufacturing networks, on which we draw to propose a conceptual framework to answer the questions above.

A framework that investigates the operational dimensions of M&A is presented by Srai et al. (2010). Based on case studies, the authors identify the different phases of industrial cross-border M&A and the operations activities associated with it. One of their foci lays on the integration activities necessary to unlock operational synergies. In this context, a key aspect the authors discuss is the notion of overlap of regions and products which might alter the post-merger integration and steps necessary for it. Their key contribution is a framework which elucidates how operations activities contribute to value creation (as measurable by free cash flows) in M&As. As regards production networks, their framework suggests that especially network access, e.g. to markets and know-how, and network efficiency would contribute to value creation. With regard to the factor of network efficiency, the authors expand that asset reduction can lead to decreased capital expenditure and therefore contribute to an increase in free cash flows. However, the previously discussed questions of which assets are strategically important in the production network and which are not, are not addressed specifically.

The work of Zhang et al. (2010) focusses on the post-merger integration phase and seeks to understand how manufacturing networks are integrated in M&A. Focussing on the aspect of network configuration, the authors investigate the key integration issues of networks following M&A activity. In the framing of the authors, the above developed questions concern the structural dimension of network configuration. The key integrative issues related to this dimension would be "geography presence and business scope" in M&As pursuing the objective of growth, and "capacity utilisation and economics of scale" for efficiency seeking M&As. Again, the main purpose of this contribution lays on the identification of key issues such as these, rather than guidance in solving them.

Even though not addressing M&A specifically, general guidance on the configuration and coordination of manufacturing networks is provided by the conceptual literature on global production networks (cf. Cheng et al., 2015). To capture the M&A context, the current production network models would need to be extended. We present an overview of frameworks prevalent in the literature before presenting our conceptual model in the next chapter.

Several frameworks have been developed that shed light on different aspects of designing and managing international manufacturing networks. The majority of them is concerned with classifying networks. For instance, the IfM Manufacturing Network Typology defines four different network types based on their linkage between factories and geographical expansion (Shi and Gregory, 1998). Similarly, the McKinsey Network Phenotype Model identifies five different network types on the basis of their realisation of economies of scope/scale and their importance of local adaption and transaction costs (Abele et al., 2008).

Other models delve deeper into the meso and micro perspectives of international production networks. Most recently, Ferdows et al. (2016) suggests a framework to delayer production networks into subnetworks, according to the complexity of the production processes in question and the level of standardisation. Taking into account the average competency of the plant subnetwork, strategic anomalies and lack of congruency between the subnetworks position and its competencies can be identified. A plant view is provided by Ferdows (1989) and elaborated on in Ferdows (1997). The original model assigns distinct roles to factories of one company according to their competence and location advantage. Plants with lower levels of competency would merely produce products, while higher level plants would be akin to centres of excellence. Resulting are six distinct factory roles – Off-shore, source, outpost, lead, server and contributor factories. The resulting typology was empirically validated by Vereecke and Van Dierdonck (2002) and has helped to engender a productive stream of research on manufacturing networks (e.g. Cheng et al., 2011; Feldmann and Olhager, 2013; Maritan et al., 2004).

Conceptual Model

We draw on the logic of the plant role model and extend it to explore some of its possible implications for M&A between manufacturing companies. This allows us to address our two research questions to which a plant-level perspective is best-suited. We map the factories of two hypothetical example companies and their production network in the matrix of the plant role model and make a further addition. As discussed, one of the core drivers in M&A is cost synergy based on reducing redundancies and eliminating overlap. Therefore, we add the factor of total factory cost to the mapping, that is, production cost plus overhead. This allows comparisons between the two other determinant factors of the model and cost, the added factor. To make differently sized factories comparable, a view of total cost per unit produced would suggest itself.

We visualise the resulting conceptual model below. The specific depiction chosen has been inspired by Vereecke and Van Dierdonck (2002) as can be seen from the layout. The factories of the acquiring (parent) company are depicted as circles. The factories of the target company (i.e. the bought or to be bought company) are depicted as squares. The size of the indicator is shown proportional to the (estimated) total production cost, similar to the visualisations in Ferdows et al. (2016).

The resulting model is able to capture horizontal M&A between companies at similar positions of the value chain in the same industry. As will become apparent in our discussion of the proposed model, a certain substitutability is assumed between specific

subsets of the mapped factories, due to their operational overlap. Hence, the mapped networks of the respective two companies are to be understood as production (sub-) networks producing comparable products. With view to the point about product and geographical overlap made by Srai et al. (2010), this means that we focus on the overlapping production geographies (more precisely, their location features) within networks with overlapping products. This way, we shed light on some of the integration (and restructuring) issues mentioned by Zhang et al. (2010) and discussed above.

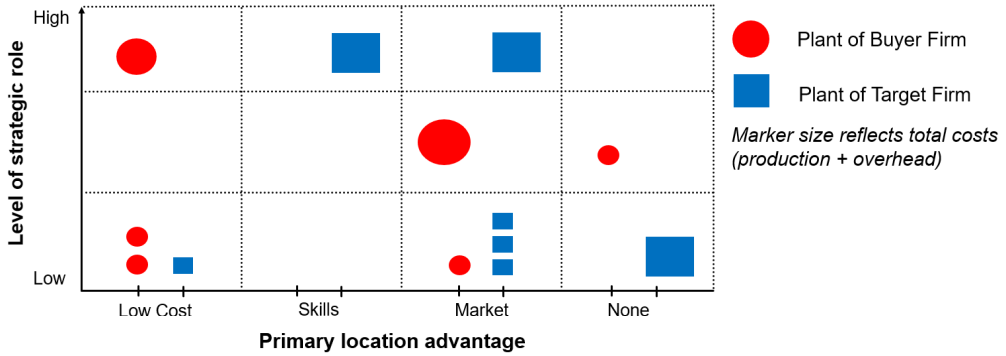

Figure 2: Extended factory role model for manufacturing M&A assessment – Mapping Example

Mapping the two production networks of the buyer and target firm reveals several opportunities existing between the manufacturing activities of the two companies. In the following, we will discuss the different implications of the mapping presented above as regards production network extension, synergy and restructuring/divestment. Where appropriate, we will highlight individual features of the mapping graphically.

Firstly, the mapping reveals core plants in the manufacturing network of the target firms which provide the buying firm a location advantage which it previously did not possess. In the example depicted above, the buyer company could gain a unique advantage in locally available skills (see second column from the left). None of the buyers current factories appears to access this location advantage as yet. In general, columns without or with only small overlap between buyer and target firm provide potential for the buyer firm to add location advantages to its network configuration.

Secondly, potential for the buyer firm to reconfigure the strategic features of its production networks can be assessed. In the shown example, the buyer firm's network appears unipolar by tendency, characterised by the existence of only one plant with a high strategic role. Acquiring the target firm depicted in the example would provide the company the opportunity of upgrade its network by taking over two plants with high strategic role. In the mapping, opportunities like these can be assessed based on row-wise comparison between the production networks of the two companies.

Thirdly, asymmetries between plant's strategic role and their total production cost become apparent. As shown in the legend, the size of the markers is displayed proportional to the total production cost of the plant. In the example above, the column "market" shows one factory with medium strategic role level which appears to cause total production costs comparable to factories with high strategic level.

The relation between factories' total cost and their level of strategic role can serve as an important input for the post-merger integration and restructuring process. In an effort to deliver on the estimated cost-savings, managers are likely to consider factories with high operating costs for downsizing, divestment or shut-down before others. By tendency, factories with higher strategic roles are likely to cause greater expenses (cf. Ferdows, 2018) and might therefore be threatened in particular by post-merger ambitions to cut

costs. Prematurely closing a factory with high strategic role might impair the competitive edge the company derives from its manufacturing network. The mapping above obviates this risk by showing the relation between a factory's cost and its strategic role in the network. As hinted above, this makes it is possible to spot cost-anomalies in the post-merger company, that is factories whose total production cost exceed the level of cost expectable based on their strategic level. This might flag factories that require managerial attention to identify potentially inefficient/wasteful practices. Should double structures exist (e.g. two firms of the same role) in case of a cost/role anomaly and no other managerial actions be preferable, the situation might call for a restructuring (compare, point five). Of course, the exact measure needed would depend on the detail context, including the ability of the more efficient factory to absorb the capacities of the less efficient factory, creating economies of scale. In case of an existing double structure, a divestment, e.g. by selling the factory, would not lead to a loss of strategic advantage, given that a factory of the same or similar role exists. However, a momentous decision like this would need to be based in a more fine-grain assessment of the existing options, industrial environment and market development. It has to be considered that the access to location advantages of different plants is not always substitutable. For instance, two factories whose predominant location advantage is market access might serve their purpose in two different regions (see highlighting No. 2 in the figure below). The figure below shows two examples for potential double structures.

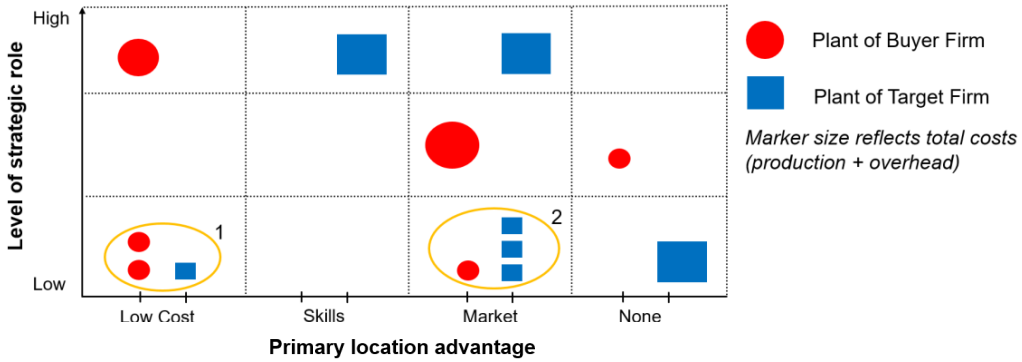

Figure 3: Highlighted potential double structures (Mapping example)

Fourthly, the model above informs the decision between which factories economies of scale and scope can be realised to achieve cost-synergies without impairing the strategic set-up of the production network. This relates back to the point on operational overlap. If the production networks' output is to remain stable but the number of sites is intended to be reduced to realise cost synergies the production of some factories needs to be integrated in others. Based on the presented model, it suggests itself to consider proceeding column-wise, integrating the production of factories with low strategic role into the production of factories with high strategic role, if possible. Restructuring this way creates potential for economies of scale from increased production volumes at the site and economies of scope from shared overhead costs, without threatening the strategic capability level of the network. Proceeding the other way around (integrating the production of higher strategic role plants into lower strategic role plants) might jeopardise the strategic edge gained from the high capability role factory, unless it can migrate to the new location as well. The latter appears to be a more costly option which is, in addition, also rendered less feasible by the relative immobility of key collar workers and engineers between regions of the world. The alternative to restructuring column-wise is restructuring cross-column. However, integrating the buyer and target firms' factories

cross-column-wise could lower a company's access to the location advantage otherwise accessed by the to be integrated factory.

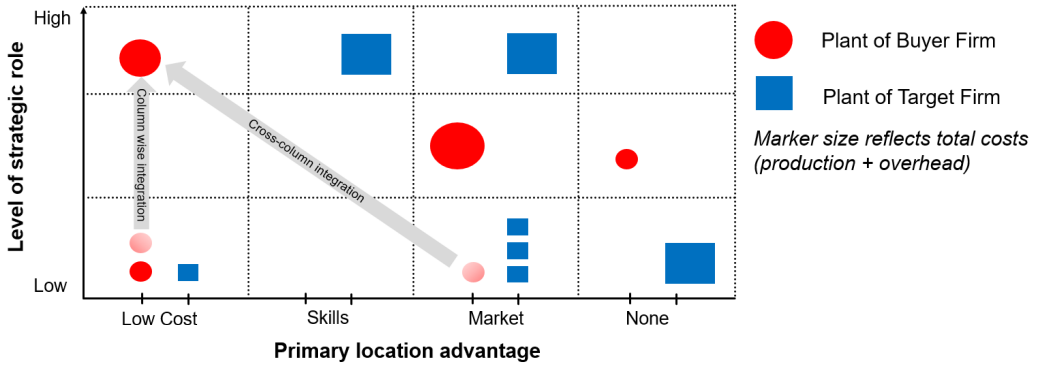

Figure 4: Examples of column wise and cross-column integration (Mapping Example)

Fifthly, mapping production networks of buyer and target firm highlights risks of losing strategic capability by means of an intended divestment targeted at realising cost reductions. As discussed above, high cost factories are likely to be in the crosshair of post-merger cost reduction measures. The presented mapping suggests to consider their strategic contribution to the network as well. This sets the total costs of the factory in context. Divesting or shutting down a factory with unique role (e.g. by innovating best practices or conducting pilot runs) might impair the strategic capability of the manufacturing network as a whole. Though short-term cost cuttings could be realised this way, the post-merger is at risk to endanger its long-term manufacturing advantage.

Lastly, a similar logic applies to the location advantages of factories. Divesting or shutting down a factory which has a unique location advantage in the post-merger production network deprives it of a strategic feature of its configuration. In the mapping example above, discontinuing the operation of the target firm's factory that accesses an advantage in skills would lead to such situation (second column from the left).

Discussion

We explored the implications of an extended plant role model for M&A in the manufacturing industry. This way, we addressed implications of M&A for global production networks, shedding light on our two research questions. Research question one inquired into the possibility of a production network perspective guiding the decision of companies on which acquired production network could complement theirs well. Question number two was concerned with the decision of which parts of the post-merger company can be divested to realise cost-synergies and which cannot. In particular, this paper suggests that the constellation of strategic roles and location advantages present in the production networks of the buyer and target firms should be key considerations when making investment, divestment and restructuring decisions in the manufacturing industry. The suggested production network view guides companies' decision on how to upgrade the strategic capability of their networks and gain locational advantages. Furthermore, it also informs between which production networks divestment and restructuring based cost-synergies can be realised without loss of strategic capability or locational advantage.

Contribution to the Literature

We provide an application-oriented framework that serves three purposes as regards the literature. Firstly, we address the gap of research on M&A in the operations management literature. This way, we also shed light on previously unaddressed production network

related issues concerning operational synergies as discussed in the general M&A literature. In doing so, we follow up and elaborate on some of the key points made in the pioneer works that proposed operational perspectives on M&A.

Limitations

As this paper is based on conceptual thought, it does not yet feature an empirical dimension. Furthermore, by considering only the primary location advantage of companies' factories, a simplification is made as factories might have several location advantages.

Conclusion and Managerial Implications

This paper has provided a production network view on M&A. For this, we drew on the factory role model and extended it. The presented conceptual thought has potential to aid strategic decisions of manufacturing companies engaging in M&A activity. It suggests which firm's production networks bear potential for ameliorating the configuration of the buyer firm's own network. It also bears implications for divestment and restructuring decisions aimed at realising cost-synergies. Mapping the production networks of the buyer and the target company as suggested might prevent the situation in which the long-term competitive advantage of a firm is traded off against short-term savings. Overall, taking into account a production network viewpoint on M&A has potential to render M&A of manufacturing companies more successful.

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Manufacturing execution systems in international manufacturing networks: from plant- to network-level

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Abstract

Manufacturing companies digitalize their manufacturing for various reasons. Those with multiple plants in an international manufacturing network (IMN) have to distinguish which digitalization steps they take on a plant-level and which ones they take on a network-level. They consider manufacturing execution systems (MESs) usually on the single plant-level. However, a recent study with manufacturing companies from the German-speaking area showed that companies with successful activities in the digitalization of manufacturing see MESs as a topic on network-level. Further research needs to deepen the understanding of the antecedents determining the applicability of MES implementations on a network-level of a certain IMN.

Keywords: international manufacturing networks, manufacturing execution systems, digitalization

Introduction

Digitalization of manufacturing is important for manufacturing companies to increase their performance (Dalenogare *et al.*, 2018) and flexibility in manufacturing (Kagermann *et al.*, 2013). Various technologies deepen the integration of the physical and digital or rather cyber dimension of manufacturing and create a smart factory(Chen *et al.*, 2018). Among these technologies are, for example, the Internet of Things (IoT), big data and cloud-computing.

Manufacturing execution systems (MESs) also support digitalization of manufacturing (Cottyn *et al.*, 2011). Moreover, they contribute "to the manufacturing related to improvement of cost, quality, flexibility, conformity and reliability" (das Neves *et al.*, 2015, p. 449).An MES is an integrated and modular system that processes real-time information along an entire manufacturing process (Gerberich, 2011; Kletti, 2015). It "fills the gap between the ERP system and the automated systems on the plant floor" (das Neves *et al.*, 2015, p. 453). According to the technical standard VDI 5600 (VDI e.V.,

2016) as well as further standards like ISA-95 (American National Standards Institute, 2010) or IEC 62264-3 (American National Standards Institute, 2016), a MES may perform the following tasks:

- Order management
- Detailed scheduling and process control
- Equipment management
- Materials Management
- Human resources management
- Data acquisition
- Performance analysis
- Quality management
- Information Management
- Energy Management

International manufacturing networks (IMNs) refer to intra-firm networks of two or more globally dispersed and coordinated factories under the full financial control of one company (Ferdows, 1997; Shi and Gregory, 1998; Colotla, Shi and Gregory, 2003; Rudberg and Olhager, 2003). Factories or plants are basic building blocks of IMNs, hence there are two levels of analysis: first, the plant-level perspective and second, the network-level perspective. To stay competitive, IMNs have to improve their network configuration and coordination continually (Colotla, 2003; Friedli, Mundt and Thomas, 2014; Cheng, Farooq and Johansen, 2015). For them, digitalization of manufacturing adds an additional lever for more efficiency to their manufacturing plants and hence to the entire IMN (Kang *et al.*, 2016; Thoben, Wiesner and Wuest, 2017). As already mentioned, MES are one tool that supports these efforts (Kletti, 2007).

International standards ((American National Standards Institute, 2010, 2016; VDI e.V., 2016) and literature (Scholten, 2009; Helo et al., 2014) relate MES to the steering of manufacturing on plant-level. Figure 1 displays this approach. Scholten (2009, p. 99), for example, considers it “more logical to install the system locally”. There is vast literature about operative and strategic implementation of MESs with a specific focus on the single plant level (Saenz de Ugarte, Artiba and Pellerin, 2009; Scholten, 2009). However, Almada-Lobo (2015, p. 18) sees MES as pivotal “in the performance, quality and agility needed for the challenges created by globalized manufacturing business”. While Helo et al. (2014, p. 646) identify restrictions and note that Current MES solutions can operate the manufacturing process, but not for distributed manufacturing”.

Only little literature extends MES to the network-level of IMNs. Benninghaus (Benninghaus, 2019, p. 207) finds that all six case companies he examined “use MES to steer and coordinate manufacturing network operations”. Scholten (2009, p. 99) recognizes that “it can be advantageous to use ‘copies’ of the same MES at the various plants, instead of developing a separate system for each plant”. However, one could imagine an even wide range of different kind of MES implementations in an IMN spanning from completely different MES (even by different providers) at each plant to one central and harmonized system connecting all plants. The last one would potentially allow steering an IMN like one virtual plant. Gölzer et al. (2015, p. 192) state it in the following way: ” In order to assure effective utilization of resources, companies have to use scale and scope effects which require mobility of product and resources volumes in the network”.

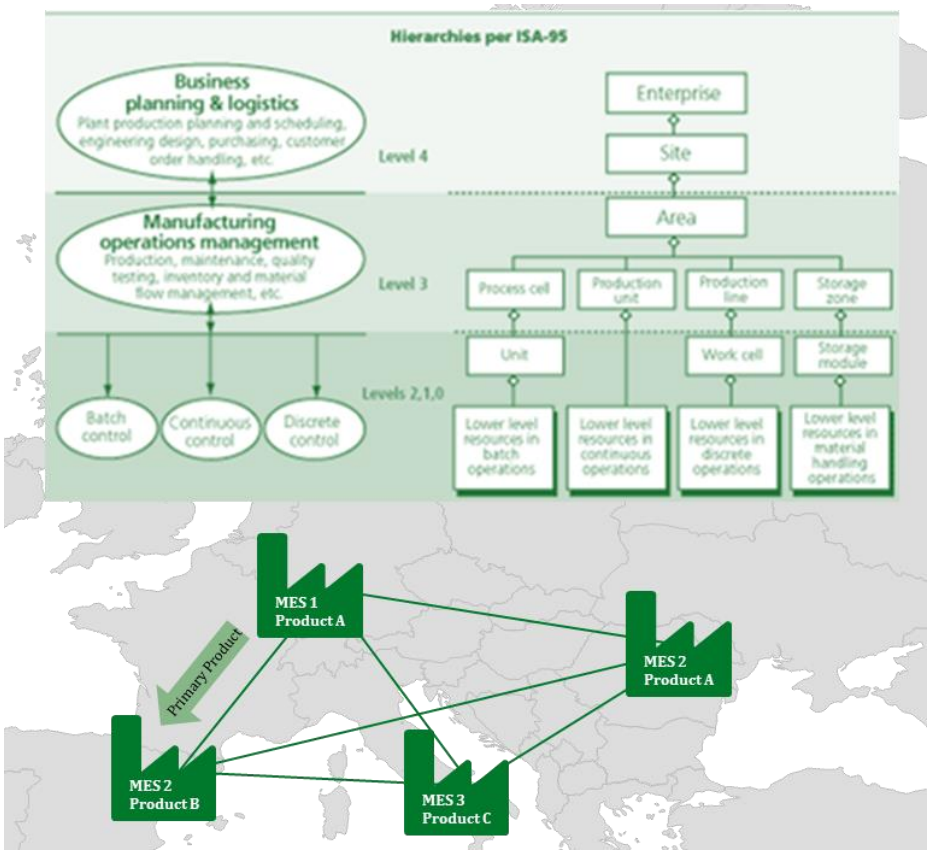

Figure 1 – MES as manufacturing operations management on plant-level in an IMN

Since literature about the kinds of MES implications in an IMN is scarce, we aim to answer the following research questions:

1. What importance do MESs have for the management of IMNs on plant and network level?
2. How can the implementation structure of MESs look like in IMNs?

Method

Our research adopts a mixed method approach in accordance with Johnson, Onwuegbuzie and Turner (2007).

A large-scale quantitative survey with more than 120 participants from manufacturing companies headquartered in the German-speaking area answers the first research question. It was conducted online between 26 February 2018 and 14 May 2018. We designed the questionnaire in collaboration with industry experts and other senior academics (Dillman, Smyth and Christian, 2014). We proposed the research scope of digitalization in IMNs to a consortium of representatives of ten manufacturing companies from the German-speaking area. In a workshop, both, the academics and industry exports discussed potential questions for the questionnaire. We later clustered and structured them for the final questionnaire. Depending on each specific question, the participants had to answer from a plant- or network perspective, which was clearly marked. The sample of the survey consists of companies from various industries for more generalizability (Jaworski and Kohli, 1993). In collaboration with industry experts and other senior academics we identified five successful practice companies from the sample. The term

successful practice company relates to the five best performing companies with regard to digitalization of manufacturing within the survey sample. We based the criteria for success on variety and maturity of implemented digital technologies.

Qualitative case study research based on interviews and workshops with company experts answers the second research question (Yin, 2009). One in depth cases shows the possibilities of implementing a MES in an IMN. The explorative nature of the research justifies this approach, but limits generalizability (Yin, 2009). We choose the cases from the survey sample because the company showed a highly successful use of digital technologies in manufacturing. It is one of the successful practice companies. Moreover, the chosen case company uses MES in its IMN and has already used two different kinds of implementations on the network-level. Thus, it is an ideal example to compare these kinds of implementation with their advantages and disadvantages. We gathered the case data during an interview with executives from the company and a workshop with managers and experts from the company. Both, senior academics as well as industry experts from the consortium took part in the workshop and evaluated the strategy and implementation of digital technologies within the case company.

Results

The five manufacturing companies within the survey sample, which perform best regarding the digitalization of manufacturing, have a higher implementation level of MES in their plants than other companies (Figure 2). All of them use a MES whereas only 25% of the other companies use fully implemented MESs and further 16% have first MES implementations. MES is the only tool or technology used by all five successful practice companies fully implemented among others such as robotics or augmented reality. While 80% of the successful practice companies use MES in a global implementation across their plants, hence, on a network-level, only 19% of the other companies in the sample use it for cross-site data processing. In contrast to the other companies, the successful practices use MES primary for data acquisition, equipment management and performance analysis as well as information and order management (Figure 3). Moreover, they see information management tasks performed by MESs as key for their digitalization activities (Figure 3).

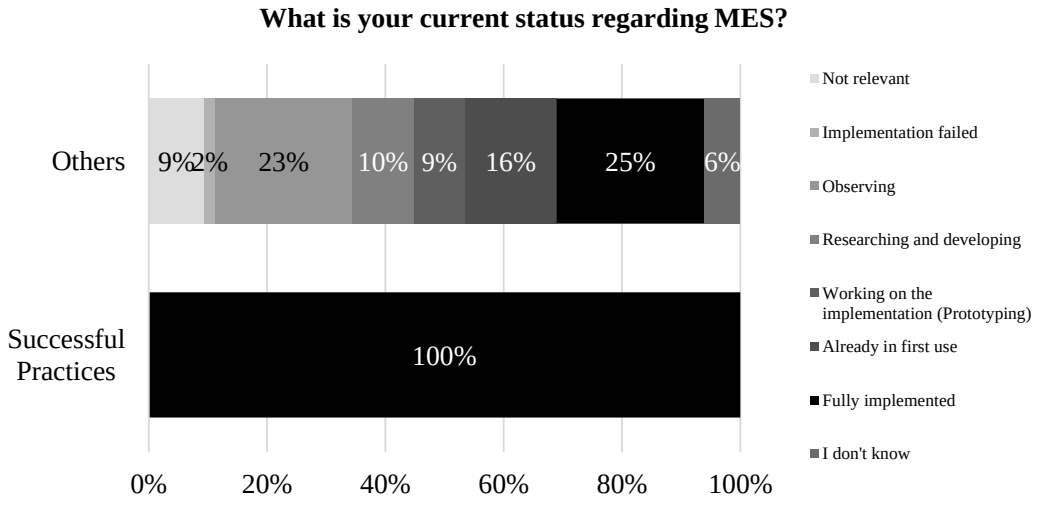

Figure 2 – Current status of survey participants regarding MES implementation

Within the five successful practice companies, we identified two types of strategic MES implementations on a network level. One completely central and one decentral approach with a global template across the plants of the IMNs. Both have in common that they connect all plants. However, especially data governance within the network differs. The selected case company has used both approaches one after another.

Table 1 – Case company overview

Industry	Manufacture of electrical equipment
Revenue	> 2 billion Euro (2018)
Employees	> 15.000
Plants	> 20 worldwide
Headquarter	Germany

The case company is a leading manufacturer of electrical motors and products based on them. Table 1 shows a short overview. It has more than 15,000 employees that generated a revenue of more than two billion Euro in 2018. The company has more than 20 manufacturing plants worldwide with internal values streams going across the plants. The company headquarter is in Germany. It started the digitalization of manufacturing in 2008 with a special focus on the connection of machines. Men, technology and organization form integral parts of its digitalization of manufacturing strategy.

The company harmonized single solutions with regard to digital manufacturing in its plants to one global digital twin. This digital twin guarantees a seamless data flow in manufacturing from customer order to delivery. At first, the company used a central MES with a central database for all plants. However, this approach had some shortcomings. Real-time data transfer from the Chinese plant was not possible due to the restrictions imposed by the Great Firewall. Hence, the central MES was not working correctly. Moreover, server updates had to be coordinated between all plants. As a result, the case company switched to a MES with a global template.

Today, all plants of the case company use the same MES template. It determines, for example, the data structure of data gathered in manufacturing and standard processes for manufacturing. However, each plant runs its own server for the MES. It is even possible to run the template from a virtual server at a cloud-computing provider. The company allows no local changes to the MES. The central IT-department deploys all updates via the global template to one plant after another.

When a physical product is transferred from one plant of the network to another, the most important data of this product in the digital twin is also transferred to the next plant. This allows, for example, quality gates in one plant based on data from another. Hence, the MES task quality management is performed on a network-level. Thereby the case company autonomously blocks non-quality parts from further process steps on machines. This is an additional measure since the company noticed that some parts, which have been tested as scrap, still find their way to the next plant in the value stream. Without the autonomous blocking of the machine, a scrap part would undergo further process steps and might end up at a customer. Hence, the case company saves money by removing the non-quality part from the production line and guaranteeing that it does not reach a customer.

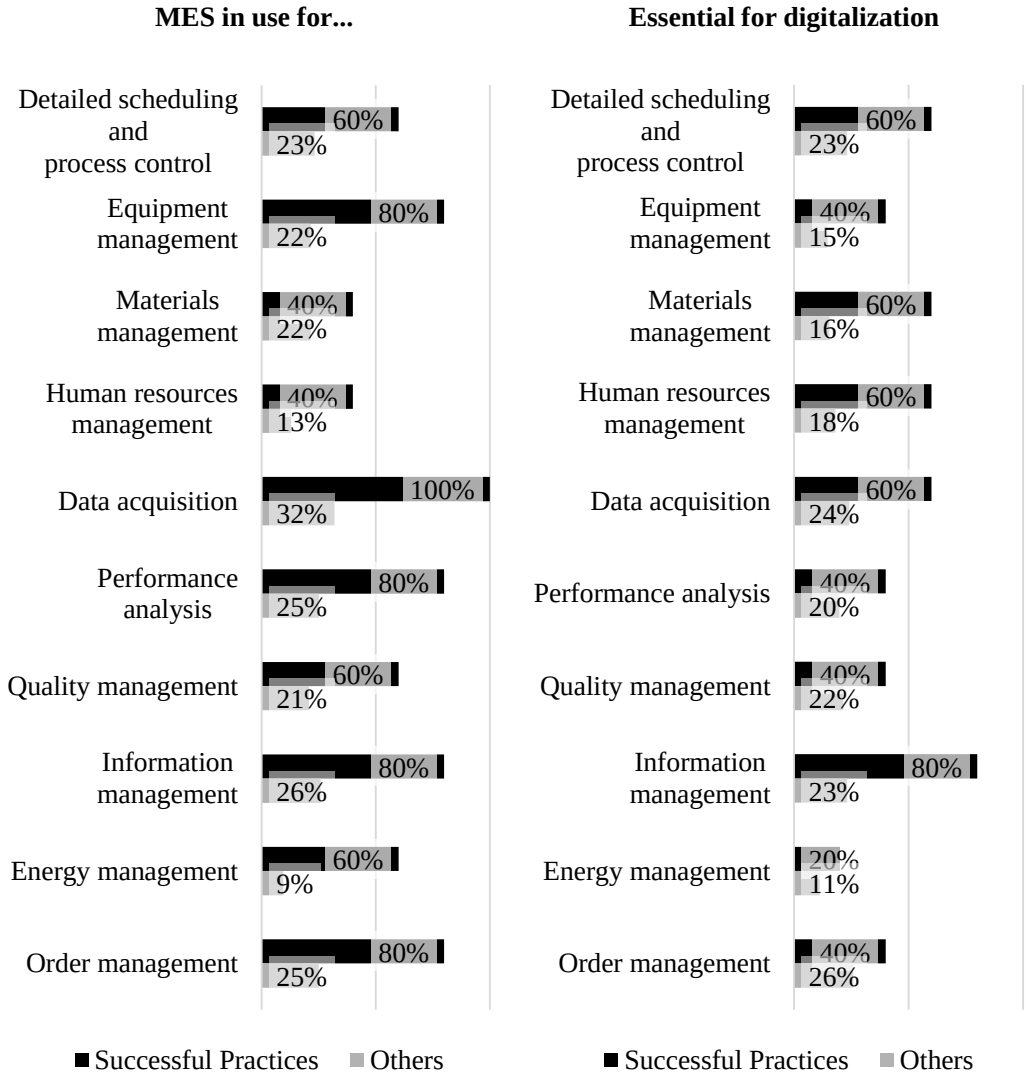

Figure 3 –Tasks performed by MES according to VDI 5600 (VDI e.V., 2016) in use at survey participants and tasks considered essential for digitalization activities by survey participants

Discussion

Our research gives insights in the importance of MESs for IMNs. They fulfil a wide range of tasks on a plant level. Additionally, the survey and case study showed that successful companies with regard to the digitalization of manufacturing also use MES on a network-level. This is in contrast to most of the findings in literature.

The case company applied two kind of possible implementations of MESs in an IMN, centrally in the network and decentral but harmonized via a global template. Both offer advantages related to a global, virtual plant. Especially the central MES handles the IMN like one local plant, allowing, for example, short-term capacity balancing. However, it also has some shortcomings for the application of the case company. That is why the company switched after a careful evaluation to the global template approach, which is also described in a similar way by Scholten (2009, chap. 6). Thereby it can overcome the disadvantages of the central approach but keep the advantages like cross-plant quality gates.

This raises the question whether there are certain antecedents determining the applicability of MES implementations on the network level of a certain IMN. The approach of the case company is particularly valuable for this company because of its cross-plant value streams with the need for cross-plant quality management. Other companies producing the same product in multiple plants might be in need for a cross-plant detailed scheduling. This is another MES task. It allows short-term capacity balancing not only between machines in a single plant but also across plants in an IMN.

Hence, further research is needed to understand which kinds of MES configuration makes sense for which kind of IMN.

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Critical interfaces for managing international manufacturing networks – A literature review

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Abstract

Coordination of International Manufacturing Networks (IMN) is connected to challenges, especially as there is a lack of comprehensive overview over interfaces on all levels of the network. The purpose of this paper is therefore to outline the critical interfaces within an IMN and explore how such interfaces can contribute to a more efficient management of the network. By establishing a definition of interfaces, a systematic literature review have been conducted, the findings are categorised into interplant-, external-, and intraplant interfaces. Concluding with a call for further research and the importance of core plants within interplant interfaces is highlighted.

Keywords: Global Production Networks, Core Plant, Coordination

Introduction

Managing International Manufacturing Networks (IMN) is associated with two main issues, configuration and coordination (Colotla et al., 2003; Shi and Gregory, 1998). Decisions related to the structure of the network falls under the configuration aspect, whereas coordination is related to infrastructural links between individual plants (Colotla et al., 2003) and affects the competitiveness of the entire network (Shi and Gregory, 1998; Srai and Gregory, 2008). The geographic dispersion of plants entail a need for interdependent coordination thus the view of the network must be expended beyond the individual plant (Cheng et al., 2016; Rudberg and Olhager, 2003; Shi and Gregory, 1998). In fact, production decisions regarding plants and networks are often made independently also when they in fact are interdependent (Colotla et al., 2003). Challenges of

coordinating plants within IMN has been outlined in previous research (e.g. Rudberg and West, 2008) and emphasis has been on the complexity of network (Shi and Gregory, 1998). Thus, changes in one plant can have minor or major consequences for the entire network, redistribution of responsibilities might be more or less necessary as both structure of the network and roles of the plants can be affected. When changes occur, the interfaces within the network require an analysis (Feldmann et al., 2013). Yet, analysing the interfaces when the need arises may delay the response to change, especially as there is a gap in research concerning a holistic view of existing interfaces as well as identification of which interfaces are critical for managing the IMN. The lack of research can be derived from the different concepts used such as coordination (e.g. Rudberg and Olhager, 2003) and integration (e.g. Cheng et al., 2016), however, these definitions cannot provide a comprehensive overlook over interfaces that surpasses the complexity of an IMN. Studies have instead been performed regarding bounded interfaces. Consequently, a complete overlook over the existing interfaces within a network have not been defined in previous research. Therefore, the purpose of this paper is to outline the critical interfaces within an IMN and explore how such interfaces can contribute to a more efficient management of the network.

Frame of reference and key concepts for the literature review

The context of IMN is provided below as well as a definition of interfaces which is derived from key concepts.

International manufacturing network

Synergising dispersed plants into networks can gain competitive advantage (Ferdows, 1997a), thus harnessing the advantages of globalisation, such as greater market share and profit (Ferdows, 1997b). IMN is distinguished by a specialisation in knowledge transfer where the knowledge is derived in a central point of the network and implemented locally (Barlett and Ghoshal, 1998). The central point is also called a lead plant (Ferdows, 1997b) or a mother plant (Vereecke and Van Dierdonck, 2002) here it is referred to as a core plant although other terms are used interchangeably. The core plant's knowledge and capabilities are exploited and diffused throughout the network (Barlett and Ghoshal, 1998; Enright and Subramanian, 2007; Ferdows, 1997b) and implementation of transferred knowledge occurs with a high degree of autonomy concerning the details (Barlett and Ghoshal, 1998).

From a network perspective, core plant is the innovator, or the knowledge creator, as it participates in the development of products, processes and technologies (Enright and Subramanian, 2007), thus being a pinnacle of knowledge (Ferdows, 1997b). Furthermore, the responsibility of production process development is connected to the core plant (Enright and Subramanian, 2007) as well as driving continuous improvements (Simon and Näher, 2008). Besides from the core plant, other plants in the network have different roles to play which in turn determines which capabilities are necessary for actualise the particular role (Demeter et al. 2017). The ultimate goal for a plant is to achieve a higher role (Ferdows, 1997b) which is possible when capabilities are utilised in an appropriate manner, for instance by exploiting current best practise and applying it in novel areas (Demeter et al., 2017).

Coordination insufficiencies such as functional separation, cultural differences, and connection of strategy and operations can be avoided by having an integrated view of the relationships with the partners in a network which involves both the company and the network itself as well as external partners (Jaehne et al., 2009). Hence, the interfaces need

to be outlined and provide an understanding of the parties involved in order to enhance management on all levels of the IMN.

Definition of interfaces

The key concepts which are used for establishing a definition for interfaces are integration and coordination. However, in an IMN context few definitions apply and are not defined in a uniform manner. Firstly, the term integration is examined in the next paragraph regarding its attributes and the IMN levels involved. Secondly, coordination is analysed in the same manner. Table 1 presents key attributes of integration and coordination as well as the IMN level they apply in the examined literature.

The concept of integration is classified as two types according to Cheng and Farooq (2018) and Cheng et al. (2016), which is external and internal where both involve collaboration and synchronisation of activities, whether that is between a plant and their external partners or within its own organisations. Similarly, O'Leary-Kelly and Flores (2002) define integration working together in a cooperative manner, which applies also to parties that are separated. Moreover, integration is used in a network level, Golini et al. (2016) define both interaction and collaboration as attributes in integration, the difference being that in the network perspective the goal is to achieve results together by utilising more than one plant. Hence, integration definitions occur at different levels of the network which is at occasions unclear. For instance, Vandevelde et al. (2002) defines integration as collaboration and exchange of information, but Kahn (1996) emphasises collaboration due to insufficiency of solely information exchange. Lawrence and Lorsch (1967) describes integration simply as the process to achieve unity of subsystems.

Table 1 - Key attributes of integration and coordination and IMN level they appear in the literature

Examined Terms	***Key attributes***	***Intraplant level***	***Interplant level***	***External***
Integration	Collaboration and interaction (Golini et al., 2016)	X	X	
	Work together in a cooperative manner (O'Leary-Kelly and Flores, 2002)	X	X	X
	Collaboration and exchange of information (Vandevelde et al., 2002)			
	Unity of subsystems (Lawrence and Lorsch, 1967)			
	Collaboration and synchronisation of activities (Cheng et al., 2016; Cheng and Farooq, 2018)	X		X
Coordination	Link or integration with other plants (Cheng et al., 2016; Cheng and Farooq, 2018)		X	
	Embeddedness (Holm et al. 2005), (Kawai & Strange, 2014)		X	X
	Integration or linking production and distribution (Fleury et al. 2015)	X		
	Synchronisation or harmonisation in complex networks (Rudberg and Olhager, 2003)		X	
	Autonomy, important mechanism (Gammelgaard et al., 2012)	X		

The concept of coordination is subjected to similar lack of uniformity. From a network perspective, Cheng et al. (2016) and Cheng and Farooq (2018) define interplant coordination as a link or integration with other plants within the network while Holm et al. (2005) and Kawai and Strange (2014) uses the term embeddedness that involves both

external and interplant collaboration, latter being on the network level. In contrast, Fleury et al. (2015) state that coordination includes linking or integrating production and distribution. Furthermore, Gammelgaard et al. (2012) emphasises that autonomy in itself is an important mechanism of coordination which McDonald et al. (2008) state allows plant managers to make strategical and operational decisions. Overall, Rudberg and Olhager (2003) explain that complex networks might settle for synchronisation or harmonisation rather than coordination.

Both coordination and integration are relevant in order to coin a definition for interfaces in the IMN context, however, the existing terminology is contradicting concerning which term should be applied on what level of the IMN and between what entities as exemplified above. Therefore, interfaces in IMN are defined as associated links between internal organisations, plants within the network and with external partners to enable an efficient coordination and integration (Cheng et al., 2016; Cheng and Farooq, 2018; Golini et al., 2016; Vandevelde et al., 2002). Thus, all possible boundaries that exist in an IMN are included. The interface definition can thereby provide uniformity as well as combining the important attributes in both integration and coordination which is not possible if the terms are used standalone in the IMN context.

Research design

Within IMN and the core plant context, the term *interface* is not commonly utilised, thus a definition of the term within the context was performed as seen in the previous section. The approach to examine definitions of existing terminology and introduce a term from another research fields provided a novel viewpoint to examine existing research within IMN. The procedure for conducting a systematic literature review was inspired by Frishammar et al. (2012) making the initial step scanning to identify existing literature within IMN, starting with a read through of frequently cited articles and dissertations in order to establish most relevant keywords. The keywords were derived from the established definition of interface and the adjacent terms that the definition contains (e.g. collaboration, link, integration etc.). Additionally, the field of core plant and the most commonly used terminology, such as master plant and lead plant, was combined along with interface, as well as with IMN. The formal search for literature was conducted in three main databases, Emerald Insight, ABI/INFORM Global and Scopus. Additional articles were found by the snowball technique and by using key literature such as Shi and Gregory (1998) and Cheng et al. (2016).

Selection of articles were limited to peer-reviewed, and written mostly from an operations management point of view, although relevant input from other disciplines have been included. Fields of product development, supply chain management, international business management, and organisational management were also scanned to provide a holistic view of the existing interfaces within an IMN, meaning that a network perspective was utilised along with a plant perspective. Articles were excluded when a correlation with interfaces were lacking or were outside of the scope of this paper, i.e. literature solely from a headquarters perspective. Totally, 27 papers were selected for analysis where firstly the abstracts and conclusions were scanned and secondly the papers were read and analysed in full. The analysis was conducted systematically by construction of a table with categories for interfaces, this was performed in two steps. Firstly, the categories were; bibliographical information, terminology correlated with interfaces, focus (whether *what, where* or *how* was answered), main findings, perspective (plant, network, external or combined) and lastly consequences for the IMN. From this categorisation new categories emerged concerning the existing interfaces, that is; intraplant, interplant and external. This categorisation intended to separate interfaces depending on the levels of

IMN where they are occurring. Accordingly a rearrangement was necessary where the different types of interfaces were on one axis and the head categories on the other axis which could be derived either to *what* the interfaces contribute with to the network and *how* they are arranged or actualised. Both what and how categories had individual sub-categories.

Results: Critical interfaces for managing international manufacturing networks

The literature analysis found three categories of critical interfaces in IMN, namely, intraplant-, interplant-, and external interfaces. The following section explain each category of interfaces in detail.

Intraplant interfaces

Intraplant interfaces are expressed through the structure of intra-organisational practices, procedures and behaviours which are supposed to be synchronised and collaborative processes across functions within a plant (Schoenherr and Swink, 2012). The effects of the interfaces are facilitation of information sharing across functions which can enhance strategic cooperation (Wong et al., 2011) as it breaks down functional barriers (Cheng et al., 2016). Examples of intraplant interfaces are between function such as purchasing and sales as well as both functions interfaces with production concerning joint decisions making and information sharing (Cheng and Farooq, 2018).

Intraplant interfaces are an enabler for external interfaces, meaning, for enhancing the latter as well as the overall operational performance, the plant could firstly improve the intraplant interfaces. However, the precondition of cooperation with external partners must also be fulfilled as close cooperation with external partners is an enabler (Cheng et al., 2016) that provides a learning opportunity (Lane et al., 2006). Similarly, well developed intraplant interfaces where the functions are able to learn from other plants in the network can enable interplant interfaces (Cheng et al., 2016). This relation between intra- and interplant interfaces also affect allocation of production and distribution among plant (Rudberg and Olhager, 2003). This is supported by Vereecke et al. (2006) who connects higher capabilities in a plant with frequent interaction with the rest of the network, making the plant a true player. Thus, Olhager et al. (2015) point out that intraplant interfaces between internal functions are viewed as important. However, all abovementioned is not feasible if the plant lacks well-established internal systems and capabilities necessary to share information on plant level, meaning there will be a lag when information becomes available within the interplant interfaces (Cheng et al., 2016).

Interplant interfaces

Interfaces between plants within IMN, and in which manner they are set up, are here defined as interplant interfaces. These interfaces are considered both from plant and network level and how a plant is supposed to integrate (Cheng et al., 2015a) and collaborate with the rest of the IMN in order to reach the strategic objective of the company (Cheng et al., 2016). Coordination of production capacity can for instance improve delivery performance (Cheng et al., 2016; Flaherty, 1996). Furthermore, exchanging production experience, knowledge and innovation, can reduce product cost and improve product quality as plants in the network can improve process and product design by gaining knowledge, resources and capabilities from other plants instead of developing them separately at individual plants (Cheng et al., 2016). Moreover, by transferring production processes from the core plant to other plants within the network, performance consistency can be reached in the network thus creating synergy (Lu et al., 2010). If the plants within the network can develop and achieve high performance without

the contribution of the core plant, a network reconfiguration can be triggered (Lang et al., 2014). When reconfiguration and change occur and new responsibilities are added to one plant, new interfaces are created in the network while also affecting the plant that previously hosted the activities and therefore may need to reduce its competence accordingly. Thus, changing roles has an effect on the network structure as well as on the roles of other plants, making the change a concern for the entire network which must adapt to new circumstances (Feldmann et al., 2013).

It is expected that the core plant coordinates activities across the interplant interfaces (Maritan et al., 2004; Tran et al., 2010), as well as interfaces to external partners (Tran et al., 2010) which can restricts the freedom the core plant has over making independent decisions for its own operations (Cheng and Farooq, 2018; Maritan et al., 2004). The core plant has for instance the same amount of autonomy over planning decisions as other plants in the network (Maritan et al., 2004). The lack of autonomy can be derived from overload of received information from the mentioned interfaces (Tran et al., 2010).

A manner in which the interplant interfaces can be organised are presented by Rudberg and West (2008) where network-based competence groups are assembled from specialists in different plants. This taskforce ensures that the knowledge is kept global instead of local by establishing a structure. The responsibility of updating the core plant on the happenings on plant level as well as transferring the information throughout the network is allocated to this groups, in other words, a platform for communication is established which eliminates the need for central functions. This sort of interface can be linked to Martinez and Jarillo's (1989) informal coordination, which involves communication within plants, training and development programs and transfer of managers. According to Ferdows (1997b), interplant interfaces are expressed as the core plant is a partner to headquarters regarding developing strategic capabilities in production. But also by continuously communicating with centres of knowledge, customers, machinery suppliers and research laboratories. Moreover, Cheng et al. (2015b) propose that a interplant interface exist between production and R&D.

Belonging to an IMN, thus having interplant interfaces where knowledge can be transferred between the individual plants, can have a positive effect on the external interfaces, in this case with suppliers. Collaborative relationships within external interfaces can thereby be developed that leads to better overall performance (Golini et al., 2016). However, external interfaces, specifically concerning customers, can have a negative effect on interplant interfaces (Cheng et al., 2016) regarding product and production transfer between plants as local adaptations must occur in order to reach an appropriate fit with the local market (Cheng et al., 2015b).

External interfaces

The definition of external interfaces is the extent of a plant’s collaboration, coordination and information sharing with its external partners. In fact, according to Zhao et al. (2011) the outcome of these interfaces are collaborative and synchronized processes and systems which can be achieved through structure of a plants inter-organisational strategies, practices, procedures and behaviours with its external partners. However, Cheng et al. (2016) point out that external interfaces are seldom investigated beyond the plant level collaboration across internal functions with suppliers and customers. Feldmann and Olhager (2013) remark that increased or added responsibilities regarding supply chain activities can besides from strengthen current activities at the plant, provide a higher degree of control over production. On the other hand, according to Camuffo et al. (2007) close collaboration with suppliers is a necessity in production relocation within the network. Furthermore, Feldmann et al. (2013) state that increasing capabilities in one site

where supply chain responsibility is assigned must also expand its supply network to match its added operations, leading to a lower need for frequent inter-continental coordination. However, some interface still remain unaffected as product and process development is confined to the core plant.

External interfaces are actualised through coordination and information sharing with key suppliers to enable effective planning and forecasting, product and process design, and transaction management. On plant level, the benefits are of receiving an insight into the suppliers processes, capabilities and also constraints (Ragatz et al., 2002). By extending the interfaces to key customers through close collaboration and information sharing, the outcome can be of insight into market expectations and opportunities (Wong et al., 2011) as well as understanding of customer preferences and development of relationships (Swink et al., 2007) and improving operational performance also for a plant belonging to a IMN. The components for external interfaces are extending to joint decision making and system coupling with key suppliers and customers (Cheng et al., 2016) and synchronised processes (Chen and Paulraj, 2004; Zhao et al., 2011). For a plant within a network, the synchronisation of operations with suppliers and sub-suppliers can enhance the material flow in the sense of speed and evenness, thereby providing cost efficiency (Shah and Ward, 2007). From a supplier point of view the gains are of the ability to anticipate and understand the plant's needs which in turn benefits the plant with on time production as well as resolving conflicting objectives (Cheng et al., 2016).

Table 2 - Interface characteristics and their connection to efficient management of IMN

	Characteristics	***Connection to efficient management of IMN***
Intraplant	Synchronised and collaborative processes across functions that facilitate information sharing and learning	Will enhances strategic cooperation within the network and allocation of production and distribution
	Well-established internal systems and capabilities to share information on plant level	Clear information will be available between plants
Interplant	Gaining more responsibility in one plant triggers reconfiguration	New interfaces can be created or rearranged, changing the structure and affecting the entire network
	Integration and collaboration with the the plants in the network are coordinated by the core plant	Reach strategic objectives of the company and gain knowledge and capabilities thereby create synergy across the network
	External interfaces affect interplant interfaces	A good collaboration with key suppliers will be established
External	Seldom investigated beyond the plant level	Supports the holistic view of interfaces
	Increased or added responsibilities can strengthen other activities on plant level	Strengthen the position or role of the plant

In summary, how the interfaces can affect efficient management of the IMN is presented in Table 2.

Discussion

This paper contributes with outlining the critical interfaces within an IMN and explored how such interfaces contribute to a more efficient management of the network by using a systematic literature review approach. The critical interfaces are identified in three

categories; intraplant, interplant and external interfaces. However, intraplant interfaces are found to be correlated with other defined interfaces in an IMN, and is therefore classified as an enabler for the rest of the interfaces. Colotla et al. (2003) state that production decisions in the network are interdependent, this paper confirms that interfaces cannot be viewed as standalone entities. Rather, they affect, enable or support each other.

Intraplant interfaces are actualised by the structure of intra-organisational practices, procedures and behaviours (Schoenherr and Swink, 2012). For instance between functions such as purchasing, sales and production as these functions are dependent upon each other's information in order to make joint decisions (Cheng and Farooq, 2018). By taking advantage of the opportunity to learn within external interfaces, the intraplant interfaces can be enhanced which can improve interplant interfaces as well. A precondition is however that well-established internal systems are in place, as well as capabilities necessary to share information on plant level (Cheng et al., 2016).

The external interfaces can be actualised through joint decision making (Cheng et al., 2016) and synchronised processes with both key suppliers and customer (Chen and Paulraj, 2004; Zhao et al., 2011). When adding on supply chain responsibilities to a plant, new interfaces can arise in the network which can lower the need of coordination. However, other interfaces, which are typically the core plant responsibility, are not affected. An example of the unaffected interfaces are with product and production development. At the same time the plant which gained the supply chain responsibility has increased control over production (Feldmann et al., 2013). Thus, a network reconfiguration can be triggered (Lang et al., 2014). Hence, the external interfaces can be a trigger which affects other interfaces, creates new ones, and can lead to reconfiguration of the network.

Another major finding is that interplant interfaces are correlated with the core plant responsibilities. Coordination of activities are performed by the core plant as Tran et al. (2010) and Maritan et al. (2004) point out, thus the activities are the manner in which the interplant interfaces are actualised. Cheng et al. (2016) also adds that exchanging of production experience, knowledge and innovation can lead to a more efficient network as plants can benefits from each other and save resources needed to develop these individually, additionally, synergy of the network can be created. A relevant study by Rudberg and West (2008) present a solution for how intraplant interfaces are structured in practice consisting of network based competence groups that updates the core plant and transfers information in the network, thereby keeps the knowledge global and within the network rather than local within the intraplant interfaces. Martinez and Jarillo (1989) write about informal coordination which links to the aforementioned empirical study and Ferdows (1997b) mentions development of strategic capabilities and communication with relevant entities where interfaces are actualised, also bringing the core plant forward within interplant interfaces. The interfaces are between the core plant and headquarters and machinery suppliers among others. A core plant is therefore here classified as both the enabler of the interfaces and a facilitator for coordination within them.

Conclusion and future work

Several finings have been presented in this paper, the foremost important being that interfaces on all levels of the IMN affect, enable and facilitate one another. Additionally, the core plant have been identified as an enabler and a facilitator for interplant interfaces which has great significance regarding how the IMN could be coordinated. However, the latter finding needs more research, preferably by using the categorisation of interfaces coined here. One of the analysis categories for this paper was how the interfaces are actually realised. Generally, there is a lack of research focusing on categorisation or

identification of present interfaces within the IMN context, or more importantly, an explanation which pinpoints how the interfaces are constructed and organised is seldom presented. Hence, deep-probing research is necessary to fully understand how interfaces are actualised and outline them in greater detail, the necessity of empirical studies is thus recognised. This paper presents a categorisation and a starting point for future research where a continuation could be to establish how interfaces on different levels of the IMN affect the strategical objectives of the company. Moreover, an examination of how the interfaces can be streamlined in order to achieve such objectives by utilising the core plant as a facilitator given the plants role would be an important contribution of future work.

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Manufacturing subnetworks in multinational companies: definition, categorization and management process

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Abstract

A wide literature about International Manufacturing Networks (IMNs) has been developed in the last decades, driven by the globalization of operations. Attention has typically been directed on plant and network level, while little emphasis was given to subgroups of plants within the same company. This paper aims at providing a definition of the "subnetwork" concept, as introduced by Ferdows et al. (2016). The research highlights the main characteristics of subnetworks, and the reasons why a subnetwork-based analysis can be useful for providing additional insights over three core topics of IMNs: the role of the plants, capabilities, and manufacturing strategy.

Keywords: International Manufacturing Networks, Manufacturing Subnetworks Definition

1. Introduction

The globalization of companies has forced managers to develop new organizational approaches due the internationalization of operations and the expansion of production, purchasing and distribution from a single nation to a global scale (Meijboom and Voordijk, 2003). In an attempt to analyze the complexity of the phenomena behind the globalization of companies, over the years a rich literature has developed with specific focus to the International Manufacturing Networks (IMNs), where attention has gradually shifted from the individual plant within the supply chain, to a network of plants mutually connected and mutually dependent (Rudberg and Olhager, 2003a).

IMNs can be studied from different perspectives depending on the level of specificity of the analysis: by considering the individual plants, groups of plants, or the entire network. Despite the borderline between the analysis of a single plant and analysis of the entire network has gradually narrowed (Cheng et al., 2015), the literature has mainly

considered only these two levels of detail. In this work we will focus on the concept of "subnetwork", as first elaborated by Ferdows et al. (2016). They suggested to divide a complex organization into smaller and more congruent parts in their production mission; they explained the subnetwork as the set of multiple plants "on the basis of complexity and proprietary information in the products they produce and production processes they use to produce them". Other authors (Golini et al., 2017) have supported the research about subnetworks, providing some further evidence.

The understanding of subnetworks in international companies is however far from being completed. In particular, a theoretical conceptualization of the underlying elements of subnetworks still need to be developed; in addition, companies and researchers lack the necessary awareness of the concept and how it can be useful in understanding operations management. Thus, the research questions we want to address in this paper are basically two.

First: *What is a subnetwork?* A subnetwork is still not a clearly defined object, and it still lacks well-defined boundaries. To our knowledge, there is an extremely weak empirical evidence that can allow us to give a univocal definition. The study of subnetworks in IMNs is still characterized by a lack of consensus on a precise definition and this issue needs to be addressed. This risks to hinder clearness: the use of the concept of subnetworks risks to be used in an inappropriate way: the term “subnetwork” is sometimes used to express diverse concepts such as network and business unit, or it is often used to indicate other criteria for grouping activities in manufacturing companies. In this paper, thus, we aim at providing a clear definition of this concept and a clear understating of its difference compared to other commonly used elements.

Second: *how can the concept of subnetwork help in the analysis and comprehension of manufacturing networks?* Once that the characteristics of subnetworks have been recognized and a coherent definition has been provided, the paper wants to show why and in which cases an approach based on manufacturing subnetworks can provide beneficial insights for the company’s management. In other words, it is not clear what is the practical relevance of subnetwork classification criteria and why could companies benefit from using subnetworks.

2. Literature background

Subnetwork approach can be included in the wider theme of International Manufacturing Networks (IMN).

In general, IMN literature can be divided into two main streams: i) the role of a plant within a defined network and ii) the network structure (Cheng et al., 2015). Shi et al. (1997) and Shi and Gregory (1998) were among the first to try to understand the structural characteristics of international manufacturing plants; they also explained how every node (every plant) in an IMN is connected and affects the behavior of other plants and cannot be managed in isolation. A similar and more recent result comes from (Cheng et al., 2011a). Besides, a special attention was dedicated to IMN categorization: there have been various attempts to model and categorize international or global companies, taking the entire network as the unit of analysis. Depending on the drivers considered, different models were developed to explain and manage the structure of IMNs (Bartlett and Ghosal, 1998, Shi and Gregory, 1998; Hayes et al., 2005; Rudberg and Olhager, 2003b). Within the literature about the network structure, a further distinction can be made between the analysis of network configuration and the analysis of network coordination. These two strands concentrate much of the global network literature (Feldmann et al., 2009). The first concerns the "where", i.e. the location of plants and activities typically involved in the value chain, i.e. it concerns itself with the structure (nodes) of the network (Meijboom

and Vos, 1997). The second deals with the infrastructure, i.e. the relational aspects and organizational processes between different plants (connections between nodes) (Colotla et al., 2003).

Close to our research, the input about subnetworks has its origins in a series of works by Ferdows (1997, 2008), through which the author, in line with what was anticipated by Skinner (1974), explains the need to simplify an international production network. Ferdows (2009) proposed a framework to guide the evolution of production networks and to guide strategic choices. In particular, he clarifies two opposite models of network management: the first model explains how to create a "footloose" network, i.e. a network that frequently moves manufacturing activities to find the best location in that time context; the other model explains how to develop "rooted" networks, i.e. networks with plants that are stable in space and time and that, despite they do not benefit from low-cost countries advantages, can maintain high-quality standard by means of a higher level of competences and know-how.

A basic point that has recently been outlined (Ferdows et al., 2016) is that the same logic of rooted and footloose network can also be applied to groups of plants within the same network and not necessarily to the entire network. Ferdows proposes that the simplification of the network should be applied to a "group of factories", that somehow work together to complete the business goal. The final objective is to reduce the complexity of the network by breaking it down into simpler and easier to manage "subnetworks". This ambitious goal was supported by the increasing complexity of the today's large organization and the set of internal and external factors that affect IMNs, which makes it complex to verify the performance and mission of the network when considered in its entirety. Ferdows' provides a matrix (with complexity/proprietary information level of products and processes on the two axes) to represent four typical types of subnetworks: besides rooted and footloose subnetworks, two intermediate and less frequent situations are depicted: "Process innovation network", with simple or standardized products but complex or proprietary process, and on the other side, "Low investment networks", characterized by simple or standard process but complex or proprietary products. Ferdows' matrix can be the starting point for a series of interpretation and analysis on IMNs. Moreover, just as the single plants must be "focused", and concentrate only a limited number of manufacturing missions at the same time (Skinner, 1974), the subnetworks must also be focused and built in such a way as to respond correctly to their mission (Ferdows et al., 2016). The skills developed and the know-how brought in must be suitable for the strategy adopted. It will be possible to focus on every single subnetwork, thus simplifying the design and management of the entire network. When the subnetwork has adequate production objectives and the factories that make it up have the necessary skills to achieve them, this subnetwork is called "congruent" (Ferdows et al., 2016). Golini et al., 2017, in line with Ferdows' preliminary work, shifts the focus especially to the product, defining subnetworks as "sets of plants that produce products or finished goods with common characteristics".

3. What is a subnetwork?

The interpretation and the analysis of what is found in the literature suggest that many different themes have strong relations with subnetworks. In this section, the contents of the above literature review are discussed and used together with related themes, in order to derive a definition of "subnetwork". Specifically, five elements are considered:

A) Basic structure: the subnetwork is identifiable through a concrete set of assets. These assets can be assigned to one subnetwork or another both exclusively and simultaneously: if a plant includes more than one production line, with different products

realized and processes used, the same plant can be assigned to more than one subnetwork. It means that in subnetwork identification, a partial overlapping can exist. Vice versa, different plants can be dedicated to different product groups and so they belong to independent subnetworks.

B) Subnetworks classification criteria: what really differentiates subnetworks from other differentiating criteria, is the fact that multiple dimensions have to be considered. Ferdows' matrix considers products on one side and production processes on the other. This means that the process of identification is decoupled in two dimensions. This highlights a completely different approach compared to the ones seen so far. While other criteria consider just one attribute a time, subnetworks must look at activities from a twofold simultaneous perspective: products and manufacturing processes. The double perspective of subnetworks introduces a brand new idea over the categorization of manufacturing networks. Furthermore, for each axis (product and process), more than one dimension is analyzed: in fact, *complexity* and *proprietary information* are required for both product and process. The weighted evaluation of complexity and proprietary information of products will thus provide a unified measure for positioning the subnetwork on the x-axis. Similarly for complexity and proprietary information of processes on the y-axis.

C) Necessary conditions: there are no indications in literature on what is the maximum number of plant or level of activities that can be included in a subnetwork. It would be too simplistic to provide some average measures of the size of subnetworks within IMNs. In the same way, literature does not explicitly show any minimum level of activities for a subnetwork to exist; however, we can say that at least one subnetwork must be identified in a network. It means that the variability among products or among processes is so limited that manufacturing activities cannot be split into multiple groups. In that case, the subnetwork corresponds exactly to the network. In addition, taking the perspective of one single subnetwork. the extreme scenario is the one in which a single plant represents one subnetwork, if all the manufacturing activities of a specific group of products are condensed in it

D) Products types: the granularity with which we look at the product portfolio of a company needs additional clarification. Products within a manufacturing organization can be observed through different levels of analysis, i.e. product types, product categories (or product groups) and products (lowest level). Starting from the more aggregate level, products can be divided into different product types, i.e. macro groups of goods with rather similar characteristics, a similar architecture or business objectives, for example, software and hardware. A product type can be divided into several categories. For instance, software may be sub-divided into Business software and Educational software categories. Each product category can further be disassembled into sub-categories up to the lowest level, represented by the single product. A single product in any company is identified by a unique code. Especially in recent years, product customizations lead to a multiplication of codes, i.e. products. International companies have a business diversification that leads them to produce goods that are very different from each other, in different businesses and even in different industries; medium-sized companies can have tens or hundreds of thousands of codes in their portfolio. Thus, it is also intuitively difficult to identify a subnetwork as a set of plants working for the same product group. The most appropriate attribution is that different subnetworks are identified by specific product families, i.e. *product types*. Products within the same type derive from a common platform, have similar characteristics and use same (or similar) production processes; furthermore, they might share the marketing strategy as well as customer segments or distribution channels. Subnetworks will thus be identified by looking at different product

types. The identification of product-types can give a first glimpse about the characteristics of the products (complexity, technological level, technical features, etc.) and so help in the phase of identification of subnetworks.

E) Plants or activities: previous research about subnetworks have always dealt with the analysis by dividing the network into subsets of plant and not in subsets of manufacturing activities. In other words, the plant has been considered as the minimum unit of analysis, that cannot be in turn disassembled into smaller entities. However, there is a clear indication that a single plant can be part of more than one subnetwork if it answers simultaneously to more manufacturing missions. This means that a single plant can produce more typologies of products and this will be identified by the detachment of the plant in different manufacturing areas or production lines. For this reasons, to avoid wording problem, we suggest that a subnetwork can be identified as a set of plants that are partially or entirely dedicated to that subnetwork, therefore considering both plants and manufacturing activities.

Table 1 summarizes these factors.

Table 1: *Summary of subnetwork characteristics*

Topic	**Characteristics**
A) Basic structure	▪ The subnetwork is a physically defined entity, including plants, assets, manufacturing processes and/or material that are grouped according to the characteristics of products manufactured and productions processes used. ▪ Within a single IMN, subnetwork can be partially or completely overlapped.
B) Subnetworks classification criteria	▪ Subnetworks are divided according to products realized and manufacturing processes used, by considering for each of them the complexity and the proprietary information levels, which must be evaluated jointly.
C) Necessary conditions	▪ At least one subnetwork can be identified in a network. ▪ A subnetwork is represented by one or more plants
D) Product types	▪ A subnetwork works on similar products represented by one (or few) specific product family or product type.
E) Group of plants or activities	▪ A subnetwork is a set of plants entirely or partially dedicated to that subnetwork. Thus, we can refer to it as a set of plants or activities.

Grounded on the literature review, on the above consideration and on the clarification suggested, we propose the following definition of subnetwork:

A subnetwork is the aggregation of a set of plants or activities that work for the same products, product families or product types and that work with similar production processes. A subnetwork is characterized by these three features:

- *Grouping categorization: the grouping criterion is based on the joint evaluation of multiple dimensions, that can be summarized as complexity and proprietary information of product and processes.*
- *Inclusiveness: the body of all the subnetworks in a company represents the entirety of the manufacturing production.*
- *Overlapping: subnetworks can be partial overlapped, in that a single plant can belong to more than one subnetworks.*

4. Why is the concept of subnetwork useful?

Operations managers in today's complex manufacturing environment require tailored and specific tools for the management of their network. It is undoubtedly true that

management models that have been successful in the past have nowadays lost part or all of their effectiveness (Friedli et al. 2014). The categorization through subnetwork introduces considerable elements of novelty. The practical implications can be reached when applying subnetworks over real industrial cases. One of the advantages is that subnetworks provide a brand-new interpretation for international companies management based on multiple dimensions; up to now, sub-groups of networks have always been created by considering one dimension at a time. Thus, the subnetwork approach provides a good insight that partially alters the former criteria for decomposing a network configuration; the topic requires additional effort to further contribute to the literature. However, the main expected advantage is that subnetwork categorization provides not only a model for the division of activities in a network but, above all, a practical framework for the management of the subnetworks created, in order for them to be more efficient in their production missions. The model is particularly effective for the plants' localization, in that it provides additional insights and help in orienting the movements/relocation of factories, especially in the case of Rooted subnetworks.

We analyze in particular the approach and the challenges that the introduction of subnetwork could bring to three different elements that support the company' strategy: the role of the plants, the theme of capabilities and the manufacturing strategy.

4.1. Role of the plants

The first topic that connects to the subnetwork concept is the one about the role of the plants within IMNs. The connection is clear in Ferdows et al. (2016) when discussing the duties that the different plants need to reach, and it is far more evident when introducing the concept of congruency in networks or subnetworks. A wide branch of literature on IMN has been dedicated to the specific role of plants in international companies. Skinner (1974) and Hayes and Schmenner (1978) can be said to be the precursors in theory about plants role. Multiple models and framework about the role of the plants have developed over the years. Ferdows, 1997; Cheng and Farooq, 2018; Cheng and Farooq, 2018; Feldmann et al., 2013; Cheng et al., 2011b). The subnetwork perspective enlarges and reconsiders the frameworks of the classification of value networks. The role of the plant is no more developed according to the whole network mission, but studied for the accomplishment of a narrower entity (subnetwork), with more specific and clear needs. Furthermore, Rooted and footloose subnetworks typically have completely different commitments and thus the role of the plants within them could change accordingly. In this perspective, the subnetwork approach separates the concept of the plant's role from the overall company's production mission

4.2. Network capabilities and plant capabilities

A wide literature about capabilities in the topic of operations has been developed over the years, from both a firm perspective and a network perspective. Starting from pioneer study of Porter, 1980 about the competitive forces approach, literature analyzing the technological, organizational and managerial capabilities inside the firm was developed (Colotla et al., 2003; Voss and C.a., 1995). Other researchers (Teece, 2018; Teece et al., 1997) shed lights on the dynamic capabilities, in regimes of rapid changes. The attention to global network capabilities has raised in the last decades. The transition to a global competition for most of the industries has led researchers to focus their attention over the network capabilities with the aim of building competitive advantage. (Bartmess and Cerny, 1993; Shi et al., 1997). Despite the large amount of literature related to network capabilities and plant capabilities, the two elements have usually been treated like different components. The introduction of subnetworks narrows the distance between plant capabilities and network capabilities. Factory and network level capabilities have shown to mutually affect each other and to simultaneously affect a series of operational

performances and dimensions (Colotla et al., 2003). While for individual plants the competitive advantage can be measured by a series of operational performance indexes, the capabilities from a network perspective need to evaluate a wider range of elements. The introduction of subnetwork can thus shed light on the interdependencies between firm and network capabilities, and it can suggest management models that take into account the relationship between firm and network capabilities.

4.3. Manufacturing strategy

One of the most important tasks of executives in a manufacturing company is to select a mission for the business in order to determine how the company will compete in the long run. Although literature about manufacturing strategy uses slightly different dimensions and terminology, the strategic configurations proposed are actually quite similar (Cagliano et al., 2005), converging on four types of strategic configurations, i.e. market-based, product-based, capability-based, and price-based. More recent researchers (Chatha et al., 2015; Friedli, 2014) classify the six fundamental factors in the manufacturing strategy as: quality, price, reliability, flexibility, service and innovation. The interest about manufacturing strategy has shifted in the last decades from the investigation of the single company, to the analysis among organizations, in particular in emerging economies (Chatha et al., 2015)

However, what emerges from the literature over manufacturing strategy, is that the analysis has generally been directed to the network as a whole, an rarely to subsets of it. The basic assumption that links subnetworks to manufacturing strategy is that the strategic choice of manufacturing strategy can be bounded to specific product types or family of products. In other words, the differentiating factors in a company can vary from a subnetwork to another. For instance, some plants have the manufacturing goals to be highly productive and highly efficient to stress the price factor, others could be more oriented to flexibility or quality drivers. Thus, we can analyze the manufacturing strategy assuming that different subnetworks would need divergent manufacturing factors.

Table 2 provides a synthesis of the above considerations.

Table 2: Usefulness of subnetwork approach

Theme	**Why should the subnetwork perspective be useful?**
Role of the plant	- Subnetwork approach can untie the concept of the plant's role from the overall company's production mission
Capabilities	- Subnetwork approach reduces the distance between plant capabilities and network capabilities, allowing to deepen the interdependencies among them
Manufacturing strategy	- Subnetworks can untie the manufacturing strategy from the overall company vision - Possibility of interpreting differentiating factors through a combined process-product criteria

The above considerations shed light on new research challenges, i.e. unsolved questions, and, on the other hand, on a series of potential new interpretative approaches and solutions to the topics. Table 3 provides a first glimpse of them. Surely, the identified challenges and interpretative approaches need further research.

Table 3: Challenges and potential interpretative approaches

	Challenges	**Interpretative approaches**
Role of the plant	- How does the role of the plant change if analyzed at a network or at a subnetwork level?	- Roles of the plant can be tailored over the subnetwork, according to specific needs

		- A single plant can have multiple roles - A single subnetwork can require a plurality of roles. - The type of subnetwork influences the roles required
Capabilities	- Do subnetwork capabilities exist? - How do they differ from individual sites capabilities and from network capabilities? - Are the network capabilities coherent with the manufacturing mission when introducing the subnetwork analysis?	- Improved alignment between plant capabilities, subnetworks' objective and corporate vision - Better management of the trade-off relationships between plant and network capabilities and among different network capabilities
Manufacturing strategy	- How can we integrate the manufacturing mission of a company with the subnetworks specific objectives? - How and how often do the manufacturing strategies of subnetworks change?	- Co-existence of different manufacturing strategies in the same organization - More frequent changes in subnetworks' manufacturing strategies

5. Conclusions

In recent years, IMNs have seen their marginality stretched to the limits, especially in developed countries. The attention of IMNs has passed from the analysis of single plants to the analysis of the network as a whole. In this context, analysis over the intermediate level is still scarcely developed. As managers strive to improve the performance of their organizations, they also need to use a common language to conform their organization to the most recent standards. In the perspective of heightening the creation of a common dictionary within IMNs, our paper aims at developing a structured and comprehensive definition of the concept of "subnetwork", as firstly hypothesized by Ferdows et al. (2016). The conceptualization of subnetworks has proved to be complex and multifaceted. The concept of dismembering an IMN into aggregates of plants with common characteristics is not new and has been addressed in the literature from different perspectives. Our work is not only a pure attempt of formal linguistic definition, but it proposes key criteria for the existence of subnetworks.

The research contribution is indeed given by the conceptualization, modeling and precise explanation of what we mean by productive subnetwork. Literature about IMN has given a first generic definition of subnetwork, but without adequate formalization and clarity about what a subnetwork really is. The importance of subnetworks is that they reinterpret the typically codified hierarchical understanding of relationships between different "parts" of the company, by fractioning the company into partially overlapped parts.

Our insights give emphasis on three basic characteristics: *first*, the non-uniqueness of the dimensions through which grouping plants and activities; the subnetworks consider two distinct elements (product and process) simultaneously and it is in contrast with all the other grouping criteria found in the literature. *Second*, the fact that on each dimension more than one factors need to be evaluated; *third* we point out the differences compared to other criteria (network and business units).

Furthermore, we provided evidence of the practical relevance and the additional contribution of subnetwork approach, by identifying the reasons why subnetwork is useful considering three core topics in IMNs: role of the plants, capabilities, and

manufacturing strategy. Moreover, we identified a series of unsolved challenges and potential interpretative approaches for each topic.

This research, therefore, seeks to encourage a debate in the academic and practitioner communities regarding the main characteristics of subnetworks. The derived considerations can be enlarged to further discussions. In particular, what we assume to be interesting in this perspective is the analysis of the questions and open points that have been raised, and the investigation of the elements that allow companies to position the identified subnetworks into a coherent general framework. These points would need additional research.

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Tracing the route in the strategic sourcing journey: development and implementation of a hybrid framework

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Abstract

This study presents a novel "hybrid" strategic sourcing framework, designed and developed in collaboration with a leading international company in the tyre industry using a design science approach. We present the main insights related to the structure of this new framework and its key constitutive components. We discuss the preliminary implementation in the company to highlight its key features in supporting purchasing managers in the coherent decision-making process through a comprehensive analysis of buyer-supplier relationships, based on the identification of the optimal number of suppliers, the analysis of the power balance and competitiveness, and the evaluation of internal complexity.

Keywords: Strategic sourcing, Framework, Implementation

Introduction

Despite providing several theoretical models to manage buyer-supplier relationship (e.g. Olsen and Ellram, 1997), the literature on strategic sourcing still lacks of practical examples of the implementation of coherent instruments able to guide companies along the strategic sourcing journey (Formentini et al., 2018): in other words to make available

to purchasing managers integrated tools to trace a route, i.e. identify the most strategic suppliers and develop specific tailored plans, control the route and if the route has not been followed, check results and take action, thus providing a feedback loop for control and correction of actions.

Considering this relevant academic and managerial need, in this study we focus on the development and implementation of a strategic sourcing framework able to integrate these three main key steps. The main objective of the proposed framework is to provide overall coherence and balance throughout the entire strategic sourcing process. This study focuses on the analysis and discussion of the implementation of the proposed strategic sourcing framework in the partner company through the evaluation of one case of application of the framework performed in 2017 and 2018. We build our analysis both on data collected in the partner company throughout the design science process. One of the key objectives of this study is to discuss the hybrid framework as a "methodology" suggested to purchasing managers in other organizations and therefore allow generalizability of the model. We aim at discussing the innovative elements of the proposed framework (i.e. the calculation of the optimal number of suppliers, evaluation of power balance between the parties, etc.) and its theoretical underpinnings (e.g. complexity theory).

Our study contributes to the Purchasing and Supply Management literature by offering detailed insights on the design, development and implementation of the framework, providing managers with an integrated to tool to support coherent decision-making and refining previous studies in the field (e.g. Formentini et al., 2018) by offering a more in-depth analysis of the strategic level concept, and a stronger connection between relevant perspectives, i.e. power balance and internal complexity. In terms of managerial implications, we believe our framework offers purchasing managers a comprehensive set of factors to be considered in the complex strategic sourcing process, ultimately leading to meaningful and coherent decisions in managing the supplier portfolio.

Theoretical background

Formentini et al. (2018) have recently addressed the gaps in the Purchasing and Supply Management (PSM) literature related to the implementation of purchasing portfolio models (e.g. Olsen and Ellram, 1997) in an integrated manner to support purchasing managers' decision making throughout the different hierarchical strategic levels (i.e. from business strategy to purchasing strategy, and in turn specific differentiated actions towards suppliers) in line with the "strategic alignment" research by Hesping and Schiele (2015) and Gonzalez-Benito (2007).

Building on the integration of three different purchasing portfolio models (i.e. Kraljic, 1983; Olsen and Ellram, 1997; Scoot and Westbrook, 1991), the strategic sourcing framework integrates three relevant theoretical perspectives, to provide a comprehensive understanding of strategic sourcing decisions considering Transaction Cost Economics, Social Exchange Theory and Resources Dependency Theory, as interconnected lenses. However, in terms of limitations, this framework is providing only a partial discussion of key factors, such as the detailed measurement of each suppliers' strategic role, and the current level of power balance characterizing specific buyer-supplier relationships.

Moreover, another important academic and practical gap is still represented by the possibility to evaluate the effective impact of these strategic purchasing decisions on performance results – given the complexity of factors influencing business performance and competitiveness - and the development of specific capabilities (Gonzalez-Benito, 2007; Knoppen and Sáenz, 2015) to support managers in strategic purchasing. It is challenging for companies to trace a route for strategic purchasing decisions, control and

take actions. We believe that the PSM literature has so far provided important insights but the main approaches are still "fragmented" and need to be integrated for more coherence and impact. Hence, we propose a new "hybrid" strategic sourcing framework, able to integrate several perspectives emerging from the PSM literature and practice.

Research design

The proposed strategic "hybrid" sourcing framework has been designed and developed through a design science research approach (Denyer et al., 2008; van Aken et al., 2016), building on recent studies (e.g. Formentini et al., 2018) and established literature on purchasing portfolio models (Olsen and Ellram, 1997) and strategic sourcing (Hesping and Schiele, 2015; González-Benito, 2007). In line with the action research method, the research objectives have been iteratively refined in order to integrate the specific needs of the partner company collaborating in this study - a leading international firm in the tyre industry - facing the need to develop a novel strategic sourcing approach for coherent decision-making. Initially, the study started by focusing on the identification of an optimal number of suppliers for a specific purchasing context; in the following iterative steps, it became clear that it was required to understand and integrate several different perspectives, beyond the initial focus on the optimal number of suppliers. Therefore, in this study we aim at answering the following research question: *"What are the key drivers influencing the selection of a coherent supply base size at the strategic level?"*.

As a result, this study focuses on the development of the proposed framework – driven by the research question - and its key constitutive components. We also provide a preliminary analysis and discussion of the implementation of the proposed strategic sourcing framework in the partner company through the evaluation of one case of application and prototyping of the framework performed in 2017 and 2018. As a result of the close collaboration with the partner company, we build our analysis and discussion both on qualitative (i.e. interviews) and quantitative (i.e. sourcing and performance data) collected in the partner company. One of the key objectives of this study is to discuss the hybrid framework as a "methodology" suggested to purchasing managers in other organizations and therefore allow generalizability of the model. We aim at discussing the innovative elements of the proposed framework (i.e. the calculation of the optimal number of suppliers, evaluation of power balance between the parties, etc.) and its theoretical underpinnings (e.g. complexity theory).

The need to define an optimal number of suppliers

The proposed framework has been developed in close collaboration with the partner company, aiming at providing support in a complex and challenging decision-making scenario and understanding the key trade-offs that characterize this context. Following an action research approach, we performed a literature review in the strategic sourcing literature to identify the availability of comprehensive frameworks able to support the company in defining an ideal number of suppliers, in line with the recent trends highlighting supplier base reduction, rationalization and optimization; it was possible to identify a limitation of the literature in terms of guidelines for the evaluation of relevant strategic suppliers, and in turn the identification of an optimal number of suppliers, especially to identify a coherent amount of incentives to allocate to the specific buyer-supplier relationship. A clear understanding of the variety of factors to be considered was lacking in the related literature.

When reviewing the literature, we noticed that the selection of the ideal number of suppliers is deeply linked with the decision of the sourcing strategy selected. Considering the main findings in the strategic sourcing literature, however, it seems that the most

important and relevant recent trends are characterized by the reduction of the number of suppliers. In fact, the majority of studies suggest that in order to effectively increase long-term and mutual co-operation with best performing suppliers, and to cope better with the strategic objectives pursued by the buyers, it is necessary to reduce the size of the supply base, and to allocate higher amount of resources to the remaining suppliers. In general, in fact, buyers' resources are limited, and highest efforts should be allocated only to most strategic suppliers, while on the other hand no-value adding suppliers should be eliminated from the base. For instance, Dowlatshahi (2000) focuses on the main reasons for the need of supply base reduction. Supply base reduction approaches are used to reduce the size of the base by eliminating the worst suppliers currently in the set, as discussed for instance by Monczka et al. (2002). However, the main studies are missing to investigate which is the optimal number of suppliers to maintain, providing indications towards the elimination of low-performance suppliers. In a similar vein, supply base rationalization (Dubois, 2003) and supply base optimization (Talluri and Narasimhan, 2005) provide insights on this reduction and focalization process.

Following this consideration, it became clear that the study should require specific considerations and analysis about the number of suppliers to include within a differentiated and strategically managed portfolio. Therefore, it is important to include in the research objective a supply base rationalization process, where the interest is not only to define a model to select the best suppliers, but also to have a clear and numerical indications on how many suppliers must be selected and managed; this is confirmed by the fact that the partner company was actually shifting from a decentralized to a centralized purchasing structure, and in this evolution process too many suppliers had been identified, thus requiring rationalization.

However, it is really important to note that supply base reduction activities may also not perform as planned, since not always the decision to simply reduce the number of suppliers could be intended as the best solution to improve the sourcing strategy potential, as well as there is no guarantee that higher collaboration will be achieved with the single supplier selected. Furthermore, other considerations must be examined, since this strategy may also impact on buyer's cost structure even in the medium-long-term differently as forecasted: if strategies are not correctly designed and the buyer only focuses on immediate operational cost reduction opportunities related to a business relationship with only one supplier (the lower the number of suppliers, the lower the coordination and operating costs), it could be risky to ignore some other highly important and linked cost considerations which may affect and harm buyers' cost structures on a long-term basis. For example, dealing with supply base rationalization processes, if the buyer solely focuses on selecting few, high performing suppliers, besides the theorized and hypothesized advantages described above, the buyer could experience low differentiation within the supplier base: "*ignoring this consideration could leave a firm undergoing supplier rationalization with a smaller but more redundant strategic supply base*" (Talluri et al., 2013). Additionally, a reduction in the supply base size would imply several consequences: buyers would increase their dependence level towards suppliers, and if they are not able to shift to a balanced power level, they may suffer of decreased performances and higher prices (Cousins, 1999).

In summary, even if the global trend seems to benefit and prefer supply base reduction activities, it is not clear whether there is any guarantee that a single sourcing strategy will perform better than a multiple one. Therefore, we decided to refine the focus of our study to develop a more in-depth understanding of the key factors influencing the identification of strategic suppliers, their ideal number, and in turn the recommended actions suggested

to managers in allocating incentives for the improvement of specific buyer-supplier relationships, in order to manage the power balance and dependence.

Towards the development of the "hybrid model"

As a result of the close interaction with the company and the continuous review of the strategic sourcing literature, it was possible to identify a trade-off including three main indicators, as represented in Figure 1, i.e. 1) the *focus on strategic suppliers*, 2) the *competition level* and 3) the *internal complexity*. It emerges that a comprehensive understanding of the optimal focus in strategic sourcing decisions should take these three indicators simultaneously into account.

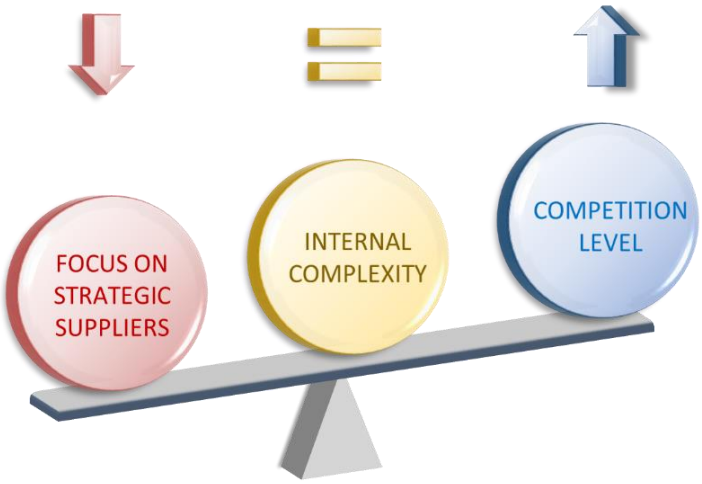

Figure 1 - Trade-off and coherency approach of the indicators within the hybrid model

Focus on strategic suppliers

Supplier portfolio models suggest that the resources available in the procurement department are limited and should be allocated mainly to the most strategic relationships. In general, the higher the focus on strategic suppliers, the lower will be the number of suppliers included in that context. As shown in the literature by qualitative models, a high focus on strategic suppliers will be beneficial for the buyer, since it allows to focus on best performing ones, reaching volume and learning cost reduction effects, high-valuable co-design activities and high level of incentives to co-operate effectively together.

In practice, this analysis requires the consideration of two dimensions:

1. The strategic level – i.e. how much each supplier is considered as "strategic", according to the buyer's criteria;
2. The incentive level – i.e. how much the buyer is currently investing resources in a specific relationship with a supplier.

In other words, the concept of *coherence* and the findings of *power balan*ce are integrated to highlight several major points, fundamental in the analysis performed:

- Focusing on less suppliers allows for higher volume shares to the selected suppliers, to gain competitive advantage;
- The portfolio should be managed coherently, in order to allocate the right level of resources in relation to the importance of the specific supplier (power balance adapted results);
- Differentiation in the supplier portfolio is required (heterogeneous product portfolio and purchasing category require numerous suppliers to be differently managed).

Thanks to this indicator the purchasing manager can investigate if he is coherently managing, in terms of volume share and relationship's investments, its supplier base according to the strategic level attributed to the suppliers, in terms of their potential performances and capabilities values. After the high-level framework has been set, it is necessary to effectively define two ways to calculate the two aspects considered: specifically, it has been decided to include the *strategic score* to convey the strategic relevance of a supplier within buyer's considerations, while to build a new tool, the *incentive level*, which ideally represents the importance that the buyer is attributing to each supplier.

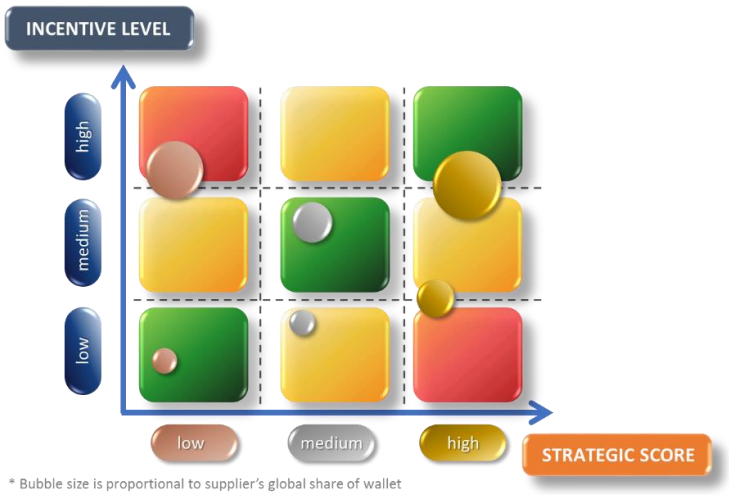

Figure 2 - Example of focus on the strategic suppliers dimension

The basis of the focus on the strategic suppliers' indicator is that coherence is obtained if a proportional level of incentives is attributed to suppliers in relation to their strategic score value.
According to these findings, quadrants in Figure 2 are represented with three different colors:

- The green quadrants are the most coherent cells, since the suppliers are managed coherently and accordingly to the importance of each of them;
- The yellow quadrants consist of situation of low incoherence, which could be solved relatively easily with little and specific changes;
- The red quadrants are the most dangerous situations, and are the ones which require the highest attentions, since it is possible to find suppliers very strategic but allocated with a very low volume share or contract importance, or vice versa.

Given these general categories, it is not difficult to imagine that a coherent sourcing strategy will generally depend on how coherently these two dimensions are managed: the more the suppliers in the green zones, the better it is. However, it is also important to remark that the coherence zone is not static and fixed, and adapt itself to the context and to the general position of suppliers within the base: because of this, the purchaser will need each time to assess, looking at the matrix, how much coherent is the current situation.

Competition level
Considering that the first indicator could effectively push for a reduction of the supply base size, the second indicator has been selected in order to counterbalance this effect.

Specifically, literature review states that, among all the possible effects, a supply base reduction may lead to two major effects:

a. Transfer of power from buyer to suppliers, with all the related consequences (higher risks, lower potential performance and commitment);
b. The reduced competition level would consequentially lead to a loss of performance and results obtained by the suppliers.

Because of these reasons, this second force, the competition level, can be logically intended as a force effectively pushing towards an increase of the number of suppliers, since the higher the number of suppliers in the base, the higher the potential competition level obtainable by the firm. This can be effectively seen as an assumption made by the model: it is modeled that higher competition directly impacts on a decrease of the risk and dependency level.

To improve the business's impact of the indicator developed, it has been searched in the literature a quantitative tool suitable to calculate this parameter: in particular, it has been found that the Herfindahl-Hirschman index (HHI) (Rhoades, 1993) seems to be perfectly adapt to the use required. The HHI is in fact a commonly shared industry ratio generally used to assess the concentration level of a market: the concentration level ratio is used to assess how much the market, in terms of volumes shares to the supplier, is concentrated, where the monopoly is intended as the most concentrated market structure, in opposition to the perfect competitive market, which is the lowest concentrated market, since all the suppliers share the same demand allocation. Since the aim is to calculate competition and not concentration level, however, this can be measured by evaluating the complementary of HHI, since the two measure are one the opposite of the other.

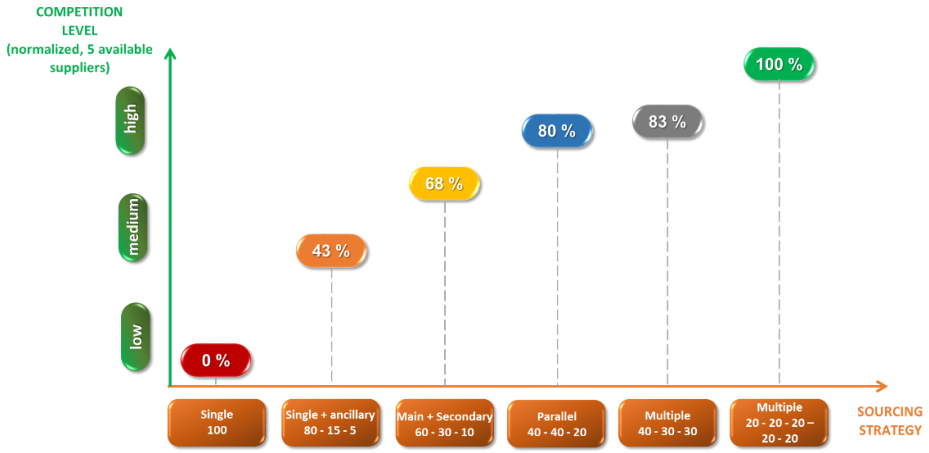

Figure 3 - Normalized competition level for a sample of selected sourcing strategies

This is also a good way to highlight how much importance is not only allocated to the number of suppliers selected, but also on how the demand has been splitted among them; furthermore, a big role is also played by the number of the available suppliers, and not only the ones effectively selected by the firm, and which have not been allocated of a specific order: their impact must be effectively considered within the normalized HHI analysis.

Interestingly, even if the two described forces could be sufficient to solve the problem, they mainly consider an external scenario, while also internal considerations must be investigated. This is necessary since a specific competition level and focus

towards more strategic suppliers, besides the advantages and disadvantages described, would impact differently on the buyer's general management efforts, in terms of number of suppliers to manage, as well as items and plants/countries served by the company, as discussed throughout the action research process when considering the different impact on operating and management costs caused by the size of different supply bases. Because of this specific company need, a third dimension has been introduced in the proposed framework, i.e. the internal complexity dimension.

Internal complexity

The internal complexity index measures the actual variety managed by the buyer, considering the dimensions under direct control. This indication is very useful for managers since it allows them to balance better the trade-off among the two forces above described. In fact, as will be shown later on, high level of performance both in strategic and competition levels must be reached through a coherent definition of the internal complexity level. Interestingly, within the internal complexity indicator, it is possible to individuate another intrinsic trade-off analysis between managerial costs and network potentials. In fact, the logic under this decision is that if it is generally assumed that higher variety to manage could be an additional burden to be controlled and monitored, with a consequent conversion into higher costs to sustain for generally no value-adding activities, it may also be noted that a certain level of variety is not only necessary, but could also be a source of advantage for the firms. For example, it could improve the resilience's level of the firm, which generally can be intended as flexibility and capability to overcome and solve eventual risks and issues within the network, especially in case of emergency, which is fundamental in a wider and graphically dispersal supply base, but also adaptability possibilities, in terms of higher capability to change the internal structure, to switch suppliers or access to better resources, technologies and other factors.

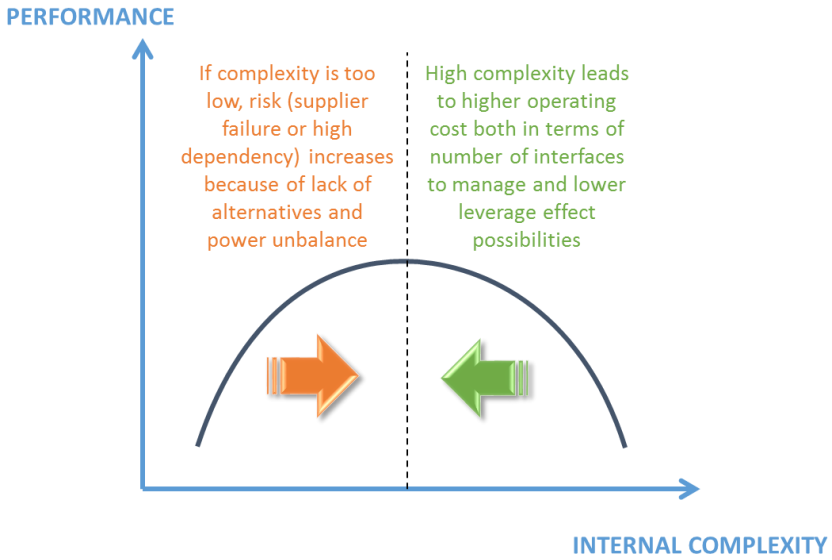

Figure 4 – Relationship between internal complexity and performance levels

In a similar way to the strategy used during the definition of the competition level and the HHI, a meaningful research has been performed to find out if some business tool could be effectively used in this decision. An interesting parameter used to calculate the

uncertainty level is the Shannon's Entropy index. This is a tool designed to measure the uncertainty level within a system: the higher the uncertainty, the higher the entropy level.

Because of this, the decision is to calculate the internal complexity by calculating the product of three factors: the *suppliers included in the base*, the *average number of items* each supplier is sourcing and the *average number of plants/countries* each supplier is shipping to. The higher this product, the higher the internal complexity to manage, the higher the cost.

Discussion of findings

The "hybrid" framework has been converted into a decision support tool in the company, able to identify the three proposed strategic decision drivers, combine them and provide their quantitative measurement. It evaluates the current "as-is" scenario, providing a holistic monitoring and control through the use of several dashboards.

We are currently studying the developments related to the integration of the proposed framework in the procurement planning process in the partner company – which is very evolved, and characterized by a high level of formalization - which first of all starts with a "long-term planning" phase. This first step is not aiming at taking decisions, but ultimately at understanding the cost plans with a 3-year horizon, since the homologation processes for new products are usually very long and they can require up to 18 months, for instance, when purchasing a new material from a new supplier. Adopting this long-term perspective, we have integrated in our framework the key insights from the original model by Olsen and Ellram (1997), following this approach to measure the "level of strategic importance" of a specific supplier.

Future developments of this study will focus on the theoretical discussion of the "hybrid" strategic sourcing framework, a tool to combine three key perspectives:

- Strategic perspective – i.e. alignment and coherence, and focus on key strategic suppliers aiming at the development and improvement of strategic buyer-supplier relationships;
- Competition and power perspective;
- Complexity perspective.

Conclusions

This study contributes to Purchasing and Supply Management theory and practice by discussing the novel "hybrid" strategic sourcing framework able to support and guide managers in developing coherent decisions to manage suppliers and in turn allocating incentives, e.g. volume share. This contributes to the literature on strategic purchasing and alignment (e.g. Hesping and Schiele, 2015; González-Benito, 2007). Moreover, the new hybrid model contributes to theory by providing a deeper understanding of the strategic sourcing trade-off, i.e. balancing the focus on strategic suppliers and suppliers' power (Caniëls and Geldermann, 2007). The hybrid model is composed by three indicators (i.e. focus on strategic suppliers, competition level and internal complexity) which are integrated to grasp the key factors, such as the supply base size or the volume share, clearly visualizing the current scenario faced by the firm. These indicators have been developed and included in the framework prototype currently implemented in the company in order to offer a good level of inter-connection among the dimensions considered. Summing up these considerations, this study contributes in analyzing a complex decision-making scenario, which has been overlooked in the strategic sourcing literature, missing to provide a "hybrid" approach able to integrate both quantitative and qualitative analyses, especially providing a practical tool for implementation.

From a managerial point of view, this study provides useful recommendations to purchasing managers through the development of a decision support system to facilitate managers in the allocation of resources to suppliers, leveraging the managers' experience with tailored decisions in line with the three integrated perspectives (i.e. strategic focus; power balance; complexity).

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The evolution of offshoring: A secondary data analysis in Europe

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Abstract

Offshoring emerged as a major business practice since the 90s. Recently the phenomenon seems to be affected by the decrease in cost advantages of developing economies, the consequences of the 2008/09 economic crisis and the advent of new technologies (Industry 4.0). This paper investigates how offshoring geographies and drivers have changed over the last fifteen years. Based on a longitudinal analysis, we identified three different phases. Specifically, while the number of offshoring cases progressively decreases, we observed that location decisions are less driven by cost-related motivations and more by technological and market-related drivers.

Keywords: Offshoring, Reconfiguration, Drivers

Introduction

In last few decades manufacturing offshoring – the transfer of production activities from home country to foreign locations (e.g. Ferdows, 1997; Feenstra, 1998; Lewin et al., 2009) – has emerged as a major industry trend and, at the same time, as a popular research topic in operations management (OM) and international business (IB). Literature has shed light on a wide set of offshoring issues, such as definitions, motivations, drivers and outcomes (e.g. Lewin and Peeters, 2006; Schmeisser, 2013; Hernández and Pedersen, 2017).

The temporal analysis of the European industrial system shows that in recent years location choices have gone through a transformation. Initially, a massive transfer of production took place. The main motivation was the research for cost advantages (e.g. Aubert et al., 1996), especially in high labour and low-tech industries (e.g. apparel and furniture) or where price-based competition prevailed. As time went by, firms realized that offshoring had not only advantages but also a number of initially unexpected costs and risks (Patrucco et al., 2016; Herath and Kishore, 2009). For this reason, companies

began to reconsider their choices with the growth of phenomena such as right-shoring and reshoring.

Nowadays, comparing with the past, the global chessboard appears deeply different due to a series of exogenous factors that are changing the drivers and therefore the geography of location choices. Among the others we can cite: the production overcapacity in Western countries (determined by the global crisis), the increase in prices in key developing countries e.g. China (Simchi-Levi et al., 2012; Arlbjørn and Mikkelsen, 2014) and the new technological trajectories, e.g. industry 4.0 (Rüßmann et al., 2015; Fratocchi, 2017; Ancarani and Di Mauro, 2018).

While the inter-temporal approach is well rooted in IB internationalization research (e.g. Lewin and Volberda, 2011), there are so far no OM studies which analyse the temporal evolution of manufacturing offshoring. This paper is aimed at solving this gap by offering an evolutionary perspective of offshoring and highlighting its evolving geography and drivers.

The study is based on the European Restructuring Monitor database (https://www.eurofound.europa.eu/observatories/emcc/erm/factsheets), that consists of secondary data related to 29 nations (28 EU members and the Norway). The used sample consists of 669 offshoring cases.

As far as the methodological approach is concerned, we employed different statistical tools in order to fully explore several aspects. First, we looked for discontinuities in the data (Kleiber et al., 2002) to define temporal milestones. Then we performed network analysis to assess the geographical evolution of the phenomenon and understand if involved countries have changed over time. Finally, exponential random graph models (ERGM) (Hunter et al., 2008; Kolaczyk and Csàrdi, 2014) allowed us to understand which determinants are considered by the firms for their location choices and connect the relocations to the drivers.

Assuming a time dependent variable we are able to show an evolution of the offshoring phenomenon through three different time intervals and to identify some underlying mechanisms that drive specific global sourcing patterns: determinants of the phenomenon have changed over time shifting from a cost- to a market- and technology-seeking perspective.

Literature background and question development

There is a wide literature focused on offshoring. It sheds light on several issues such as: ***motivations***, ***geography***, firm ***performances*** and ***risks*** of the phenomenon. The considerable interest in the phenomenon is due to the fact that since the 90s offshoring has emerged as one of the most widely pursued location strategies by Western companies in order to increase or at least maintain their competitive advantage (Contractor et al., 2010).

Some studies have tried to analyse the offshoring ***motivations***. In this context, the reference model is the Ownership-Location-Internalization (OLI) paradigm, which provide insights into foreign direct investment decisions (FDI) (Dunning, 1988; Rugman, 2010):

- Efficiency seeking: firms that take advantage of cost differences in traditional production factors, or otherwise that "take advantage of economies of scale and scope" and differences in consumer tastes (Dunning, 1993; Bevan and Estrin, 2000; Kinoshita and Campos, 2003).
- Resource seeking: firms offshore to have access to high quality resources not available in the home country e.g. natural resources (Hart, 1995), human capital

(Karakaya and Canel, 1998) and knowledge related resources (Alcácer and Chung, 2007; Mudambi, 2008).

- Market seeking: firms aim to penetrate new markets. FDI is also often used to overcome customs barriers, countertrade requirements (Nassimbeni et al., 2014), special regulations (Bozarth and McDermott, 1998; Shi and Gregory, 1998) and to serve key customers (Ellram et al., 2013; Kinkel, 2012).

A second stream of research of offshoring literature is focused on the ***geography*** of the phenomenon. While the geographical context has evolved considerably over time – let us think for instance to the 2004 EU enlargement (Buckley and Casson, 2009; Onaran, 2011; Casson, 2013) – we do not find many contributions about this topic. Among the few available we can mention: Merino (2017) who has studied how important offshoring and relocation strategies are in terms of economic activity across different European regions and Cusmano et al. (2010) who shed light on the impact of offshoring on the industrial geography of Lombardy.

Third, previous studies mentioned various ***performance implications*** of offshoring, such as the development of foreign sales activities (Bozarth et al., 1998; Shi and Gregory, 1998), the improvement of delivery performance (Frear et al., 1992) and the impact on R&D performances (Lampert and Kim, 2018; Steinberg et al. 2017). The improvement of products quality is also highlighted by some studies, but this is a niche which only affects some specific countries and industries (Ettlie and Sethuraman, 2002).

Finally, the literature is not exempt from the description of ***risks and problems*** related to offshoring practices. Among the most important there are: country risk (e.g. Meldrum, 2000), risks of transfer of know-how (e.g. Ranganathan and Balaji, 2007; Gewald and Dibbern, 2009) and risks related to the quality of production (e.g. Bahli and Rivard, 2005; Belcourt, 2006). Some of the problems highlighted above could help to explain recent changes in phenomena with even the appearance of reshoring (Fratocchi et al., 2014; Ancarani et al., 2015; Fratocchi, et al., 2016; Di Mauro et al., 2018) or more in general of relocation of second degree (Albertoni et al., 2017).

The analysis of the motivations and of the few studies on geographic implications of offshoring point out that there has been an evolution in the phenomenon. The evolutionary perspective is inborn and revisable in many disciplines of economic and managerial studies, first and foremost in the IB field. Among the others, we can cite the following IB studies: Lewin and Volberda (2011), that tried to develop a co-evolutionary offshoring decision model, Lahiri and Kedia's (2011) that studied the co-evolution of institutional and organizational factors in explaining offshore outsourcing and Youngdahl and Ramaswamy (2008) that examined the evolution of roles in offshore operations. However, as far as the internationalization of production is concerned, there are few studies that empirically shed light on whether and how this phenomenon has changed over time.

For this reason, we developed the following research questions for our study:

RQ1: Has the offshoring phenomenon changed over the years?

- RQ1A: Have offshoring drivers changed over the years?
- RQ1B: Has offshoring geography changed over the years?

Methodology

Database European Restructuring Monitor

The main source of information for our study is the European Restructuring Monitor (ERM) database. Made by Eurofound (the European foundation for the Improvement of Living and Working conditions) using secondary data (announcements in such media sources as newspapers, magazines, specialized websites, and business press), this

database contains factsheets regarding restructurings undergone by European subsidiaries of Worldwide firms. Information have been collected since 2002 and nowadays there are more than 22000 restructuring events that cover 29 countries (28 EU members plus Norway).

The unit of analysis is the single restructuring decision. Therefore, each firm may have made several restructurings and thus appear in several records of the database, each containing: size, headquarter country, industry, year of the event, number of jobs involved, home country, destination country and the motivations.

It is worth pointing out that an event is included in the database only if involves the loss or creation of at least 100 jobs, or alternatively if it concerns at least 10% of the workforce in production facilities employing more than 250 people.

The ERM database has already been used in previous operations management research on relocations of second degree (Barbieri et al., 2019), task offshoring (Goos et al., 2009), graphical patterns of value chains in the automobile part suppliers (Frignant and Layan, 2009) and firm restructurings carried out in Ireland (Gunnigle et al., 2013).

Sample

The ERM database is organized into different categories according to the type of restructuring that the company has undergone. From the ERM database, we selected all the cases classified as “offshoring/delocalization” and this led to a final dataset of 669 records covering 29 countries and 34 industries. As previously said, data only consists of offshoring cases having an European country as origin. So, while outgoings flows are precise, incoming flows can only be assumed. In our specific case we assumed that all jobs lost in the origin country were fully transferred to the destination.

Data analyses

Temporal milestones detection

Usually inter-temporal studies are characterized by a certain arbitrariness due the subjective choice of milestones. However, in our specific case we used the “flat-step" approach that, analysing the average values of a given phenomenon, identifies the transition from one stage to a subsequent one with different characteristics. This methodology allows to define an empirical milestone devoid of subjectivity and has already been applied in the biological field (Ficetola and Denoël, 2006) and for studies related to climate changes (Mariani, 2006; Chiaudani et al., 2008) to verify in which years there have been structural changes in the maximum annual average temperatures of a given area over a given period. This analysis has been carried out through the package “strucchange” (Kleiber et al., 2002; Zeileis, 2005) for the statistical software R.

Inter-temporal comparison

Network Analysis is used to study complex systems of any kind, as long as they can be represented with a graph. Application fields of this technique are varied and complex and include: economics, mathematics, sociology and industrial psychology. This leads to a great variety of perspectives and approaches based on the specific target of use. Recently some studies have begun to deepen the use of this methodology also in the field of operations management (e.g., Barbieri et al., 2019; Pilkington and Meredith, 2018).
In our paper we used network analysis to provide a geographic perspective of offshoring, highlighting the countries more able to attract investments and the ones more affected by industrial restructurings.

Networks data are interdependent and generally have unknown distributions, so their statistical analysis requires care. For this reason, we adopted a particular exponential model applied to networks (Exponential Random Graph Models – ERGM) (Hunter et al.,

2008; Kolaczyk and Csàrdi, 2014) which uses permutation-based approaches and does not require an early knowledge of population and sample distributions. In the economic-managerial field ERGM was previously employed to study knowledge transfer processes (Su et al., 2010; Harris et al., 2012), alliances in product markets (Lomi and Fonti, 2012) and recruitment (Arrieta-Paredes and Cronin, 2017).

In our specific case exponential random graph models were used to analyse the determinants of relocation choices. Consistent with previous works (e.g. Buckley et al., 2007; Barbieri et al., 2019), we included in our ERGM models 5 variables associated to efficiency, resource and market seeking motivations (Dunning, 1980):

- Gerd: gross domestic expenditure on R&D per capita; includes expenditure on research and development by business enterprises, higher education institutions, as well as government and private non-profit organisations and is used as a proxy for the technological situation of the country.
- LabCost: average hourly labour cost for each country including wages, salaries and non-wage costs (employers' social contributions and taxes).
- GDPpp: gross domestic product per capita at purchasing power parity used as proxy for the size of the market.
- Ore: ratio of ore and metal exports to merchandise exports of the country used as a proxy for the availability of resources.
- Patent: number of resident annual patent registrations in the country used to capture the innovation activity.

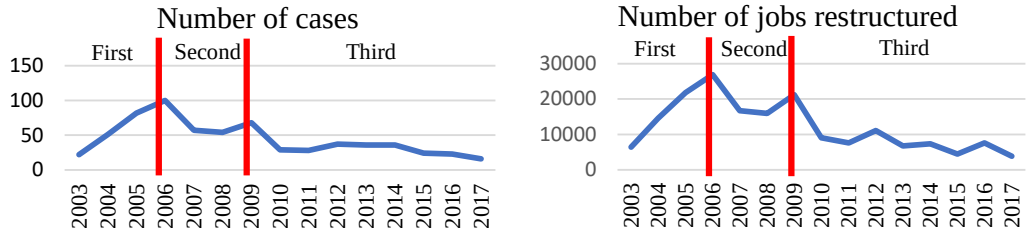
The values of the considered variables were taken from the Eurostat and World Bank databases.

Findings

Temporal analysis

Through the "sc test" of the R package "strucchange" we performed a temporal analysis of the number of cases recorded and of the number of jobs restructured (Figure 1). Results showed two empirical time milestones (i.e., 2006 and 2009) devoid of subjectivity.
Based on these findings we split the dataset into three time periods:

- First period cases up to 2006 n=264
- Second period cases from 2007 and 2009 n=172
- Third period cases from 2010 onwards n=233



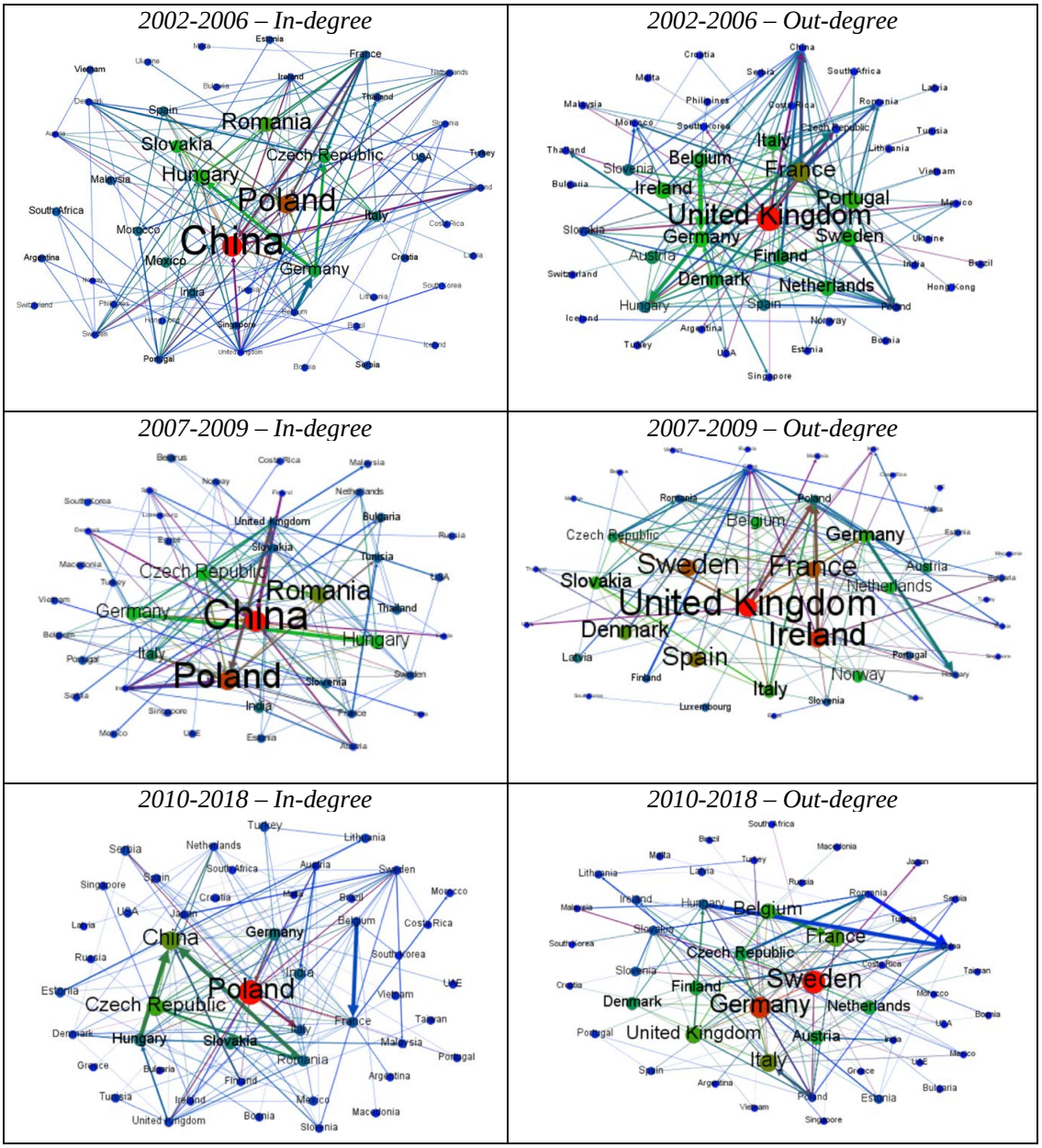
Variable	Discontinuity year(s)	P-value	Variable	Discontinuity year(s)	P-value
Number of cases	2006-2009	0.01	Number of jobs restructured	2006-2009	0.001

Figure 1 - Temporal trends and discontinuity analysis

Network analysis

As far as network analysis is concerned, we defined first of all a standard coding for all the networks to compare the results. Within each graph, nodes (also called vertexes) represent different countries and arrows are the transfer of jobs. Specifically, the tail of

the arrow is the origin country while the tip is the destination. In addition, the size of each arrow is proportional to the flows between the two nodes. We then represented the in-degree and the out-degree networks (see Table 1 for their interpretation) of the three temporal periods identified in the previous section (Figure 2).



Note: nodes have different colours and sizes:

- Red and big: countries most involved in the phenomena.
- Green and medium: countries in an intermediate situation.
- Blue and small: marginal countries.

To have a greater accuracy we choose to make the colours blend, in this way we are able to identify countries in an intermediate situation.

Figure 2: Network analysis

Table 1: Metric description

Metric	Meaning	Interpretation
In-degree	Number of incoming connections	How a country attracts jobs
Out-degree	Number of outcoming connections	How a country loses jobs

Analysing the networks, we can notice a progressive transition with marked differences especially between the first and the third period, both for the in-degree and out-degree. As far as the ***in-flows*** are concerned (left graphs in Figure 2), there is a clear downsizing of some countries over time, primarily Romania and Hungary. At the same time, it is also clear that China has lost its role of hegemony in favour of Poland. On the other hand, as far as far as ***out-flows*** are concerned (right graphs in Figure 2), we can see that they mainly regard the more developed European countries. Again, there are differences over the years. In particular, the most affected country in 2002-2006 was the United Kingdom, while the most affected countries in 2010-2018 were Germany and Sweden. However, a subsequent analysis of the individual cases shows that the out-flows of these two countries belonged to companies operating in high technology or niche sectors that have moved their production to other highly developed countries such as Japan.
We then calculated the average distance between origin and destination country (Table 2). This analysis shows that the geographical dimension of the phenomenon is gradually shrinking.

Table 2: Displacement statistics

	Up to 2006	From 2007 to 2009	From 2010 onwards
Mean displacement distance (km)	3767,44	3403,1	2716,19

Exponential random graph model
In order to shed light on whether and how offshoring drivers changed over the years, we run three exponential random graph models one for each period previously identified (Table 3).

In the first time period (Model 1 – 2002-2006), we noticed a strong significance of labour cost (LabCost=-2.99, $p<0.0001$). This leads us to conclude that in this historical phase firms were mainly interested in cost savings for their location choices.

As far as the second period is concerned (Model 2 – 2007-2009), cost savings (LabCost=-2.54, $p<0.001$) are always dominant but have lost part of their significance, while GDPpp has become significant (GDPpp=1.28, $p<0.01$). A possible interpretation is that companies begin to revise their strategic plans, adding to the mere research for cost savings also the research for new markets.

Finally, the situation from 2010 onwards (Model 3 – 2010-2018) appears further different. LabCost has lost its significance, while technological variables (Gerd=1.42, $p<0.0001$ and Pat=9.44, $p<0.001$) have become significant. This makes clear that determinants of location choices have changed and, nowadays, companies are more attracted by technological aspects. The variable GDPpp (1.54, $p<0.001$) is still significant thus indicating that market seeking is always important in firms' strategies.

Table 3: Statistical models

Dependent variable=**Prob. that the node is selected as destination country**	Model 1 (n=264) (2002-2006)	Model 2 (n=172) (2007-2009)	Model 3 (n=233) (2010-2018)
Independent variables			
LabCost	-2.99x10^(-2)±9.06x10^(-3)***	-2.54x10^(-2)±8.01x10^(-3)**	-1.49x10^(-2)±9.57x10^(-3)
GDPpp	3.07x10^(-6)±5.42x10^(-6)	1.28x10^(-5)±5.24x10^(-6)*	1.54x10^(-5)±5.59x10^(-6)**
Gerd	-3.99x10^(-4)±3.47x10^(-4)	-9.61x10^(-5)±2.96x10^(-4)	1.42x10^(-3)±2.79x10^(-4)***
Ore	1.18x10^(-1)±2.09x10^(-1)	3.33x10^(-1)±1.9x10^(-1)	1.21x10^(-1)±2.06x10^(-1)
Pat	-1.14x10^(-6)±1.12x10^(-6)	-2.71x10^(-7)±1.01x10^(-6)	9.44x10^(-7)±2.95x10^(-7)**
AIC	971	1158	1028
BIC	1007	1194	1064

*p<0.01, ** p<0.001, *** p<0.0001.

Discussion

The analyses carried out in our study showed the existence of two ***temporal*** milestones: 2006 and 2009. These two years are part of a context characterized by deep changes that have probably accelerated latent processes. Indeed, both number of cases and number of jobs restructured (Figure 1) change their trend from 2006 onwards and, although there is a local maximum in 2009, they no longer return to previous levels.

In this period the economic crisis has led to a contraction of internal European consumptions and therefore to the need for firms to enter new markets where to sell their products. This can be observed in the evolution of the ***geography*** of offshoring phenomena. A detailed analysis of Figure 2 shows that until 2009 low cost countries (e.g. Romania and Hungary) were at the centre of incoming delocalization flows and then, in the following years, they have lost their attractiveness. On the other hand, taking into account out-flows, we notice a decrease of flows from United Kingdom (Figure 2) and an increase of flows from Italy. This country is struggling to adapt itself to new possibilities offered by recent industrial paradigms (Viharos et al., 2017) and, in the last period, has seen an increase in the number of jobs relocated. Because of all these findings we can therefore state that the most virtuous countries in terms of innovation are those with the greatest ability to attract (and not to lose) firms and jobs.

Results (Table 3) showed that until 2006 (Model 1), location decisions were driven only by cost-seeking ***drivers***. Subsequently, over the years, companies seem to have changed course and already in 2007-2009 (Model 2) motivations related to market-seeking began to appear. But, as already said, after the economic crisis of 2009 (Model 3) we saw more significant changes. Firms start to move to countries with market opportunities or technological competencies.

A possible explanation for these changes is that the new industrial paradigms (e.g. Industry 4.0) can reduce production costs (Rüßmann et al., 2015) and enhance competitiveness in the global market even without relocations. In this regard, the literature shows some examples, and, among the others, we can report the fact that substituting old technologies such as injection moulding with new ones like additive manufacturing could allow customized and cheap production locally, even in high wage countries (Atzeni et al. 2010; Buonafede et al., 2018).

In addition, as more and more firms are trying to avoid low cost competition adopting differentiation strategies, the manufacturing in low cost countries no longer seems

compatible with choices of competitive positioning in high-end segments where quality and quick response are demanded (Grossman and Rossi-Hansberg, 2008; Kinkel and Maloca, 2009; Ritter and Sternfels, 2004, Byeong and Han-Mo Oh, 2017).

Another point to keep in mind is that, over the last 10 years, Asian countries had a strong increase of labour costs (Pearce, 2014; Wu and Zhang, 2014) and, at the same time, developed countries a significant rise of labour productivity (Sirkin et al., 2012). This brought the labour costs per produced unit between developed and low-cost countries much closer.

Based on the studies of Taglioni and Winkler (2016) we used two OECD variables - i.e., the Share of Re-Exported Inputs on Total Imported Inputs and the Foreign Value Added in Exports as a Share of a Country's Exports - to track the GVC participation of each country. Due to space limits of the conference papers we do not report the tables, but we limit to say that these data partially confirm our findings, highlighting the same changes in terms of geography. At the moment, instead, we are still working for time milestones confirmation.

In sum, our study allowed us to shed light on the evolution of the offshoring phenomenon with reference both to the countries and the individual firms. In this regard, we could identify three main phases:

- ***Expansion phase*** (*low-cost offshoring* – 2002-2006). Firms were interested in better economic conditions (low cost countries) with a very high and growing number of reconfiguration events.
- ***Reconsideration phase*** (*low-cost and market seeking offshoring* – 2007-2009). The number of cases is still high but starts to fall and there is a first change in the drivers pursued by companies with an initial interest also for new markets.
- ***Rationalization phase*** (*optimal mix of offshore and domestic production* – 2010 onwards). The number of cases remains low and stable. But above all, a greater experience and awareness of companies in their location policies emerges. Indeed, the drivers sought by firms have changed: companies are strongly interested in technologies and new markets. Moreover, in this period new location strategies, such as re-shoring (Ellram et al., 2013; Fratocchi et al, 2014) and right-shoring (Joubioux and Vanpoucke, 2016; Abbasi, 2016) emerged.

Conclusions

Contributions

This paper has significant implications for operations management and international business research. First, the evolutionary approach adopted made it possible to develop a map with well-defined time milestones and phases of offshoring, highlighting both qualitative (driver) and quantitative (extent of the phenomenon) changes. Indeed, we pointed out that firms are moving from low-cost towards technologically more advanced countries and among different reasons we can include benefits offered by initiatives like industry 4.0 (Schönsleben et al., 2017). Second, our work provided important information on why a particular country has changed (or maintained) its position within the global location dynamics. Finally, we were able to better define some of the characteristics of recent shoring strategies (i.e. right-shoring).

The findings might also contribute to practice and policy makers. We highlighted the need for managers to have a dynamic approach of internationalization being ready to move their facilities to pursue evolving location drivers. Specifically, managers should take into account not only the initial costs to set a plant, but also any other future cost of relocating activities to another country. Furthermore, the identification and comprehension of offshoring drivers and motivations might help policy makers to find

tools to strengthen the manufacturing base and to re-attract offshored firms, thus improving employment and GDP (e.g., investment to improve the country's technological aspects).

Limitations and future research

The results of our study should be viewed in light of some major limitations. First, we used secondary data based on public announcements of restructuring initiatives. However, the fact that data was collected by a rather reliable organization and that studies based on secondary data have already been published in the past (e.g. Elia et al., 2014) give us high confidence about their reliability.

Second, Europe has always played a central role in firms' location decisions, both in terms of offshoring and reshoring, making this region the ideal place for our study (Barbieri et al. 2019). However, excluding flows coming from extra-EU countries causes the loss of information. For this reasons, future research may include in our study also other geographical contexts (e.g. Asia and North America). Related to the previous point another limitation emerges: we know how many jobs have been moved away from Europe, but we are not aware about how many of these will be transferred to the destination country.

Finally, the ERM considers only corporate restructurings of a certain size. SMEs are worldwide dominant thus unmapped restructurings could be several. Even if in this case the dimension of the single relocation is likely not large, these relocations are likely to have unique characteristics with respect to those of large multinationals. It could be interesting to check which are the offshoring determinants of SMEs and compare them with those highlighted in our paper. Indeed, there are some studies showing that also small companies play an important role in offshoring and in general in internationalizing markets (e.g. Liesch and Knight, 1999; Oviatt and McDougall, 1994).

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Critical cost factors to consider in a manufacturing reshoring decision

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Abstract
Manufacturing reshoring is a booming topic in both research and practice. The existing literature is limited but rapidly growing. One area that is fairly covered are critical factors in a reshoring decision, commonly grouped within quality, cost, market and strategy. Within the cost category, hidden costs are a common problem. This problem arises due to lack of holistic view on cost factors. A comprehensive framework on cost factors for reshoring decisions is missing. The aim of this research is to identify critical cost factors to consider in a reshoring decision and structure them into a costing model.

Keywords: Reshoring, Manufacturing location decision, Cost factors

Introduction
Globalization has increased over the past two decades, and companies are facing increased competition from low-cost countries. In order to deal with this, companies in high-cost countries have moved parts of their manufacturing to the low-cost countries, termed as offshoring (Stentoft et al., 2016a). Over the years, rising wages and increased commodity prices have increased the cost of operating in these countries. Academics and consultants have concluded that offshoring was not inherently beneficial from a cost perspective, and have classified offshoring decisions as a 'strategic mistake' (Denning, 2013; Tate et al., 2014). This is due to the difficulties in estimating total cost due to too simplistic cost-based decision models (Brown, 2010).

As a correction measure, companies have taken decisions to repatriate manufacturing back to home country, termed as reshoring (Gray et al. 2013). There has been a large number of factors that has been addressed to drive reshoring. Many of them have been categorized into broader sets such as cost factors (Engström et al., 2018), quality factors (Stentoft et al., 2016a), market factors (Kinkel et al., 2012), risk factors (Tate et al., 2014) and supply chain factors (Ellram et al., 2013). From a manufacturing location decision point of view, an important category is costs. Often it occurs that the true costs of manufacturing location are not the same as calculated during the decision-making stage.

Manufacturing location decisions based on too few cost factors, lead to hidden costs that are unanticipated during the decision-making process and first discovered during the implementation process (Holweg et al., 2011; Larsen et al., 2013). Some of the hidden costs are related to complexity, coordination with the clients, language and cultural

barriers (Holweg et al., 2011; Larsen et al., 2013). These are not integrated in cost models, such as product costing- which is used to calculate the cost of the product. The cost of the product can be categorized from an activity point of view, into manufacturing cost, distribution cost, administration cost, and sales and marketing cost (Hundal, 1997). The cost categorization provides managers hierarchical relationship between the costs and distinguishes between expenses that are consumed on product level and those consumed on batch level (Cooper and Kaplan, 1991).

Several studies have focused on reshoring drivers and a holistic view on costs of reshoring have not yet been explored (Ancarani et al., 2015). Therefore, is a need to holistically study the costs that are involved in manufacturing reshoring decisions and integrate these costs into an existing costing model. The aim of this research is to identify critical cost factors to consider in a reshoring decision and structure them into a product costing model. The specific research questions are '1. What are the important cost factors that needs to be considered in a manufacturing reshoring decision?', and '2. How can the cost factors be integrated into a product costing model?'. These questions will be answered through a systematic literature review.

Methodology

A systematic literature review is defined as "an explicit and a reproducible design" of collecting and analyzing the existing body of literature (Fink, 2019). The systematic literature review was chosen for few reasons. Firstly, a comprehensive view on the cost factors is missing from manufacturing reshoring decision perspective. Secondly, the application of a search algorithm improves the quality of the process and generates better results than traditional review processes. This is due to the clear definition, transparency and repeatability of the procedure (Seuring and Gold, 2012). Mayring' s process model (Mayring, 2000) is carried out, that consists of four distinct steps.

In the first step (material evaluation), the search was conducted in Scopus and Web of Science databases. These databases were chosen due to their overall size, scope and relevance in the field of international business. Only peer-reviewed academic journal paper in English language were selected since they have the highest impact in the given research. The search was conducted in the month of December 2018. No time delimitation was put since the interest in reshoring domain is only recently increasing (Wiesmann et al 2017; Barbieri et al., 2018). The main search terms and the search process are presented in Table 1. The final sample consists of 80 articles from years 2009-2018. The search for literature ended in December 2018, hence it includes a complete year.

Table 1. Main search terms, search process and results

Search strings	Search process	Scopus	Web of Science	Note
"reshoring" OR "re-shoring" OR "reshore" OR "re-shore" OR "reshored" OR "re-shored" OR "backshoring" OR "back-shoring" OR "backshore" OR "back-shore" OR "backshored" OR "back-shored" "onshoring" OR "on-shoring" OR "rightshoring" OR "right-shoring"	Sample after database search	567	1344	366 were duplicates, these were excluded
	Sample after title/ abstract review	125		Articles that had other areas of focus were excluded (e.g., construction, marine, microbiology, earth sciences)
	Sample after full paper review	80		Articles that did not address 'reshoring' in a similar way were excluded.

In the second step (descriptive analysis), the descriptive analysis of the sample was performed. This analysis included aspects such as distribution of articles over the years,

across various journals, applied research methodologies and the home country focus of reshoring.

In the third step (category selection), some predefined categories for the content analysis were selected. The categories were selected based on standard product costing models usually consisting of manufacturing cost, distribution cost, administration cost, as well as sales and marketing cost (Hundal, 1997). Costs that did not belong to the product costing were organized into a "other cost" category. The reason for the selection these categories is to provide managers with a hierarchical relationship between the costs (Cooper and Kaplan, 1991).

In the fourth and final step (material evaluation), the content analysis of the sample was preformed base on the predefined categories. The entire research process is documented to ensure transparency and reproducibility of the research process.

Descriptive analysis

The distribution of articles across the timeframe along with a trendline is shown in Figure 1. The figure shows that literature on reshoring is exponentially increasing due to the growing academic interest in this area. The number of articles had peaked in the years 2014 and 2016 due to special issues on reshoring in prominent supply chain journals such as *Journal of Purchasing and Supply Management* and *Operations Management Research* respectively.

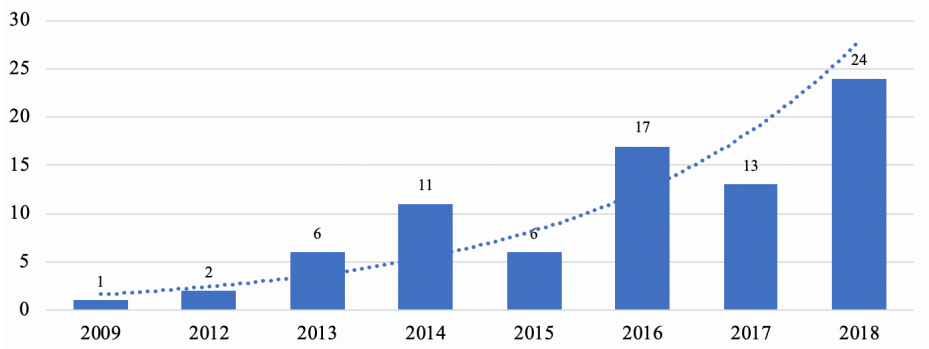

Figure 1. Distribution of articles over the years (n = 80)

The articles are spread over a number of different journals (Figure 2). Most of the journals are from operations and supply chain management area, due to the importance of reshoring from a supply chain perspective.

Within the sample, nine research methodologies have been identified: case studies, surveys, conceptual, secondary dataset research, modeling, literature reviews, experiment, Delphi and mixed methods (Figure 3). Majority of the papers have adopted case studies and surveys, in order to explore the reshoring phenomenon in its natural setting and increase the understanding of the context.

Within the sample, ten home countries were identified (Figure 4). The country with highest number of studies focusses on USA, followed by UK, western Europe and the Nordic countries. There has been only one study focusing on New Zealand.

Figure 2. Distribution of articles over the journals (n = 80)

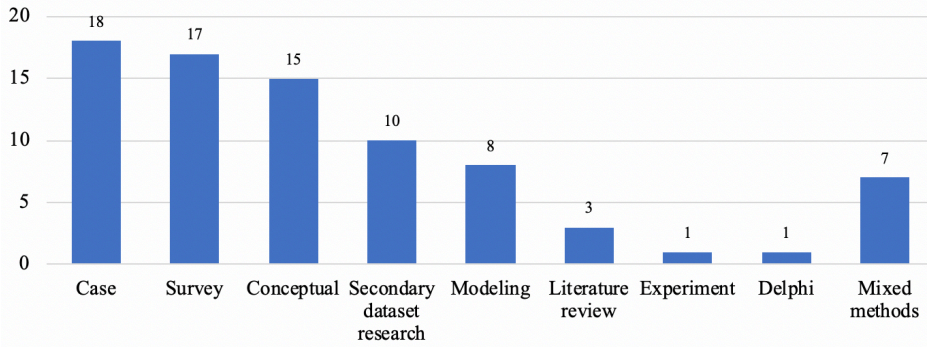

Figure 3. Distribution of research methods (n = 80)

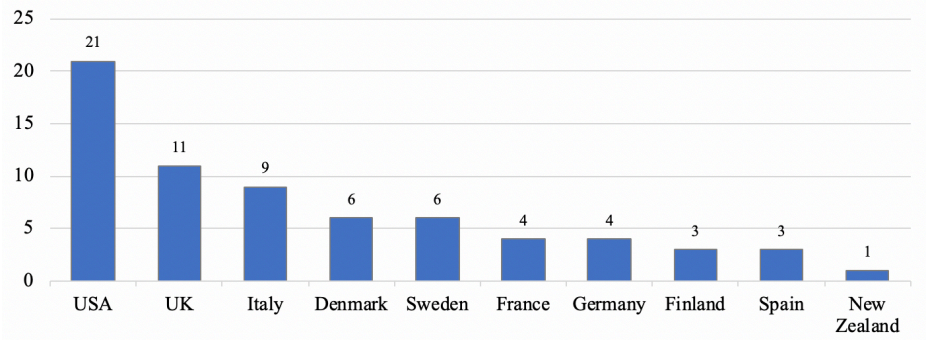

Figure 4. Distribution of home country focus

Within the sample, the articles were mapped based on category selection. The graph shows the number of articles that address each of the cost categories from a reshoring point of view (Figure 5). The cost category that was addressed the highest is manufacturing cost, followed by total cost, distribution cost, administration cost and sales and marketing cost.

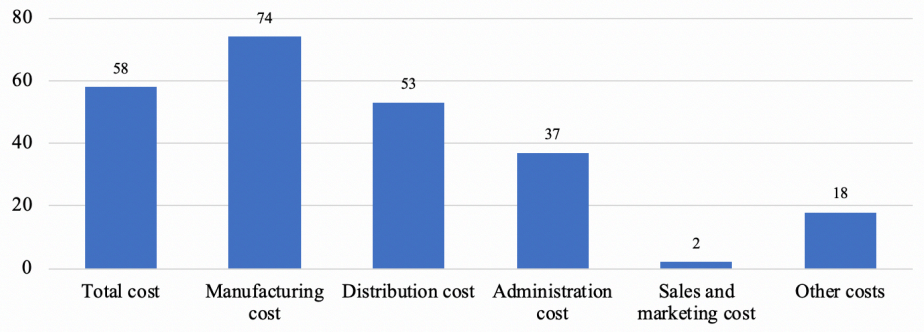

Figure 5. Distribution of costs addressed in the sample

Content analysis

In total, 29 cost factors were found in the systematic literature review (Table 2). The cost factors were structured at four hierarchical levels.

Level 1 costs

On the first level, we have total cost and other costs. The total cost is the sum of all the costs involved in bringing a product to a market. Total cost is an important factor to consider since managers need to have a holistic view on financial and supply chain factors (Hartman et al., 2017). The other costs consist of project costs.

Level 2 costs

On the second level the total cost is further divided into manufacturing costs, distribution costs, administration costs and sales and distribution costs. The manufacturing cost is the cost of manufacturing a product over a given period. Manufacturing cost calculations have evolved from high component of labor costs to high component of overhead costs (Abbasi et al., 2016). The distribution cost is the cost of physically distributing the product. Some papers also use the term logistics cost that also concerns the cost of physically distributing the product (Ancarani et al., 2015; Tate et al., 2014). The increase in distribution costs is due to higher transportation costs in global supply chains (Tate et al., 2014; Wu et al., 2014). The administration cost is the cost of running an organization. The increase in administration cost is due to higher costs of maintaining foreign operations and relationships and excessive paperwork (Fratocchi et al., 2016; Moradlou and Backhouse, 2017). Higher administration costs are associated with "captive" type of reshoring, when ownership is retained (Heikkilä et al., 2018b). The sales and marketing cost include the cost of advertising and marketing-related activities. The increase in sales and marketing cost is due to companies' investment on marketing-related activities in the offshoring country (Pearce, 2014). Also, for marketing-intensive companies, the marketing costs should be taken into consideration to avoid "unpleasant surprises" to managers (Kinkel, 2009).

On the second level, the other costs are divided into switching costs and product redesign costs. Switching costs is the cost of relocating operations (to the home country). High switching costs can prevent reshoring of certain product lines (Gray et al., 2017). Product re-design cost is the cost of redesigning or developing a product. High investments in R&D and re-design is a crucial factor for location decision (Kinkel and Maloca, 2009).

Table 2. Framework of cost factors from reshoring literature

Level 1	Level 2	Level 3	Level 4	Selected references
Total cost	Manufacturing cost	Material cost (direct)		Abbasi (2016); Bals et al. (2016); Engström et al. (2018a); Engström et al. (2018b); Gray et al. (2017)
		Labor cost (direct)		Arlbjørn et al. (2014); Denning (2013); Heikkilä et al. (2018a); Johansson et al. (2018a); Kinkel and Maloca (2009); Yu and Kim (2018)
		Factory cost	Labor cost (indirect)	Stentoft et al. (2016a); Zhai et al. (2016)
			Material cost (indirect)	Gylling et al. (2015); Vanchan et al. (2018)
			Energy cost	Gray et al. (2017); Gray et al. (2013); Srai and Ané (2016); Stentoft et al. (2016c)
			Inventory holding cost	Chen and Hu (2017); Di Mauro et al. (2018); Ocicka (2016); Pearce (2014)
			Quality deficiency cost	Baldassarre and Campo (2015); Bals et al. (2016); Joubioux and Vanpoucke (2016); Kinkel (2012); Tate et al. (2014); Vanchan et al. (2018); Zhai et al. (2016)
			Land cost	Bals et al. (2016); Pearce (2014); Vanchan et al. (2018)
			Facility cost	Denning (2013); Engström et al. (2018a); Foerstl et al. (2016); Robinson and Hsieh (2016); Tate et al. (2014)
			Equipment cost	Fratocchi et al. (2016); Gray et al. (2017); Gylling et al. (2015); Hartman et al. (2017); Heikkila et al. (2018a); Nujen et al. (2018); Stentoft et al. (2016a); Stentoft et al. (2016b)
	Distribution cost	Warehousing cost		Baldassarre and Campo (2015); Gray et al. (2017); Hartman et al. (2017); Ocicka (2016); Yu and Kim (2018)
		Inventory holding cost		Bailey and De Propris (2014a); Bailey and De Propris (2014b); Fratocchi et al. (2016); Gray et al. (2017); Martínez-Mora and Merino (2014); Pal et al. (2018)
		Transportation cost		Benstead et al. (2017); Chen and Hu (2017); Joubioux and Vanpoucke (2016); Wiesmann et al. (2017); Wu and Zhang (2014)
		Customs cost		Barbieri et al. (2018); Benstead et al. (2017); Di Mauro et al. (2018); Gray et al. (2017); Ocicka (2016); Srai and Ané (2016); Tate et al. (2014)
		Order fulfillment cost		Ocicka (2016)
		Stockout cost (lost sales)		Ocicka (2016); Yu and Kim (2018);
		Late deliveries cost		Barbieri et al. (2018); Fratocchi et al. (2016); Yu and Kim (2018)
	Administration cost	Coordination cost		Benstead et al. (2017); Foerstl et al. (2016); Martínez-Mora and Merino (2014); Ocicka (2016); Pal et al. (2018);
		Monitoring cost		Ancarani et al. (2015); Baldassarre and Campo (2015) Benstead et al. (2017); Di Mauro et al. (2018); Foerstl et al. (2016); Fratocchi et al. (2016); Tate et al. (2014)
		Non-compliance cost		Gray et al. (2017); Pal et al. (2018); Vanchan et al. (2018); Wiesmann et al. (2017)
		Legal cost		Grappi et al. (2015);Martínez-Mora and Merino (2014); Stentoft et al. (2016a); Tate et al. (2014)
	Sales and marketing cost			Kinkel and Maloca (2009); Pearce (2014)
Other costs (project costs)	Switching cost			Ellram et al. (2013); Engström et al. (2018a); Engström et al. (2018b); Uluskan et al. (2017)
	Product redesign cost			Kinkel and Maloca (2009); Nujen et al. (2018); Pearce (2014); Vanchan et al. (2018)

Level 3 costs

On the third level, the manufacturing costs are further divided into direct material cost, direct labor cost and factory cost. The direct material cost are those material costs that are

directly involved in making the product such as raw material costs or component prices (Engström et al., 2018; Fratocchi et al., 2016; Tate et al., 2014). The direct labor cost are those labor costs that are directly involved in making the product. Majority of reshoring cases have been a counter move to increasing labor costs (Zhai et al., 2016). Labor costs is a significant reason for reshoring decisions (Johansson and Olhager, 2018a; 2018b). The factory costs are those costs that are required to run the factory. They represent fixed costs or manufacturing overheads (Vanchan et al., 2018). These are further broken down under level 4.

On the third level, the distribution costs are further divided into warehousing cost, inventory holding cost in distribution centers, transportation cost, customs cost, order fulfillment cost, stockout cost (lost sales) and late deliveries cost. Warehousing cost is the cost of handling the product in the warehouse, including packaging prior to shipping. Higher than expected warehousing costs have reduced the benefits of offshoring (Gray et al., 2017). Inventory holding cost is the cost of holding the inventory at the distribution center. This increases when capital is tied up on slow steaming boats (Tate et al., 2014). Transportation cost is the cost of physical movement of goods. Increasing transportation cost have reduced the benefits of offshoring (Barbieri et al., 2018; Wiesmann et al., 2017). Customs cost is the cost of customs and duties that are paid for export or import. Changes in customs costs can reduce the attractiveness of offshoring (Benstead et al., 2017). Order fulfillment cost is the cost of fulfilling an order. Higher cost of fulfilling order can reduce the attractiveness of the offshoring market (Ocicka, 2016). Stockout costs are the cost when the lost sales due to out-of-stock products. Late deliveries cost is the penalty that is paid for late deliveries. Long customer lead times can increase the stockouts, late deliveries and lost sales (Fratocchi et al., 2016; Yu and Kim, 2018).

On the third level, the administration costs are further divided into coordination cost, monitoring cost, non-compliance cost, and legal cost. Coordination costs are the costs of coordinating different locations and this cost increases when manufacturing is located in different regions (Ancarani et al., 2015). Monitoring costs is the cost of monitoring the operations of business. Monitoring costs can also include the cost of auditing operations and personnel (Gray et al., 2017; Robinson and Hseih, 2016). Another part of administration cost is the cost of non-compliance. This cost is occurred when a firm fails to comply with local regulations. The last part of administration cost in the framework is legal costs. In one of the case companies, complicated and bureaucratic legal system increased costs of legal counselling and tax lawyers (Engström et al., 2018).

Level 4 costs

On the fourth level, the factory costs are divided into indirect labor cost, indirect material cost, energy cost, inventory holding cost at the factory, quality deficiency cost, land cost, facility cost, equipment cost. The indirect labor costs are those labor costs that are not directly involved in making the product. These costs include the salaries of management and supervision of the factory (Vanchan et al., 2018). The indirect material costs are those cost that are not directly go into the product. These costs are incurred in maintaining machines and buildings (Vanchan et al., 2018). The energy cost is the cost of energy at a location. Cheaper energy costs have caused reshoring in the USA, in contrast to UK where the energy costs are much expensive (Bailey and De Propris, 2014a). The inventory holding cost is the cost of holding the inventory at the factory. Streamlining the flow in production processes can reduce the cost of holding inventory at the factory (Bals et al., 2016). The quality monitoring cost is the cost of controlling the quality through inspection. High quality monitoring costs were incurred in order to keep the quality standards in the offshore location (Bals et al., 2016; Gray et al., 2017). The land, facility

and equipment costs are the cost of land, facility and equipment at the manufacturing location respectively. In a Swedish case study on reshoring, investments had to be made in new facility to reshore a product (Engström et al., 2018).

Concluding discussion

Many location decisions have been taken without a complete view on the cost factors, leading to "hidden costs" in the supply chains. This is also supported by Ellram et al., (2013, p. 19) that "*developing a comprehensive risk assessment analysis and a total cost of doing business in a particular region will help organizations make the appropriate decision*". The focus of this study has been to uncover the cost factors that need to be considered in manufacturing reshoring decisions. In total, 29 cost factors were found in the systematic literature review with sample size that is larger than previous literature reviews on reshoring (e.g. Barbieri et al., 2018). The cost factors were structured at four hierarchical levels. The structure of the cost factors provides a holistic view on the costs that need to be considered in manufacturing reshoring decisions. This can serve as a checklist and help managers identify those cost factors that influence the reshoring decision. Moreover, understanding the costing structure can provide insights to create decision models. It should be noted that reshoring decisions are influenced by strategic factors as well and basing these decisions purely on cost is not recommended. However, understanding the hierarchical levels of costs can help create more complete decisions models.

For future research, the decision-making process is still of high priority (Bals et al., 2016; Barbieri et al., 2018). Recently, intelligent techniques of decision making have been demonstrated in the reshoring domain (Hilletofth et al., 2019). Hence, it would be useful to implement such intelligent techniques to model reshoring decisions using the costing framework. Also, it would be interesting to perform empirical studies that focuses on the framework of cost factors of reshoring, particularly in-depth case studies. Another avenue of future research would be to study the extent to which the cost factors impact on the reshoring decision. Within the framework, it would be meaningful to explore the sales and marketing costs and other costs that affect manufacturing reshoring decision.

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* Part of the sample in the literature review. Complete list of the sample is available on request.

Reshoring and firm performance: A longitudinal analysis

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Abstract

The reshoring phenomenon has gained momentum among managers, scholars and policy makers. Literature has mainly focused on reshoring motivations/drivers, locations, and activities. Only a few papers have studied its performance impact and they are characterized by significant limitations. Our study seeks therefore to present the first systematic analysis on the impact of reshoring on operational performance based on balance sheet data. Our analyses show that reshoring does not allow a better profitability, nor an increase in sales or in labour productivity. It seems however to allow an improvement in operating margins thanks to the increase in value per unit.

Keywords: Reshoring, Backshoring, Firm performance

Introduction

In the last decades an increasing number of companies have decided to reshore – i.e., bring back home – their manufacturing activities (Fratocchi et al., 2016). In the US, reshoring has achieved a high level of popularity since the jobs created in 2016 by reshoring and foreign direct invest surpassed those exported by offshoring (Reshoring Initiative, 2016). The reshoring phenomenon has gained momentum also among policy makers and scholars (Barbieri et al., 2018).

Despite the number of open questions that arise about the performance impact of reshoring, only few papers have dealt with this issue (Brandon-Jones et al., 2017; Johansson and Olhager; 2018; Stentoft et al., 2018). These studies are however characterized by significant limitations concerning both the performance measures considered and the methodological approaches (see "background and research framework" section for further details). As a consequence, the impact of reshoring on firm performance is far from clear.

Based on secondary data from the Bureau van Dijk's Orbis database, which contains balance sheet information on over 250 million companies worldwide, and the Uni-CLUB MoRe back-reshoring database, which contains data about more than 700 reshoring cases drawn from a

wide range of sources (e.g., newspapers/magazines and white papers from consulting firms), this paper tries to fill the above-mentioned gap.
Our evidences suggest that reshoring does not allow a better profitability of assets, an increase in sales, or even an increase in labour productivity. On the contrary, reshoring seems to allow an improvement in operating margins thanks to the increase in value per unit. Therefore, the reshoring choices analysed in this study seem to support consolidation or repositioning strategies in market segments associated with premium prices. The qualitative analyses carried out on a sample of some cases seems to confirm this interpretation.

Background and research framework

An increasing number of papers have focused on the reshoring topic. As pointed out by some recent systematic literature reviews (Barbieri et al., 2018; Wiesmann et al., 2017), reshoring literature has mainly focused on reshoring motivations/drivers, locations, and activities (Barbieri et al., 2018). Reshoring has been seen both as a correction of a managerial mistake (Gray et al., 2013; Kinkel and Maloca, 2009) and as a strategic decision to face exogenous or endogenous changes (Fratocchi et al., 2015; Gylling et al., 2015; Martínez-Mora and Merino, 2014). A wide set of specific motivations have been highlighted and classified in various ways (e.g., Foerstl et al., 2016; Stentoft et al., 2016; Fratocchi et al., 2016; Srai and Anè, 2016). Stentoft et al. (2016) highlighted for instance the following categories of reshoring motivations: cost, quality, time and flexibility, access to skills and knowledge, risks, market and other factors. Similarly, Wiesmann et al. (2017) identified five categories of reshoring drivers and barriers: global competitive dynamics, host country, home country, supply chain (cultural or physical distance), and firm-specific motivations. Fratocchi et al. (2016) proposed instead a theory-driven classification framework based on two dimensions: the firm's strategic goal (increasing customer perceived value vs. improving cost-efficiency) and the level of analysis (internal to the company vs. related to the external environment). Reshoring appears therefore aimed at improving one or more internal performance, such as costs, delivery times and reliability, quality. However, is such an internal performance improvement achieved through reshoring? And does it positively affect economic-financial performance (e.g., sales, productivity, profitability)?
There are only a few papers on the impact of reshoring on firm performance. Brandon-Jones et al. (2017) analysed the impact of 37 reshoring decisions announced by US firms on shareholder wealth. Johansson and Olhager (2018) shed light on the relationship between offshoring and reshoring motivations and the performance outcomes. Stentoft et al. (2018) showed that reshoring has a negative effect on delivery lead time and no effect on cost performance and cost accounting capabilities. These studies are however characterized by a set of significant limitations. The study of Brandon-Jones et al. (2017) is based on a small sample and consider a specific performance measure (stock returns) which might not reflect the economic and financial performance of the firm; the other two papers are instead focused on a single country (i.e., Sweden and Denmark) and use perceptual performance measures. The impact of reshoring on firm performance is therefore far from clear.
Based on previous reshoring literature we develop below a set of hypotheses on the impact of reshoring on various economic-financial performances.
Previous reshoring research (e.g., Fratocchi et al., 2016, Kinkel et al., 2014) showed that most of reshoring cases are from South-East Asia and Eastern Europe to Western Europe and USA. Labour productivity is in general significantly higher in the Western World. Evidence of this can be found in macro-economic data. Even if productivity of Chinese workers has increased in the last years (+9.5%/year on average in 2007-2012, +7.3%/year in 2012-2013 and +7% in 2014, Nofri, 2015), in 2015 each employed worker in China generated only 19% of the amount of GDP produced by an American worker (Schuman, 2017). We can therefore hypothesize that:

H1: There is a significant positive relationship between reshoring and labor productivity.
Various reshoring motivations – such as "made-in" effect, improving delivery reliability, improving quality – could have a positive effect on the relationship with customers and more in general with the brand image (Di Mauro et al., 2018). We can therefore hypothesize that:
H2: There is a significant positive relationship between reshoring and sales growth.
On the one hand, previous studies included among possible reshoring motivations the labour costs (which raised significantly in emerging countries in the last years), the logistic costs, and the total cost of ownerships. On the other hand, some studies argued that reshoring could allow companies to charge premium prices thanks to the made-in effect or the better brand image. We can therefore hypothesize that:
H3: There is a significant positive relationship between reshoring and Gross Profit percentage.
Finally, considering the potential positive effect of reshoring both on sales and on costs, we can hypothesise that:
H3: There is a positive relationship between SA8000 adoption and profitability.

Methodology and data

This study is based on secondary data from the Bureau van Dijk's Orbis database, which contains balance sheet information on over 250 million companies worldwide, and the Uni-CLUB MoRe back-reshoring database, which contains data about more than 700 reshoring cases drawn from a wide range of sources (e.g., newspapers/magazines and white papers from consulting firms). From the matching of the two databases, we obtained a sample of 160 firms, whose year of reshoring, country of origin and Standard Industry Classification (SIC) code is showed in Table 1 and 2.

Table 1 – Classification of the sample according to the reshoring year and country

Number of observations per country

Continent	Country	Number of firms	Percentage
EUROPE	Austria	2	1.3%
	Belgium	2	1.3%
	Finland	3	1.9%
	Denmark	1	0.6%
	Sweden	7	4.4%
	Spain	2	1.3%
	France	12	7.5%
	Germany	12	7.5%
	Italy	41	25.6%
	Luxembourg	1	0.6%
	Netherlands	3	1.9%
	Norway	2	1.3%
	Poland	1	0.6%
	Slovenia	3	1.9%
	Switzerland	1	0.6%
	UK	20	12.5%
ASIA	South Korea	2	1.3%
	India	1	0.6%
	China	1	0.6%
	Japan	3	1.9%
AMERICA	USA	39	24.4%
AFRICA	Egypt	1	0.6%

Number of observations per year of reshoring

Year	Number of firms	Percentage
2006	1	0.6%
2007	2	1.3%
2008	13	8.1%
2009	33	20.6%
2010	13	8.1%
2011	13	8.1%
2012	24	15.0%
2013	29	18.1%
2014	25	15.6%
2015	7	4.4%

Table 2 – Classification of the sample according to the industry sector

SI	Industry name	Num	Percent
20	Food and kindred products	7	4.4%
22	Textile mill products	3	1.9%
23	Apparel and other finished products made from fabrics and similar materials	5	3.1%
24	Lumber and wood products, except furniture	3	1.9%
25	Furniture and fixtures	4	2.5%
26	Paper and allied products	1	0.6%
28	Chemicals and allied products	6	3.8%
30	Rubber and miscellaneous plastics products	12	7.5%
31	Leather and leather products	2	1.3%
32	Stone, clay, glass and concrete products	2	1.3%
33	Primary metal industries	4	2.5%
34	Fabricated metal products, except machinery and transportation equipment	2	1.3%
35	Industrial and commercial machinery and computer equipment	19	11.9%
36	Electronic and other electrical equipment and components, except computer	30	18.8%
37	Transportation equipment	30	18.8%
38	Measuring, analyzing and controlling instruments; photographic, medical and	8	5.0%
39	Miscellaneous manufacturing industries	4	2.5%
50	Wholesale trade, durable goods	4	2.5%
51	Wholesale trade, nondurable goods	4	2.5%
55	Automotive dealers and gasoline service stations	1	0.6%
56	Apparel and accessory stores	3	1.9%
58	Eating and drinking places	1	0.6%
59	Miscellaneous retail	3	1.9%
73	Business services	2	1.3%

We employed the event-study methodology to detect abnormal performances between the 160 reshoring firms and a wide set of control firms, following the procedure proposed by Barber and Lyon (1996).

The event study is a statistical methodology used to assess the impact of an event on the firm, and specifically, it evaluates if there has been an abnormal performance following the event by analyzing the performance that there would have been without the event and comparing it to the performance that has actually been measured. To calculate the abnormal performance, we use the formula:

$$AP_{(t+b)} = PS_{(t+b)} - EP_{(t+b)}$$
$$EP_{(t+b)} = PS_{(t+a)} + \left(PC_{(t+b)} - PC_{(t+a)}\right)$$

Where AP is the Abnormal Performance, EP is the Expected Performance, PS is the actual performance of the sample firm, and PC is the median performance of the control firms. The subscripts regard the time period considered. The t is the reshoring year, b is the ending year of comparison (which can be -1, 0, 1, 2, 3) and a is the starting year of comparison (which can be -2, -1, 0, 1, 2).

The statistical analyses used to determine if the abnormal performance is significantly different from zero are the t-test (parametric), which is well specified for symmetric and normal distributed data and the Wilcoxon Signed Rank test (non-parametric), which has less stringent requirements. To check the validity of the p values obtained, the Benjamini-Hochberg procedure has been employed with a false discovery rate of 10% and 5%. In this way, we should

get rid of type I error in null hypothesis testing, which occurs when there is a rejection of the null hypothesis when the null hypothesis is true.
The following steps were adopted to find the sample of control firms to calculate the expected and abnormal performance. The procedure consisted in finding, for each of the 160 firms in the sample, other firms which are similar in terms of size (total assets in the last available year), industry and performance measure in the year considered, that is the reshoring year (t) minus one, which we considered the pre-event year. As Barber and Lyon (1996) state, tests statistics are well specified only when sample firms are matched to control firms with similar pre-event performance. In fact, performance matching adjusts for the mean reversion in accounting data that reflects a transitory component of operating income, component which can confound analyses. More specifically, matching the firm's performance will allow researchers to avoid evaluation mistakes that derive from wrong conclusions about the performance development. In fact, if a firm performs very well or very poorly in a certain period of time, it is supposed that its performance will stabilize to a more "normal" level after a while. The steps we followed to select the firms of the control sample to evaluate the expected performance are taken from the Barber and Lyon procedure and are:

- Step 1: find companies with at least two-digits SIC code, 50-200% of firms' total assets and 90-110% of the considered performance in the year t-1.
- Step 2: If no not-reshored companies were matched in step 1, use at least a one-digit SIC code, 50-200% of firms' total assets and 90-110% of the considered performance in the year t-1.
- Step 3: If no not-reshored companies were matched in step 2, use 50-200% of firms' total assets and 90-110% of the considered performance in the year t-1.

Once these companies were found, companies that ever did reshoring were removed from the control sample and then the median of the performance considered was calculated in the time window considered for the event study, which is from year t-1 to year t+3, where t is the reshoring year.
In selecting the control firms, we deleted firms that had not available data from year t-1 to t+2, with the exception of companies that did reshoring in year 2015, for which we did not apply this rule for the year t+2 (2017) and for companies that did reshoring in year 2014, for which we did not apply the rule in the year t+3 (2017), because of the scarcity of performance information available in that year.
We used the main performance measures adopted by previous event studies (e.g., Orzes et al., 2017; De Jong et al., 2014; Lo et al., 2014): ROA (EBIT/Total Assets), Gross Profit Margin ([Operating Revenues – Cost of Goods Sold]/Operating Revenues), labour productivity (EBIT/Number of Employees), and the relative sales growth ([SALESt – SALESt-1]/SALESt-1). We then defined the event period as the year in which the reshoring decision was implemented or announced (year t) and identified for each reshoring firm a portfolio of non-reshoring control firms using the following criteria: (1) the same two-digit SIC code; (2) 50-200% of firms' total assets; and (3) 90-110% of the considered performance in year t-1.
We finally estimated the abnormal changes in performances of the sampled firms in comparison with the control firms and tested whether they differed significantly from zero.

Results

Table 3 shows the descriptive analyses of the sampled firms in the year t-1.

Table 3 – summary statistics of the performance of the sample firms in year t-1

Companies that reshored production	Mean	Median	St. deviation	Min	Max
ROA	5.97	5.92	8.05	-28.04	26.28
Gross profit percentage	36.04	31.69	17.39	9.64	79.47
Sales growth	3.47	2.55	19.16	-36.88	79.77
Labor productivity	23391.76	14386.24	35592.29	-87914.11	153214.29
Inventory turnover	5.32	4.61	3.98	0.84	31.98

Tables 4a-4d presents the results of the event study, dintinguishing three main time periods: *pre*, i.e., before reshoring (t-1 to t); *post*, i.e., after reshoring (t to t+3); and *full* (t-1 to t+3), and a *control* period (t-2 to t-1) to tackle the endogeneity issue.

Our analyses show show a general decrease of ***labor productivity*** in the years after the reshoring decision (Table 4a). There is in particular a significant negative abnormal performance in the full period (from year t-1 to t+3). The result is significant also after the Benjamini-Hochberg correction for the Wilcoxon Signed-Rank test with a False Discovery Rate of 10%. As a consequence, hypothesis H1 should be rejected.

We find then no evidence of increase (nor of decrease) of ***sales*** in the periods considered (Table 4b). Hypothesis H2 should therefore be rejected.

As far as ***Gross Profit percentage*** is concerned, we find an increase in the post (from year t to t+3) and especially in the full period (from year t-1 to year t+3) (Table 4c). The test of the full period is significant also after the Benjamini-Hochberg correction with a false discovery rate of 10% for the t test and the WSR test and of 5% for the t test. Given these results, H3 can be accepted since there is a significant positive relationship between reshoring and Gross profit percentage.

Finally, there is a slight significance of a decrease in ROA (AP mean of -1.076) in the year prior to reshoring (from t-1 to t) (Table 4d). This result is anyway not significant if we apply the Benjamini-Hochberg procedure with a false discovery rate of 10% or 5%. Hypothesis H4 should therefore be rejected.

In conclusion, H1, H2, and H4 should be rejected since reshoring does not seem to lead to improvement of labour productivity, sales performances, or profitability. H2 can instead be accepted since we found a positive effect of reshoring on Gross Profit percentage.

Table 4a – Mean and median abnormal performance of labor productivity

	Period	N	AP mean	AP median	p value t test	p value WSR	Normality	p value t test FDR10%	p value t test FDR5%	p value WSR FDR10%	p value WSR FDR5%
PRE	t-1 to t	121	-1892.800	-663.422	0.415	0.241	no	0.075	0.038	0.050	0.025
POST	t to t+3	93	-704.133	-2102.445	0.857	0.294	no	0.100	0.050	0.100	0.050
FULL	**t-1 to t+3**	**95**	**-3578.342**	**-5586.914**	**0.279**	**0.021****	no	0.050	0.025	**0.025***	0.013
CONTROL	t-2 to t-1	106	3534.383	614.002	0.162	0.277	no	0.025	0.013	0.075	0.038

Table 4b – Mean and median abnormal performance of sales growth

	Period	N	AP mean	AP median	p value t test	p value WSR	Normality	p value t test FDR10%	p value t test FDR5%	p value WSR FDR10%	p value WSR FDR5%
PRE	t-1 to t	122	-1.381	-3.203	0.420	0.166	no	0.050	0.025	0.025	0.013
POST	t to t+3	85	1.436	3.272	0.586	0.297	no	0.075	0.038	0.075	0.038
FULL	t-1 to t+3	87	-0.249	-1.438	0.865	0.478	no	0.100	0.050	0.100	0.050
CONTROL	t-2 to t-1	88	2.144	1.829	0.342	0.178	yes	0.025	0.013	0.050	0.025

Table 4c – Mean and median abnormal performance of gross profit percentage

	Period	N	AP mean	AP median	p value t test	p value WSR	Normality	p value t test FDR10%	p value t test FDR5%	p value WSR FDR10%	p value WSR FDR5%
PRE	t-1 to t	99	0.280	-0.300	0.596	0.771	no	0.100	0.050	0.10	0.050
POST	**t to t+3**	**75**	**1.804**	**0.459**	**0.056***	**0.161**	no	0.050	0.025	0.05	0.025
FULL	**t-1 to t+3**	**75**	**2.260**	**1.089**	**0.010****	**0.023****	no	**0.025***	**0.013****	**0.025***	0.013
CONTROL	t-2 to t-1	86	-0.781	-0.187	0.252	0.521	no	0.075	0.038	0.08	0.038

Table 4d – Mean and median abnormal performance of ROA

	Period	N	AP mean	AP median	p value t test	p value WSR	Normality	p value t test FDR10%	p value t test FDR5%	p value WSR FDR10%	p value WSR FDR5%
PRE	**t-1 to t**	**142**	**-1.076**	**0.089**	**0.053***	**0.142**	no	0.025	0.013	0.025	0.013
POST	t to t+3	107	0.358	-0.037	0.666	0.618	no	0.100	0.050	0.100	0.050
FULL	t-1 to t+3	107	-0.654	-0.320	0.365	0.529	no	0.075	0.038	0.075	0.038
CONTROL	t-2 to t-1	120	0.530	0.246	0.237	0.525	no	0.050	0.025	0.050	0.025

*p<0.1, * p<0.05, ** p<0.001. The p-values shown are those for the one-sided test of the null hypothesis of no abnormal performance, using a t-test and a Wilcoxon signed rank test, respectively. Given that the hypothesis of normally distributed abnormal performance was rejected in most cases by the Shapiro-Wilk test at the 1% level, the t test is not very appropriate; but reported for the sake of completeness.
The p values are corrected with the Benjamini-Hochberg procedure with a False Discovery Rate of 10% and of 5%.

Discussion

Labor productivity results show a significant decrease in the full period, against hypothesis 1. This may be due to the decreased EBIT or to an increase in the number of employees, which may result from the relocation of activities back home. In fact, when relocating with an insourcing mode, firms might have to hire new employees, and these should be trained for a certain period to reach the desired level of productivity. Another reason for this result could be that labor productivity in Asian countries continued to improve in the last years, reaching closer levels to the Americans and Europeans. Furthermore, the availability of skilled labor may have been deteriorating (Porter and Rivkin, 2012).

We then do not find any effect of reshoring on **Sales Growth**. This is quite surprising considering that many reshoring motivations highlighted by previous reshoring literature are potentially related to sales, such as made-in effect, quality, and delivery reliability. In order to be better understood, this result should be considered together with the other performances.

Our analyses show a positive effect of reshoring on **Gross Profit Margin**, for which we accept hypothesis H3. Gross Profit Margin, which is equal to *(Operating Revenues – Cost of Goods Sold)/ Operating Revenues*, can be expressed as follows: *([unit price*sales volumes – unit cost*sales volumes])/ (unit price*sales volumes).* Considering that *unit price * sales volumes*

does not change, since there is no difference in the relative sales growth, we can argue that increase in Profit Margin is due to a reduction in *unit cost*sales volumes*, which may be due either to (1) a reduction in *unit cost* or to (2) a reduction in *sales volumes* (associated with an increase in *unit price* since *unit price*sales volumes* should be constant). While hypothesis 1 seemed to be less likely than hypothesis 2, since usually companies reshore to higher-cost countries (Fratocchi et al., 2016), we qualitatively analysed a set of cases from the dataset (by reading the case descriptions/narratives and/or the media sources) to better explain our results. In many cases, we noticed that reshoring seems associated with a strategic choice of repositioning towards high-end segments, characterized by premium prices.
Finally, the decreased **ROA** in the years before the reshoring may be due to an increase of the total assets in view of this transfer. In fact, when firms relocate production at home from an outside location, they could invest on facilities or machinery for production. This depends from the relocation mode that the ownership re-rentry mode (outsourcing vs insourcing) and by the volumes. In the sample, the proportion of firms that did reshoring with an insourcing mode is 83,7% (134/160 firms). This considerable amount could explain this ROA trend. The big incidence of firms that employ reshoring and insourcing together is also confirmed by the research of Bals et al. (2016). As we stated in the hypothesis, if the majority of firms would have employed the outsourcing reshoring mode, probably the impact on ROA would have been demonstrated to be more significative. Another reason for the lack of significant results may be that the portion of production reshored is too small to highlight a significative impact.

Limitations
The study presents some limitations that should be taken into account.
First of all, we have no information about the percentage of reshored activities on the total. Reshoring regards sometimes just a limited part of the production in a company. In the case of partial reshoring, we expect that the initiative cannot have a significant impact on performances.
Another limitation of the research regards the sample composition: it mainly constists of large companies (80,6% of the sample). We expect that the reshoring impact on the latter ones could be much more significative and coud affect the results of this kind of mixed sample.
Another limitation concerns possible joint effects: the sampled firms could have other projects implemented when reshoring (for example renovations, collaborations, FDI decisions etc.) and this could have an influence on the performance. Moreover, a relevant part of the sampled firms did reshoring in the years from 2006 to 2013, which is the period of the economic crisis. This event could influence the results since that was a period of depression and decline. We don't consider these aspects and therefore the results obtained may not be directly linked only to reshoring.

Directions for future research
An interesting development could be the analysis of a new sample of firms in more recent years in the post-crisis. It could be interesting to estimate the impact on performances of the tax reform of the President Trump has come into force and that the government incentives are more pronounced. Future analyses should also be more focused on assessing some categories, for example taking into consideration only small and medium firms or only large firms, e.g. comparing US or Europe. Another future investigation to be done is to understand if there has been an impact on the costs and, to be more specific, a reduction in the cost of goods sold. In our analysis, in fact, this result is not very clear and therefore the employment of more efficient measures to assess the impact on performance, such as the evaluation of the voice of the balance sheet "cost of goods sold", could be employed. However, to have more reliable results it is essential that the entity of production reshored is known (e.g. a single component, the total

production or a percentage of the production), so that a more precise and focused analysis can be made.

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What do we want to know about reshoring? A conceptual framework for case study research

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Abstract

This study aims to develop a framework for reshoring case study research, specifying the aspects encompassing a full case description. The meta-synthesis methodology was applied on a sample of 14 articles including 36 cases of offshoring and subsequent reshoring activities. By focusing on findings by the original authors, the study allowed to build a comprehensive framework to lead future case study research, and accumulate knowledge by using a methodology never applied to this field. In doing so, the article contributes to reshoring research. Furthermore, the study generates practical implications, by condensing all the evidences about reshoring in one single study.

Keywords: Manufacturing relocation, Offshoring, Backshoring, Meta-synthesis

Introduction

Reshoring of manufacturing as a means for international firms to optimize their global manufacturing footprints has gained increasing attention in academia. It is a relatively new research stream that has primarily been studied conceptually. For example, a number of frameworks describing the reshoring process are presented in previous literature. These typically only cover relocation in one direction, i.e. offshoring (Mihalache and Mihalache, 2016) or reshoring (Bals et al., 2016; Benstead et al., 2017; Foerstl et al., 2016), or consider reshoring as one of several possible subsequent relocation alternatives to offshoring (Joubioux and Vanpoucke, 2016). However, it is now widely acknowledged that reshoring cannot be pursued unless there has been previous offshoring (Gray et al., 2013). Accordingly, there is a need to take a broader perspective and study reshoring in relation to the previous offshoring decision in order to understand the complex dynamics behind a firm's internationalization process. Thus, it is timely to develop a reshoring framework that includes all elements needed for a full understanding of the reshoring process. Several case studies have been performed to gain a deeper understanding of why and how location decisions are made. These have made substantial contributions, but there has been little accumulation of the knowledge gained from these studies. This has

important implications for knowledge development, because the rich findings from case studies can reach disparate conclusions, and the knowledge produced tend to remain isolated, stand-alone works. The meta-synthesis methodology has thus been developed with the purpose to aid the evolution of knowledge in management studies, by revisiting the findings of other researchers and discovering rich complexities and insightful nuances that cannot be obtained from individual case studies (Hoon, 2013).

The purpose of this study is thus twofold. Following the suggestion by Benstead et al. (2017), we first aim to develop a framework for reshoring case study research, specifying the aspects encompassing a full case description. Second, we will use the meta-synthesis methodology to analyze existing reshoring case research, with the aim to refine the framework and advance the knowledge within the field. Thus, we review 14 articles with 36 cases of offshoring and subsequent reshoring events. The unit of analysis in this study is the two connected events, i.e. reshoring and previous offshoring, with offshoring being considered as an antecedent to reshoring. The novelty of this research is that we include both offshoring and subsequent reshoring operations in a conceptual framework for reshoring case research. In addition, we conduct a meta-synthesis, which is a methodology that has not yet been applied within this field.

Related literature

Offshoring has been referred to as "the assignment of business activities to locations outside a firm's national borders in order to support existing business operations" (Mihalache and Mihalache, 2016; p. 1105), thus highlighting that the offshoring decision is considered to be a rational choice based on the assumption that a host country provides a comparative advantage with respect to the home country. As such, the offshoring decision is far from being irreversible. As a consequence, a new phenomenon, which entails the reverse movement from the offshore location to the home country, has started to spread in the last decades. Interestingly, both academia and practice have struggled to find the right terminology, as well as to set the boundaries for this phenomenon (Foerstl et al., 2016; Wiesmann et al., 2017). In this paper, we will use the term "reshoring", given that it is the most widespread among recent studies, and we define it as "a voluntary corporate strategy regarding the home country's partial or total re-location of (in-sourced or out-sourced) production to serve the local, regional or global demands" (Fratocchi et al., 2014; p. 56).

As a starting point for this study, we reviewed frameworks from existing literature, summarized in Table 1.

Table 1 – Overview of reshoring frameworks

Source	Framework	Elements included	Relocation directions considered	Applied in empirical research?
Bals et al. (2016)	Reshoring and insourcing decision-making and implementation process	Decision-making and implementation	Reshoring	No
Foerstl et al. (2016)	Reshoring/insourcing drivers-outcome relationship	Drivers; Contingencies; Outcomes	Reshoring	No
Fratocchi et al. (2016)	Motivation for reshoring strategies	Drivers	Reshoring	Di Mauro et al. (2018)
Joubioux and Vanpoucke (2016)	Conceptual model for location decision-making	Decision-making; Drivers	Offshoring; Reshoring	Joubioux and Vanpoucke (2016)
Benstead et al. (2017)	Conceptual framework for the reshoring process	Drivers; Implementation; Contingencies	Reshoring	Benstead et al. (2017); Moore et al. (2018)

In particular, we noticed that the frameworks developed in the reshoring field are relatively recent, given that they started to appear in 2016. Interestingly, they all focused on different and concurrent aspects of reshoring. Bals et al. (2016) developed a framework focused on the reshoring decision-making and implementation process, while Foerstl et al. (2016) presented a framework pinpointing the relationship between drivers and outcomes and the moderating role of contingencies. Fratocchi et al. (2016) developed a theory-based framework of reshoring drivers, dividing them into four quadrants depending on if they are either internal or external and oriented either towards cost efficiency or costumer perceived value. Joubioux and Vanpoucke (2016) developed and empirically refined the only framework encompassing both offshoring and reshoring, thus supporting the relevance of studying the two phenomena together. Finally, Benstead et al. (2017) highlight the relevance of contingencies in their framework, by assuming that both drivers and implementation considerations change according to multiple contingent factors. They develop an empirically refined framework that start to show comprehensiveness towards the main aspects that need to be considered by a reshoring company.

Framework development

In order to guide the research process, we developed an initial conceptual framework by integrating the elements considered in previous literature, see Table 1. Most of the frameworks focus on the decision-making process and the drivers, but the implementation process (Bals et al., 2016; Benstead et al., 2017), contingencies (Benstead et al., 2017; Foerstl et al., 2016) and outcomes (Foerstl et al., 2016) are also acknowledged as important aspects. Thus, we incorporate all identified aspects to provide a complete framework. We give offshoring and reshoring equal importance, in order to understand their relationship and thereby fully understand the reshoring decision. As a starting point, we used the framework developed by Benstead et al. (2017), which we consider to be the most complete and intuitively accessible framework of the reshoring process in existing literature. The framework is depicted in Figure 1.

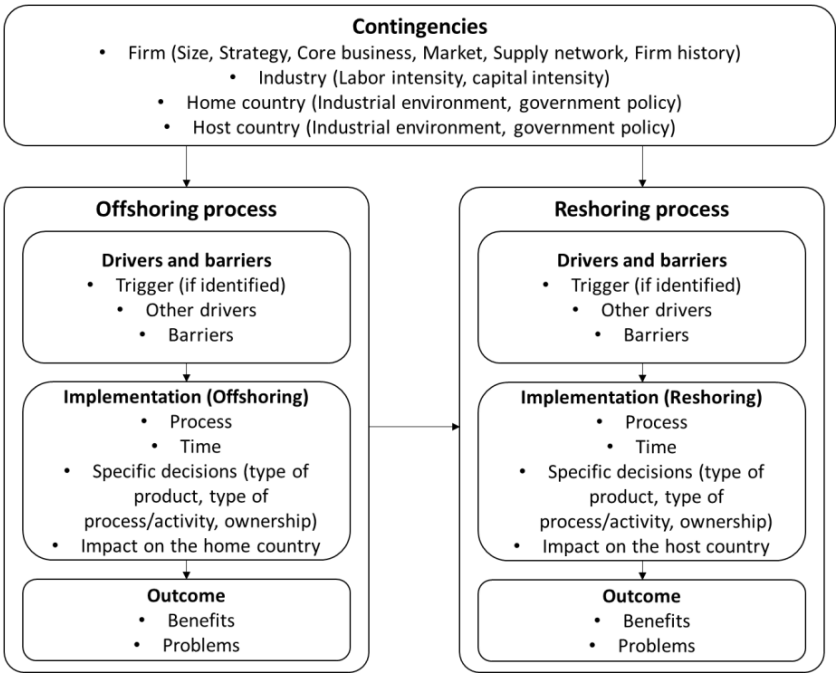

Figure 1 – Initial conceptual framework

Methodology

This study follows the meta-synthesis methodology developed by Hoon (2013), which is an exploratory, inductive methodology aimed to make contributions beyond those presented in original primary qualitative case studies (Hoon, 2013). It has been described as an "analysis of the analyses", as it focuses on the insights and interpretations of the original authors, rather than on the firsthand data about the specific cases.

First, we located the relevant research by developing a search strategy for case study research on the reshoring phenomenon, including descriptions of the preceding offshoring process. We used the search terms "reshoring" and "case study", and related terms (reported in Figure 2), as identified in previous literature. The potentially relevant literature was retrieved from Scopus and Web of Science since we focused on peer-reviewed sources with strong academic contributions that are relevant to synthesize, and not merely providing illustrative examples of manufacturing relocation. The initial sample consisted of 365 articles. Here, we applied a set of clearly specified inclusion and exclusion criteria in order to ensure a high validity of the synthesis. Particularly, we only included articles from peer-reviewed sources that used case-based methodologies, including both offshoring and subsequent reshoring decisions of manufacturing activities in specific. After initial reading and preliminary coding of the articles, a number of articles were excluded since they did not report enough information to be analyzed. Thus, the final synthesis sample includes 14 articles and 36 cases. Figure 2 summarizes the full literature search process. Second, we coded the article content following the suggestions by Durach et al. (2017). Thus, we developed a coding scheme in two levels; (i) first according to the ontological and epistemological study artifacts, and then (ii) following the aspects in our framework. The coding and analysis were done iteratively in two phases, following the recommendations by Hoon (2013). First, we made an initial coding scheme based on the initial framework. After the first round of coding of the articles, we refined the framework based on the articles evidence. Then, we conducted a second round of coding using an updated coding scheme following the final framework. To keep track of the coding process and to support the data analysis we used the software NVivo Plus 12. In order to avoid any potential bias along the process, two researchers were involved in all the phases and results were discussed after each phase with experienced researchers knowledgeable within the field.

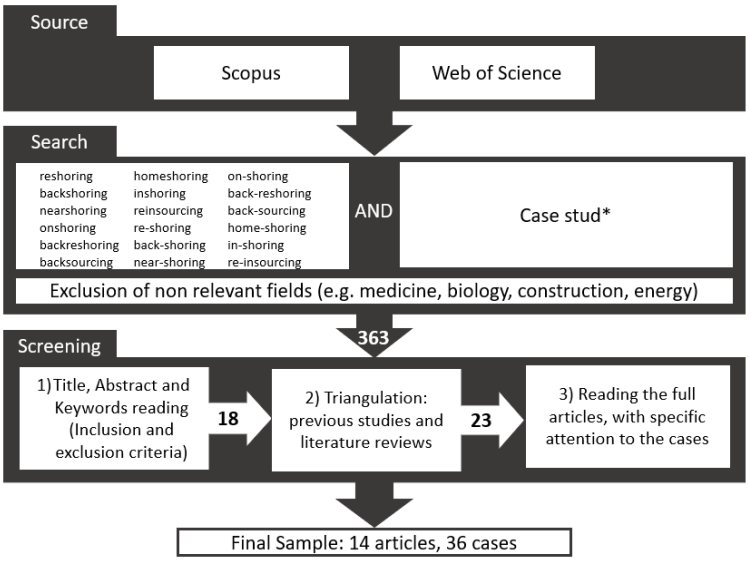

Figure 2 - Literature search process

Results

Case study research on reshoring is in its early stages. All studies found in our literature review could be considered recent, with the first publication in 2014 following an increasing number of publications each year. The articles are mainly published in OM or SCM journals. Concerning geography, the studied articles are mainly conducted from a European perspective, with only one study conducted outside of Europe (i.e. in the US). In terms of host countries, firms have moved activities to multiple locations, mainly to China or India but also Eastern European countries. Table 2 presents the sample articles.

Table 2 - Sample articles

ID	Authors	Journal/Book	Home country	Host country
A	Martínez-Mora and Merino (2014)	Journal of Purchasing and Supply Management	Spain	China
B	Gylling et al. (2015)	International Journal of Production Economics	Finland	Taiwan
C	Joubioux and Vanpoucke (2016)	Operations Management Research	Multiple	Asia
D	Robinson and Hsieh (2016)	Operations Management Research	UK	Asia
E	Stentoft et al. (2016)	Operations Management Research	Denmark	Germany
F	Benstead et al. (2017)	Operations Management Research	UK	China
G	Gray et al. (2017)	Journal of Operations Management	US	Asia
H	Nujen and Halse (2017)	Breaking up the Global Value Chain	Norway	Multiple
I	Baraldi et al. (2018)	Industrial Marketing Management	Italy	Romania
J	Di Mauro et al. (2018)	Journal of Purchasing and Supply Management	Italy	Multiple
K	Engström et al. (2018)	Journal of Global Operations and Strategic Sourcing	Sweden	Multiple
L	Nujen, Halse et al. (2018)	Journal of Manufacturing Technology Management	Norway	Multiple
M	Nujen, Mwesiumo et al. (2018)	Journal of Global Operations and Strategic Sourcing	Norway	Multiple
N	Sayem et al. (2018)	BRQ Business Research Quarterly	Multiple	Multiple

According to Durach et al. (2017), studies within SCM normally use a range of different ontological and epistemological artifacts. Accordingly, we analyzed the sample articles to understand if we needed to apply a specific contextual lens when comparing results. The studied articles do indeed use a plethora of theoretical perspectives. Five studies mention several theories related to reshoring or manufacturing relocation in general, but they do not explicitly take a stand and use either of these theories. Three studies do not mention any theoretical perspective, but only discuss the results of previous offshoring and reshoring studies. Interestingly, the remaining studies use different theoretical perspectives. This indicates that there is no dominant or generally accepted theory for reshoring, which allows us to analyze the results without applying a specific lens. Further, the unit of analysis was not clearly mentioned in as much as 50% of the articles. However, the perceived unit of analysis in these cases was the firm. Thus, in ten studies the unit of analysis was the firm, while the decision was used in two articles, and intra-firm network and external network were studied in one article respectively. The majority of studies (86%) only collected data from one entity in the supply chain and used multiple respondents. In general, data had been collected at the top management level. The majority of the studied articles use the term reshoring, defined as the activity of moving manufacturing activities back to the home country or original location, regardless of ownership mode (alternatively not mentioning the ownership mode). Six studies use different terms, but their definition is similar to reshoring, with just a stronger emphasis on the ownership mode in the sense that some studies mention insourcing specifically (i.e. the activities are re-integrated with the domestic activities internal to the firm). Most studies are multiple case studies, with number of cases varying between two and 14 (the

average number of cases is 5.1). Five studies are single case studies. Two studies are mixed method studies, using both case study methodology and survey data or simulation. As could be expected, the amount of information provided about the cases differ significantly between the papers depending on number of cases included. In general, single case studies are richer and provide more information. The studied firms are operating within a variety of industries, from clothing, textile and shoe manufacturing to construction, automobile, aeronautics and maritime industries. In terms of firm size, all sizes are represented. We can thus conclude that offshoring and reshoring are occurring in a variety of industries and they are not limited to certain firm sizes. Investigating the offshoring and reshoring time span, it is clear that the majority of studies are represented by firms that have operated offshore for more than ten years. Only one study represents a shorter time span, where the offshoring was made during 2007 and 2008 and activities were repatriated in 2010. Quite surprisingly, four out of fourteen studies did not mention the time period for offshoring and reshoring at all.

The second level coding scheme was applied on the analyses of the original authors, i.e. the results, discussion and conclusions sections of the studied articles. First, we analyzed which elements were discussed by the original authors for each article, showing that all the elements in the framework have been discussed by at least one article in our sample. Thus, we conclude that the coding scheme is complete, and the framework sufficiently covers everything that is reported in our studied articles. Second, given that we allowed to code the same sentence in a specific article with multiple codes, we assessed the cross-coding (i.e. how often two codes appeared together). The coding similarity was checked with a Sørensen's similarity metric, as displayed in Figure 3, which clearly highlights which codes are discussed together in our sample articles.

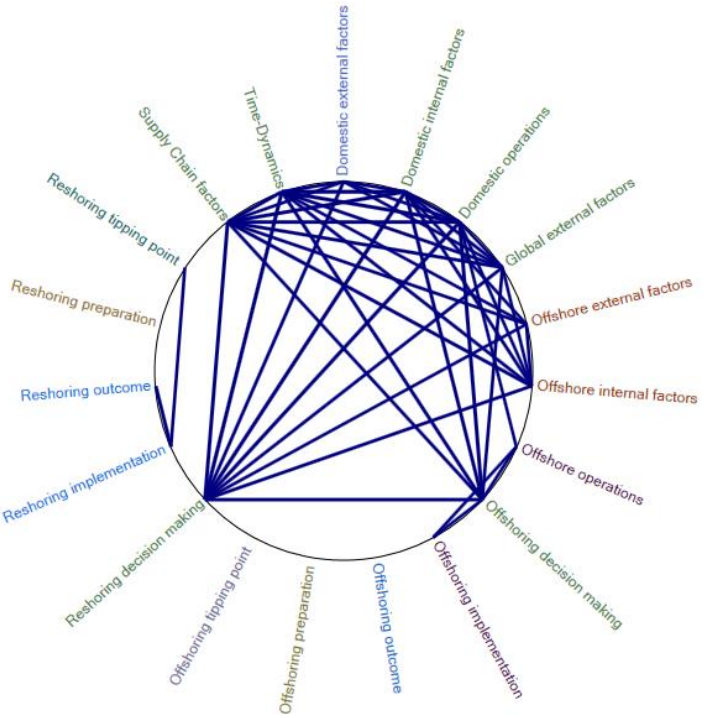

Figure 3 - Codes clustering by coding similarity

The analysis allowed to easily find relationships among the framework elements. The lines indicate associations among codes characterized by Sørensen's coefficient ranging

between 0.8 and 1. In line with the current debate on reshoring, an interesting result is related to the comparison between offshoring and reshoring motivations. From Figure 3, it is easy to notice that the offshoring decision is strongly connected to domestic internal (e.g. firm strategy, efficiency, cost reduction), supply chain (e.g. relationship with suppliers, commercial agreements) and global external factors (e.g. differences in labor costs). The reshoring decision instead is related to a wider set of motivations, given that the similarity is high with all the factors. Another interesting result is the time/dynamic element that is strongly connected to both the offshoring and reshoring decisions, thus confirming that such strategic decisions require a time-consuming process. Moreover, the connections with all the factors indicate how these elements might evolve over time while the companies are making decisions, as well as while they are operating offshore.

Discussion and framework refinement

Based on the results of the coding, we refined the conceptual framework as depicted in Figure 4. The framework is structured in a way that makes it intuitively easy to follow, guiding the data collection for a full case description in case study research. Time, and the dynamic nature of manufacturing relocations, emerged as an important factor in the analysis. Therefore, the horizontal axis in the framework is illustrating time, while the domestic and offshore operations are depicted on the vertical axis. Influencing factors (i.e. drivers and barriers) can be found in the middle and are related to both offshoring and reshoring. Their categorization is inspired by Wiesmann et al. (2017), but the terms are adapted to fit our framework, using the differentiation between internal and external as suggested by Fratocchi et al. (2016). Below, each aspect of the framework is discussed together with illustrations from the studied papers.

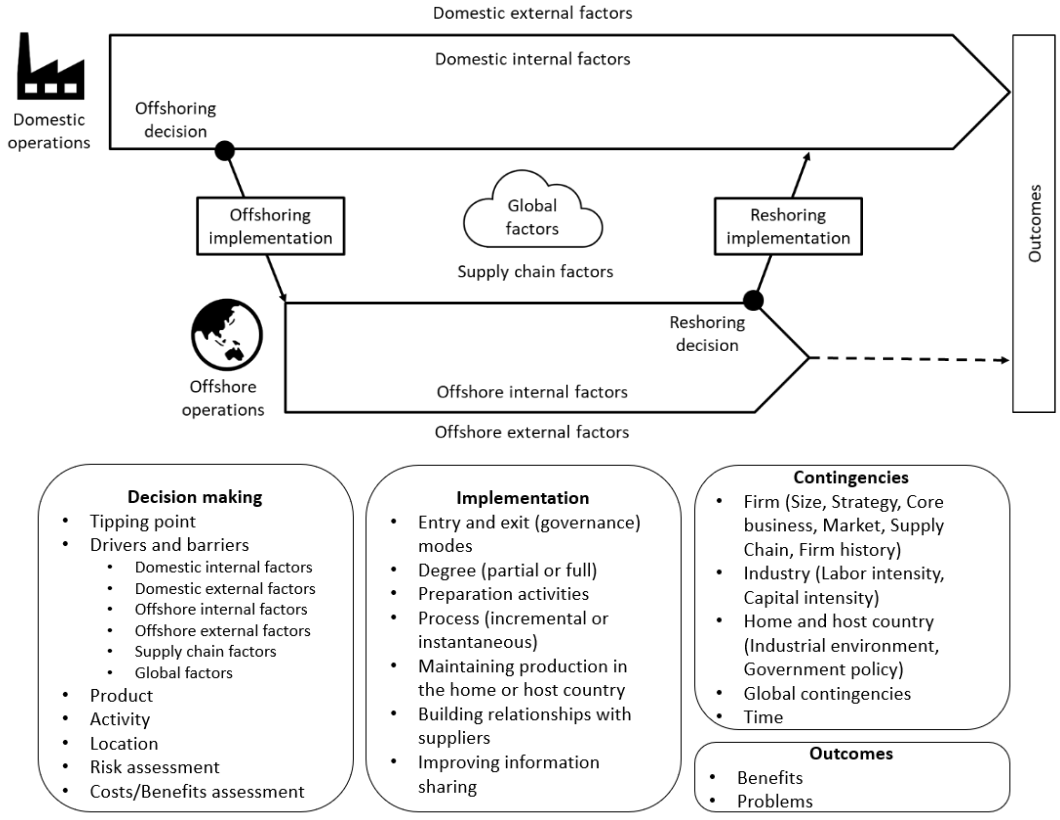

Figure 4 – Refined conceptual framework of the offshoring and reshoring processes

Decision-making

Decision-making is related to aspects included in the decision, such as the specific product and activities to be relocated, the location decision, and the decision-making process, in terms of phases and people involved. It also includes the motivations of the offshoring or reshoring. In the final framework we avoided to refer to these elements as drivers or barriers. Instead, we prefer to use the term factor, thereby acknowledging that they can change over time and turn from drivers to barriers and vice versa. Several of our reviewed papers specifically focused on the reshoring decision-making, and the drivers and barriers in particular (papers A, B, C, F, G, J, and K from Table 2). Only paper G studied the actual decision-making process, from a heuristic decision-making perspective. As part of the decision-making, firms need to make a risk assessment related to the new location. For offshoring, financial risk and quality issues are considered the main threats (paper C). For reshoring, the risk of lost know how and access to knowledge needs to be assessed (both within the firm and in the local network), as this could possibly reduce the possibilities to repatriate manufacturing and thus act as a major barrier for reshoring (papers C, H, and I). As part of the drivers, we specifically distinguish the tipping point, as it emerged as relevant in several of the studied articles. For offshoring, the tipping points mentioned were requirement from a key customer (paper I) and bad profitability at the domestic site (paper B). For reshoring, negative events at the offshore site (e.g. quality issues or IP violation) (papers F and G), diminished cost differentials (paper B and F), free capacity at the domestic site (paper M), and a new business model (paper D) triggered the decision. In all of these cases the firms had more than one reason to relocate manufacturing. But each of these reasons were not important enough to drive the decision. Instead, the issues were building up and the firms had to reach a tipping point when one driver made the current situation unsustainable, leading to the decision to repatriate. As part of the decision-making, we also include the product as well as the specific activities to be relocated. Interestingly, paper J finds that the product seems to be interrelated with the location decision for the offshore activities. The activities that are offshored are mainly considered as non-core (papers A, C, H, and N). For reshoring, activities are fine sliced, which means that firms are reshoring very specific activities that fit within the current activities at home. In fact, reshoring was in many cases made partially.

Implementation

The implementation process of reshoring has been highly unexplored, according to Bals et al. (2016). Of our reviewed articles, only paper F explicitly studied how the reshoring implementation can be operationalized. Thus, we included their aspects such as governance mode, degree of relocation, incremental or instantaneous process, maintaining production at the domestic site, information sharing, and preparation activities. Several studies in our sample reported on aspects related to the implementation process, even if they did not explicitly study it. For example, it becomes evident from the studied papers that offshoring in most cases is implemented gradually (papers B and J). It could even be hard to distinguish the boundaries between the decisions (paper F). On the other hand, some firms are being flexible in terms of "degree of reshoring" (papers B, C, and F), thus still producing the same products as they offshore but in smaller volumes. This strategy provides flexibility and the possibility to shift volumes between locations. In terms of governance mode, offshoring is made in all forms (from outsourcing to joint ventures and fully owned factories). However, paper C found that the preferred governance mode for offshoring was outsourcing, given that it reduces the risks and provides flexibility as well as facilitates repatriation since it is considered relatively easy to end the relationship with a supplier. Reshoring, on the other hand, is primarily made in

a captive mode, i.e. activities are insourced. Interestingly, three papers out of fourteen were specifically studying the organizational readiness for reshoring, concerning for example how to deal with the shortage of skills and competences at the domestic location. Thus, as part of the implementation process, a preparation phase has been identified. This is a new aspect compared to existing frameworks. Surprisingly, also articles with a focus far away from the preparation phase mention details that help in structuring its characteristics. Among others, some of the mentioned elements are the development of in-house training programs (paper B), improving efficiency and freeing space (paper K), and organizational readiness (papers H, L, and M). Naturally, after having found evidence of the reshoring preparation phase, we expected to find information also about the offshoring preparation. Even if this aspect was not widely discussed in the sample articles, some details were mentioned, as the transfer of knowledge, competences and technology from the home to the host country (papers B, C, and J), and the preparation of managers to face offshoring challenges (paper G). The offshoring preparation phase is an absolute novelty of our framework with respect to previous reshoring frameworks.

Outcomes

The offshoring and reshoring outcomes were included as new aspects compared to previous frameworks. The outcomes, categorized as problems or benefits, are highly interesting from a managerial perspective, as they could be used to derive the success factors of manufacturing relocation. But they are also relevant from a decision-making perspective, since the offshoring outcome in many cases act as a driver of reshoring. For example, insufficient quality at the offshore site is an offshoring outcome, but it is also a main driver of reshoring. This is true in survey studies as well as in several of the studied papers (papers C, G, I, J, K, and N). One question that has received quite a lot of attention is whether reshoring is reflecting a strategy change or if it is a correction of a previous offshoring mistake, i.e. if reshoring is a reaction to an offshoring failure (Fratocchi et al., 2016). From the studied papers it is evident that reshoring could be both. For example, paper G concluded that the reshoring decisions could not be completely explained by changes in relative costs between locations. Instead, they say that offshoring was made without completely evaluating risks and performance challenges, and that reshoring thus was a correction of a prior offshoring mistake. Similarly, paper C found that reshoring was implemented after continuous problems with quality at the host country site. On the other hand, in some studies the firms had explicitly stated that offshoring was not a failure (papers A and J). Paper J argue that the offshore duration (over ten years) in combination with the strategy change driving the reshoring decision, indicate that offshoring was not a failure. Interestingly, the outcomes of reshoring were not discussed widely in the studied articles. However, reshoring success or failure could possibly influence the location strategy of a firm, thus influencing the trajectory of its global operations.

Contingency factors

Concerning the contingency factors, from the analyzed articles it was clear that many contingencies play a role in influencing the offshoring and reshoring processes. However, contrarily to what was expected from the initial framework, we found that contingencies were spread all over our final framework, given that every part of the framework can become contingent to the others. A clear example is represented by the debate on the relationship between offshoring and reshoring, many studies claims that reshoring is strongly influenced by the previous offshoring decision, so much that it is worthwhile to study them together (Joubioux and Vanpoucke, 2016). Therefore, the offshoring decision can be considered a contingency factor influencing how the reshoring decision is

managed. As an example, paper J argue that a captive offshoring mode makes firms less inclined to repatriate operations. The spreading of contingencies across the framework reveals the challenge to control for all the contingencies that might affect reshoring.

Conclusions

In this study a comprehensive framework was developed, with the purpose to lead future research in the field of reshoring. This represents a first effort in making research more comparable, thus overcoming the "contingencies control" challenge. Moreover, the research clearly demonstrates that even if articles are grounded on different characterizations of the ontological and epistemological artifacts, it is possible to conduct a successful meta-synthesis. This provides a clear contribution for researchers in the field of reshoring. The implications for managers are connected to the possibility to gain a wider picture over the offshoring and reshoring processes, and to have useful insights about the dynamic nature of such processes as well as of the variety of challenges that previous cases faced in multiple contexts. This study thus provides an important contribution for companies that are relocating manufacturing. The paper does not come without limitations. First, the meta-synthesis method relies on secondary data. Second, the choice to limit the considered papers to peer reviewed sources allowed to control the quality of the studies, but at the same time it might have caused the exclusion of some interesting papers. Future researches, besides trying to overcome the hereby presented limitations, could focus on the application and testing of the proposed framework in real cases, as well as on quantitative data collection.

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What is the future of IT offshoring operations?

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Abstract

In the past decades, IT outsourcing grew steadily and eventually shifted outside the boundaries of the client's base location to low-cost economies (Han and Mithas, 2013). These events led to the commencement of offshore IT outsourcing, popularly known as 'IT offshoring' (Edwards and Sridhar, 2005).

Our research study is exploring academic literature and research models concerning outsourcing from international literature coupled with its validity in the IT offshoring context. As the study progressed, it became evident that although there are frameworks existing for outsourcing practices in various disciplines, only a few studies have been undertaken which are related to the critical factors and its effective management in IT offshoring context (Moe et al., 2014; Kern and Willcocks, 2000; Khan et al., 2012). This research gap indicated that there was substantial scope to contribute in the sphere of the dynamics of IT offshoring within the areas of relationship intensity management.

Keywords: IT offshoring, trust, relationship management

Introduction

Often IT outsourcing is viewed as a valued business performance mechanism to enhance productivity, cut costs and boost competitiveness for organisations (Lacity et al., 2010). The origin of IT outsourcing is linked with the externalisation of functions of facility and operations management support services in the early 1960s, as revealed by Lee et al. (2004). However, the momentum started in 1989 with Kodak's strategy to outsource its IT (Kern and Willcocks, 2000). Consequently, the number of outsourcing engagements increased, and outsourcing was considered as a vital business strategy for managing IT (Loh and Venkatraman, 1992). Here onwards IT outsourcing grew steadily (McCarthy, 2004) and eventually shifted outside the boundaries of the client's base location to low-cost economies. These events led to the commencement of offshore IT outsourcing, popularly known as 'IT offshoring' (Edwards and Sridhar, 2005).

Originally, low-cost back office services were the primary reason for

offshoring, but gradually during the late 1980s, firms outsourced substantial IT activities offshore (Oza et al., 2006). Besides software application development and maintenance activities, the magnitude of diversified IT services offshoring has steadily grown over the last decade and continue to grow further (Krishna et al. 2004). Accordingly, McCarthy (2004) claimed this trend is expected to accelerate as offshore IT services offerings are extending with significant value addition coupled with the establishment of offshore delivery facilities of large client companies globally. These centers have been created in countries such as India, China, Brazil and Russia. The developing countries evolving to undertake IT offshoring activities support such tremendous growth in offshoring.

Offshoring attained an extraordinary momentum following 2001 and continues to accelerate due to economic recession (Khan et al., 2011). Offshore suppliers increasingly upgraded their capabilities and service quality with the diverse experience of implementing complex IT projects and this way rose up the value chain. In recent years there has been the application of state-of-the-art technology, world-class infrastructure and high-quality technical manpower to cater to clients' requirements (Khan et al., 2012). India and China are the major players in the recent years in executing a substantial number of outsourced contracts offshore. Some major offshore IT service providers in India are TCS (Tata Consultancy Services), HCL Technologies, Infosys and Wipro (Chou and Chou, 2011).

With such extraordinary progression in the volume of IT offshoring services, the proportion of failure is also escalating (Foote, 2004; Moe et al., 2014) which is becoming a major anxiety for the client firms engaged in offshoring.Therefore it elicits a need to explore this area of IT offshoring with the objective of building a framework that can contribute towards achieving a potentially improved success rate.

This study is exploring current organization theories and research models concerning outsourcing from international literature coupled with its validity in the IT offshoring context. As the study progressed, it became evident that although there are frameworks existing for outsourcing practices in various disciplines, only a few studies have been undertaken which are related to the critical factors and its effective management in IT offshoring context (Moe et al., 2012; Kern and Willcocks, 2000; Khan et al., 2014; Lacity, 2002). This research gap indicated that there was substantial scope to contribute in the sphere of the dynamics of IT offshoring within the areas of relationship intensity management and thereby this topic of study was selected.

Prior studies on the offshoring client-supplier relationship has been primarily literature reviews, case studies and opinion polls. Dibbern et al. (2004) state that although several prior studies highlight on the importance of relationship management, there is a definite lack of positivist research approach examining this aspect. Also, there are very limited research evidences on the relationship management domain viewed through the lens of social exchange theory, in the general outsourcing literature. Picking up on this gap, we intend to suggest identifying and analysing such factors that may potentially result in favourable outcomes enabling overall engagement success.

Although IT offshoring is an established business practice, the success of such engagements cannot be always predicted. Increasingly complicated nature of activities/tasks being offshored, together with the diverse execution models of offshoring engagements, may require a fresh approach to examine the client-supplier relationship implications on the overall outsourcing success. There have been an

attempt to understand some of these challenges in the operations management of IT offshoring engagements in the literature (Niazi et al., 2013; Lonsdale and Cox, 2000; Kern and Willcocks, 2000) and these studies clearly recognised the need for more focussed research in the relationship management attributes of IT offshoring. Our research study therefore is an attempt to initiate a baseline platform by which the relationship management development factors can be appreciated and recognised by the clients in order to make informed decisions relating to the identified critical factors enabling success.

The first research objective of this study is to suggest measures that can potentially increase the success rate in IT offshoring engagements by studying the interplay between the critical factors influencing the relationship intensity level of the exchange partners and. Secondly this study will identify the relevant critical factors and explore its causes and effects on the relationship intensity significance level.

Research background and purpose

IT outsourcing grew steadily and eventually shifted outside the boundaries of the client's base location to low-cost economies (Han and Mithas, 2013). These events led to the commencement of offshore IT outsourcing, popularly known as 'IT offshoring' (Edwards and Sridhar, 2005).

This study is exploring academic literature and research models concerning outsourcing from international literature coupled with its validity in the IT offshoring context. As the study progressed, it became evident that although there are frameworks existing for outsourcing practices in various disciplines, only a few studies have been undertaken which are related to the critical factors and its effective management in IT offshoring context (Moe et al., 2014; Kern and Willcocks, 2000; Khan et al., 2012). This research gap indicated that there was substantial scope to contribute in the sphere of the dynamics of IT offshoring within the areas of relationship intensity management.

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Research methodology

This study is mainly based on in-depth literature review, several European case studies and interviews of companies who are engaged in offshoring their work to non-European countries. A collective observation of IT offshoring from literature and interviews from IT offshoring user company officials helped identifying the

critical factors behind IT offshoring and highlighted specific challenges in their engagement success with IT offshoring operations.

The positivist perspective of research was followed in this study. Sekaran's (2000) suggested certain steps of the research process which were adopted. These include, a systematic literature review, analysis, and the unbiased role of the researcher(s). The study setting is realistic, unit of analysis is the individual outsourcing client firm(s), and the time frame is cross-sectional.

All the critical factors identified are adapted from validated studies in the literature. Thereafter a preliminary assessment of these critical factors was carried out by industry practitioners of IT offshoring to further validate the context of the relationships among them (the critical factors). Clients in Europe participating in IT offshoring being the target population, the information collection was difficult. As the unit of analysis being individual client firm, it was rather tedious to get the interview response from senior management authorised to participate in such research studies. In the interviews, the senior management respondents had undertaken the role of authorised representative of firms and furnished information as a consolidated organisational experiences rather than personal attitudes and perception.

Literature review

By outsourcing of non-core activities, it reduces the effort required to manage peripheral tasks, except for the efforts needed to manage the supplier. This may allow management the opportunity to focus on the important business functions (Kakabadse and Kakabadse, 2000; Jennings, 2002; McIvor, 2000). Further, Kakabadse and Kakabadse (2005) exposed that there is a need for a greater focus on the core competency area in order to remain competitive in the market, based on interviews with 50 CEOs and findings from 747 survey responses. However, in a fast-changing economy the definition of non-core and core must be revisited on a continuous basis, as per McIvor (2000).

Cost effectiveness

There are alternative ways by which cost reductions can be achieved. It can be through an improved efficiency due to the application of sophisticated technology or processes and/or through the savings of manpower costs. Cost reduction in manpower costs is based on the presumption that a supplier can provide a specified service more cost-effectively due to its lower operating costs in the offshore location and access to economical manpower (Kakabadse and Kakabadse, 2000; McIvor, 2000). The offshore suppliers can provide more cost-effective services to their clients also due to having economies of scale and specialization in certain type of services contributing to increased productivity (Abraham and Taylor, 1996).

Capitalise on supplier innovation and investment

Rapid technological change in the market is encouraging firms to offshore services based on the specialization and availability of leading-edge skills with the supplier firm (Henley, 2006). Quinn and Hilmer (1994) recommends, collaboration with suppliers can provide access to high-quality artefacts and very efficient services without the required level of proficiency, investment in human capital, processes or information technology and infrastructure.

Enhanced flexibility

In order to stay competitive in the market the client firms leverage on latest

technology competence of the supplier firms coupled with the scalability features available in the offshore outsourcing engagements. Therefore, offshoring is proved to be a beneficial mechanism in the long run, through which the clients can draw these added benefits besides getting their work done at a lower cost (Deavers, 1997). Besides this, offshoring is a favourable practice as in-house style of operations may restrict flexibility by using a specific type of technology as per company internal norms (Quinn, 1999). Wang et al. (2008) also confirmed this by examining 120 companies' performance after offshoring their IT functions.

IT offshoring to leverage supplier competencies

It is feasible to achieve increased service levels as clients can gain access to superior competencies from their suppliers, studied by Quélin and Duhamel (2003). Also, McIvor (2006) revealed that clients can take the advantage of access to highly skilled technical manpower resources in the supplier country that are not so easily available or highly expensive in the client's country.

Therefore, literature revealed four main motivation categories behind offshore outsourcing:

- Focus on core competency
- Increased cost effectiveness
- Capitalise on supplier investment and innovation
- Greater flexibility and scalability
- Leverage supplier competencies (e.g. technical and process)

Offshore outsourcing is thus considered to be a highly valuable corporate strategy whether used in a tactical or strategic way. Although offshoring is a valuable business strategy it also poses a lot of challenges needing special attention.

Critical factors for overall success in IT offshoring

Various outsourcing studies claim across other discipline suggest effective management of relationship is extremely critical to the success of an outsourcing engagement. There are only a few studies (Kishore et al., 2003; Lacity et al., 2010; Kern and Willcocks, 2000) emphasised on the importance of relationships within IT offshoring based on some of the most commonly visible factors like cultural dynamics, communication and contractual issues. This particular section discusses all the critical factors recorded in the literature of outsourcing studies.

A study of Kern and Willcocks (2000) state, factors like information exchange, effective communication and cultural integrity are critical to relationship management in outsourcing. Another study in supply chain (Brereton, 2004) also reflect similar factors stating that preparedness of parties to share information coupled with mutual respect for each other is critical to success in relationship. Meeting expectations was considered as a critical measure of success relationship success by Stralkowski and Billon (1988). This also relates to client satisfaction level in terms of success achievement that may reflect in the continuity of the engagement. Information sharing as a critical factor is also considered by Kishore et al. (2003) and is related to the aspect of level of co-operation between the engaged parties. Other researchers (Dibbern et al., 2004; Niazi et al., 2013) claim that the skills & commitment to the deliverables that was initially decided in the contract, cope with change, and to recognise added requirements may arise during the engagement time frame are the identified critical factors of success.

Therefore, based on structured literature review, the current study attempts to answer the question: What are the critical factors for the overall success of IT offshoring relationship?

The structured literature review revealed the following top 7 factors have the highest occurrences in the literature as the critical factors for overall success in relationship management of the engagements.

1. Legal contracts / contract management
2. Relationship specific investments
3. Information and knowledge sharing
4. Information security practices
5. Trust
6. Minimisation of uncertainty risks
7. Outsourcing success (expectations match).

Additionally, some of the other studies place the above factors to have an echoing effect on trust in relationship management (Sabherwal, 1999; Kern and Willcocks, 2000; Kishore et al., 2003). Therefore, this study identified trust as the central theme for the success or failure of any IT offshoring engagement.

Trust

Though the highest mention of trust was found as a critical factor based on the structured literature review, its importance is found to be predominantly abstract in most studies. Trust is the most significant critical factor in successful relationship is evident in the literature. The majority of research focus into trust has been found in various other disciplines like organization behavior, economics, supply chain management, social science and marketing. Level of trust in a relationship can be a measure of relationship intensity in an exchange relationship between the partners (Doney and Cannon, 1997; Tian et al., 2008).

This study adapts this view of relationship intensity combined with closely associated attributes of trust to explore further, linked with the aims and objectives. This closely related relationship attributes of trust (e.g. commitment, loyalty, dependency, reliability, sincerity, fairness, co-operation, collaboration and other variants of trust) to signify the relationship intensity are backed by literature evidence (Ganesan, 1994; Anderson and Weitz, 1989; Morgan and Hunt, 1994; Das and Teng 2002; Doney and Cannon, 1997; Dyer and Chu, 2011; Kennedy et al., 2001).

Failures and challenges in IT offshoring

Although IT offshoring has multiple benefits, it is not totally devoid of failures and challenges. Several industry reports enumerate the benefits and unprecedented growth of offshore outsourcing without revealing much on the rate of failures. Moe et al. (2014) debated that most papers only report the positive aspects of offshoring. There are only a few research evidences found in the area of challenges and failures in offshoring (Khan et al. 2012).

Foote (2004) examined 90 offshoring engagements and revealed that more than 50% of the offshoring engagements fail to achieve the desired objectives of offshoring, i.e. all the above listed basic motivation objectives. One such important factor that has always been under estimated is the importance of relationship issues and this was well articulated by Foote (2004).

In the literature several failures have been highlighted in the areas of requirement analysis, execution of contract, development and implementation of product and post execution support (Moe et al., 2014). However, the basis of some of the known failures are due to poor management of client-supplier relationship (Kishore et al., 2003).

There are crucial issues such as communication skills, culture adjustment, operational behaviour, and time zones difference which are significantly critical for offshoring. It is therefore needed to handle the cultural difference between the client and supplier respectfully. Foote (2004) identifies that managing cultural difference in offshoring may be more challenging than local outsourcing. Existing studies reveal a number of difficulties faced while offshoring such as increased costs of coordination (Aubert et al., 1998), distant geographical location (Herbslab and Moitra, 2001), threats associated with information security (Blackley and Leach, 1996), lack of direct communication (Pyysiainen, 2003), absence of real-time information regarding all outsourced activities (Gonzalez, 2006) and problems due to infrastructure (Barthélemy, 2001). These are illustrated as below

Offshoring relationships are dynamic and evolve over time due to rapid changes in the global business environment and the client's internal requirements (Kishore et al., 2004). Additionally, continuous technology improvements allow not only more volume of work but also other different types of work that are related. Changes evolving in the new business models in IT offshoring seem to require closer and more complex relationship management approaches between client and supplier to make it a success for both parties (Niazi et al., 2013).

Initial analysis and findings

IT offshoring is always faced with new challenges and may develop substantial risks for the clients if they are not managed properly. There are significant legal challenges to IT offshoring, which makes the achievement of strong contracts difficult and enforcing the same even more challenging. As all the activities and operations cannot be closely monitored from a distance; development of trust to complement the legal contract demands more attention to combat these challenges (Kanawattancachai and Yoo, 2002).This makes effective information security and information sharing practices as a prerequisite for success (Khalfan, 2004; Costa, 2000).

Relationship-specific investments are beneficial in developing client’s trust, cultivating supplier motivation through flexible contracts that aid in building trust as most contracts are incomplete, according to Bakos and Brynjolfsson (1993a).

As suggested by Poppo and Zenger (2002), the relational governance as a framework for control, and monitoring combined with trust-based relationship building enables reducing uncertainty risks.

Achieving greater alignment between scope, task, rewards, objectives and goals directing to the success of the engagement for both involved parties (clients and suppliers). These can be accomplished through the concept of partnership model proposed by Das and Teng (2004), considering the fact that offshoring motivations within each organisation may differ significantly.

There has been an attempt to understand some of these challenges in the operations management of IT offshoring engagements in the literature (Niazi et al., 2013; Lonsdale and Cox, 2000) and these studies clearly recognised the need for more focused research in the relationship management attributes of IT offshoring.

Our research study therefore is an attempt to initiate a baseline platform by which the relationship management development factors can be appreciated and recognised by the clients in order to make informed decisions relating to the identified critical factors enabling success.

Our initial analysis supported main motivation categories behind offshore outsourcing, namely Focus on core competency; Increased cost effectiveness; capitalise on supplier investment and innovation; Greater flexibility and scalability. Also, it added a greater emphasis for leveraging supplier competencies (e.g. technical and process). The common challenges in IT Offshoring includes outsourcing core competencies, supplier selection, poor or tight contract, personnel issues, losing control over the supplier, uncertainty risks management, long-term or exit strategies and hidden costs (Das and Teng, 2002).

Focusing on a trust-based relationship, encourages both parties, specifically the supplier to accomplish contracted tasks to exhibit enhanced performance thereby promoting performance beyond the contract (Lee and Choi, 2011).

Conclusion

This study identifies key factors via systematic literature review that are necessary for establishing a strong platform in IT offshoring relationship development. Understanding these factors may assist IT offshoring companies in addressing issues relating to establishing a strong relational intensity. Consequently, it also aids to ensure the successful outcome of IT offshoring engagements with long-lasting relationship between the clients and suppliers (Ali-Babar et al., 2007; Sabherwal, 1999).

Typical issues in client-supplier relationships are well documented in the literature (Palvia, 1995; Tian et al., 2008; Parkhe, 1998b; Krishna et al., 2004). These problems are a major cause of complex challenges being faced in the engagement that at times make the clients re-think on the IT offshoring strategy itself and some clients reverted back to the classical model of in-house or insourcing services, as reported in the literature (Foote, 2004). In case of failures, the investments (tangible and intangible) made by both parties are completely sunk. Further, it may call for additional investments to revert to the old system of in-sourcing.

The supplier side of relationship management understanding is limited to timely payments and long-standing contracts (Oza et al., 2006). The other aspect is governed by the fact that if an engagement fails, clients are at more loss than the suppliers. However, results of the study is not expected to be mutually exclusive and may be applicable to both client firms (in Europe) as well as their supplier firms, in the sense that identified critical factors will be applicable to both partners equally to realise success through strengthening their relationship.

This study is particularly relevant to the client-supplier firms already engaged in a relationship but can also be useful to those who are planning to begin their journey in IT offshoring in the near future, as a preparatory and planning platform.

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Foundations for Decision Models on Captive Offshoring from an (Theoretical) Evolutionary Perspective

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Abstract

Though many have written about the concept of domestic outsourcing and offshore outsourcing, rather few conceptualisations have been elaborated for captive offshoring. Reaching beyond classic approaches, such as core competencies and knowledge transfer, we enclose captive offshoring in a framework derived from (theoretical) evolutionary biology. The resulting framework, conjoined with a literature review, brings new aspects to the decision making on captive offshoring. A research agenda is presented based on the framework and its implications. The undertaken literature review proves that this research area is a Greenfield approach and there are several questions that have not yet found an answer.

Keywords:

Captive offshoring, (theoretical) evolutionary biology, mutations, decision making

Foundations for Decision Models on Captive Offshoring from an (Theoretical) Evolutionary Perspective

1.1 *Scope and Outline of Pape*

Based on this evolutionary conceptualisation that captive offshoring is a mutation of the company subject to evolutionary forces, derived from (Dekkers, 2005, p. 46), this paper provides a comprehensive review of decision-making models for manufacturing companies with regard to captive offshoring by evaluating the relevant literature.

This approach complements other attempts to capture decision making for offshoring. For example, Schmeisser (2013, p. 392 ff) presents a framework that is rooted in literature rather than derived from a theoretical framework. However, those that have used conceptualisations based on theoretical frameworks have limited themselves to theories that could be contested. A case in point is the work by Jahns et al. (2006) based on: transaction cost economics, the resource-based view, and the market-based view (the last related to comments by Priem and Butler (2001) with regard to the resource-based view); transaction cost economics and the resource-based view have been found inadequate for long-term effects by Dekkers (2011, p. 959) for outsourcing. From this perspective, Wiener et al. (2010, p. 481) call for strengthening the theoretical basis for research into offshoring. Thus, we intend to extend the theoretical basis for outsourcing by including a framework derived from (theoretical) evolutionary biology; this framework should also capture long-term effects better.

After classifying and delimitating captive offshoring from other related concepts in the second section, we introduce an evolutionary framework for captive offshoring in the third section. The fourth section summarises the methodology of this particular systematic literature review, and the fifth section presents the results of this review. We present our conclusions together with a research agenda based on the developed framework in the final section.

1. Positioning and Defining 'Captive Offshoring'

Before embarking on the development of this framework and linking it to the literature, it is necessary to delineate captive offshoring from other related concepts. For this purpose, the paper of Jahn et al. (2006, p. 222), provides an illustration, from which results that the term 'buy' includes also onshore (as well as nearshore and offshore) outsourcing – a concept representation we will rely on -when we use 'buy' as synonymous to 'outsource'. Note that the decision to outsource or make-or-buy implies that external to the company capabilities are available to a firm that could substitute for internal processes. Thus, the interchangeability of these activities implies that even if a company has the capability to perform specific processes, it scans the (international) market in order to find some other organisation, that can also deliver this product or service, as good as itself, if not better, faster or cheaper – and opts for it. There is also an 'in-between' option, called 'hybrid' by some (Jahns et al., 2006, p. 221); we choose the term 'shared ownership' to stress that in which form whatsoever the companies agree to (legally) act together in order to achieve their common goal, e.g. joint venture, consortium or business partnership, the end-product is commonly owned, even if not necessarily in equal parts. This means that in distinguishing captive offshoring from other related conceptualisations, a dimension of ownership and a dimension of geographical distance should be taken into account.

[INSERT FIGURE 1 ABOUT HERE]

Thus, the classification we provide for our purpose, see **1,** has two dimensions: ownership and geographical proximity, similar to Jahns et al. (2006, p. 222). This is based on the following descriptions of the dimensions:

- *Make*: in-house production, whether in the domestic country or a foreign (neighbouring) country, either before or after the decision about outsourcing or offshoring.
- *Buy*: any form of production resulting from a transaction between the company and a third party organisation, whether in the domestic county or a foreign (neighbouring) country.

- *Shared ownership*: a separate legal entity is created either under the domination of one party (dominant parent) or under equal shares (shared management). Youngdahl et al. (2008, p. 4) describe it as 'build, operate and transfer'. Though cross-border and international shared ownerships, e.g. joint ventures, are used as synonyms, we propose this term in order to acknowledge the different vertical dimensions. We will not go into further detail about its concepts in this paper because of the focus on captive offshoring, but have included it for a holistic overview.
- *Domestic country*: the country of residence of the company, from where it conducts its economic and legal transactions.
- *Neighbouring country*: a country that has at least one common, direct border between itself and the domestic country.
- *Foreign country*: a country, that has no common, direct borders with the domestic country, because there is at least one independent territory between them.

Similar to our representation in 1 is the one provided by Jahns et al. (2006, p. 222) with the difference of chosen terminology of 'wholly – owned' versus 'contractual/ legal'. We do not make the distinction between onsite and offsite (same country), as we do not consider it to be a distinct territorial dimension relevant for positioning captive offshoring.

From here on, 1 will guide the classification of terms and the evaluation of papers found during the systematic literature review.

2. Evolutionary framework

3.1.*Evolutionary Analogy*

For the purpose of considering mutations of organisations as analogous to organisms, and we consider captive offshoring from this perspective, Dekkers (2008, pp. 51-55) has found the following similarities between organisms and organisations; these similarities will be reflected on for captive offshoring:

- *Selection acts on mutations.* Such a process exists for organisations where the selection process finds itself in competition for customers, the acquisition of resources, e.g. suppliers, and the changes in the ecosystem of which a company is part. Thus, captive offshoring as a mutation is a restructuring of resources and processes, including control, managerial processes and interactions between actors in a company (note that captive offshoring does not change the boundary of a company in contrast to outsourcing).
- *Organisations and organisms are structurally closed.* In the case of captive offshoring, organisations remain structurally closed because the ownership of resources does not change, the boundary of the company with the environment remains principally intact.
- *Organisations, like organisms, have the possibility of self-cognition and learning.* Although the boundary at company level does not shift, the changes in resources and interrelationships may induce differences in self-cognition and learning in the case of captive offshoringat the level of manufacturing departments.
- *Developmental pathways seem to exist for both organisations and organisms. T*hough there is a difference between them, **Figure 2** exemplifies such a developmental model, where genetic and non-genetic mutations lead to form and function trajectories, according to developmental pathways coded in the structure of the organisation. This raises the question whether there are developmental pathways for captive offshoring.
- *The mutations are selected by the environment based on adaptive walks and the criteria of sustained fitness and evolvability*. (Dekkers, 2005, p. 150). Thus, companies that have opted for captive offshoring should be subject to adaptive walks and selection criteria.

The major difference between organisms and organisations in evolutionary terms is the *presence of foresight*; whereas organisms principally propagate through random mutation – ignoring group selection –, organisations have the capability of foresight. Therefore, mutations are teleological, though subject to selection and environmental changes. This also means that captive offshoring should be a result of foresight. However, there are also other evolutionary mechanisms, such as mimicking, that could lead to

the mutation of captive offshoring. Thus, captive offshoring could be a result of foresight or other evolutionary mechanisms.

From here on, we will view offshoring as a (teleological) mutation that is subject to developmental pathways for increasing fitness and to evolutionary forces caused by population dynamics and ecological changes. Thus, captive offshoring could be a result of either foresight or other evolutionary mechanisms, such as mimicking.

[INSERT FIGURE 2 ABOUT HERE]

3. Analysis of Retrieved Papers

5.1 *Decision Making on Captive Offshoring from an Evolutionary Perspective*

The detailed analysis showed that of the 50 papers, only 16 are written around the terms ‘captive offshoring’ and ‘decision making’. Hence, we are particularly interested in finding those which applied a game theoretical approach in finding an optimal solution for the decision problem of captive offshoring. We further constrained the results subject to the condition that the study also mention, or even better apply, any concept related to game theory. Only four out of 16 papers complied with this requirement: (Eischen & Singh, 2005; Gonnet, Ikeya, & Starkov, 2011; Mugurusi & Bals, 2017; Srivastava, 2008). Mugurusi and Bals (2017, p. 64) pursue the impact of offshoring based on a case study into the purchasing and supply organisation in a global engineering company. However, it does not refer to the approach we were aiming to find. The next paper we obtained from this search is Gonnet et al. (2011, p. 1). Whereas its bibliography refers to game theories, it does not apply any of its concepts to the decision-making process. Similarly, the doctoral study of Srivastava (2008, p. 147) does not address any of the decision-making models for captive offshoring we were looking for, but rather focuses on ‘offshore sourcing (or offshoring)’ within the IT sector. The last paper, Eischen and Singh (2005, p. 1) brings into play a new discussion, which might also be related to ‘captive offshoring’, but it analyses universities, not companies, and their related workforce development in a highly competitive and technological leading environment. Although three relevant papers and one doctoral thesis out of 16 mention game theories in some way, none does more than mention the concepts.

However, there are three papers that use game theories for offshoring. One such paper, which resulted from the search of the MPEC approach to offshoring in general, is Igami (2013, p. 1). It models the effects of offshoring for investigating industry dynamics and its results suggest the incentive to offshore increases as more rivals offshore due to competitive pressure (ibid., p.1). One possibility is to apply this model to captive offshoring to see if it holds, and, if so, does it deliver the same results? The doctoral dissertation of Arisoy (2007, p. 5) into determining the most advantageous offshoring location and distribution strategies, also provides an empirical study into captive offshoring. Not incorporating any evolutionary theory, the study (ibid., p. 5) mentions stochastic methods as one way of providing a "Pareto optimal solution set for a multi-objective problem", which can also include evolutionary algorithms. The disadvantages mentioned, including that this approach 'does not guarantee optimal solutions and their performance depend on many factors, such as the initial population and adjustment parameters' (ibid., p. 5), may be one of the reasons the methodology focuses on other approaches in the pursuit of the research question. Mirani (2013, p. 663) has a new perspective compared with the other studies discussed so far in our literature review. He 'applies a morphogenetic change framework to the case study of a financial information services provider's relationships with offshore IT application vendors over a six-year period, in order to discover the underlying causal mechanisms' (ibid., p. 663). Mirani (2013, p. 663) characterises each change 'by a morphogenetic cycle of three phases – structural and cultural conditioning, socio-cultural interactions, and structural and cultural elaboration'. Thus, three papers that describe offshoring refer to concepts related to game theory, but this does not yet prove their models extend to captive offshoring.

5.2 Evolutionary Biology and Game Theory

A search for 'evolutionary biology' and 'game theory' provided an overwhelming number of over 12,100 results on Scholar Google alone, but when restricted to MPECs it was limited to only 4 references. We were particularly interested in publications that combine the game theoretical approach, used to solve the dynamic environment of evolutionary biology, that is applied in an economic or macroeconomic context.

Since we already elucidated on Igami's (2013) paper in the previous section, we will focus this analysis on the remaining three. Kroshl (2015, p. 41) mentions in his doctoral thesis that 'Another approach to finding solutions to Stackelberg games is founded in evolutionary biology', without investigating this avenue further; but concludes by providing an MPEC computational approach for a case of '… interactions between [...] companies in the electricity and emission allowance market … (ibid., p. 54)'. A similar approach is also provided in a paper he co-authored: Kroshl et al. (2015). Sen and Shanno's (2008) research into new algorithms for computing Nash equilibria of stochastic games combines a dynamical system with nonlinear programming to find stable equilibria. This approach is motivated by evolutionary biology reasoning – providing additional motivation for using MPECs in this regard. The authors make a valid point from an evolutionary point of view, when applying game theoretical approaches in order to solve the system, namely that 'replicator dynamics have the undesirable property that 0 is always a fixed point. This might be reasonable in evolutionary biology (an extinct species cannot rise from the dead), where the idea of course originates, but is problematic in games with individual agents. A player might very well start taking a particular action that he was avoiding before. A further source of dissatisfaction with all dynamics proposed thus far is that convergence to a Nash equilibrium cannot be guaranteed, and is often quite rare' (ibid., p. 984). Given the fact that 'even a two-player stochastic game gives rise to a nonlinear problem, which in general will be nonconvex' (ibid. p. 986) leads, once again, to the formulation of an MPEC, for which they provide a solution in their research. Their approach could offer a possibility for formulating an MPEC approach for captive offshoring. Mordukhovich and Outrata's (2007a, b) research concerns a class of hierarchical games called equilibrium problems with equilibrium constraints (EPECs). They equate equilibrium problems with complementarity constraints (EPCCs) as a type of generalised Nash equilibrium problem, which includes several complementarity constraints. The beauty of the EPECs is that their constraints are themselves MPECs and thus create a comprehensive, recursive system; see Figure 5. These papers might not be directly related to an evolutionary approach, but do provide necessary optimality conditions and propose a numerical method to solve the class of EPCCs..

4. Concluding Remarks and Further Research

The lack of literature from this perspective gives us a Greenfield approach. We offer a new insight into captive offshoring, relying on the analogy between captive offshoring and evolutionary biology, aiming to provide an innovative foundation for decision making models. This perspective is reliant on three theoretical foundations: the wholly owned externalization of production and R&D, i.e. captive offshoring, evolutionary theory and artificial intelligence. The aim of this research is to offer an overview of the current body of knowledge at the intersection of these three theoretical approaches, to introduce a new and innovative approach.

One main limitation to this method is that originates in an analogy-based approach and there might be several characteristics from the analogized theories, that might not find a corresponding interpretation when placed in the new setting. Nevertheless, if taken two by two, namely economics and evolutionary biology, economics and game theory, evolutionary biology and game theory, we found underlying literature pointing the way to this approach (see section 3). Taking advantage of the transitivity of a logical connection, in theory at least, our analogy and its underlying mathematical approach, is just as valid as the existing connections made so far in the literature.

Managerial Implications

Though, it is not a practical in its current state, this particular paper is the first step into the theoretical foundation of our vision. Based on the main characteristics of a genetic mutation, namely fitness and adaptability, and adding foresight to the equation, we look into the future possibility of proving a tool, that can predict economic failure or success for captive offshoring by evaluating if the externalization of a specific process is an advantageous step or not. Our further research will focus precisely on this topic and, if successful, can provide a model that is able to “complete” the picture for this specific decision-making process.

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Table 1 Overview of retrieved publications.

Author 1	Author 2	Author 3	Author(s) 4 - n	Title	Published in by	Year	Offshoring	Outsourcing	Captive offshoring	Game Theory	MNE/FDI	Dickerson Offshoring	Stackelberg model	Equilibrium (Vendor or Customer Optimum)	Industry equilibrium	Trade	Ownership Size / Ownership Dilution	Knowledge Spillovers	Adaptive Dynamic model	Theory / Landscape
Aridto R.	Cocchetti G.	Naser G.		On structural safety assessment by load factor maximization in piecewise linear plasticity	European Journal of Mechanics-A/Solids	2008	x			x	x									
Arroyo O.				Offshoring and Offshoring in Global supply chains and networks. (Doctoral Dissertation)	University of Pittsburgh	2007	x		x				x	x			x			
Baier E.	Rammer C.	Schubert T.		The Impact of Captive Innovation Offshoring on the Effectiveness of Domestic Innovation	Journal of International Management	2016	x		x											x
Bassett J.				Innovation management and dynamic capability. The SAGE Handbook of Strategic Supply Management	SAGE Publishing	2013	x													
Bastl M. M.	Phillips W.			Offshoring and Reshoring: Risk Offshoring	Stekelolf of Copenhagen	2014	x		x			x	x				x			
Buljat V.	Cocchetti G.	Naser G.		Calibration of brittle fracture models by sharp indenters and inverse analysis	International Journal of Fracture	2013	x			x	x									
Burger A.				Dynamic effects of international fragmentation of production: empirical evidence from service offshoring during the Great Recession	University of Ljubljana	2009	x		x				x							
Cernelic P.	et al.			Location drivers, governance models and performance in service offshoring	International Journal of Production Economics	2015	x		x			x								
Chang S. J.	Chung J.			A Cross-Experimental Approach to the Multinationality-Performance Relationship: An Application to Learning-by-Exporting	Global Strategy Journal	2016	x		x				x							
Dedrick J.	Kraemer K. L.	Carmel E.	Dunkle E.	Strategic orientation in the globalization of software firms	Lecture Notes in Business Information Processing	2010	x		x			x								
Elsthen K.	Singh N.			Lost: (Dysfunctional or evolving? A view of Business schools from Silicon Valley	University of California, Santa Cruz - Department of Economics	2005	x		x	x		x	x							
Elia S.	Cerrato F.	Luzzini D.	Piscitello L.	Governance Choice in Global Sourcing of Services: The Impact on Service Quality and Cost. Saving Performance	Global Strategy Journal	2014	x		x			x								
Feldmann C.	Pumpe A.	Vallée F.		Disruption and Deglobalistic Global sourcing of services - How well are the new EU- member states	e-journal	1994	x		x				x							
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Ghibutiu A.	Polastien S.			Global sourcing of services - How well are the new EU- member states	Romanian Journal of Economic Forecasting	2009	x		x			x								
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Gomes E.	Ilieg M.	Stanley, V.		Value Offshoring: Perspectives and studies	NEW Economic Consulting	2011	x		x	x		x								
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Kramer T.				Software component allocation in distributed development settings	CAISE 2012 Doctoral Consortium, Gdansk	2012	x			x		x								
Kroshl W. M.				Allocation of Resources to Defend Spatially Distributed Networks Using Attack-Dependent Fatalities and Multilevel Spatially distributed Networks using agent-based simulation	The George Washington University	2016					x						x			
Kroshl W. M.	Sarkani S.	Mazzuchi T. A.		Allocation of Resources to Defend Spatially distributed Networks using agent-based simulation	Risk Analysis	2016					x	x					x			
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Lindfors K.				Manufacturing Investments in Finland 2005-2015: an Analysis of Published News in the Finnish Media Archives	e-Journal	2016	x		x				x							
Lucy Y.	Wang S.L.	Jayaraman V.	Zheng Q.	Offshoring to a poorer country: Process, products, and preferred modes	Journal of World Business	2013	x		x			x								
Marco G.				Motivating Innovation	The Journal of Finance	2011	x			x	x									
Mirani R.				A case study of morphogenetic change in long-term offshoring relationships: Exploring cultural inequalities as applications to stability and optimization	International Journal of Information Management	2013	x			x			x				x			
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Qian C.	Delios P.			The impact of SSE on the internationalization of Chinese firms: Offshoring innovation to emerging markets. Organizational control and informal institutional distance	Journal of Finance	2011	x		x			x	x							
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Tuljan-Blasco D.	Munoz R.	Bautis E.		Breakthrough Innovations: The impact of foreign acquisition of knowledge (No. 2018-01)	University of Barcelona, Research Institute of Applied Economics	2018	x					x								
50	34	17	4		50	50	46	1	34	19	15	19	14	4	0	2	6	0	2	

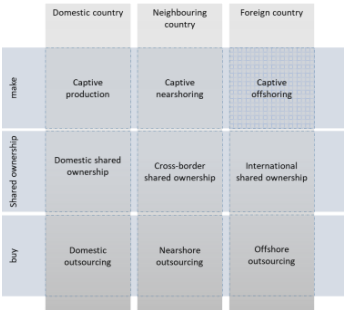

Figure 1 Delimitation of captive offshoring

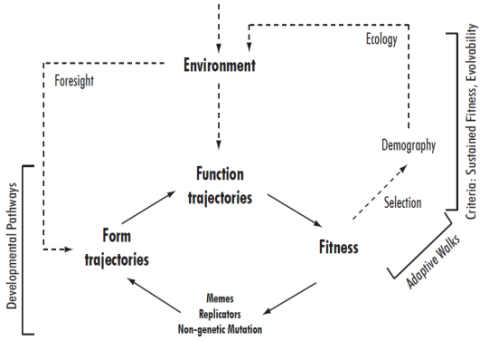

Figure 2 Evolutionary Mechanisms for Organisations Based on Biological Concepts (Dekkers, 2005, p. 150)

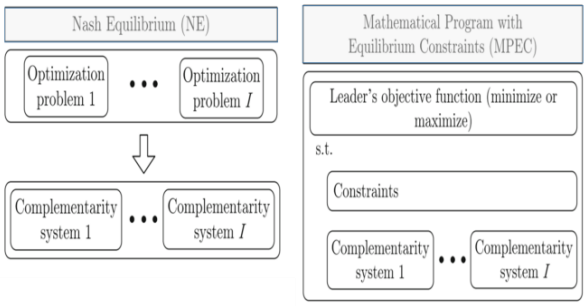

Figure 3 Nash versus MPECs (Ruiz et al., 2014, p. 6; 10)

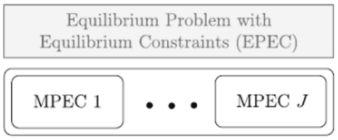

Figure 4 EPEC: joint solution of several interrelated MPECs (Ruiz et al., 2014, p. 102)

Healthcare Operations Management

The Role of Team Dynamics in Health Operations: a Case Study in Surgery

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Abstract

Teamwork, although important in all Operations Management sectors, plays a highly relevant role in healthcare, where the main services are provided by teams.
Leveraging the novelty and potential of wearable sensors, this research investigates the relationships between team coordination and surgery performance, exploring how team dynamics and communication may influence the likelihood of adverse events during routine surgery. Breast surgeries of an Italian hospital were monitored using Sociometric badges for collecting objective and systematic measures of team behaviors. Results show the importance of team coordination dynamics and team cohesion for improving surgical performance and patient safety.

Keywords: Behavioral Operations, Wearable sensors, Healthcare Management

Introduction

In the last decades, due to the increasing complexity and interdisciplinary nature of healthcare services, the use and relevance of teams has grown significantly in healthcare organizations making teamwork an essential part of effective care delivery (Valentine et al., 2015). Healthcare teams, especially in the dynamic domains (like operating rooms, emergency medicine, intensive care), commonly are assembled ad-hoc and multidisciplinary, work under quickly changing conditions, and stay together for a short period with a dynamically fluctuating team membership (Leonard et al., 2004; Manser, 2009). These peculiar characteristics, also found in aviation, military, and sport teams, make healthcare teams very difficult to study (Shah & Breazeal, 2010; Wheelock et al., 2015; Chang et al., 2017).

As shown in other business sectors, most research in healthcare claims the relevant effect of teamwork, specifically team coordination and communication, on team

performances in terms of high quality and safe patient care (Leonard et al. 2004, Manser, 2009; Burtscher and Manser, 2012; Berry et al., 2016). This position is supported by many authors in different healthcare areas: surgery (e.g. Mazzocco et al., 2009; Yule et al. 2006; Siu et al., 2016); intensive care (e.g. Dietz et al., 2014); mental health (e.g. Deacon and Cleary, 2013); neonatal resuscitation (e.g. Williams et al., 2010); and across entire hospital systems (e.g. Berry et al., 2016). Accordingly, researchers and health managers have widely investigated team behaviors in different healthcare settings to understand the possible determinants/influencing factors and to define strategies for improving teamwork and process performance (Manser, 2009).

In this context, surgery has attracted the greatest attention as a result of its preeminent repercussion on hospital budgets and its highly relevant impact on patient care and safety (Yule et al., 2006; Gupta, 2007; Jebali et al., 2006). Indeed, the operating room is one of the most complex and challenging work environments in healthcare, where teamwork failures and human errors have been shown to cause the greatest amount of unintentional harm in a hospital (Sun et al., 2018; Wheelock et al., 2015). Accordingly, past studies recognize the remarkable influence of team coordination and communication on surgical performances (Yule et al. 2006; Mazzocco et al., 2009; Wheelock et al. 2015; Siu et al., 2016).

In particular, two main aspects seem to play a leading role for the management of dynamic teams, like surgical teams: the way in which the team members coordinate themselves and the cohesion of team (Mathieu et al., 2008; Rico et al., 2008). The team coordination takes place through explicit and implicit coordination mechanisms and patterns. The balance between explicit and implicit coordination, which occur simultaneously in surgical teams, has deeply influences team performance (Malone & Crowston, 1994; Crawford & LePine, 2013). Although implicit coordination appears to increase team effectiveness, the best equilibrium between explicit and implicit coordination depends on the specific features of the tasks involved (Espinosa et al., 2004; Gorman, 2014; Butchibabu et al., 2016). For example, a higher proportion of implicit coordination compared to explicit communications leads to higher team performance for routine tasks with high interdependency, like routine surgery (Rico et al., 2008; Riethmüller et al., 2012).

On the other hand, the cohesion of team, usually enabled by the existence of Shared Mental Models (SMM) defined as common knowledge structures held by team members, facilitate the cooperation and increases the efficacy and efficiency of team coordination and communication (Cannon-Bowers et al., 1993; DeChurch & Mesmer-Magnus, 2010). Thanks to the greater sharing of objectives and ideas and to supportive behaviors, team cohesion seems to have a relevant positive effect on team performance for many different team configurations and contexts (Fisher et al., 2012; Gorman, 2014).

In spite of increasing interest and a significant amount of rhetoric around teamwork in healthcare, relatively few quantitative researches have evaluated the relationship between team coordination and surgical performance (Schmutz and Manser, 2013; Siu et al., 2016). In particular, evidences of a direct link between team coordination dynamics and surgical outcomes are scarce and not conclusive (Sun et al., 2018; Mazzocco et al., 2009). The creation of a valid and reliable measurement system is one of the main obstacles for studying team behaviors in such a context, but also elsewhere. In fact, the two most adopted approaches, self-report (e.g. interviews and questionnaires) and direct observation (or mediated through video recordings), are costly and of low reliability since they are affected by subjectivity, memory effect,

influence of the observer, and high time need for data collection (Barley, 1990; Leonard-Barton, 1990; Kim et al., 2012; Chaffin et al., 2017).

The recent advent and availability of wearable sensors and similar technologies, also referred to as sensor-based measurement tools, is offering the opportunity of measuring and evaluating teamwork through data-driven methodologies. Providing automatic and objective measurements of team behaviors, these tools can efficiently collect a big amount of data in real time, avoiding the main bias linked to typical approaches to teamwork studies and increasing the data richness, quality, and reliability (Rosen et al. 2014; Chaffin et al., 2017). Thanks to direct and quantitative measurements of individual and team behaviors, the adoption of such technology may effectively help scholars to evaluate team coordination and its relationship with the healthcare outcomes, for instance in term of care effectiveness and safety. In so doing, this approach allows to overcome or, at least, to mitigate the main limits of common approaches to the study of teamwork in healthcare and elsewhere (Chaffin et al., 2017; Rosen et al., 2014; Kim et al., 2012).

Leveraging the novelty and potential of wearable sensors, this work aims to investigate the relationships between team coordination behaviors of surgery teams and the related performance during surgical activities. In particular, this paper explores how the team behaviors and communication may influence the performance of routine surgery. A preliminary case study within the Breast Unit of an Italian university hospital was carried out to understand the effect of team coordination and team cohesion on surgical outcome.

This research also contributes from a methodological perspective, by showing the suitability of wearable sensor approaches (Chaffin et al., 2017) for studying links between team behaviors and process performance. Thus, the paper proposes this novel approach as a valid method for discovering or confirming/denying relationships between team coordination and team performance in healthcare and other fields.

Hypothesis development

Past research showed that several errors and adverse events during surgery are caused by failures in team coordination and communication or, more generally, by non-technical aspects, rather than a lack of technical expertise (Yule et al. 2006; Schmutz and Manser, 2013; Siu et al., 2016; Gjeraa et al., 2017; Sun et al., 2018). Thus, team coordination and effective communication play a preeminent role for providing high quality and safe patient care in surgery (Bogdanovic et al., 2015; Manser, 2009; Singer et al., 2016). Accordingly, a growing number of empirical studies shows that the most severe disruptions during surgery are related to communication and coordination problems.

According to the contingency theory and past evidences of coordination studies, the communication and coordination strategy, though always very relevant, should be adapted to the specific type of surgery (e.g. Donaldson, 2001; Crawford & LePine, 2013). Indeed, the appropriate balance between explicit and implicit coordination strategies depends on the characteristics of the task involved such as the level of task uncertainty and task interdependence.

Specifically, surgical features are highly dependent on the specific surgery context, thus surgical teams should adapt their behaviors based on the peculiar surgery characteristics (Bogdanovic et al., 2015). The main aspect that characterizes surgeries is the degree of routine (uncertainty) of surgical procedures, which allows researchers to classify surgical treatments as routine and non-routine ones and to distinguish accordingly between different coordination best practices (Manser, 2009; Bogdanovic et

al., 2015). Regarding task interdependence, its level tends to be quite high in all surgical procedures though it can slightly change based on the specific surgical context.

Research seem to confirm that for routine surgeries, similarly to all routine tasks, a lower level of explicit communications brings higher team performance while a high level of implicit coordination has a positive effect on performances (Manser, 2009; Wheelock et al., 2015; Butchibabu et al., 2016). The explanation may be that a larger proportion of implicit coordination for surgeries with high level of standardization permits a greater focus on surgical task, thanks to the increased individuals' free mental resources and more effective and efficient communication (Manser, 2009; Gorman, 2014). On the other hand, the exclusive use of implicit coordination has a negative effect on surgical performance when the level of task routineness is low, because explicit coordination may better synchronize team members in high uncertainty environment (Rico et al., 2008; Manser, 2009; Riethmüller et al., 2012).

First studies in this field suggested that surgical teams during routine interventions should stay focused on the tasks, limiting the discussions and avoiding unnecessary conversations (Wheelock et al., 2015; Singer et al., 2016; Keller et al., 2016). Indeed, many discussions/talks in routine surgeries are associated with poorer surgical performance and increased risks for patient safety (Tschan et al., 2015; Wheelock et al., 2015; Singer et al., 2016). Past evidences show the importance of remaining vigilant throughout a case and maintaining a high functioning team operating in a silent environment, especially when the surgical procedure presents a high level of routineness (Wheelock et al., 2015; Keller et al., 2016; Tschan et al., 2015).

On the contrary, the amount of explicit coordination behaviors and verbal communication should increase when the surgical procedures are non-standard and the level of task uncertainty is high (Sun et al., 2018; Tschan et al., 2015). Operating teams, where tasks are uncertain/not well defined at the beginning and affected by frequent change of patient conditions and needs, require more unique acts and thus need explicit coordination to synchronize team members (Bogdanovic et al., 2015; Riethmüller et al., 2012). This does not mean that implicit coordination is irrelevant, but the importance of explicit coordination and unambiguous communication rises.

Our preliminary case study involved breast surgeries, specifically quadrantectomy and mastectomy. These surgeries are done on a high level of task routineness and low uncertainty (e.g. McLaughlin, 2013), with the procedure being well defined before the start of the operation. We thus postulate a negative effect of too much explicit coordination, which implies increased communication overhead and reduced focus on surgical task. The results are affected by the specific context (routine surgery) where the procedures to be followed are well defined before the start of the operation.

Thus, considering past studies and the context under analysis, we hypothesize:

H1: The lower explicit coordination of the surgical team by verbal interaction, the higher is the performance of the team

The dynamics and the effectiveness of team coordination and communication in surgeries depend also on team cohesion, recognizing, in particular, the important role of Shared Team Mental Models and of a collaborative environment for providing high quality and safe patient care (Cannon-Bowers et al., 1993; Catchpole et al., 2008; Manser, 2009; Mazzocco et al., 2009; McComb and Simpson, 2014; Siu et al., 2016). Indeed, team cohesion permits team members to anticipate and support each other, to enhance implicit coordination and harmonize team behaviors, and to communicate more efficiently (Gjeraa et al., 2017; Burtscher and Manser, 2012; Gorman, 2014; Sacks et

al., 2015). This in its turn indirectly improves surgical performances in term of quality and safety.

In addition, a trusting and inclusive team climate seems to decrease conflicts and discussions during surgery, enhances the ability to cope with surgical problems, and increases the performance of each team members by reducing their level of stress (Dahl et al., 2017; Singer et al., 2016; Wheelock et al., 2015).

The positive effects of team cohesion on team dynamics, e.g. favoring implicit coordination, and on final surgical outcome have been shown in many different surgery contexts, regardless of the routine nature of the activities involved (Manser, 2009; Rico et al., 2008; Sacks et al., 2015). For example, Gjeraa and colleagues (2017) found that team cohesion and shared mental models may increase the patient safety during video-assisted thoracoscopic surgery. Catchpole and colleagues (2008) showed that also in more routine surgeries, like low risk orthopedic operations, team building and understanding of others' needs decreases the occurrence of surgical problems. Nevertheless, the positive effect of team cohesion appears to be greater in contexts that need a high level of implicit coordination and for highly interdependent tasks (Rico et al., 2008; Manser, 2009; Gorman, 2014; Bogdanovic et al., 2015).

Consistent with past evidence on team cohesion we hypothesize thus:

H2: The higher the level of team cohesion, the higher is the performance of surgical teams

Method and Case study

For an effective evaluation of such relationships, a novel systematic measurement approach powered by the Sociometric Badges is adopted to obtain quantitative and reliable measures of team behaviors during surgeries. Indeed, one of the most important challenges in studying teamwork in highly dynamic domains of healthcare, like operating rooms, intensive care, and emergency medicine, is related to the measurements of team dynamics (data collection phase) that are commonly assessed by interviews, direct observations, questionnaires, and reports (Manser, 2009). Thus, they often suffer from subjectivity and memory effects, or face problems through the influence of the observer on the system (Barley, 1990; Leonard-Barton, 1990; Kim et al., 2012; Chaffin et al., 2017).

Sociometric Badges are wearable sensors invented at the MIT Media Lab, for catching the "honest signals" inherently related to human behaviors and group interactions (Pentland, 2008; Olguin et al., 2009b). Indeed, they can automatically and directly measure individual and collective dynamics in a quantitative way, exploiting four different sensors: accelerometer, microphones, Bluetooth, and IRDA (Olguín et al., 2009). Thanks to its sensors and the increased stability, sociometric badges offer a systematic way to quantitatively investigate the individual and collective patterns of behavior overcoming the limitations previously cited.

Moreover, sociometric badges are able to guaranty the privacy as it is impossible to determine the content of the conversation or identify the speaker from the sociometric data. This way, these badges prevent obstacle related to privacy laws (very important in the healthcare field) and are likely to be far less intrusive than human observers, potentially limiting any social distortions to the data (Olguín et al., 2009; Rosen et al. 2014). The suitability and usefulness of Sociometric Badges for monitoring behavioral variables is proven by past research (Kim et al., 2012), also in the healthcare field (e.g. Olguín et al., 2009b; Bucuvalas et al., 2014).

Given the lack of research systematically evaluating the behaviors of surgery teams and the novelty of the measurement approach, an exploratory case study (Yin, 2017) was carried out for this preliminary investigation.

Case study

We collected data from 66 breast surgeries in the Breast Unit of an Italian University Hospital. All cases are about cancer related problems and were chosen randomly. The surgical team composition is the following: two surgeons, one scrub nurse and one assistant nurse. Frequently there are also one or two additional surgeons or nurses. In general, the analyzed team were composed by a minimum of 4 to a maximum of 7 people.

To study the surgical team dynamics and their influence on performance, we collected the individual and collective behaviors of surgical team members for each surgery using the Sociometric Badges. Each team member wore the Sociometric Badge for the entire duration of the surgery. Sensors allowed collection of team interaction data thought the accelerometer, microphones, and Bluetooth data. Due to the position of the Sociometric Badges under the surgical scrub for safety reasons, IRDA data was not collected. In the end, we collected and analyzed the behavioral data of 292 individuals for about 380 hours of recording.

In addition to the sociometric data, we also gathered the main features of the surgeries (as for example the duration) and we requested team members to fill out a survey about the "team cohesion" for each different team they take part. Finally, the surgical performance was evaluated though the occurrence of surgical glitches (the binary variable Glitches ON/OFF was reported for each surgery), given that providing a safe and effective operation is the main goal of surgery and that a surgical glitch may have a highly relevant repercussion on patient health and on hospital expenditure.

Findings

To assess the proposed hypotheses, Pearson's correlations and logistic regression were performed using the data collected during the 66 breast surgeries. The behavioral variables, recorded using the Sociometric Badges, and the "team cohesion" were taken as independent variables, while the *Glitches ON/OFF*, useful for evaluating the surgical performance, was employed as dependent variable. In addition, three main features of the surgeries, i.e. the surgery duration, the number of people inside the operating room, and the size of the monitored operating team, were used as control variables.

"Pearson's correlation" was useful for getting a first insight of the data and supporting the next phases of regression analysis. The significant correlations obtained were quite numerous and, for reason of brevity, are not reported here. However, it is noteworthy to point out that there are no significant correlations between the control variables and the dependent variable.

To measure the potential effect of independent variables on the dependent variable, we use logistic regression because the dependent variable, Glitches (ON/OFF), is binary (Hosmer and Lemeshow, 2004). A logistic regression model using three independent variables (*Silence*, *Team Cohesion*, and *Mirroring*) was build. This model is strongly significant, with all the variables included statistically significant, and explained a significant portion of the variance as reported by the Nagelkerke R^2 obtained (Nagelkerke, 1991).

The logistic model discloses the positive effect of *Silence*, i.e. the percentage of time in which the team member and all others in their proximity were silent, on performance. Indeed, a higher value of *Silence* implies a lower likelihood of experiencing a surgical

glitch. The model also showed that *Team Cohesion* has a positive effect on performance, diminishing the chance of glitches during surgeries. *Mirroring*, included as third variable of the model, appears to have a positive effect on surgical performance, by decreasing the surgical glitches. Considering *Mirroring* as a proxy for assessing the level of implicit coordination during surgeries, the regression model suggests that implicit coordination behaviors positively affect team performance.

The model achieved supports hypothesis H1, by confirming that a high level of explicit coordination (high level of verbal interaction) negatively affects the outcome of routine surgeries while implicit coordination (high level of mirroring) appears to favor it. If team members have to coordinate continuously through explicit verbal interactions they tend to lose focus on specific tasks and the probability of glitches increases. This result is aligned with the insights gained from informal interviews we had with practitioners and direct observations carried out to explain the findings obtained.

The model also supports hypothesis H2, showing the positive influence of the cohesion of teams on the surgical outcome through decreased likelihood of glitches. Team cohesion increases the supportive behaviors by team members, the team communication efficacy, and the practitioners' engagement, and thus positively affects surgical performance.

In order to confirm the validity of findings, regressive models using the control variables were tested. The first check was to add the control variables, individually and together, to the logistic regression model obtained. In any case, model performance did not considerably improve and the inserted control variables were non-significant. The second test was to build the model simply using control variables. Also in this case, no model built with the control variables was significant. These tests appear as a strong confirmation for the validity of our findings, ruling out any potential effect of the control variables.

Conclusions

This paper investigates the relationships between the team coordination behaviors of surgery teams and related surgical performance, using wearable sensors for the analysis. The use of direct and quantitative measures for evaluating team behaviors helped to overcome the main limits of popular approaches for measuring team behaviors and teamwork, and permitted us to find more reliable linkages between team coordination and process performance.

The results of this explorative case study show the impact of team coordination on performance, supporting the idea that surgical performances and adverse events during surgery are affected by team behaviors and non-technical aspects of the team as argued by past authors (e.g. Gjeraa et al., 2017; Yule et al. 2006; Siu et al., 2016).

Specifically, our findings support hypotheses *H1* and *H2* highlighting that:

- The likelihood of adverse events and errors during routine surgeries is lower if the members of surgical teams coordinate implicitly rather than through explicit communication. This confirms the positive effect of implicit coordination and the negative effect of explicit communication on routine surgery performances.
- The likelihood of adverse events and errors during routine surgeries is lower if the surgical team displays a higher level of team cohesion. This confirms the relevance of team cohesion for obtaining better surgery performances.

In line with past literature on team coordination (e.g. Rico et al., 2008; Butchibabu et al., 2016; Manser, 2009), a first interpretation of findings seems to endorse that a higher

proportion of implicit coordination leads to greater performance in this context, thanks to a larger focus on tasks and more effective and efficient team communication.
Moreover, team cohesion appears to have a positive influence on surgical performance because it seems to harmonize team behaviors, to increase the communication effectiveness, and to create a collaborative environment where people are inclined to back each other up (Rico et al., 2008; Fisher et al., 2012; Gorman, 2014).
From a methodological perspective, this research exploiting the Sociometric Badges also provides a contribution to the problem of "how to" quantitatively investigate behavioral aspects in dynamic environments. Findings support the effectiveness and suitability of wearable sensors for investigating team dynamics and their relationship with process performance in healthcare, overcoming the restrictions of previous approaches like memory effect, subjectivity, and the influence of the observers.

Managerial implications

This study also provides a relevant contribution from a managerial perspective. The results obtained and their interpretation allow us to provide some practical insights for healthcare managers, medical staff, and their training activities. Regarding routine surgery, we recommend to increase the proportion of implicit coordination behaviors, for example fostering deliberative communication rather than reactive communication (e.g. Butchibabu et al., 2016). Healthcare managers may plan appropriate training sessions to help medical staff. In addition, we suggest to the surgical team to set up a well-defined task distribution, and to be more focused on the job, by avoiding unnecessary conversations during surgery. For enhancing the ability to prevent and cope with surgical problems, as also supported by past evidence (e.g. Sacks et al., 2015), healthcare managers should pay attention to the formation of cohesive teams and to the creation of collaborative environments.

Limitations and suggestions for future research

This research has several limitations that point out directions for future research. The first is due to the exploratory nature of the work. Drawing on a single case study, results might be affected by the particular application/cultural context. This is a common issue for many behavioral studies that limit generalization (Tröster et al., 2014). Besides, although findings are statistically significant, the sample size is quite limited. In the near future, it may be interesting to repeat this study in a different cultural context to confirm our findings and to strengthen the practical recommendations. In addition, since different surgery contexts (routine vs innovative procedure) may require different coordination needs and interaction patterns (e.g. Manser, 2009), we suggest extending the research by reapplying this methodology to different types of surgical operations.
Finally, more teamwork research enabled by wearable sensors is also desirable to further prove the effectiveness and suitability of this novel approach.

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The intersection between patient flow, care pathways, and IT: a preliminary literature review and model development

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Abstract

Health care systems are under pressure to improve care performance. Patient flow has been recently gaining increased focus, supported by developments in care pathways, IT, and new management principles. There has been limited research, however, looking at these elements together. This paper serves as a preliminary review of care pathways and health IT, aiming to highlight the main aspects that can contribute to patient flow improvement. In addition to reviewing a selection of literature, a model is proposed showing the relation of the research elements. This paper will serve as input to a full systematic review at a later stage.

Keywords: Patient Flow, Care Pathways, Health information technology

Introduction

Health care systems are under pressure to improve quality of care and performance (Radnor et al., 2012, van Lent et al., 2012). Health care organizations in many countries have tried many approaches to improve care performance, though these improvement projects are often seen as either to local, specific, limited – or downright failures (Radnor et al., 2012). Recent studies in Operations and Supply Chain Management (OM/SCM) have emphasized how analyzing and improving patient flow from a larger, chain perspective can increase efficiency and maintain or improve care quality (Drupsteen et al., 2013, De Vries and Huijsman, 2011). These initiatives, however, need to *align* with clinical practices and tools, such as *care pathways* and *health IT* – since these phenomena are an essential part of the work life of physicians, nurses and other health personnel, and are likely here to stay for the foreseeable future.

Care pathways, also known as clinical pathways, are being used extensively in health care organizations to improve and standardize care (van Lent et al., 2012, De Bleser et al., 2006). A care pathway is a "method for the patient-care management of a well-defined group of patients during a well-defined period of time (De Bleser et al., 2006)," which also includes facilitating communication, and coordination of activities in patient care.

Care pathway research has had a mainly clinical focus, aiming at for example improved clinical guideline adherence; however, care pathways have potential in improving integration and coordination of patient care processes and services – i.e. in the *planning* and *control* of patient flow from a managerial perspective (De Vries and Huijsman, 2011).

Health care consists of a growing number of IT systems, including Electronic Health Record (EHR) systems, Computerized Physician Order Entry (CPOE) systems, etc. (Jones et al., 2014). However, these systems mainly serve clinical, administrative or financial purposes, and therefore are not used as a tool to effectively integrate and coordinate the patient flows within and between organizations. Procuring, implementing and adopting an IT system that transcends the internal and external boundaries of departments and organizations in the health sector may allow for improved coordination and integration of care processes – and thus, improved patient flow (De Vries and Huijsman, 2011, Devaraj et al., 2013). To realize this potential, however, it is necessary to explore how health IT can support care pathways (Neame et al., 2019).

This paper is a precursor to a full systematic review on care pathways and health IT, as they relate to patient flow from an OM/SCM perspective. The main aim is to (i) provide a preliminary review of the extant literature, (ii) propose a conceptual framework showing the relationship between care pathways and Health IT in supporting patient flow, and (iii) define the key dimensions to be expanded upon in the full systematic review. The full systematic review will serve as a stepping-stone to improved patient flow both by highlighting the key mechanisms of care pathways in patient flow and the necessary functionality that health IT must have to support patient flow.

The paper has the following structure. First, a short review of OM/SCM in health is gone through, where after an explanation of patient flow. Second, the research methodology is described, relating to how this paper was developed and how it will relate to the later full systematic review. Third, the selected articles are summarized – one section with care pathway literature, another section with IT support for care pathways. Fourth, the insights on care pathways and health IT are discussed in relation to patient flow improvement, where after a conceptual model is developed and key dimensions identified. Finally, the paper concludes with describing the research relevance of the coming full systematic review.

Health care from an OM/SCM perspective

OM/SCM research aims at improving the delivery of products/services through effective design, management, and planning and control of resources. Recently, literature and research on OM/SCM in health care has attempted to tackle various issues ranging from operational to strategic developments in managing patients, materials, resources and many others (Dobrzykowski et al., 2014). The way forward, however, still does not appear to be straightforward. Radnor et al. (2012), for example, analyzes Lean literature in the context of health care, exploring why Lean appears to be an "unfulfilled promise." When so many authors suggest Lean could "solve" the problems of suboptimal health care performance, why do problems still subsist?

Other authors, such as De Vries and Huijsman (2011) focus on a broader SCM view, noting the relevance of SCM in improving the health care systems and mitigating the challenges that have arisen. By viewing health care organizations as a part of a supply chain, integration can be assessed and improved through a variety of phases – taking into account a holistic view of the care processes. Thereby, value-adding processes can be identified and focused on in improvement initiatives. Ultimately, however, the priority for health care is to provide high quality care to patients – and thus, *patient flow* improvement is of utmost importance (Drupsteen et al., 2013, Devaraj et al., 2013).

Patient flow from an OM/SCM perspective

Patient flow refers to the transferring of patients along various care steps, which can be both *within* and *between* organizations. Many studies have focused on studying patient flow within hospitals (van Lent et al., 2012, Devaraj et al., 2013), however a need for broadening the scope to include more care steps in and between various organizations has been called for (Drupsteen et al., 2013, De Vries and Huijsman, 2011). Improving patient flow requires us to understand the drivers and barriers to patient flow (Drupsteen et al., 2013, Devaraj et al., 2013). The Theory of Swift, Even Flow (TSEF) can be used to shed light on this (Drupsteen et al., 2013, Devaraj et al., 2013, Schmenner and Swink, 1998).

Schmenner and Swink (1998) proposed TSEF in an attempt to create an encompassing theory, based on OM/SCM principles, to explain productivity differences of factories – and later applied the theory to services (Schmenner, 2004). The authors initially describe a variety of "laws" that have surfaced in the OM/SCM field (Schmenner and Swink, 1998) including i) *Laws of variability:* the greater the variability in the process, the less productive the process will be, ii) *Law of bottlenecks:* the bottleneck in a process will limit the throughput of the entire process, iii) *Law of scientific methods:* the use scientific methods can improve productivity, iv) *Law of quality:* increasing quality of a process will also improve productivity, and v) *Law of factory focus:* focusing on a limited number of tasks will be more productive than carrying out many tasks.

TSEF which states "the more swift and even the flow of materials (or information) through a process, the more productive that process is (Schmenner and Swink, 1998)." TSEF explains *why* the laws described earlier hold true. TSEF ultimately rests on three concepts, namely *value-added and non-value-added work*, *bottlenecks* and *variability*.

Value-added and Non-value-added work: Work can be either value-added, or non-value-added, meaning that some work adds value to the process whereas other work is unnecessary and considered "waste." As such, for example, the law of scientific methods, when applied on the value-adding processes, will in fact yield higher performance.

Bottlenecks: The bottleneck is that point in a process that has limited capacity, compared to the other process steps. The bottleneck will therefore limit the throughput of the entire process, given that the bottleneck is necessary for the process. As such, using the law of scientific methods specifically on processes that relate to the bottleneck can improve performance. The law of quality also explains how "temporary bottlenecks" may prop up if a process needs to stop due to errors or defects, therefore higher performance can be increased through improved quality.

Variability: Variability, measured by variance in time spent per process step, timing, or quantities, impacts the ability to attain even flow. Therefore, reduction in variability is desired to attain an even flow. For example, the concept of factory focus is logical in that a focused factory will naturally reduce the variability by only producing a handful of products and limiting the number of possible process steps.

As can be seen, TSEF can explain performance of certain processes through the careful examination of value-added work, bottlenecks and variability. Thus, if the concepts and tools used in health care directly address the concepts as described in TSEF, then a more swift and even *patient* flow may be possible. Therefore, TSEF will be used as an underlying framework exploring which elements of *care pathways* and *health IT* are conducive to improving patient flow. Care pathways and health IT will be treated as two different constructs that can be used in conjunction with each other to improve patient flow performance - represented in Figure 1. The double-sided arrow shows that care pathways and health IT may or may not influence, support or put constraints on the other.

Based on the theoretical framework, two discussion questions have been developed. These questions serve to position the literature and findings in relation to the goal of patient flow improvement. The questions are as follows:

1. *Which aspects of care pathways are conducive to patient flow improvement?*
2. *Which health IT functionalities are conducive to improved patient flow in care pathways?*

In the discussion, the various attributes identified from the literature for care pathways and health IT are then discussed in relation to TSEF, and more specifically, their impact on value-adding work, bottlenecks, and variability. See Figure 2 below. The double-sided arrow again shows the relationship is not necessarily one-directional.

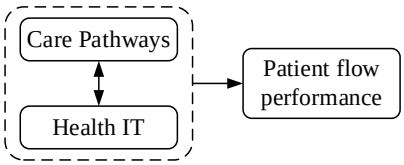

Figure 1 Theoretical Framework

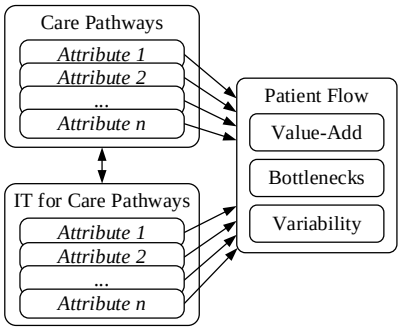

Figure 2 Structure for Discussion

Research methodology

As stated earlier, this paper is a preliminary review that will be used as input to a full systematic review later on. The research design for the full systematic review is a modification of the process outlined by (Tranfield et al., 2003, Kitchenham, 2004). The process consists of four main phases, including 1) Planning, 2) Preliminary search, 3) Full systematic review, and 4) Reporting and Dissemination. This paper will cover the preliminary search phase, as the aim is to identify the main aspects of relevance for patient flow improvement. This paper will therefore contribute to refinement of the key dimensions to be explored in the full systematic review.

For this preliminary review, a selection of relevant articles were taken from a structured search on Scopus, Science Direct, Emerald and Google Scholar. Search strings were used to focus on the two main domains. Combinations of “care pathways” and “literature review” and synonyms were used to select literature relating to care pathways. For the second domain, “care pathways” and “information technology” along with various synonyms were used.

The goal for the first selection of literature on care pathways was to gain an understanding of the definition, content, outcomes, and unresolved problems that care pathways have in the health care sector thus far. The goal for the second selection on care pathways and information technology was to understand which functionalities are necessary to support care pathways, and the issues that exist in relation to these functionalities and systems – including availability of current systems and/or implementation challenges.

The search was initially conducted for the period of 2008 – 2018. However, one article outside this time period was included in this preliminary review, Lenz et al. (2007), due to the high relevance. The articles were chosen if they included a) a thorough literature review, b) had at least 50 citations and c) had a main goal as previously described for the literature selection. Four articles for each research stream were chosen to ensure a manageable, yet representative, view of current research.

Overview of selected literature

This section goes through a selection of literature from care pathways and health IT research. Table 1 lists the selected literature reviews, along with notation of the journal, research method, and corresponding research area (RA) to which they pertain. These articles are summarized independently, focusing on the main message and issues of each article. The material identified in the summaries provides input in subsequent discussion section where care pathways and health IT are discussed in relation to TSEF.

Table 1 Overview of selected literature reviews

RA	Reference	Journal	Method*
Care Pathway	Allen et al. (2009)	Intl. J. of Evidence-Based Healthcare	SR
	Rotter et al. (2010)	Cochrane Database of Systematic Reviews	SR
	Schrijvers et al. (2012)	Intl. J. of Integrated Care	C
Health IT	Lenz et al. (2007)	Intl. J. of Medical Informatics	CS
	Wakamiya and Yamauchi (2009)	Intl. J. of Medical Informatics	CS
	Gooch and Roudsari (2011)	J. of the American Medical Informatics Assn.	QM

**SR = Systematic Review, NR = Narrative Review, C = Conceptual, CS = Case Study, QM = Qual. Meta-synthesis*

Care Pathways

Care pathway research has not agreed on a single term, so articles may use care pathway, clinical pathway, care path etc. Here, the term "care pathway" is used for simplicity.

Allen et al. (2009) is a systematic review of care pathways. They aim to explore when care pathways are effective (and not), depending on their context and content. In general, care pathways were found to improve coordination, efficiency, guideline adherence, service quality, to name a few benefits. However, the authors suggest that it is not enough to know the benefits, it is also necessary to explore exactly what care pathways are and why certain elements of the care pathways lead to improvements. This can range from development, implementation, and content, to the actual use of care pathways. The authors are adamant that, for relatively predictable care pathways, improvements in service quality and efficiency can be expected. Less predictable care pathways could serve more difficulty in extracting any benefits from care pathway implementation. In general, care pathways could need further research looking at the "supporting mechanisms" for both *implementation* and *adoption*. The authors also suggest that the research has not focused on the ability for care pathways to serve as both an accounting tool, as well as a coordination tool.

Rotter et al. (2010) is a systematic review from the Cochrane database. This review focuses on evaluating the effects of care pathways on professional practice, patient outcomes, length of stay and hospital costs. The authors limit the review to articles that show a rigorous, quantitative methodology including randomized controlled trials, controlled before and after studies, and interrupted time series analysis. Care pathways are defined as being a structured multidisciplinary plan of care. In addition to this, the authors conclude that care pathways must fulfil three of the following four criteria: translate guidelines/evidence into the local context, include detailed steps of care, include timeframes, and standardize for a specific disease or condition. The findings that favor

care pathways in improving care focus on reducing complications, improving documentation and reducing the length of stay. Costs proved difficult to evaluate with some studies reporting reduced costs whereas others reported increased costs. The study focused on hospitals, and therefore did not look at the impact of costs or other outcomes on other organizations involved in the care processes.

Schrijvers et al. (2012) is a conceptual paper, looking at care pathways from an OM perspective. The authors use the European Pathway Association (EPA) definition of care pathways, and state that care pathways should improve patient outcomes, safety, satisfaction, and optimize resource usage. The authors distinguish between "clinical" and "care" pathway – stating that clinical pathways are located solely within a single clinic. The authors also discuss "care streets," which refer to care pathways within focused clinics for specific illnesses. The authors then review the scientific basis for care pathways, including Critical Path Method (CPM), Business Process Redesign (BPM), and others. The paper ends with advantages and disadvantages of care pathways. Advantages include reduced waiting time between processes, reduced errors, increased coherence in the care process, cost reduction, and job satisfaction increase (due to clearer responsibilities and more autonomy). The disadvantages include dehumanization of work, increased costs in data collection, reduction of job satisfaction (due to pressure to meet time constraints *and* reduction in variation).

Health IT support for Care Pathways

Care pathways do show potential in being supported by IT, however research has been lacking (Neame et al., 2019). The following literature highlights studies that attempt to distinguish the main elements for supporting care pathways.

Lenz et al. (2007) discusses guidelines, care pathways, and IT applications that can support these. Guidelines are evidence-based and used to inform physicians, and care pathways are used to implement guidelines. Therefore, based on the equipment a hospital has, guidelines may be adapted. In addition, care pathways often designate which resources are needed, including staff and equipment, and time horizons for processes in the pathway. IT applications, as the authors explain, can support care pathways – though are not necessarily required. To improve care, IT applications need to become an integral and routine part of work. The authors develop and test an IT application for a care pathway. Lessons learned included 1) make the application clear, simple, and not overloaded, 2) clearly separate "recommendations" from actual decisions that are carried out, and 3) do not automatically select "default values" in the workflow. The authors also stressed that suitable training and knowledge were essential – for example, if the pathway suggests a treatment that was not normally done, the staff might document in the system that the treatment was done but not actually carry it out. Documentation and the care process are therefore closely related since documentation of the steps are only "promises" if documented *prior* to administering them. Thus, feedback is critical to ensure the care process is actually carried out.

Wakamiya and Yamauchi (2009) focus mainly on the necessary functions of Electronic Medical Records (EMR) to support care pathways. The need for integrating care pathways with electronic systems, such as EMR, is argued both due to inevitability of a technological transition, and due to opportunities technology holds in improving care pathways. The authors propose six standard functions for "electronic" care pathways, including 1) *displaying*: displaying the care pathway in relation to the electronic medical

records, 2) *recording:* records should be computerized, such that all events are recorded, 3) *ordering:* it should be possible to order and cancel orders for medications, rehabilitation, etc., 4) *editing:* It should be possible to edit care pathways at the organizational level, 5) *variance:* variance from care pathways should be recorded, and 6) s*tatistics:* statistics should be possible to be extracted from the systems. The authors explore the availability of these standard functions in several IT vendors. Most of the suggested functions are available; however, no single vendor provided a "complete product." Therefore, the authors urge that the functions listed be used in future software development of vendors of "electronic" care pathway solutions.

Gooch and Roudsari (2011) focus care pathways and information systems, but also reconcile this with the concept of "workflows." Clinical workflows refer to tasks related to the care process and the allocation of the tasks to the various providers involved. The authors explain differences between clinical guidelines, clinical protocols, and care pathways. These range from high level, generic to specific and variance-based. EHR systems are seen as a possible support tool, where care pathways can be "computerized." Ultimately, the authors aim to explore and develop guidelines to implementation of a process-oriented health information system where care pathways are a foundation for the workflow. They review the challenges of implementing process-oriented systems, and various approaches to facilitate implementation – ranging from EHR integration, clinical workflow integration, and general systems implementations. The authors conclude by stating the implementation issues are a major challenge, and that pathway and system implementation research needs to be richer and focus on both processes and outcomes.

Discussion, model development and key dimensions

In this section, two broad questions are addressed regarding which aspects of care pathways and health IT are conducive to patient flow improvement. A conceptual model is developed, and thereafter the key dimensions for further study are highlighted.

Which aspects of care pathways are conducive to patient flow improvement?

As can be seen in the literature, care pathways are multifaceted and may lend themselves to facilitating a swift and even patient flow within hospitals and between health organizations.

Care pathways have a unique role in the identification of *value-added* and *non-value-added* care processes. On one hand, care pathways actively implement evidence-based practices, which, in theory, should improve patient outcomes (Rotter et al., 2010). However, in some cases, the patients may not necessarily need to go through each and every care step, as stated in a standardized care pathway. This brings out the question of whether certain care steps should actually be undertaken, even though they may not necessarily be value-added, or whether each care pathway should be individually adjusted based on the patient's specific context.

In addition to the value-added *care* processes, care pathways inherently are applied in a specific *organizational* context (Allen et al., 2009), with various supporting processes such as capacity planning, purchasing, inventory management etc. These supporting processes, although not contributing directly to the patient care, are necessary given the fragmentation of healthcare (Drupsteen et al., 2013). As such, developing organizational processes to support care pathways, and the related planning and control, is a crucial yet underdeveloped research area. Care pathways in themselves are based on CPM and other such principles (Schrijvers et al., 2012), yet the organizational context needs to be addressed to a further extent (Allen et al., 2009).

The standardization of care processes for specific illness or conditions, as found in care pathways, serve to *reduce variability*. This can limit the variety of decisions made in coordination of the patient care, when different people in different departments or organizations carry out the various process steps. Care pathways may even serve to guide the development of a focused factory or specialized clinic to handle specific illnesses (Schrijvers et al., 2012). This can reduce the variability substantially, and thus improve the flow of patients. Much of the literature on care pathways also addresses the concept of coordination, and that applying care pathways will improve coordination by easing the transition from one stage to the next in the care process (Allen et al., 2009).

Care pathways can plainly state which resources are necessary for the entire care process for specific illnesses or conditions, based on evidence-based medicine (Allen et al., 2009, Rotter et al., 2010). For the local context, this allows for the analysis and improvement of *bottlenecks* in the care process. Bottlenecks will necessarily have a negative impact on the ability of care providers to perform steps within necessary timeframes. The literature reviewed did not necessarily consider bottlenecks as a necessary impediment to patient outcomes, though a reduction of throughput time (as measured in length of stay) was a desirable outcome of implementing care pathways (Rotter et al., 2010). Research on planning and control of such critical resources often addresses care pathways only in passing (Hans et al., 2012, De Vries and Huijsman, 2011). The link between planning and control and care pathways is of relevance, however, given the increase in care pathway usage (Rotter et al., 2010, van Lent et al., 2012).

In conclusion, care pathways have many elements that can help support a swift, even flow of patients. They serve to identify value-added and non-value-added processes for the care, as well as supporting organizational processes. Care pathways can reduce variability of patient care by allowing for a standardized offering, based on the latest clinical evidence, in which health personnel are involved and up-to-date on exactly which processes should be carried out. They also, in identifying the various processes, can be then followed up based on indicators, such as throughput time, to manage the bottlenecks that are present in the care pathway.

Which health IT functionalities are conducive to improved patient flow in care pathways?
The literature on health IT is mainly positive to the ability of IT to support care pathways, however the necessary functionalities and quantitative impact of IT remain elusive. Some aspects will be discussed now, which could facilitate a more swift and even patient flow.

Based on the value-added and non-value-added processes identified by the care pathways, Health IT can be used to create a standardized workflow for certain illnesses, therefore reducing variability that clinical staff face when treating patients (Gooch and Roudsari, 2011). *Value-added* and *non-value-added* steps can also be individually evaluated more effectively through the help of clinical decision support.

Health IT can reduce *variability* by making the next steps in the process of care explicit and easily accessible. This can be done through the use of checklists which give a routine and systematic follow up of the care processes (Wakamiya and Yamauchi, 2009, Lenz et al., 2007). Given that the checklists and routines are in a system does not, however, ensure that health personnel do in fact carry out the various tasks. This means that the health IT must lend itself to being a part of the everyday tasks of health personnel and give *feedback* if one of the tasks has not been carried out.

Health IT can allow for access to capacity availability, as well as historical information on performance of care pathways. This can highlight the *bottlenecks* that exist within each particular care pathway. In this way, IT could support the better

planning and managing of resources in each of the care pathways for each individual patient – given for example if some tasks can be done in a different order, in parallel, or with a different resource.

As a conclusion, the literature on IT support for care pathways is quite limited, with a focus on improving the workflow at an operational level – that is, for use by doctors, nurses and other health personnel. Nonetheless, applying IT in support of care pathways for inter-department and inter-organization coordination, planning, and quality management – as to address improved value, reduced variability, and effective bottleneck management – may provide a more swift, even flow of patients in hospitals and other health organizations (Devaraj et al., 2013, Drupsteen et al., 2013)

Key Dimensions and Conceptual Model development

Based on the discussion of the research questions regarding care pathways and health IT, the following key dimensions are used to understand the relationship between care pathways, health IT, and patient flow:

- Care pathways attributes:
  - Care process steps identification
  - Time horizon of care process
  - Resource identifications
- Health IT attributes:
  - Documentation of care process
  - Workflow and checklist functionalities
  - Planning and decision support functionalities
- Organizational context of care pathway and IT
- Evidence-based medicine

These key dimensions are supported by the use of care pathways and health IT, and serve to support the three foundations of swift, even flow as described by Schmenner and Swink (1998). Therefore, a conceptual model has been developed which has included care pathways, health IT, the key dimensions identified. The result is shown in Figure 3.

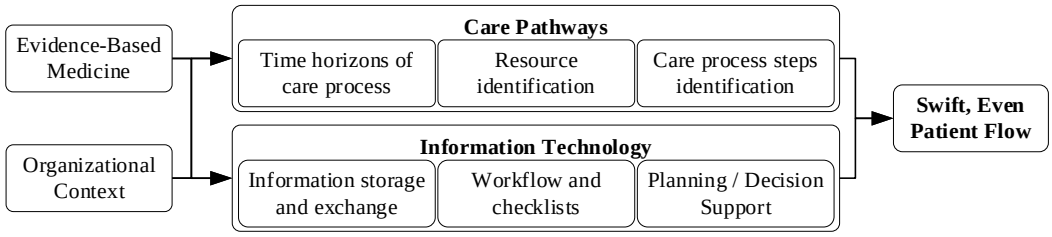

Figure 3 Conceptual Model relating Care Pathways and IT to Patient Flow

The conceptual model illustrates how the organizational context and evidence-based medicine directly impact the care pathway and IT required to provide care. Care pathways, with the identification of standard time horizons, resources, and process steps may serve to support value-added care, bottleneck management, and variability reduction. Health IT may provide support for documentation and information sharing for the care pathway, facilitate good routines through workflows and checklists for health personnel, and enable decision support both for clinical and organizational planning processes.

Conclusion

This preliminary review, and the planned systematic review, will be the first to the author's knowledge to consider care pathways and health IT in relation to patient flow

from an OM/SCM perspective. Shedding light on the ability of care pathways and IT to improve patient flow can be of great value, especially in terms of the developments in technology, such as the increasing adoption of mobile devices, cloud-based services, and ubiquitous sensors, which can integrate clinical, logistical, and financial information.

In addition, more research on specific functionalities and design of IT based on the elements of TSEF should be carried out. The impact of home-based follow-up technologies should also be considered in the context of TSEF.

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Contingency between managerial practice and supply chain integration – exploring a hospital's supply chain of medical consumables

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Abstract
The relevance of the integrative component in supply chain management (SCM) has been linked to the positive impact of integration on performance. Hospitals, which are under pressure to improve performance because of increasing costs, are a unique context to explore integration since the supply chain (SC) is multi-functional. By combining a semi-structured literature study and an in-depth single case study, this paper analysis the managerial practices that are contingent upon the integration in the SC of medical consumables in hospitals, and proposes interventions that can secure performance.

Keywords: supply chain integration, managerial practice, hospital materials management

Introduction
The relevance of the integrative component in supply chain management (SCM) has been linked to the positive impact of integration on performance (Frohlich and Westbrook, 2001). However, doubts about the applicability of integration have been addressed, particularly related to the context, arguing that performance depends on the contingency under which integration is applied (Van der Vaart and van Donk, 2008), i.e. the position of the supply chain (SC) partners, the level of uncertainty or type of suppliers. An empirical study of supply integration in the Mexican apparel industry conclude that tight coupling does occur and are vital to SC success, but also that tightness at one point in the network might require looseness elsewhere depending on the context of the SC (Arroyo et al., 2018). Contingency and managerial practices, i.e. how integration is realised, is crucial. There are concerns about integration, however, since it is not very well defined, difficult to measure empirically, and different aspects of integration might be important under different contexts.

With increased costs and restricted budgets (Volland et al., 2017, Chen et al., 2013), the pressure to improve performance and deliver high quality health services, more efficiently is evident. The SC of hospitals, containing multiple integrative aspects (a broad set of clinical care services and materials, covering multiple specialist functions and managerial levels, involving patients), is an interesting and unique context to explore integration, managerial practices and the relation to performance. Drupsteen et al. (2013) suggests that hospitals, with their many specialties, functions and sharing of resources

could pose different barriers and enablers to integration. Hospitals are expected to provide high availability of quality services and materials critical for patient care under circumstances with varying and unpredictable care pathways (Moons et al., 2019). Thus, there is a strong case for integration mechanisms between functions and managerial levels (strategic, tactical and operational) in order to fulfil the objectives of hospital SCs.

In literature, there is limited understanding of the integrative aspects in hospitals (Drupsteen et al., 2013, De Vries and Huijsman, 2011), particularly the managerial practices of the integration context (Volland et al., 2017, De Vries and Huijsman, 2011). Compared to patient treatment, material management has not been given high priority in hospital management research, except from the few studies mainly focusing on operative material flow issues (Moons et al., 2019). This study aims to explore this, by analysing the managerial practices that are contingent upon the specific integration requirements of the medical consumables SC, and to propose interventions that can secure adequate performance. As De Vries and Huijsman (2011) put forward, SCM in health care should especially address integration in terms of the multi-dimensionality of the operations.

The remainder of this paper begins with elaborating on the literature before a discussion of the research methodology. Thereafter, a hospital case is used to analyse the integrative context and managerial practise. The paper concludes by discussing the findings in relation to the previous literature while proposing recommendations for improving performance in hospitals and future research.

Theoretical background

This section explores the literature about integrative managerial practises in hospitals and proposes an analytical framework.

The supply chain literature, in general, defines integration according to *constructs* such as interaction, collaboration, and cooperation (Flynn et al., 2010, Pagell, 2004, Frohlich and Westbrook, 2001) which characterise integration as a removal or dampening of functional barriers appearing within and between organisational units. van Donk and van der Vaart (2004) propose five integrative aspects that can be used to understand the practices performed within interfaces in the SC, namely; organisation, physical flow, information flow, product development and planning and control. We adopt these five aspects when exploring the hospital SC literature, and add integrative performance attributes. Each aspect is analysed below, first with a reference to the general integration literature and second to the literature on hospital operations.

The integrative *organisational* aspect concerns the relationship and the type of partnership with buyers, suppliers and internal company units (van Donk and van der Vaart, 2004). Drupsteen et al. (2013) distinguish between the *span* of integration (which and how many units are integrated), the *scope* of integration (which aspects of the organisation are integrated), and the *intensity* of integration (the level of integration). For hospitals the span of integration include external SC operations which are supplier related processes, as well as the internal operations of functions (Moons et al., 2019). The scope of the integration can be the flow of patients, or the materials flow (Volland et al., 2017, De Vries and Huijsman, 2011). For the intensity of integrations, the literature seems to focus on the relationship, such as different types of collaborative models, and does not address the management practices to a large extent.

The integrative *physical flow* aspect relates to the connections of the material flow (Frohlich and Westbrook, 2001) in the SC. The hospital literature has particularly explored collaborative concepts such as vendor managed inventory (VMI) (Haszlinna Mustaffa and Potter, 2009), stockless replenishment method (Rivard-Royer et al., 2002), two-bin Kanban system (Moons et al., 2019), and “ward box” (Bhakoo et al., 2012) in

order to find better ways to increase performance. Common between these concepts is the need to manage resources and control cost by reducing stock levels (De Vries and Huijsman, 2011). However, the literature suggests that in spite of the performance potential of these concepts, integration might be hindered due to a lack of information and information sharing (Moons et al., 2019, Volland et al., 2017).

The integrative *flow of information* aspect relates to the connectivity of information and information- and communication technology (ICT), e.g. what information is shared and use of technologies such as electronic data interchange (EDI), scanners and material requirement planning (MRP)-systems. In hospital SCs, limited access to information about stock levels, lack of universal product number classification systems, low forecasting accuracy, and limited information sharing across the SC often hinder tighter integration (Volland et al., 2017, Chen et al., 2013). Adoption of management information systems, data standards and data capturing technologies (barcoding, radio frequency identification device (RFID)) has been slow in hospitals (Rossetti et al., 2012); these require personnel time for scanning, human accuracy and include high costs of adoption and implementation (Moons et al., 2019).

The integrative aspect of *product development* is the mutual involvement in developing new products and process improvement. The volume and variety of physical goods carried by hospitals is high and increasing. Categories of consumables, custom procedure trays and sterile items constitute the majority of the products applied (Moons et al., 2019). For process improvement, the hospital SC literature is rich, particularly regarding hospital supplier collaboration and how to improve processes by performing planning and operations together (Mandal, 2017). For the product development dimension, however, this integrative aspect in literature is scarce.

The integrative *planning and control* aspects relates to the directing of activities, making the situation predictable and dampening uncertainty (Childerhouse et al., 2002). The manufacturing literature argues for the need to design the planning processes according to the environment (Kaipia and Holmström, 2007, Jonsson and Mattsson, 2003). If the planning environment is characterised by high uncertainty, as in hospitals, due to being unique, complex and dynamic causing uncertainty (Moons et al., 2019, Bhakoo et al., 2012, De Vries and Huijsman, 2011), a high level of integration is recommended, and vice versa. Relevant planning variables are product, operations, demand and supply (Ivert et al., 2015). For hospitals, the *demand related variables* include high variability, uncertainty and unpredictability of demand (Moons et al., 2019). Demand is driven by the patients diagnosis and physicians preferences which are based on their medical training, experience with specific brands and context specific demands. There is a disconnect between those who make the buying decisions, those who actually do the buying and those who pay for the consumables which might affect demand. The *product related variables* include the material cost which varies between high value special equipment used in operating rooms, and thousands of different types of less expensive consumables used for patient care (Bhakoo et al., 2012). The *operational related variables* are logistics, inventory/storage, procurement and ordering. Multiple storage rooms exists within the hospitals (Moons et al., 2019), often with limited stock tracking possibilities. The logistics responsibility is often fragmented among several units causing coordination and integration problems. Logistics related activities are often performed by medical staff, taking away time from patient care. The *supply related variables* include a fragmented supplier base (Moons et al., 2019).

Performance indicators that can improve processes at hospitals can be categorised as quality, time, cost and productivity metrics (Moons et al., 2019). In this study these metrics are applied when analysing the present performance of the SC of medical

consumables. The categories of performance indicators are operationalised as *lead time*, *stock levels, turnover rate* and *warehouse capacity*. The metrics serves as a input for decision making and to identify inefficiencies.

To summarise the literature the following analytical framework is proposed and applied to analyse the case study (Table 1):

Table 1 Analytical framework for contextual integrative aspects and managerial practices based on (Moons et al., 2019, Drupsteen et al., 2013)

Contextual integration aspects	**Managerial practices**
Organisation	*Scope:* the aspects of the organisation which are integrated
	Span: which and the number of units integrated
	Intensity: the level of integration
Physical flow	*Connectivity of material flow:* replenishment procedures and inventory policies
Information flow	*Connectivity of information flow:* access, flow and information technology
Product development	*Product and process development:* new and improved products and processes
Planning and control	*Demand variability:* variability, uncertainty and unpredictability
	Product: product range complexity
	Operational: level of fragmentation
	Supply: supplier base complexity
Performance	*Indicators*: lead time, stock levels and turnover rate

We shall also briefly reflect on the findings from the analysis from a system theory perspective, in particular De Leeuw's (1976) control paradigm (it should be noted that "control" in this context refers rather to the overall goal of *managerial practises,* than to control as described in the integrative planning and control aspects). Four basic aspects are required to be able to effectively control a certain system, i.e. keep its performance within an acceptable range (1) the availability of a goal (2) a sufficiently rich set of steering actions (3) a model of the controlled system and (4) information about the state of the system. We are interested in gaining a better understanding of how integration, or the lack of it, is related to achieving effective control.

Research methodology

This section describes the research methodology of the study.

A literature study was conducted, drawing on the current body of knowledge about integration in hospitals SCs. The literature was explored by adopting a semi-structured approach based on keywords and snowball technique, searching in Google scholar, Science Direct and Scopus. An analytical framework was developed from literature and guided the case study.

The integrative aspects are analysed by an in-depth single case study of a Norwegian hospital. The case study was the preferred strategy (Yin, 2009) since the aim was to explore the managerial practices that are contingent upon the integration features of the hospital. A call for in-depth case study research has been made, emphasizing the complexity in the various medical SC (Mandal, 2017). Medical consumables, as one of the main medical SCs, are a significant component of hospitals budgets and highly interrelated to patient care. The selection of the case is motivated by the characteristics of the hospital; consisting of the many specialist functions, patient categories, centralized

sourcing and logistics units containing a supplier base, and warehouse system. The hospital is also one of the largest hospitals in Norway in terms of employees and patients. The unit of analysis is the medical consumables flow through the suppliers, warehouse, and specialist units at the hospital. The method gave access to rich and in-depth data.

Findings are based on data from interviews of key personnel, observations at the hospital and warehouse, and analysis of quantitative SC data from the ERP system. Data are analysed according to the analytical framework proposed in Table 1.

Case analysis

In this section, the case study is analysed according to the framework presented above.

The SC of consumables consists of the care units at the hospital, and a logistics unit (inventory/distribution) located outside the hospital. The inventory contains a central warehouse that receives, stores and/or cross-docks all consumables from external suppliers to the hospital's many stocking points at the care units. Thus, the external interface of the supply chain is between the suppliers and the hospital, and the internal interface is between the logistics unit and the hospital's care units. The following Tables (Table 2 to 4) summarize the analysis of the case data.

Table 2 Integrative organisational aspect

Organisation	Scope	External suppliers. Logistical unit consisting of a central warehouse and distribution centre. Hospital clinics and operations units.
	Span	The stocks at the care units are mostly replenished by (personnel) the central warehouse based on VMI principles. However, when required care personnel may also order. The central warehouse manages the central inventory and stocks at hospitals, ordering from suppliers and distribution/logistics. A central procurement unit at the hospital is responsible for sourcing and supplier/contract management.
	Intensity	For replenishing stocks at the hospital, a VMI model is applied. Supplier relationships are regulated by yearly contracts following public procurement clauses. Functional organisation of internal supply chain domains.

Table 2 indicates that the interfaces in the SC are managed in different ways. The VMI model applied between the logistics unit and the care units at the hospital indicates a high level of integration between the internal functions, while the relationship between the hospital and its suppliers seems to be less intensive.

Table 3 Integrative physical and information flow aspects

Physical flow	Replenishment procedures/ inventory policies	MRP principles, periodic inspections and reorder point is the replenishment and inventory policies applied at storages in hospital care units. MRP is applied for approximately 20 % of the assortment and 80% ordered by manual inspections. The delivery frequency is four times/day.
Information flow	Connectivity of information flow; access, flow and information technology	The information flow is organised in the ERP-system, connecting the hospital care units with the warehouse and procurement units. SAP has mainly a transactional applicability. If reporting and analytics is needed this will be provided by the centralised ICT unit.

At the hospital, the push principle is the mechanism driving the majority of the physical flows, and ordering and replenishing decisions are based on demand expectations and experiences, adjusted by variability in demand and lead time (Table 3). For these items, the only information available about stock levels and replenishment requirements is acquired through manual inspections. Approximately 20% of the stock at the hospital is

controlled by MRP-principles, while the central inventory is fully controlled by MRP-principles.

The case study did not reveal any data indicating product or process development between the units in the supply chain.

Table 4 Integrative planning and control aspects

Planning and control	Demand variability	High variability in orders from hospital and order deliveries from suppliers per day. See figure 12 and 13. Table 4.
	Product range complexity	Total number of items 2.826. The pareto-analysis show that out of the total number of items, 50% of the demand stems from 132 items, while 20% of demand contains 2.304 items. See figure 8.
	Operational; level of fragmentation	Numerous stocking points at the hospital. Multiple layers of stock locations and buffers. Orders placed by care and logistics personnel. Care and specialist decides which item is ordered (based on preferences).
	Supplier base complexity	In total, there are 180 suppliers. The pareto-analysis show that 50% of the supply to the warehouse comes from 8 suppliers, while 20% of the supply comes from 128 suppliers. See figure 10.

Table 4 characterises the SC planning and control environment as complex, consisting of demand and supply variability shown by the variability per day in the number of order lines to and from the warehouse (Figure 1 on the next page).

The Pareto-analysis shows that a low number of suppliers are responsible for supplying a high share of the items, and that a low number of items represent a high share of the assortment (Figure 2). These figures indicate a planning environment consisting of supply and demand variability, and a limited number of items and suppliers that dominate, while a high share of items and suppliers are not highly active. Additionally, considering the fragmented (multiple types of stock) stock structure at the hospital, where care and specialist preferences decide which or type of item to be ordered, the inventory system can be considered complex and multi-layered.

Metrics indicating the performance of the SC of medical consumables are illustrated in Figure 3 and Figure 4. The average lead-time from suppliers and the standard deviation of the lead-time are shown in Figure 3. The average lead time is approximately one week, while the standard deviation is up to three days. We also see that for the standard deviation there is a long tail, which indicates a high uncertainty for some few products. Further, a detailed analysis shows that for the top-20 suppliers, the lead time is short and varies between 3-8 days, but the standard deviation is much higher than for other suppliers.

Figure 4 illustrates the level of cycle stock (the number of consumption days covered by the stock level), which indicates the level of over- or understocking. From the figure, it can be seen that the coverage for many of the products are high, and clearly above the level needed in order to compensate for demand and lead time variability. Figure 4 shows the inventory turnover rate at the warehouse. A high turnover rate indicates a good fit between the demand and stock level, and vice versa. The analysis shows that for a high number of products the turnover rate is low, and for several products the turnover rate is less than 5 times/year and not more than 10 times/year.

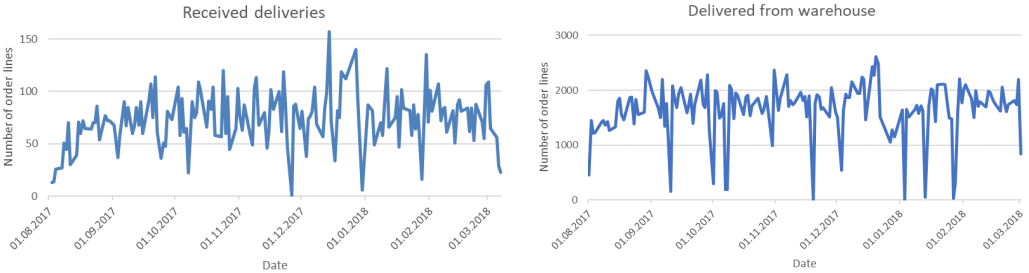

Figure 1 Number of order lines to and from the warehouse/months

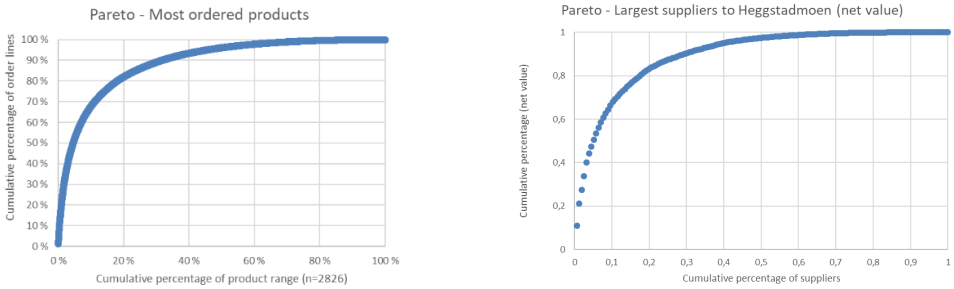

Figure 2 Pareto analysis products and suppliers

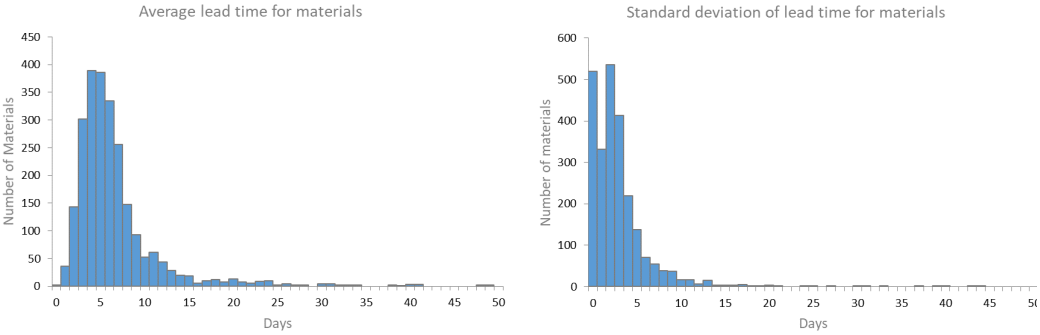

Figure 3 Average lead time and standard deviation lead time

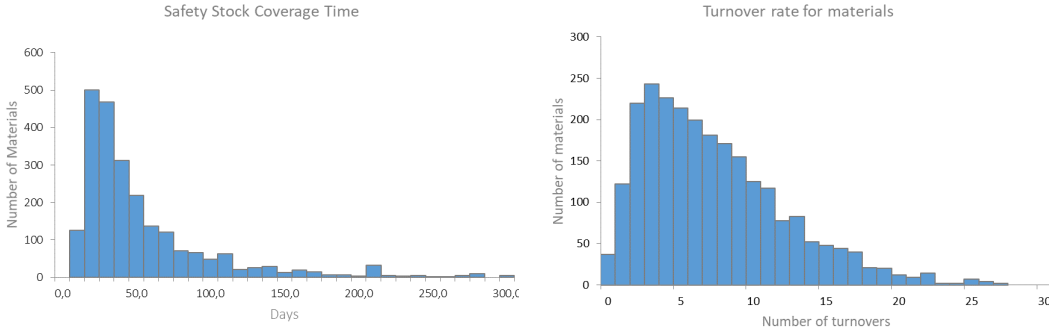

Figure 4 Level of cycle stock and turnover rate

Discussion

This section discusses the managerial practices of the integration of the SC of medical consumables, and proposes interventions that can ensure adequate performance.

Hospitals operations has a long tradition for specialised and functional organisation of work/responsibility by applying management practices based on knowledge from clinical

disciplines. In hospitals, the primary activity is centred around patient treatment and care provision, resulting in specialised units and competence centres organised in a logical sequence of treatments supported by resources such as physicians and nurses, medical devices, operating theatres and consumables (De Vries and Huijsman, 2011). This creates value and organising activities according to a value chain logic where the aim is to perform a fixed set of activities (typical for manufacturing operations), while the actual value hospitals create is in solving patients' problems, which requires a different value chain logic and organisation (Stabell and Fjeldstad, 1998). Recent studies indicate a need for alternative management practices in hospitals because of inefficiency caused by increased demand for hospital services, treatment complexity and budget restrictions (De Vries and Huijsman, 2011).

In the case, the *organisation* of the SC of medical consumables is functional, with logistics, procurement and stock at hospitals as the main internal units and suppliers as the external actors. This is a practice followed by most hospitals (Moons et al., 2019). The integration between the supplier and the hospital is manged by standard contractual terms/conditions with limited focus on logistical performance. The interface between procurement and logistics is also restricted, since the logistics unit does not provide any input about logistical criteria or performance requirements to procurement when suppliers are selected or contracts negotiated. The managerial practises are less focused on collaborative mechanisms which can lead to sub-optimal behaviour in the SC; suppliers acting upon contractual terms lacking specific criteria (such as lead time, frequency) securing an efficient flow of consumables, and logistics/replenishment decisions influences by risk of either overstocking or understocking of items. The level of safety stock, turnover rate and lead time metrics in Figure 3 and Figure 4 may indicate inefficiency caused by less integrated interfaces. Collaborative SC contracts typically contains incentives for risk sharing between the supplier and customer based on principles such as buybacks and revenue sharing (Wong et al., 2009), having a positive impact for the SC. Integrated planning models such as S&OP would secure integrated process between the involved actors, including suppliers (Ivert et al., 2015).

The basic *flow* principle in the SC of consumables is the "push/deliver-to-stock" principle, applying buffers of items along the SC and in each unit (multiple socks the hospital) to minimize risk and secure availability. This managerial practice and limited integration, indicates first the need of high quality and safety requirements (availability) at the hospital, but can also be an indication of a less coordinated stock system since the performance metrics shows high stock levels and low turnover rate of items (Figure 4). However, the opposite practice (high level of integration) is demonstrated by the stock replenishment model applied (VMI) between logistics and hospital units. VMI models at hospitals are found to give a positive performance impact due to the improved quality of the replenishment decisions (product and quantity) (Haszlinna Mustaffa and Potter, 2009). These management practices secure high availability, dampens the risk of understocking, and are critical for physicians in carrying out their work.

Exploring the replenishment process, reflections about the efficency of the manual stock inspections and ordering procedures, and the lack of integration to electronic information and ICT support are evident. Not only is this practice highly labour intensive, but it can also lead to risk of over- or understocking due to incorrect decisions. Additionally, for the logistics and procurement units the functionality of the ERP-system is restricted to transactional purposes (replenishment, order tracking, inventory monitoring), and is not integrated with the analytical functionality of the system. This prohibits them from monitoring performance. This functionality is only accessible through the ICT-competence centre that makes reports based on requests from users.

The *SC planning environment* of consumables contains several of the complexity features indicated in literature, with demand uncertainty, supply variety and heterogenous product mix as the most distinctive characteristics (Chen et al., 2013). In order to mitigate uncertainty, the managerial practices for such environments in order to mitigate uncertainty should be able to adapt to a planning horizon covering the length of the variety cycle, to align demand and supply, and the strategic and operational planning level (Dreyer et al., 2018). The planning horizon of consumables at the hospital are short-term; weekly operations plans and weekly input from hospital units and suppliers. This might lead to sub-optimal utilization of resources, such as the warehouse capacity and the distribution system to the hospital units, particularly the workforce (using overtime in peak-periods and excess capacity in off-peak periods). Figure 1 illustrates the variability of the warehouse operations. To level the capacity, the proposal is to design an integrated planning process with a longer time horizon, covering the length of the variety cycle, integrating planning across functions, suppliers and planning levels.

To summarize the discussion and to propose integrative interventions, we apply the control paradigm of De Leeuw's. Effective control of the entire SC is achieved by breaking it down into a set of smaller sub- and aspect systems, each controlled by its own controller focussing on a specific goal (or set of goals), e.g. a centralized purchasing organization focussing on establishing frame agreements that secure reasonable prices, adequate product quality and environmental performance, the logistical unit focussing on cost efficient storage at the warehouse and further distribution to the hospital, and the care units at the hospital focussing on securing availability of the items close where they are used by the medical personnel. In the case each controller seems to meet the four conditions for effective control in the context of its own system, and thereby, contributing to the stability of the "entire" system (Ashby, 2013). Still, the analysis also showed how the performance of one system can influence, or set the premises for another one, e.g. the purchasing system providing the "input quality" with which the logistical unit has to work. This leads to the proposal of the following integrative interventions that can secure adequate performance for the consumables SC:

- Introduce an integrated tactical planning process: across internal hospital units and levels, includes suppliers
- Apply a longer planning horizon, covering the variety cycle
- Change to collaborative supplier relationships and contracts, containing coordination mechanisms
- Collaborative and automated replenishment models supported by ICT, access to real time information about stock levels and information sharing in the SC.

Conclusion

The study is the first to analyse managerial practices of integrations of medical consumables SCs for hospitals, contributing to proposals of interventions that can ensure adequate performance. Collaboration, integrated planning and information access are proposals for managerial practices that are contingent upon the medical consumable SC. The study adds to the existing literature by identifying the need for collaborative and tactical integration between levels and across functions/organisations. Managerial contributions are the interventions proposed.

The study can be strengthened by a full systematic review. Also, by including several suppliers' elements in the study, the managerial and integration dimensions can be enriched. To further strengthen the financial and performance impact of the managerial practices, adding a more quantitative and systematic approach to measure performance can be added.

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Supply Chain Integration in Healthcare sector: what strategies are implemented?

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Abstract

The study sheds a light on the SCM integration strategies in the healthcare arena. This type of projects tends typically to target the most complex items: (i) medical devices and (ii) operating room materials.
Healthcare organizations look for industrial partners capable of offering high quality standards of logistical services; in fact, the key economic benefits are represented by (i) stock's management optimization and (ii) reduction of warehouse management costs.
As for enabling conditions, (i) standardization, (ii) top management commitment and (iii) strategic relevance of the logistical function are widely considered as key aspect for the successful implementation of these projects.

Keywords: healthcare, supply chain, integration, partnerships

Literature Background

The Supply Chain Management (SCM) field is widely recognized as part of the main scientific literature of Operations Management (OM) and it has been in the last years a hot topic of the top OM journals becoming a dominant theme in operations management research (P. Kouvelis et al. 2006; L. G. Sprague, 2007; N. DeHoratius, E. Rabinovich, 2011). The SCM term appeared for the first time in literature in the mid-1980s and it's fundamental pillars are attributable to operations research assumptions of 1960's. However, in the last 30 years, the Supply Chain literature has been growing up especially in the industrial and manufacturing sectors with a straight focus on product-based firms (M.C. Cooper et al., 1997; D.Q. Chen et al., 2013). In fact, many researchers have been studying the supply chain strategies of firms coming from different industries, like automobile, manufacturing or fashion industry (Brun and Castelli, 2008; Vanichchinchai, 2012; Qi et al. 2009).

At the origin, the SCM was seen as a simple process of planning, implementing and controlling the operations of the supply chain (P. Pounder et al. 2013), however the

concept has evolved in the years and today it is recognized in literature as "*the integration of business processes from end user through original suppliers that provides products, service and information that add value for customers*" (M.C. Cooper et al., 1997, pp. 2). Around the SCM concept, both in academia and practice, there isn't a clear vision and meaning (J. T. Mentzer et al. 2001) and, additionally, it's commonly confused with a logistic concept; however, unlike the latter, SCM is better comparable to a more comprehensive approach that aims to coordinate the functions, the processes and the relations within the organizations and across the supply chain; whereby supply chain shall mean a "*network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer*" (Christopher 1992, p. 17)
Recently, the healthcare sector has attracted the attention of researchers in the area of Operations and Supply Chain, mainly because it is becoming increasingly complex and dynamic. SCM in healthcare is a recent concept that is getting attention due to the promotion of activities integration (procurement, logistics, production and distribution of goods). Especially in the Italian National Health System, the SC integration (or partnership) is seen as a tool to increase both productivity and quality within healthcare processes. Nevertheless, the implementation of the Supply Chain Integration (SCI) strategy in the healthcare sector is still far from common, although the use of SCM is expanding rapidly between healthcare provider (G. Bensa et al., 2010), also due to the performance improvement pressure in the healthcare services linked to the limited resources and to the need to achieve more value (F. Lega et al. 2013).

The partnership along the supply chain is a relatively new concept that has been gaining a strategic importance; indeed, Supply Chain Integration is viewed by management as a tool to increase productivity and improve quality (Lega et al. 2013). In the literature, Supply Chain Integration has been studied from different perspectives. Many researchers have focused the attention on the integration with customers or buyers; while others have analyzed the upstream integration or rather the integration with suppliers (C. Gimenez et al. 2012). The implementation of a Supply Chain strategy based on partnership is useful to overcome the traditional competitive barriers between supply chain members and create mutual benefits leading towards information flows increment, low uncertainty and a more profitable supply chain. The benefits born form this alliance allow supply chain members to gain higher financial and operational performance through reductions of costs, low inventories throughout the supply chain, and increased levels of shared information (M.J. Maloni, W.C. Benton, 1997; Z. Yu et al. 2001).

In this study, we will focus the attention on the partnership between suppliers and healthcare providers (Hospitals, Local Health Authorities, etc.). The Supply Chain Integration in the healthcare field, specifically related to the hospital-supplier partnership, was defined by Chen et al. (2013) as "*the extent to which the business processes between a hospital and its key suppliers are strategically coupled and unified as a whole*" (pp. 392).

As underlined in the past studies, mainly in the industrial sector, it's possible to implement integration along supply chain in numerous ways. In fact, the buyers (in this case the healthcare provider) can choose different integration approaches that have growing up exponentially due to technological innovations (e.g. RFiD system, Electroni Data Interchange, Electronic deposit account) (A. Chircu et al. 2014). Because of technological innovations, it's possible to reach a greater information flows and achieve real-time processing and transmission of information required for supply chain decision-making (D. Prajogo, 2009; B. Ageon et al. 2013). Other types of integration practices, such as Vendor-Managed Inventory, pro-active management of expired goods (Y. Yao et

al. 2005; D. Power, 2005), Just in Time approach (S. Qrunfleh, M. Tarafdar, 2013), consignment stock and physical management of the warehouse by the supplier (S. Villa 2012) are moreover in rapid expansion even among healthcare firms.

SCI can be supported by organizational requirements to strengthen the collaboration with suppliers; previous researches have highlighted several enabling conditions that can be summarized in eight organizational conditions needed to allow collaborative relationship, these are: i) IT endowment of logistic process to make information transparent and available at the right place, at the right time, and in the right hands; ii) process standardization; iii) strong commitment of top management; iv) strategic relevance of logistics; v) skilled employees across department and organizational functions; vi) bargaining power; vii) control system of Supply chain of performance and viii) clear goals of improvement; (D. Power, 2005; T. R. Crook et al., 2007; S. E. Fawcett et al. 2008; S. Villa, 2012). However, it's suggested that there could be some principal conditions that allow a successful partnership with supplier (M.J. Maloni, W.C. Benton, 1997; S. Babbar et al. 2008), but isn't still clear what are the major bridges in practice.

Many authors have underlined several benefits that lead managers to implement a successful supply chain integration; generally, when the management choose to integrate supply chain, it expects an important return from the suppliers in terms of process improvement and a positive impact on operational performance (C. D. Brennan, 1998). On the other hand, there is a substantial body of literature that has identified barriers that obstruct the successful integration with suppliers (S. E. Fawett et al. 2008). In previous literature, managers have reported many difficulties in the process implementation of SCI strategy. Nevertheless, the research regarding the effects of the variables that impede the implementation of integration is still lacking, which limits the ability to find effective solutions to the processes integration along supply chain. Thus, it is worthwhile to investigate the main barriers to supply chain integration (R. G. Richey et al. 2009).

For this reason, the present paper tries to address three different questions:

- What are the integration strategies that Healthcare Firms try to implement with their suppliers?
- What are the benefits and the barriers of different integration strategies?
- What are the organizational conditions for a successful integration strategy?

It's also important take into account that the healthcare processes are characterized by a series of specificities that inevitably influence the range of available SCM strategies. The healthcare industry has historically viewed itself as operationally different from other businesses (J. De Vries, R. Huijsman, 2011). The Hospital Supply Chain (HSC) is fairly unique and characterized by a high complexity that doesn't affect the industrial sector; this due to the clinical operations that need an adequate and accurate supplies of goods (e.g. drugs, medical device, etc.) to meet appropriately the different patient's needs. Moreover, the complexity is due to the thousands of different types of healthcare goods implicated in the supply processes, which can assume diverse classification (e.g. there isn't a universal number classification for the same product), characteristics, volumes and economic values (D.Q. Chen et al., 2013). Besides, the procurement process is influenced by physicians that step inside the decision-buying process of healthcare goods (e.g. medical devices) requesting precise product specifications and making, as a matter of fact, the buying decisions (E.W. Ford, D.P. Scanlon, 2007).

These characteristics, that distinguish the HSC from the traditional concept of supply chain, make it management more complicated and knowledge-intensive.
In addition, it must be noted that in Italy – as in many other developed countries – healthcare delivery organizations are publicly owned and, therefore, the design and execution of SCM strategies need to take into account all the features and specificities that make public institutions different from the private ones.

First, the range of actions available to public managers is limited by a series of political constraints. Political dynamics result in frequent policy changes and the imposition of short time horizons on public managers mainly guided by institutional rhythms linked to political elections. Developing sound long-term SC strategies and innovation projects is therefore more difficult in this context (Zanjirani et al., 2009). Secondly, public organizations face a variety of stakeholders who place demands and constraints on their managers. The presence of different stakeholders (e.g., taxpayers and recipients of services or industrial groups) requires public organizations to pursue different and sometimes conflicting objectives. Furthermore, it has frequently been argued that public agencies have distinctive goals, such as ethics, equity or accountability, that do not exist in the private sector (Flynn, 2007). To this extent, government often use procurement as a tool to promote a variety of important, broader public policy objectives (Arrowsmith, 1995; Harland et al., 2007) such as economic goals, social goals, environmental goals. Thirdly, public organizations are often designed and structured around the principles of the bureaucratic model. Public sector organizations have more formal, less flexible and more risk-averse decision-making procedures than do their counterparts in the private sector (Farnham and Horton, 1996; Bozeman and Kingsley, 1998). For example, public contracts are often awarded subject to rules and principles that are intended to ensure equal supplier treatment, nondiscrimination, and transparency and to reduce the risk of corruption. In this sense, as outlined by Moore (1995), often in the case of publicly owned organizations the value added has nothing to do with the actual result accomplished, but it is linked on how the process itself is designed and executed. In this case the respect of laws and regulations, in the execution of the procurement process, is essential in order to accomplish relevant public goals (such as equity, accountability and legality).

Research question and methodology

In order to address these three research questions, the authors have adopted a survey research strategy (Forza, 2002), targeted to the Purchasing/Logistic Managers of Healthcare organizations (Hospitals, LHA, IRCCS, etc.) placed in North-Centre Italy. The purpose of the survey was to capture the state of the art in the healthcare sector regarding supply chain integration (SCI) strategies. After an initial section concerning general information on the respondent and on his/her organization, the second section of the questionnaire aimed at capturing the perceived benefits, barriers, and organizational conditions of SCI, through questions that required answers on a 1 (strongly disagree) to 7 (strongly agree) Likert scale. The last section of the questionnaire consisted of open questions focused on the most relevant integration project undertaken by the healthcare organization in the recent years, with the purpose of identifying and reaching a deeper understanding of the top three improvement projects experienced by the management.

As suggested in the literature on survey-based studies (Forza, 2002; Hensley, 1999), because a new scale had to be developed for this study, we relied on existing contributions in order to state our questions. Before administering the questionnaire, we tested it first with academics and then with a selected number of managers, who could follow in the target population. Such checks let us gain a positive feedback on the completeness of the

questionnaire's items (as reliable descriptions of the main constructs addressed in our study) as well as on their ability to clearly convey such concepts to target participants to the survey.

The study has been conducted on a restricted population of healthcare organizations, in fact the initial population consisted of nearly 200 units. In this study only those placed in the Northern-Central Italian regions that met one of these two criteria were included: i) public healthcare organizations (either hospitals or Local Health Authorities - LHAs) ii) private hospitals with more than 400 beds. The final target population for this analysis consisted of 135 units. With 54 collected questionnaires, the response rate was 40%. The breakdown of the sample was as follows: 9 public hospitals; 6 private hospitals; 26 LHAs. The average length of stay in the current organization was 15.3 years; the numbers of year of experience in the current position was 8.4. These numbers let us assume that respondents were experienced managers, fully aware of the phenomenon under analysis.

In order to better interpret the findings stemming from the survey, we carried out interviews with the respondents of 8 organizations that had described the most innovative/interesting integration projects (in the third section of the questionnaire).

The final step of this research consisted of a focus group with the respondents to the survey and with the Purchasing/Logistic Managers of some selected healthcare organizations, who attended our presentation and provided feedbacks on the evidence of the study.

Empirical evidence

The evidence from the survey shows that, among the 54 sampled organizations, 78% of them have implemented at least 1 integration project, while the average number of projects undertaken in this field is 6.4, the maximum being 30.

Available data shows that, out of a total number of 261 implementation projects reported in the survey (classified by type of integration practice adopted and area of implementation), sampled organizations try to achieve a higher level of integration with their suppliers through the adoption of just in time, which is by far the most widespread practice mentioned in this survey (41 projects reported). It is followed by collaborative forecasting (38 projects reported) and then by consignment stock (36 projects reported). Details on the integration practices adopted are reported in Table 1.

Table 1 – Projects by integration practices adopted

Integration practice	**No. projects**
Just in Time	51
Collaborative planning and forecasting	43
Consignment stock	41
EDI	33
Proactive management of expired items	31
Vendor Management Inventory	23
Warehouse managed by the supplier	23
RFiD	13
Others	3

Focusing on the area of implementation, the most recurrent ones concern medical devices and materials used in the operating rooms (54 projects for both), followed by prostheses (39 projects). Details are provided in Table 2.

Table 2 – Projects by area of implementation

Area of implementation	No. projects
Medical devices	64
Operating rooms - materials	64
Prostheses	39
Healthcare goods	28
Pharmaceuticals	26
General goods	24
Others	16

The evidence reported in Tables 1 and 2 shows a remarkable degree of maturity of the sampled organizations, since the most recurrent types of projects and areas of implementation demonstrate a preference toward challenging projects (e.g. JIT for medical devices).

Moving to the benefits achieved through supply chain integration, reliability and timeliness rank in the top positions (average values 5.7 and 5.3), while exploiting the innovation potential of the supplier and establishing long-term relationship reports the lowest means (4.5 and 3.8). Because, especially for some benefits, values were characterized by a rather remarkable degree of variability, we synthetized the evidence on the most relevant benefits by classifying all of them on the basis of their average and standard deviation. The outcomes of this classification are described in Figure 1.

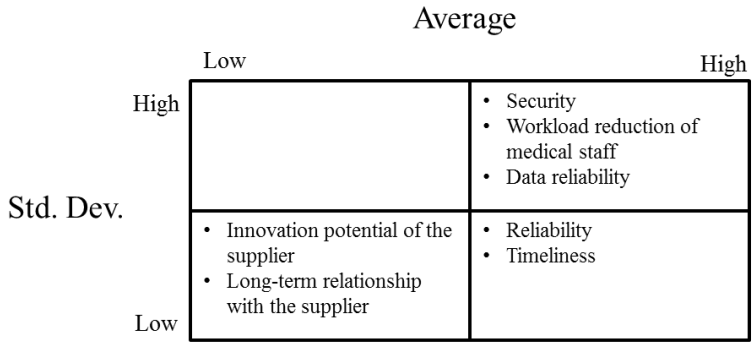

Figure 1 – Organizational benefits

An item was considered either “high” or “low” comparing its mean with the average value reported by all the others. According to this description, only items characterized by a low standard deviation and a high average are likely to be relevant in and highly regarded by most organizations, regardless of their specificities. Similarly, benefits with low standard deviation and low average are unanimously raked low by the vast majority of the respondents.

The same approach was used in order to assess the impact of supply chain integration on the economic benefits, enabling conditions and barriers. The outcomes are reported in Figures from 2 to 4.

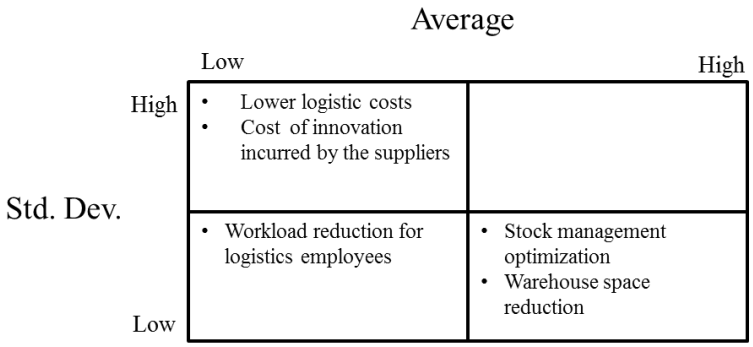

Figure 2 – Economic benefits

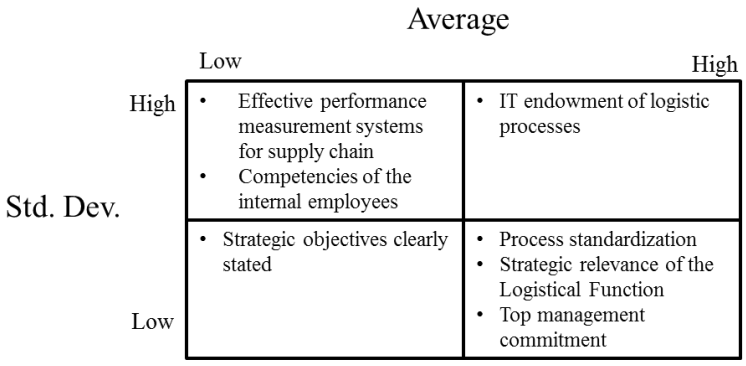

Figure 3 – Enabling conditions

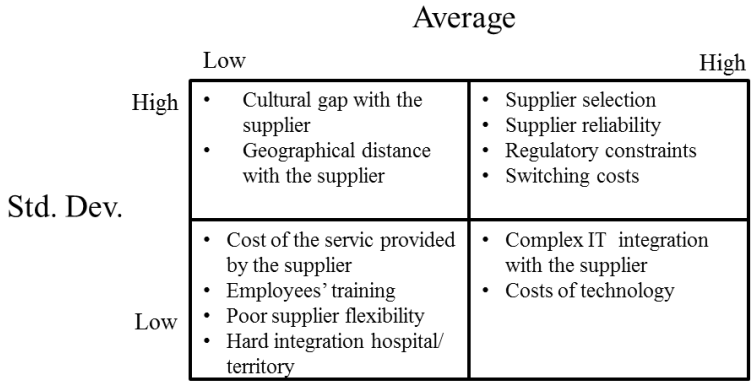

Figure 4 – Barriers

Concerning the economic benefits, those related to stock management seem to be most widespread and appreciated (namely stock management optimization and warehouse space reduction). Moving to the enabling conditions, our survey highlights the relevance of some organizational factors, as the strategic relevance of the Logistic function as well as the commitment of the top management for the success of an

integration process. Also process standardization appears as a critical condition, in line with what is commonly suggested in extant contributions on the prerequisite of change initiatives' success. Finally, concerning barriers to implementation, the cost of the technology and, in particular, the integration of IT systems with the suppliers seem to be critical issues to be addressed.

Correlations between the number of projects implemented by the organizations, on the one hand, and organizational and economic benefits, enabling conditions and barriers, on the other, have been computed. These indices, reported in Table 3, witness a sort of "learning effect", in that the higher the number of projects implemented, the better the perception on the benefits that can be achieved and the lower the one concerning the barriers. However, it is worthy pointing out the positive correlation with enabling factors, which seems to show that over time respondents gain a high awareness about the conditions that must occur in order to successfully implement an integration project.

Table 3 – Correlation indices

	Organizational benefits	***Economic benefits***	***Enabling conditions***	***Barriers***
No. projects implemented	0.08	0.05	0.15	-0.06

Finally, we controlled for the nature of the sampled organization, in order to understand whether such a feature drives the perceptions of the respondents. Indeed, we found out that average values of LHAs are lower for economic and organizational benefits and for enabling conditions, while such an average is higher for the barriers (see Table 4).

Table 4 – Average values by type of organization

	Organizational benefits	***Economic benefits***	***Enabling conditions***	***Barriers***
Public hospitals	4.49	5.36	5.64	4.43
Private hospitals	5.19	5.13	5.48	4.24
LHAs	4.36	4.33	5.20	5.2

Conclusions

The study sheds a light on the SCM integration strategies in the healthcare arena. As expected, given the wide diversity of supplies that characterize this sector, the study has identified different types of practices; however, it must be noted that the majority of the projects have focused on the two most complex hospital items: (i) medical devices and (ii) operating room materials.

Despite the diversity of practices, the study has identified common trends along all the different dimensions investigated.

First of all, healthcare delivery organizations look for industrial partners capable of offering high quality standards of logistical services in terms of reliability and speed/timeliness. This is confirmed by the wide agreement about the fact that the key economic benefits, derived from these partnerships, are represented by (i) stock's

management optimization and (ii) reduction of warehouse management costs. On the contrary, the possibility of establishing long-term relationships with the suppliers is not considered a positive spill-over of these strategies. This is mostly likely strictly related to the public nature of these institutions where, due to the political rhythms, it is difficult to define long term relationships and, furthermore, legal constrains make impossible arranging for long-term contractual agreements.

Standardization (either process and product standardization) in not considered a positive consequence of this integration strategies but, on the contrary, an essential condition to successfully implement these projects.

This confirms the necessity – outlined by an extensive body of literature (Vissers 1998, Haraden and Resar 2004, Litvak et al. 2005, Walley and Steyn 2006, Villa et al. 2014) – to eliminate, within the healthcare delivery organizations, the so called artificial variability through organizational strategies such as better scheduling and capacity management systems or the introduction of clinical pathways to standardize the clinical decision making process. Reductions in products' variety and higher levels of process standardization should allow relevant improvements along the whole healthcare supply chain.

Furthermore, in terms of enabling conditions, the study confirms some robust findings found in the scientific literature (cfr. Infra) about the relevance of (i) top management commitment and (ii) strategic relevance of the logistical function. However, the results of the study do not really clarify what specific type of organizational model actually favors the strategic relevance of this function.

A final interesting finding is the presence of different respondents' patterns on the basis of the institutional nature of the organization, particularly Local Health Authorities perceive less the benefits and more the barriers linked to this type of projects. This is due to the fact that LHAs – besides the publicness feature that characterize also public hospitals – are also required to manage supplies in the primary care settings, an area characterized by higher levels of complexity that would deserve more attention by both academics and practitioners.

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Process flow, Multitasking and Collaboration in a Collaborative Resource Sharing setting: the case of clinical pathways implementation

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Abstract

This paper examines the interaction between shared resources, collaboration and deliberate flow in healthcare processes. The research design was a single in-depth case study of the adoption of the acute stroke care pathway in a UK hospital. Our findings clearly show the multifaceted nature of the process. Variations in deliberate process flow are also driven by resource sharing and active collaboration among professionals. Additionally, professional autonomy should be seen as an extra process dependency. Failing to consider the multifaceted nature of the process the implementation of coordination mechanisms is contested, creating further issues to the process.

Keywords: Operations Management, Process Dependencies, Healthcare

Introduction

Motivated by the implementation of standardized processes in professional settings, we examine the interaction between three different phenomena; process flow, shared resources and collaboration. The paper takes as its point of departure the simple observation that there is an over emphasis on flow dependency in the world of process design; particularly healthcare operations. As Bo et al. (2018) recently note, "[m]ost operations management textbooks use the following simple approximation to illustrate the computation of the capacity of a process: the capacity of each resource is first calculated by examining that resource in isolation; process capacity is then

defined as the smallest among the capacities of the resources, that is, bottleneck capacity." Yet, recent literature judges the validity of this traditional capacity analysis for collaborative networks based on conventional bottleneck analysis (Bo et al., 2018). As Malone and Crowston (1994) articulate in their paper, there are actually multiple forms of opposed process dependency, including sharing and fit dependencies. A point reinforced by Gurvich and Van Mieghem (2013), where they describe how, in the presence of collaboration and multitasking, this "bottleneck formula" can be inaccurate. In sum, if interactions between flow, sharing and fit dependencies are unavoidable (see figure 1), what do we know about the characteristics of these interactions and how operations respond to their consequences?

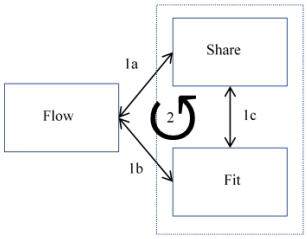

Figure 1: Conceptual model of the study

We address the gap identified above, by investigating the implementation of a nationally standardized acute stroke care pathway in a healthcare setting. Care pathways are interdisciplinary care plans that summarise the optimal sequencing and timing of interventions for patients with a particular diagnosis, procedure or symptom (Campbell *et al.*, 1998). These are introduced in healthcare organisations to improve both effectiveness and efficiency of the organization. Once deployed (or once it moved from in vitro to in vivo) processes no longer exist in isolation, but confront with the need to interact and share resources with a range of other activities and indeed other specific care pathways (Gurvich and Van Mieghem, 2013; Drupsteen, van der Vaart and Van Donk, 2016). Therefore, from an operational point of view, this efficiency may decrease when multiple pathways are united and combined in an entire healthcare setting.

Intriguingly, although there have been exhortations to carefully considering the interactions between related pathways and some wider recognition of the need for a systematic approach to process (Smart, Maddern and Maull, 2009), the broader question of interacting dependency logics remains under-explored in (Healthcare) operations management (OM) and leads to the motivating research questions for this paper:

RQ1. How do different process dependencies interact (1a: flow-share; 1b: flow-fit; 1c: share-fit)?
RQ2. What are the managerial responses to the effects of these interactions?

Theoretical Framework and development of the conceptual model

The literature provides some guidance when it comes to factors that can explain the interaction among process dependencies. Figure 2 illustrates the conceptual model of our study.

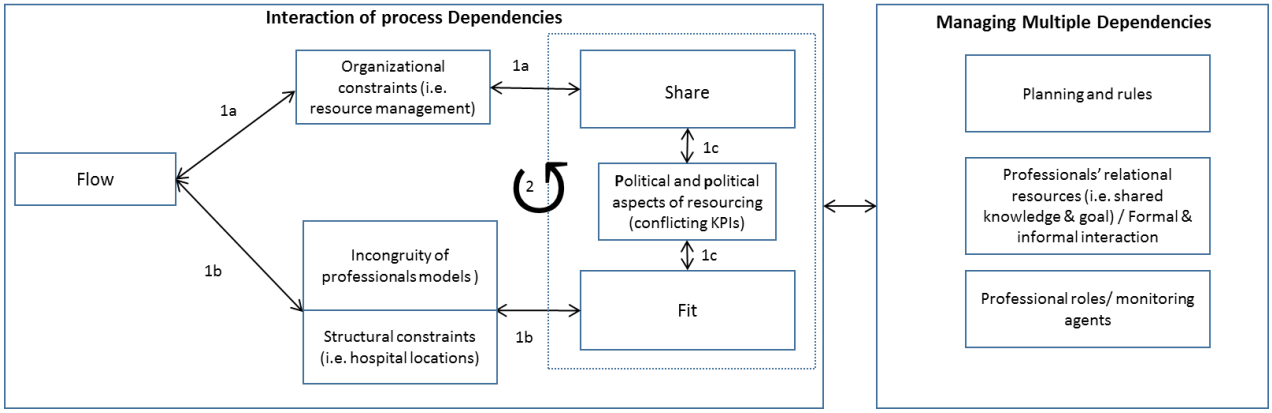

Figure 2: Conceptual model of the study

Flow -Shared dependencies

Capacity utilization is an important variable that affects patient flow performance. Lack of resources and the associated organisational staffing model impacts the efficiency and effectiveness of workers, undermining flow performance. Tucker et al. (2004) found that staffing model entails a situation where healthcare practitioners may be working intensively and without respite, whilst providing little care for patients, and may be delaying care processes, creating unnecessary steps or making clinical errors. In such circumstances, rather than eliminating expenses as desired, inadequate staffing resources add costs.

Additionally, organisation's resource management impacts communication among professionals. In acute care, communication often takes place in a busy and time-limited setting, challenging the professional's ability to exchange timely and accurate information when this is necessary (Dobrzykowski, McFadden and Vonderembse, 2016). For example, Vargas et al.(2015) found that inadequate staffing level led to an increase of professionals' workload and consequently limited time available to make use the communication methods; provide sufficient if not any information on the patient referral forms. Similarly, Radaelli et al. (2015) noted that increases in practitioners' workload affected the amount of time and degree of resources that staff can devote to exchanging information and sharing knowledge, negatively impacting process performance.

However, a deficit in communication of professionals can cause ineffective care of the patients and increase of medical costs. Breakdowns in flow of processes and the ineffective administrative information exchange, can result in confusion regarding treatment plans, duplicative testing, discrepancies in medications, and missed physician follow-up, increased length of stay, ultimately leading to fragmented care and patient dissatisfaction (Vargas *et al.*, 2015)

Flow – Fit dependencies

Patient flow issues have been studied both from scholars in the operations research and operations management field (Villa et al., 2014). Our study is built upon insights from the second stream of literature. We adopt the concept used by other authors (Campbell et a., 1998; Durpsteen et al., 2013) of the process as a structured multidisciplinary plan, which details that essential optimal sequence and timing of interventions of patients with a specific clinical problem. OM scholars recognize that part of patient flow variation may stem from patients' characteristics and needs (Litvak *et al.*, 2005). Although some processes, such as CT scans, can be relatively standardised, new tasks are evolved based on individual patients' needs (Nembhard et al. 2009) making

information exchange among professionals vital to enable efficient and timely decision-making (Gittell and Weiss, 2004). Authors explain that hospital organisational and structural characteristics such as information technology (Durpsteen et al. 2016), hospital size and layout (Pagell *et al.*, 2015) are sources of communication issues among professionals. Lahiri and Seidmann (2012)found that lack of medical information exchange facilities, leads to professionals timely gathering of medical information facilitates and thus, timely delivery of time-critical services. Durpsteen et al. (2016) and Pagell (2004) note that organisational layouts inhibited informal information sharing among professionals found to enhance process integration. Some authors note that part of the variation is due to the fact that multiple professionals with different knowledge and skills are involved in the process making accurate and timely communication between them challenging (Nembhard *et al.*, 2009; Dobrzykowski and Tarafdar, 2015). Relational resources of professionals have been found to overcome such professionals and organisational boundaries, supporting information exchange among them (Gitell et al., 2011; Nembhard et al., 2009; Dobrzykowski and Tarafdar, 2015).

Shared – Flow dependencies

Although the deployment of (physical) resources is covered in the HOM literature (Villa., 2009; Brand et al., 2005; Stirman et al., 2012), extant theory lacks significant explanation of how these resources are allocated and shared when they interact with multiple standardised processes (i.e. with specific resource requirements – outside of traditional professional judgement – for resource use) (Durpsteen et al., 2016). One explanation found in the literature was the political dimension of resourcing (Grove *et al.*, 2010). Drupsteen et al. (2016) report that emphasis on resource utilisation and the particular performance requirements of the relevant departments creates a battle between the department which supplies the particular resource and the healthcare delivery departments' need for access to the resource. This resulted in process timeliness and capacity issues. Although this is an important insight of how shared resources impact the capacity of the process, there is still need for OM scholars to explore this healthcare settings.

Fit – Flow interaction

Simultaneous collaboration among healthcare professionals has been studied from numerous scholars in HOM literature (Gurvich and Van Mieghem, 2015; Senot et al., 2016; Dobriyskowsky et al., 2016; Avgerinos et al., 2017). By virtue of control of their specialized knowledge, professionals are given ultimate authority over their work practice (Nembhard et al. 2009) to make decisions independently and decide the principles of their own work activities. Recognizing this characteristic of professional work, OM scholars focus on understanding the different dynamics that can explain and subsequently improve team performance in a professional setting (e.g. see Senot et al., 2016 and Avgerinos et al. 2017 and the relevant references). Incongruity in professionals'' understanding and knowledge regarding the process associated with individual agency, was stated as a barrier to team performance. Pagell et al. (2015) note that while all the healthcare professions share a common goal i.e. caring for the patient, they have different knowledge and understanding of the process, which can lead to divergences on the approach to delivering care (Pagell et al., 2015; Senot et al., 2016).

Recently, Avgerinos and Gokpinar (2017) showed that the existence of a pair with very low shared experience, compared to the average familiarity of the team may act as a bottleneck for the whole team's operation, resulting in lower productivity performance. A number of other studies, have suggested a positive effect of previous collaboration experience among professionals on team performance (Edmondson, Bohmer and Pisano, 2001) through the development of transactive

memory (Wegner et al., 1991; Brandon et al., 2004), relational resources (Tucker et al., 2017; Dorbyskowsky et al., 2015, 2016; Gittel et al., 2011) and psychological safety (Edmondson et al., 1999; Tucker et al., 2017). Dobrzykowsky et al. (2015, 2016) and other studies (Gittell et al., 2011; 2002; Mura et al., 2016; Radaelli et al., 2016) show that relational resources among professionals promote knowledge sharing, thus shared understanding and enable members to assimilate each other's knowledge and expertise. The authors note internal integration "can unlock improved performance for PSOs" where outcomes are driven by interdependent professionals characterised by high degrees of autonomy and the need to share information to coordinate their work (Dobrzykowski et al. 2016, Dobrzykowski and Tarafdar 2015).

Managing multiple dependencies

In order to manage multiple dependencies healthcare organisations use planning coordination mechanisms. These imply the alignment of actions of interdependent actors beforehand, by suggesting behaviors that should be followed by the actors in order to coordinate the process. In healthcare settings these take the form of process artefacts, physical manifestations of the organisational processes in documents or software by which managers try to promote pathway knowledge - constrain, coordinate, control and improve work practices (Greenhalgh, 2008). Numerous scholars have shown how healthcare professionals use artefacts to enhance their cognitive work and develop shared understandings regarding the nature of their work (Nicolini *et al.* 2012; Mura *et al.*, 2015), such as to align and synchronize their work, as well as produce compatible outcomes.

Additionally, professional roles of monitoring agents such as departmental coordinators, team leaders or specialist nurses are developed in an attempt to react to changes in the relevant information resources or the environment, fuse the appropriate information, and notify the work coordination and collaboration processes. Mintzberg (1979) refers to it as the coordination mechanisms of *direct supervision* while Gittell et al. (2002) as boundary spanners.

Recognizing the dynamic nature of healthcare processes, the involvement and interdependence of different professional groups with various knowledge and skills, hospitals adopt also less formal and more implicit mechanisms to manage dependencies. When plans and routines change, or when these are no longer appropriate to the task, or when the tasks have has very little or no routine aspects, formal coordination mechanisms are less effective because dependencies can no longer be managed in a programmed way. Recent literature (Gittel, 2002; Dobrzykowski and Tarafdar, 2015;2016; Pagell et al, 2015; Sting and Loch, 2016) defines the importance of professionals' relational resources as implicit mechanisms to manage process dependencies. For example, Dobrzykowski and Tarafdar (2015) showed that social interaction ties of professionals are vital element of the formal processes for information exchange in healthcare settings. When professionals have a shared knowledge on the process, share the same goals and trust the work of each other they act in support of the goals of the whole process (Gittell, 2011; Baker, 2001; Haque, 2010; Gittell, 2011; Dobrzykowski and Tarafdar, 2015).

Methodology

The research was carried out in a medium-sized UK hospital (565 beds, approx. 5000 staff). Our unit of analysis is the acute stroke care pathway. We chose to focus on acute stroke care partly because stroke is the third most common cause of death and of complex disability in the UK and worldwide. Moreover, the acute stroke care pathway was selected because stroke patients are

relatively inactive in the process, which allows us to capture variability factors related to systems and processes.

Stroke care is consisted from five key stages: patients arrive to the hospital by ambulance or by own means from home or as general practice (GP) referrals, they receive an initial assessment in emergency department (ED), have a diagnostic computerised tomography (CT scan) in the radiology department (RD), then return back to ED where a decision on their diagnosis and treatment plan is made. Finally, if they are diagnosed with stroke they are admitted to an acute stroke unit (ASU) to receive further specialised stroke care. Several professionals located in these groups participate in the process.

Data collection and analysis

Our research is based on four data sources: semi-structured interviews, non-participant observations, archival documents and secondary individual patient data. Data were collected during an eleven-month period, from March 2015 to February 2016 and the process was divided in five different phases.

In the first phase we conducted 15 interviews to familiarise ourselves with the stroke care process and the role of everyone in it. The interviews were all recorded and typicaly lasted 30-45 minutes on average, were loosely structured using a topic guide that covered: ideal stroke care process, causal factors of its variation, and suggestions for improvement options. Additionally, we analysed several formal and informal process documents and non-participant observations. In the second phase, we combined all of the collected data and developed a first draft of a detailed process map, using a horizontal swim lane flow chart. We followed this up, in the third phase, by conducting 8 interviews with medical staff to evaluate this process map and in parallel, we continued conducting non-participant observations. Field observations took place across several locations, including the ED, the ASU, RD and the emergency medical assessment unit (MAU).

In the fourth phase, we conducted an additional 19 semi-structured interviews. These interviews followed the framework of a modified Sequential Incident Technique (SIT), which has been used in the literature to unravel irregularities, limitations and bottlenecks associated with a process (Stauss and Weinlich, 1997). We used the process map that was developed in the previous phases-walking through this with the participants, noting any stated variations to it, and the main causal factors and issues behind variations. Participants were also asked to describe in detail any specific incident, when possible, to illustrate their statements. And, at the last, fifth stage, we organised a workshop inviting all care professionals involved in the pathway (16 attended). The attendance of 16 people in total comprised of several practitioners involved in the process. The whole workshop lasted one and a half hours, beginning with a 30-minute presentation outlining the background, methodology and findings of the study, and followed by an informal discussion between the researcher and the participants for around an hour. During this discussion, the researcher was asked by the participants to clarify and explain some of the findings, and suggestions and ideas for improvement were discussed.

In total our qualitative data collection comprised of 192.5 hours of non-participant observations, 42 formal interviews and detailed documentation of 52 instances of patients following the acute stroke care pathway.

Findings

Flow – Shared dependencies

Our analysis shows that, in line with classic OM logic, variation from 'standardized work' is driven in part by flow dependency considerations. In many instances, we observed that lack of professionals to communicate in an accurate and timely manner, resulted in flow process issues: *"Many times, not having an ED or stroke consultant available with you to assess the patient and make that decision can delay the process. I can assess the patient, but I cannot make the final decision on my own" (SNP2).* We observed that such communication failures among professionals were caused due to the way that resources were managed locally. Particularly, we observed that the availability of hospital resources affected professional workloads inhibiting their ability to carry out tasks: *"it is the workload of the doctors … they have to prioritise other things over accompanying the patient to the scanner" (ED2).* When practitioners were unable to carry out their tasks, in order to mitigate the variation and to proceed with the pathway, some tasks were undertaken by other available and eligible staff involved in the pathway, resulting in issues with their workload and process flow.

Additionally, resources specifically dedicated to stroke care (i.e. stroke nurses and beds) were also frequently used to support the function of other hospital departments: *"Usually there are problems in finding an ASU bed. There is no bed available and you try to sort out a bed, and if there is no way to locate a bed, this will cause significant delays" (Stroke nurse*). When professionals were busy, the exchange of administrative and medical information – important for the facilitation of the pathway – varied and created process communication issues: *"Sometimes there is a delay because we (the Radiographers) forgot to tell the Radiologist. When we get very busy and the communication site is lost" (SR1).* Such issues were more pronounced between individuals located with considerable distances between them.

Flow – Fit dependencies

Similarly, we noted that, none of the medical practitioners shared precisely the same understanding of the care process. Practitioners tend to have different medical and coordination understanding regarding the stroke care pathway, undermining process flow: "*I feel that some of the ED doctors do not agree with the stroke doctors. Thus, when it comes to decision making, there are some cooperation issues there, this delays the process."*

Physical distance among members of professional groups constrained information exchange and development of a shared process (Radaelli, Lettieri and Masella, 2015). For example, the ED nurses who had frequent interaction with the SNPs were observed to always inform them for the arrival of stroke patient in the ED. Similarly, SNPs worked more efficiently with ED staff compared to the stroke doctors. SNPs had significantly more interaction with the ED staff, and consequently, were more familiar with their working approach. In contrast, the stroke doctors who had limited interaction with the ED staff and environment found it more difficult to adapt to the ED environment when they needed to go and assess the patient: *"I do not know how they work down there. It is not clear to me like in my department where I know who manages which bed all the time. That might cause issues to the communication because it is not clear with who to communicate" (Stroke Doctor).*

Relational resources of professionals, positively related with their location were found to support their communication. SNPs needed to communicate with the stroke team, they called practitioners directly on their personal phone numbers, and thus communicated more quickly. In cases where the SNPs could not contact a colleague directly, they would contact an alternative member of the

team whom they knew would be able to assist them. In contrast, in the event of requiring information from a colleague in a different practitioner group, the SNPs had to use the formal and highly impersonal hospital communication system (the bleep); which caused delays.

We found that compliance with the stroke care pathway was strongly associated with individual professionals' interest and knowledge: "*I think again nursing wise it depends on who is on. It matters who is there, I think nurse Y who is involved in many projects related to stroke and she is aware of what the priorities are. The level of awareness of importance and priorities of stroke is patchier for the nurses in the ED."*

Moreover, pathway artefacts (physical representations of processes such as protocols, scripts, process diagrams etc.) it was one more representation of the diverse knowledge, understanding and interest of professionals on stroke care. We found that even for a single standard pathway implemented in a single hospital, there were 9 different versions of it in different forms: 4 flow diagrams, 3 scripts and a combination of script and flow diagram. Each department involved had its own protocols employed to carry out the work, which viewed as problematic by clinical staff, creating variation in their performances: "*We have no clear protocol shared between us which complicates our work" (SNP2).*

We found that guidelines and protocols are most frequently developed and used by experts in each professional group, and they are used by people with varying levels of expertise (Patel, Arocha and Kaufman, 2001). However, there were continuous inherent conflicts between the autonomy and improvisational tendencies of professionals that caused the development of alternative pathways of routine practice challenging their collaboration. Particularly, the absence of sufficiently detailed information (both medical and coordination), within the pathway documents hampered the practitioners' ability to efficiently and effectively carry out their tasks: *"There are some patients that have coordination problems that are not easily picked up by the medical test that we are using. So the paramedics are not alerted to their condition. And do not recognise that they have had a stroke." (ED 2).*

Share – Fit dependencies

Misalignment of the pathway targets with the other pre-existing portfolio targets and goals, induces 'quasi-competition' of the pathway with other hospital treatments and pathways for the necessary resources*: "We have so many KPIs and these are conflicting" (SR1).* Particularly, we observed that different performance requirements within the departments delivering care processes created a conflict of interest between the department which supplied the particular resource and the demanding departments' (customer) need for the use of the resource: *"ED has other competing priorities. So, in order to meet the 4hr you have to transfer the patient out of the ED to the ward. So, that will come ahead in theory of the stroke." (SNP 2)*

Individual care professionals create variation in the care tasks and make decisions regarding which type of care is needed or is the priority, resulting in a negative effect both for the pathway (allocation of resources) and the patients: *"So, from the ED nurses the comments that you get is that: "You are not the only priority". Which proves exactly that there are multiple priorities. ED knows that stroke care is important but they do not know how to prioritise it really. That is why they need us; that is why they leave it to us." (SNP 3).*

Discussion

The research suggests three areas where there are novel theoretical (OM) insights and specific implications for both healthcare practitioners and policy makers. Firstly, for theory, stressing the

need for a multi-faceted/level notion of process is a key insight. In considering how the pathway works in practice the research revealed ample evidence of a common feature of flow dependency, communication failures among professionals. In the hospital setting, geographical (i.e. it is an old, small site) and organisation structural constraints (i.e. different departments have common locations, based in large part on history) information exchange between caregivers was challenged. This had an impact on the timing and use of resources across the mandated pathway. It also hindered the development of trust/social capital, etc. which enhance professional collaboration and, consequently, support the flow. The study reinforced this observation, highlighting that those individuals who had superior social capital (perhaps the result of frequent interaction, etc.) were able to collaborate better, adjust in a timelier fashion to effectively manage any unexpected variation and to minimise the impact on interdependent flow.

A series of observations indicated that the pathway simultaneously exhibits additional dependencies that interact between them affecting its operational performance. Stroke care pathway is also a sharing resource dependency. Although OM researchers have highlighted the negative impact of variability in care, this study shows that attempts to blindly implement standardised work can also create capacity issues. Fragmentation of capacity creates continuous interruptions in the process and causes a negative effect both on its effectiveness (i.e. accuracy in decision making) and efficiency (i.e. timeliness and use of resources). Extending the discussion of shared resources to the broader question of how a hospital reconciles – or fits - all its different care pathways (explicit and implicit, formal and informal) together in a coherent way. The research confirms that such fit dependency issues were not considered in the pathway design; made manifest in a wide range of hospital KPIs, flow charts (and other artefacts) diagnostic disputes and the basic geography of the hospital creating variation to the process. Individual care professionals create variation in the care tasks and make decisions regarding which type of care is needed or is the priority, or how to practice performance measurement.

The study also highlights the political dimension of resourcing. There is a direct connection between pathway adoption, professional responsibilities/judgements, resource competition, and consequently political dynamics. This potentially unstable dynamic system is underexplored in the HOM literature. Therefore, even if the care pathway approach is a rational attempt to solve the flow dependency (integration) puzzle, in attempting to address the fit dependencies, there was a strong and continuous stress on performance measurement in parallel (Power, 1997) which autonomous professionals can easily undermine the game.

Second, the study illustrates the role that professionals play in how the process dependencies are managed and that they are much more than just co-ordinators or pilots (Lewis and Brown, 2012). We show that professional autonomy is equally present in the reconciliation of shared resources, fit and flow dependencies. A carefully designed pathway rapidly became incoherent as it encountered resource-sharing decisions made by autonomous medical staff and managers. Autonomy frequently led to minimally shared mental models of care, perspectives on the best interests of the patient, and (often highly dysfunctional) competition between individuals and groups causing a negative effect both on its effectiveness (i.e. accuracy in decision making) and efficiency (i.e. timeliness and use of resources).

Third, this study illustrates how not considering the multifaceted nature of the process, the performance of used coordination mechanisms is contested. Particularly, our findings show how a pathway artefact is a zone of two types of autonomy: that of the modeller who designs it and the professionals who use it. Even if artefacts are designed by the hospital managers to coordinate flow

and standardise professional work, these are only aspect of the design process. The artefacts are then used by autonomous professionals who design and redesign the process differently every time they follow it. Professionals generally work with heuristics and rules. Professionals do not learn only from flow charts, but they study, see and apply, and learn from each other. Consequently, although pathway artefacts represent flow dependency, through their failure to recognise the professional autonomy associated with knowledge specialisation, their role as professional boundary spanners is tested.

Numerous scholars who study the role of artefacts in healthcare practice, have shown how healthcare professionals use artefacts to enhance their cognitive work and develop shared understandings regarding the nature of their work (Nicolini *et al.* 2012; Mura *et al.*, 2015). Professional expertise depends on, and develops through, the mediatory work of many artefacts that professionals use to carry out their work. However, the findings of this study the findings reveal that even for a single standard pathway implemented in a single hospital, there were multiple pathway artefacts. Visual representations were different for different professional groups: ASU stroke team, ED staff and Radiology department. The interesting question is the extent to which this is simply a manifestation/representation of ingrained points of difference, or whether the multiple pathway artefacts actually serve to exacerbate these performative differences of the process. Individuals from the different practitioners' groups shared diverse competence on stroke care and the absence of sufficiently accurate (both medical and coordination); information undermined the exchange of correct and timely information and decision-making. For example, not all the ED staff knew how to thrombolyse patients and the absence of such procedural information in the process artefacts resulted in breakdowns of the care process.

Similarly, to the process artefacts, the creation of a process 'pilot' role (the Stroke Nurse Practitioner) to help navigate patients along the pathway is one more organisational mechanism for managing process interactions. We found that such mechanism is indeed effective for coping with the sharing and fit interactions, but at the same time the successful implementation of such initiative was influenced from sharing and fit dependency issues.

On one hand, this study confirms previous findings that the specialised nurses have a positive effect on the efficiency and effectiveness of the process (…..). Particularly, we observed that due to their role and ability to interact with all the professionals in the process, SNPs were provided enough information and understanding about the working approach of the other colleagues and the system to predict their future behaviours. Thus, being capable enough to make and set accurate judgments and expectations accordingly, such as to accommodate variations in colleagues' performances and to support them when needed, which would otherwise negatively affect the process. Fitzgerald *et al*. (2007) call this 'theory of mind'; "the ability of individuals to understand others' behaviours, mental states and intentions, and use this knowledge to advantage". On the other hand, we found that shared dependency issues (i.e. practitioners not being available to carry their tasks) led to SNPs increase of workload and consequently created both flow and fit issues. SNPs had limited/no power in controlling the competence/ interests and associated actions of other practitioners, resulting in staff blurring issues, pathway timeliness issues and inaccurate decision-making. Again, this is an indication that financial resources and the associated organizational scale affects the implementation of process management initiatives in SMEs (Alkoharaif et al., 2018).

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Managing Patient Flow: a cross case analysis.

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Abstract

This paper considers how the manufacturing origins of lean management (LM) and theory of constraints (TOC) characterize distinct flow management approaches before evaluating how they have been effectively applied to improve patient flow. Both of these approaches originated in distinct environments and this multi-case research explores how the assumptions and associated practices transfer to healthcare. The case analysis considers complex flow across health and social care including outpatient, community and mental health. The paper focuses on how the management signaling tools of Kanban and time buffer management have been interpreted, identifying the common theoretical assumptions and implications on practice.

Keywords: Health and Social Care, Lean Management, Theory of Constraints

Introduction

Worldwide healthcare service providers have been exposed to growing pressures to simultaneously minimise operational costs and improve the access and quality of care they deliver. Changing demographics and increasing demands facing healthcare delivery systems have created more complex pathways to access healthcare services and necessitated the integration of social care to enable safe discharge of patients (Alderwick et al., 2015). The growing pressures within health and social care delivery indicate operational challenges that reflect the primary need to synchronise capacity and demand in enabling patient flow (Karakusevic, 2016; Tabish and Syed, 2015).

According to Olsson and Aronsson (2015), many healthcare services across the globe have implemented process improvement approaches like lean management (LM) and the theory of constraints (TOC) that focus on flow as a proxy for system productivity. However, there is a tendency to adopt one or other approaches irrespective of the healthcare environment with little consideration of how these manufacturing approaches might be theoretically developed to meet the needs of different health and social care environments. Where LM and TOC have been applied, there have been mixed results regarding the success and assumptions underlying the application of such approaches to healthcare (Blackmore and Kaplan, 2016: Radnor et al., 2012; Stratton and Knight, 2010).

This research aims to broaden academic understanding of how established flow management approaches have been developed to meet the distinct conditions within the wider healthcare system, with specific reference to the origins of LM and TOC. Three questions provide focus for this largely exploratory case research:

- How can LM and TOC approaches be effectively applied to improve the patient flow across health and social care?
- Why do these management approaches work better in different health and social care environments?
- What are the assumptions underpinning their effective use?

Literature

Improving patient flow is seen as a major factor in improving hospital performance (Litvak, 2009), as flow performance is an important aspect of organizational performance. The changing demographics and increasing demands faced by the healthcare delivery systems have created complex pathways to accessing healthcare and have necessitated the integration of health and social care to support the safe discharge of patients (Alderwick et al., 2015). Considering the current budget faced by the NHS, the healthcare delivery system's current capacity challenges, and that over 40 per cent of the NHS England's budget is spent on older people, the importance of patient flow between acute services, primary care and social care in the NHS and the UK healthcare delivery system can never be overlooked (Karakusevic, 2016; Robineau, 2016). However, evidence from manufacturing suggests that enabling flow based management is not easy due as the the different elements in the healthcare system are directed, supported, controlled and structured in silos that fight the flow imperative (Fillingham et al., 2016). Delayed transfer is indicative of this deeper failure of the system to provide the right care at the right place and at the right time (Humphries, 2017). Therefore, this literature review firstly considers the paradigm shift in thinking associated with manufacture and particularly the emergence of two distinct approaches, namely LM and TOC. The influence of these approaches on flow management in healthcare is then explored alongside the development of healthcare specific flow management approaches.

System flow thinking

The adoption of a systems approach to managing operations is commonly associated with managing variability and flow as opposed to local optimization based on cost and efficiency. These developments were sustained because they were accompanied by seminal innovations that offered a practical means of embracing the management of variability and flow across the delivery system. This is illustrated by Ford's physical flow lines (1926), Shewhart's (1931) statistical process control, Ohno's (1988) kanban control and Goldratt's (1999) time buffer management (TBM). These signaling tools provided a means for management to adopt a systems perspective that guided the organization in enhancing value creation.

Skinner (1969) introduced the concept of operations strategy by highlighting the limitations of local sub-optimisation based on cost and efficiency that dominated operations management practice. He acknowledged performance trade-offs and the need to focus, separating out delivery system design to meet distinct environmental factors which was subsequently allied with variation and volume (Hayes and Wheelwright, 1979).

Each of these developments were concerned with adopting a longer term systems approach to managing operations that is now embraced in operations theory; as in cumulative

capability (Ferdows and de Meyer, 1990), Performance frontiers and swift and even flow (Schmenner and Swink, 1998).
All of these developments have had wide ranging influence on operations practice but two in particular have contributed to flow management in health and social care, that of LM and TOC.

The TPS was clearly designed to meet the needs of Toyota and the relatively stable demand and standard pathway design in a dedicated facility. This resulted in a number of tools and techniques concerned with reducing variability and improving flow that as we shall discuss are linked through the Kanban signaling tool.
TOC was designed with a broader mission but initially aimed at the make to order (MTO) environments typified by low volume aerospace including repair and overhaul. This more generalized concern resulted in the underlying flow issues being explored and with it the conflict between flow and cost/efficiency. Goldratt (1999; 2009) more explicitly identified the importance of capacity buffering and the role of control points in the management of complex systems. Time Buffer management (TBM) emerges as a central signaling tool in all the TOC applications and has more recently been developed to meet the specific needs of patient flow across health and social care.

Kanban
Kanban which means signal is aptly named and Ohno consider it to be key to the success of the TPS in bringing together the six rules/fuctions of Kanban (Ohno, 1988:30).

> *'In reality practicing these rules [the six rules of kanban] mean nothing less than adopting the Toyota Production System as the management system of the whole company.'* (Ohno, 1988:41)

This tool was more flexible in use than Ford's flow line but still needed the flow path to be precisely defined and direct (Spears and Bowen, 1999:98) ensuring that variability can be continually exposed and addressed through the systematic reduction of inventory (Junior and Filho, 2010). The many other tools are effectively used to support this ongoing process that sustains the TPS.

Time Buffer Management
Kanban signaling was too structured to meet the wide ranging processing needs of MTO and engineer to order (ETO) but it was still necessary to control and improve work flow across these more complex pathways. Goldratt adopted the concept of aggregated time buffers focused on control points, acknowledging the need to more effectively manage the excess capacity that characterizes this level of complexity and termed this time buffer management (TBM) (Goldratt, 2009).

Applying System Flow Thinking to health and social care
Let us now consider how LM and TOC thinking have been directly and indirectly applied to healthcare flow management.

Lean Management (LM)
As in manufacturing practice has led academic theory in improving patient flow with hospitals taking the lead (Graban, 2010) and notable hospitals leading the application of LM including *The Pittsburgh Way* (Grunden, 2007), *The Royal Bolton Hospital* (Fillingham, 2007*) and Virginia Mason Medical Centre* (Kenney, 2010). However, much of this has

involved secondary processes such as consumables, pharmacy and test procedures rather than patient flow and although there have been significant improvements in patient flows these are typically associated with the redesign of medical pathways (Fillingham, 2007). These applications are consistent with TPS LM improving flow through the redesign of the physical flow path (Hicks et al., 2015).

Theory of Constraints (TOC)

In addition to LM the application of TOC thinking to healthcare has been encouraged through various NHS education improvement bodies in the NHS and worldwide, typically centering on *The Goal* (1984). This guidance primarily acknowledged the role of bottleneck management and the need to focus the planning and control around constraints (limiting factors) in the delivery system. As with LM some hospitals and NHS foundation trusts in the UK and the Netherlands have at times adopted TOC as an overall management approach. Typically with the support of TOC expertise, as in the case of QFI Consulting which developed applications used by two of the case companies in this research. Prior research studies have reported on these results which is centred on the use of TBM (Umble and Umble, 2006; Stratton and Knight, 2010). A broader view of the approach is presented in *Pride and Joy* (Knight, 2014) a healthcare centred version of *The Goal* (Goldratt, 1986).

Due to the case evidence making specific reference to this healthcare based TBM the key features are covered here.

TBM is concerned with time in the manufacturing and project management applications and this is also the case in healthcare and it incorporates feature from both but in many ways taking on a simpler design. Time runs from left to right in Fig 1 which illustrates how the planned discharge date (PDD) for all patients is set based on the patients' medical needs. This is the means of exploiting the constraint of time. Going beyond this date would result in a delay and typically today measured in the NHS by delayed transfer of care (DToC). The vertical dotted line represents the current time, signifying a review of this patient by a muti-disciplinary team (MDT). The purpose of the TBM signaling tool is to ensure the PDD is met so avoiding any DToC. To do this all the activities required for discharge need to be completed by this date and these activities and their expected durations are represented by horizontal lines in the Figure where each resource provider is a different colour. TBM effectively manages progress through four functions (prioritise, expedite, escalate and improve) (Stratton and Knight, 2010). The Figure is currently showing the orange activity is in the yellow indicating priority over brown and black with the blue activity is in the red which signals the need to expedite. The blue resource (e.g. octpational theropy (OT)) would see this patient on the aggregated worklist in colour order (R,Y,G) prioritizing patients based on the PDD which is subject to change. A growing number of reds and blacks signals the

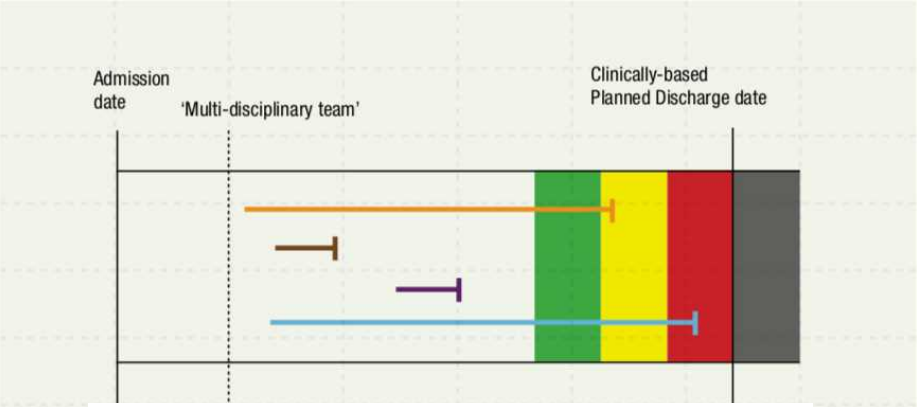

Figure1: Time Buffer Management: conceptual: conceptual view typically used in healthcare (source: Knight 2014)

need to escalate the growing instability of the system. Buffer management meeting are held daily and monthly to address short term and longer term improvement activity.

Red 2 Green

An approach currently being widely promoted with in the NHS that acts in a similar way to TBM is called 'red2green'. The approach is a visual management system that supports the identification of wasted time in a patient's journey and as with TBM has been applied in both an acute and community settings to minimise internal and external delays and deliver improved patient flow (England.nhs.uk, 2019). Red days are when patients receive little or no value adding care while green days are when patients receive value adding care, advancing their path towards discharge.

The red and green day process uses ward improvement boards to link flow, safety and reliability with visual demonstration (Improvement.nhs.uk, 2019). Using ward level metrics, the process identifies what limits (constrains) a wards ability to convert red days to green days and proactively manages these at ward rounds. Where improved solutions are not immediately available there is an escalation process where processes are put in place to actively manage these limitations. The top five constraints are reviewed by senior operational managers and are formalized in a local improvement plans.

SAFER patient flow bundle

Again, there are clear similarities with The SAFER patient flow bundle aims to promote engagement and continuous improvement through combining five elements of best practice: Senior review; expected discharge date and clinical criteria for discharge for all patients; flow of patients at the earliest opportunity; early discharge; and senior review for patients for management and discharge decisions (Improvement.nhs.uk., 2019). This SAFER patient flow bundle is considered to work more effectively when implemented with the Red2Green days approach and when all five elements are implemented there are considered to be cumulative benefits (England.nhs.uk, 2019).

Design/methodology/approach

This ongoing research adopted a multi-case approach to address the research questions for the study involving over 30 interviews and the selective use of documentation and observation in five case studies across three NHS Trusts. These involve a range of delivery systems where there has been a transformative approach to improving patient flow. The first three cases were selected to exemplify specific LM and TOC implementations with other two chosen in line with theoretical sampling logic in the light of the earlier case findings.

The cases incorporate acute and rehabilitation hospital care, social care, outpatient services and GP led community care and community mental health. Data were gathered through semi-structured interviews, observation and documentary evidence comparing performance in relation to the interventions over time. The interviewees were selected due to their managerial or operational involvement together with external consultants where relevant, with interviews taking between 40 and 90 minutes. The interviews covered several questions on the process, description of original design, process issues in the original design, the recorded changes and results achieved.

Findings

The Speech and Language Therapy

This NHS case provides speech and language therapy for children between 0 and 18 years of age with more specific and complex needs. Prior to the intervention there were complaints about the growing waiting lists that breached the NHS 13 week assessment and 18 week start of treatment targets. An external consultancy was brought in to provide a TOC solution. They found a lack of management visibility with therapists tending to work in isolation managing their own patient lists. Figure 2 shows the patient journey within the speech and language therapy prior to the intervention. To address this issue, the consults established a new process that prioritized patient appointments in one aggregated list on a first in first out approach with a two week initial assessment target. At that meeting they also planned the whole package of care typically involving multiple therapy appointments effectively resulting in a PDD.

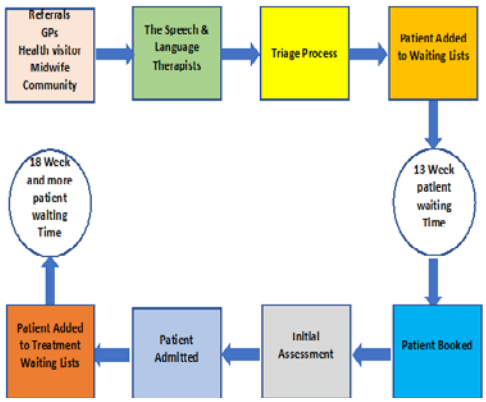

Figure 2: The Speech and Language Therapy Process before the Intervention

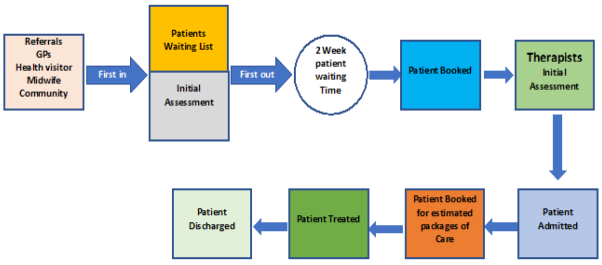

Figure 3: The Speech and Language Therapy Process after the Intervention

Figure 3 illustrate the new process where there was a two week internal target for the initial assessment which was achieved through short term additional capacity. This system was supported by a rudimentary spreadsheet based buffer management system due to policy restrictions on the introduction of TBM software.

Adult Nursing Community Services

This LM case involved nurses, OTs, support workers, physiotherapists and community matrons, who focus on assisting people aged 18 and above to live independently and accelerating their discharge from hospital. Before the intervention here were no formal processes and the processes lacked standardization resulting in poor productivity and patient facing time while increasing waste as non-value adding activities consumed the nursing staff's time. The intervention involved the widely adopted LM based productive series with significant improvement in some communities. This included the application of 5S and other tools in the workplace, creating a clean, safe and orderly environment to work in. Better process orientation resulting in improved control of inventory and waste elimination. The 5S created the platform for efficient production planning and directed the Trust's focus to structurally reorganise the operation process to increase patient facing time and productivity.

Although the efforts were based on a national agenda to improve service delivery the improvements recorded were realised only in some community services and did not reflect on the overall service across the county. This widely applied LM practice has provided significant improvements across the country but the improvements are inherently local and dependent on local management practice. As with Kaizen Blitz projects these local redesign activities are difficult to sustain (Radnor et al., 2012) arguably without an overarching management signaling tool.

Community Hospital

This NHS Foundation Trust is an integrated community healthcare trust that provides health services to both children and families, patients with learning disabilities, substance misuse needs and mental health problems. This is a long standing TOC application including the adoption of software to support patient flow and the application of the TBM. This TOC approach was introduced 12 community hospitals although some have since been closed. The system had been in operations 9 years and the initial average length of stay (LOS) was reduced from over 60 days to around 20 days on average today.

> *"Eight or nine years ago, the average length of stay would have been 60 plus days and I'm delighted to say that now we report exceptions on the basis of any length of stay over 20 days." (P01)*

The system design is consistent with the TBM approach presented in Fig 1. And the patient discharge date is determined together with a plan on arrival.

> "*One really important thing that has been embedded in the process is that you start planning someone's discharge from the moment they arrive."*

The Trust results indicate that prior to the implementation of this Jonah system, they were not aware of any barriers to flow within the system.

> *"So before Jonah I was not aware of there being any central visibility and understanding whether flow is efficient or whether there are any barriers."*
>
> *"One thing that Jonah did was to promote clarity about what we are trying to achieve and how we are trying to do it….."*

The Trust initially adopted this TOC based system due to the need to replace hospitals and reduce the number of beds and this process of reducing LOS and synchronizing transfer of care with social care has proved to be very effective. The system is very effective at supporting the management of DToC and they are some of the lowest in the UK. .

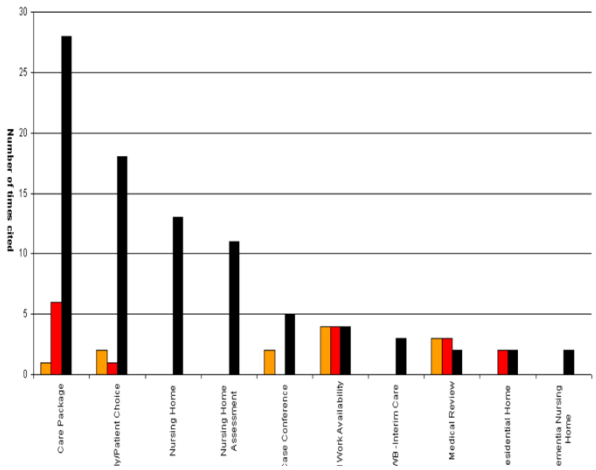

Figure 4: The top reasons for delay

Consistent with the functions of TBM the weekly top delay meeting focuses on reviewing patients who are in the red zone or already a delayed transfer. These meetings are multi-disciplinary and attended by general managers and social workers. As illustrated in Figure 4, waiting for care packages is the typical major reason for delay. This Pareto data provided by the Jonah software provides focused data to support these meetings.

Identifying and overcoming the principal cause of delay across health and social care provides a systematic process

that sustains the continuous improvement culture. It is interesting to note that the Trust retain Jonah even with the need to duplicate data input as the centralized System One, now rolled out across the NHS does not provide the data in a form suited to managing patient flow.

Mental health case

This case is still in progress and is showing significant improvements primarily through adopting new flow management rules akin to SAFER patient flow and Red2Green introduced earlier. This, as discussed embraces many of the same features as TBM with some interesting distinctions.

Social care housing case

This case is also ongoing and illustrates how the local authority has gained awards for their emergency housing provision supporting the discharge of vulnerable adults from acute wards. This case is particularly interesting as it highlights the tension associated with budgetary control. This is evidence by how this very successful programme is repeatedly under review primarily due to this successful cross-functional patient flow activity falling between the local management priorities associated with localised cost control.

Discussion / Conclusion

- *How can LM and TOC approaches be effectively applied to improve the patient flow across health and social care?*

LM and TOC have developed distinct approaches to managing flow to meet the needs of distinct manufacturing environments but their success has resulted in flow being widely acknowledged as a proxy for system productivity. Healthcare management similarly acknowledges the importance of flow, but to what extent do the associated LM and TOC signaling tools (Kanban and BM respectively) support patient flow? TBM has been shown to be a central feature of TOC across its core manufacturing applications and the common four functions have also been shown to apply in healthcare and social care systems. Kanban is often perceived to be one of many tools aimed at reducing variability and improving flow in LM however its critical importance in sustaining flow improvement is sometimes forgotten. This is achieved in manufacturing by establishing clearly defined flow paths and this need for a clear physical path is a key distinction between TOC and LM. Therefore, where the LM redesign is narrowly defined, as in kaizen blitz activities, the isolated improvements are not linked to the wider delivery system and commonly lack this important means of sustaining the improved flow. Although the case evidence was limited in this regard the Productive Ward evidence and the use of 5S is consistent with prior research that identified this problem (Radnor et al, 2012) even though these finding challenge the subsequent evaluation (Radnor et al., 2013).

- *Why do these management approaches work better in different health and social care environments?*

LM and TOC shift the emphasis from local performance to system performance by enabling flow across the delivery system. This can be achieved by reducing variability and uncertainty which is the emphasis of LM whereas TOC is firstly concerned with changing the rules concerning the management of flow and the strategic location of buffers. Whereas LM is associated with a wide range of tools to support the reduction of variability and improving

flow TOC essentially has one, TBM. TBM is the means of providing management signals to ensure delivery system activities subordinate to the exploitation of the system constraint. In healthcare, as in manufacture, this is 'time' and setting a PDD is critical to exploiting the time constraint in the healthcare environment. The 4th function of BM is to identify strategic opportunities for improvement and the LM tools are deployed to achieve this.

Although LM is associated with many tools the kanban signaling tool was key to the sustained operation of the TPS. However, its application is more operationally demanding as there needs to be clearly defined flow paths and the improvement activity is distributed rather than focused. Whereas, BM uses aggregated buffers that is more accommodating to variability and uncertainty kanban is more sensitive to flow disruptions and therefore higher performance in a well-defined delivery system.

Healthcare is characterized by a range variability and uncertainty and where there is opportunity to define the process flow tightly LM can be readily applied. This includes patient flow but these findings suggest it is more suited to elective surgery or emergency pathways that are predefined. Where the pathway is unknown, poorly defined and involves transfer of care the signaling is better suited to TBM. This was evident in the TBM solutions witnessed, including the need to subordinate the flow focus to the PDD, so synchronizing all activites around this patient, whether in outpatient or inpatient environments.

LM, deriving from the more structured TPS supports physical flow requirements to be structurally entrenched. The adoption of the 5S in the implementation of the productive toolkit at the adult nursing community represents efforts to structurally reorganise processes and ensure all resources are at the right place at the right time. This supports the establishment of flow paths through standardised processes.

More varied and uncertain environments benefit from the adoption of aggregated buffers as advocated by TBM in the Speech and Language Therapy case, moving to a central patient queue allowed more effective priority control with the centralised allocation of therapists as opposed to a locally distributed resource. This key feature allows therapists to focus on managing one queue and adopting a common priority system. The scheduling of the treatment plan at the first consultation (initial assessment appointment) is also consistent with flow management by setting a PDD, so ensuring that the number of patients in the system is kept short.

In the DCHS case the establishment of a PDD was key to enabling the other support activities to be prioritized around the patient needs and so proactively managing the threat DToC, a particular issue for the elderly with transfer between healthcare and social care providers. In this case the use of formalized software (Jonah) enables the functions of buffer management to be more effectively realized including Pareto data to support buffer management meeting seeking means of improving performance.

Table 1Kanban and Time buffer Management assumptions

TPS Kanban assumes:	TOC TBM assumes:
Predefined process steps, time and transfer paths	No predefined processing steps, time and transfer paths
Buffering is based on inventory and held at each processing step	Buffering is based on time and aggregated (pooled)
Process delays (quality problems) are not passed on to the next process	'Delays' are expedited based on rules concerning the consumption of the aggregated buffer.
Level scheduling	Demand may vary, triggering (timely) escalation
Continual improvement is encouraged through reducing inventory to expose problems that are then targeted.	Continual improvement is enabled by targeting the causes of delay (e.g. red zone penetration) then reducing the buffer.

- *What are the assumptions underpinning their effective use?*

The assumptions underpinning kanban and TBM apply across both manufacturing and healthcare are presented in Table 1. The less restrictive assumptions underpinning TBM and therefore wider potential application is arguably supported by the wide use of TBM related developments as in SAFER - red2green, but the findings need to be discussed further.

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Analysing supply chain strategies in healthcare from patient flow perspective: A systematic literature review

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Abstract

The paper aims to focus on systematically analysing and synthesising the extant research published on supply chain strategies (SCS) in healthcare. More specifically, the authors aim to answer three questions: "Q1 – What are the strategic intent of SCS?", "Q2 – What are the operational measurement?" and "Q3 – What are the inhibitors factors of SCS?" Furthermore, the paper strives to address the question of how SCS can help in redesigning an efficient patients' flow in response to face hospitals dual challenges of reducing cost whilst building the capability to accommodate growing numbers of patients with different and increasingly complex needs

Keywords: healthcare, patient flow, (Hybrid, Lean, and Agile) supply chain.

Introduction:
In response to healthcare system challenges, where limited resources are the main characteristics of the public healthcare on a global scale (Ix, 2009), redesigning of healthcare systems to deliver efficiency alongside quality care has become a demand of healthcare leaders, if not the public itself.

There has been a great deal of literature is available on supply chain management in manufacturing sector; however, little research exists on managing services especially healthcare services (Cherian et al. 2010). In healthcare, supply chain management processes have three types of flow: physical product flow, information flow and financial flow (Singh *et al.*, 2006). In this paper, the discussed supply chains are the patients (physical product) flow through the healthcare system, such a hospital. Addressing the question of how supply chain management can help in redesign an efficient patients' flow in healthcare organization.

This paper aims to focus on systematically analysing and synthesising the extant research published on supply chain strategies in healthcare. More specifically, the authors presented categorization of these strategies in healthcare that considers types of supply chain strategies, the strategic intents, operational measures and inhibiting factors of each strategy implementation. Furthermore, the paper strives to address the question of how supply chain strategy can help in redesigning an efficient patients flow in response to hospitals dual challenges of reducing cost whilst building the capability to accommodate growing numbers of patients with different and increasingly complex needs.

Methodology
This paper adopts a systematic or evidence-based literature review methodology based on the five-step approach developed by Tranfield et al. (2003) and Denyer and Tranfield (2009) as show in Figure 1. The advantages of the systematic literature review (SLR) approach over narrative reviews is that choices made during the literature search, selection, and analysis are reflected on and made explicit to result in a transparent and reproducible repository of knowledge.

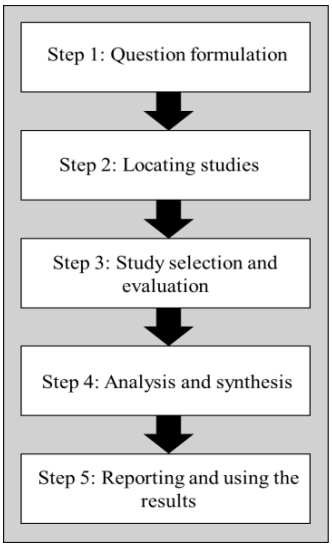

Figure 1: Five-step SLR process (adapted from Denyer & Tranfield, 2009).

Taking heed of advice for the conduct of structured reviews, Rousseau et al. (2008) guidance on study selection criteria in management and organizational sciences has been followed. Furthermore, as Durach et al. (2017) calls for a 'theoretical lens on the phenomenon of interest' to provide greater focus during the review, this study has chosen to look at patient flows from a supply chain strategy angle which fits with the research motivation as outlined in the introduction section.

To select relevant publications for review, firstly duplicates among the 11919 publications identified in the previous step were removed, which resulted in 10609 publications taken forward. Next titles and abstracts of the remaining publications were screened using a set of inclusion and exclusion criteria, which are shown in Table 1 below together with accompanying rationales for each criteria. To ensure the reliability of this process and prevent researcher bias, each of the authors independently reviewed a sample of 80 random abstracts with inclusion and exclusion choices subsequently discussed collaboratively between the three authors. This ensured that the criteria were understood and applied similarly. Subsequently the selection process based on titles and abstracts was undertaken by the first author while being consulted in borderline cases. This resulted in 10053 publications being removed from the pool.

Table 1: Inclusion and exclusion criteria applied during publication selection.

	Selection criteria	**Rationale**
Inclusion		
Year	Publications after 1999.	Naylor et al. (1999) & Mason-Jones & Towill (1999) were the first to define the leagility/ hybrid SC concept.
Source type	Academic journals, monographs, chapters of edited books, conference proceedings, working papers, professional publications, reports.	A wide range of sources were considered to ensure that all related and applicable published works were included. While not all of these sources can be expected to feature the same academic rigour as peer-reviewed journal articles, they may still provide useful knowledge and/ or current knowledge on a field that has received limited attention to date (compare Masi et al., 2017).
Scientific field	Healthcare industry, supply chain management, managing hospitals, health service quality and healthcare management.	These scientific fields are closely related to the topic of interest.
Exclusion		
Language	English language journals.	This is due to limited language capabilities of the authors.
Healthcare operations focus	Manufacturing-like level (pharmacy, radiology, laundry, etc...), Managerial and support (IT, finance, etc...) and Organisational level (design a strategy)	The objective of the research is the highlight the service issues in healthecare system (patient flow) not the logistic processes.
Journal quality	Publications in non peer-reviewed journals.	While non peer-reviewed knowledge is necessary to draw on in this immature field, particularly in the form of conference proceedings that report current developments in practice faster than journals may, it was chosen to exclude publications from non peer-reviewed journals on quality grounds.

Following these publication selection steps ultimately resulted in 58 publications to be selected in this review. Figure 2 below provides an overview of the different steps and how many publications were rejected or taken forward at each stage.

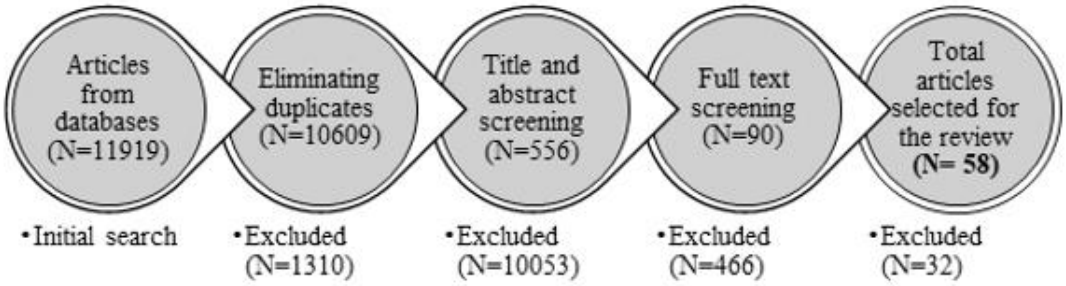

Figure 2: Summary of the publication selection process

Descriptive Analysis

It becomes apparent that research activity on supply chain management in healthcare has increased relatively steadily from 2010 onward, look at figure 3, with sparse publications prior to that year, before peaking in 2016. Given the cut-off point for the literature search in January of 2019, also shows that case studies remains the dominant research methodology in this area as 34 out of 58 publications use either a single or multiple case study approach.

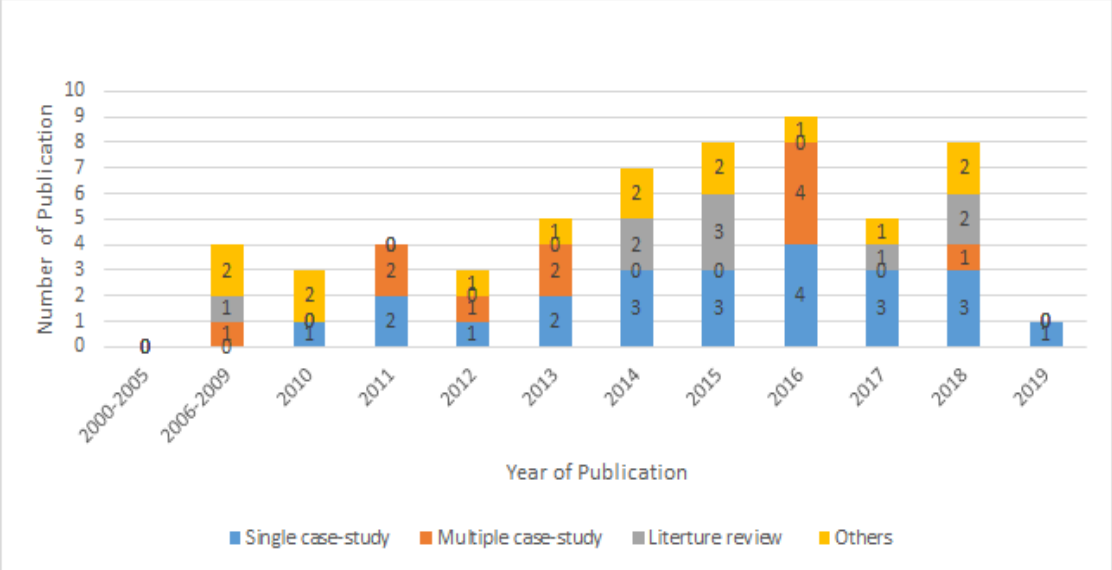

Figure 3: Number of publications and their respective methodologies across years

This strong base of qualitative empirical work is juxtaposed with a smaller number of studies using a variety of quantitative approaches.

In respect to the disciplines of research field, the findings illustrated in figure 4, where the field of supply chain strategy is still immature and requires further academic investigations.

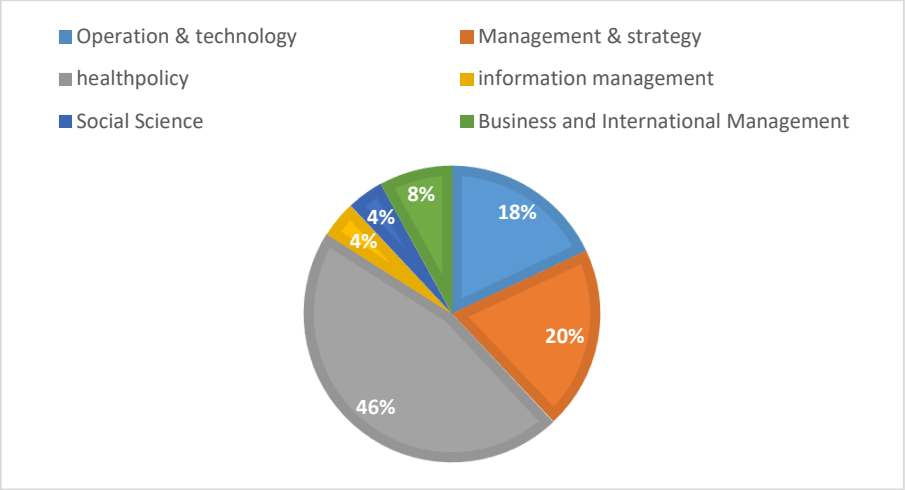

Figure 4: Publication distribution regarding disciplines of research field

Considering the geographical location of the first authors' institutions, a strong interest in SCM in healthcare appers to originate from the UK as being home institutions TO 39% of publications' first authors. Northen Europe and the Netherlands share their second place by accounting for 22% of publications each. A common trait among these countries may be their strong research base combined with the circumstance that healthcare has been conceived as a public rather than private good, which could ease data accessibility. The USA follows this field at (12%) of publications, with Italy accounting for (8%) and then other countries at (4%) or less, with eight countries being the origin of a single publication each.

Lastly, Figure 5 shows that 58 publications can be classified as either analysing a lean, agile, or hybrid supply chain strategy in their respective contexts.This imbalance suggests that academia has progressed further in the area of lean healthcare provision, which may be explained by the implementation of lean initiatives in healthcare before the backdrop of mounting cost pressures put on public healthcare in European countries with aging populations especially.

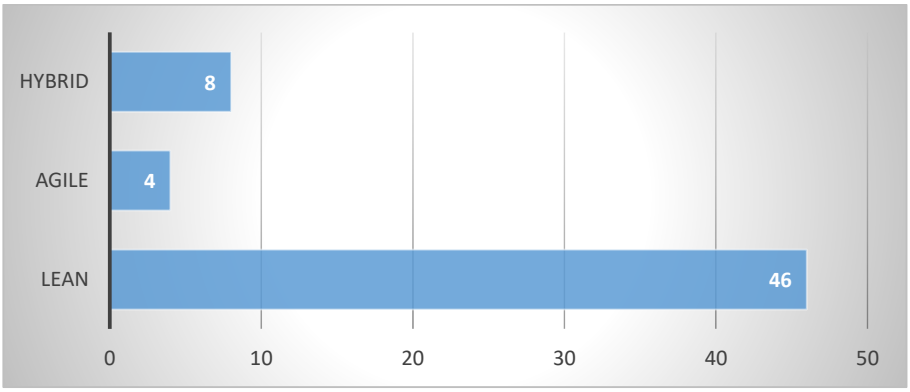

Figure 5: Number of publications adopting different supply chain strategy lenses in their healtcare contexts

Thematic Analysis

Having analysed the publications descriptively, this section will report the thematic findings.

Strategic intentions of lean, agile and hybrid supply chain approaches and operational measures:
Selected publications were divided into three themes based on their adopted or analysed supply chain strategy, which were lean, agile, and hybrid.

Five strategic intents for adopting either of the strategies were synthesized from the literature, which are a) improvement in patient care, b) elimination of waste, c) improvement in hospital performance, d) improvement in employee satisfaction, and e) increased responsiveness and flexibility. While there is overlap in some areas, these five intents represent the diversity of expectations researchers and practitioners hold for lean, agile, and hybrid supply chain strategies when attempting implementation.

An initial intent is the *improvement of patient outcomes*. Operationally this is typically measured by looking at how fast and with which level of safety patients move through the healthcare environment, although there are also authors that look at patient's overall quality of care (Crema & Verbano, 2016; Lillrank, et al., 2011; D'Andreamatteo ,2015). Another identified strategic intent relates to the *elimination of waste* – here three different perspectives emerged in the literature despite a conceptual overlap between the two in the understanding of lean strategies. One operational indicator that has been used as a proxy for the purpose of waste elimination are process times (e.g. Kollberg *et al.*, 2006; Manos, *et al.,* 2006; Souza, 2009; Hwang, *et al.,* 2014; Kreindler, 2017). The second understanding of waste refers to the issue of costs; (compare Radnor and Holweg, 2012; Hwang *et al.*, 2014; Roemeling *et al.*, 2017). The third intent is *improving hospital performance*, which is measured via a variety of indicators reflecting the diverse and conflicting goals endemic to the healthcare context, of initial interest here are hopes for increases in hospital productivity as measured through its efficiency – (Jorma *et al.* ,2016; Rahimnia and Moghadasian, 2010; Olsson and Aronsson, 2015). The fourth construct in *improving the satisfaction of healthcare professionals* is named by fewer authors than the previous three but can be expected to contribute to performance indirectly (Simons *et al.*, 2017 & Rees and Gauld, 2017). These initial four constructs that were identified feature heavily in the literature on lean supply chain strategy in healthcare. It appears that the terminology and purpose of the lean approaches with a focus on speeding up processes while striving to maintain quality has been directly adopted from other industries' successes of lean supply chain strategy. The fifth construct was only identified in papers on agile and hybrid supply chain strategies and aims to *increase responsiveness and flexibility*. (compare Rechel *et al.*, 2010; Aronsson *et al*., 2011; Converso *et al.*, 2015).

The inhibiting factors of lean, agile and hybrid adoption in healthcare:
Three problem area for adopting either of the strategies were highlighted from the literature, which are a) context-related, b) strategy-related, and c) human-related. These three restraining components represent the diversity of expectations researchers and practitioners hold for lean, agile, and hybrid supply chain strategies when attempting implementation. The existence of challenges in the healthcare setting may explain the slower adoption of either of supply chain strategies.

The first identified problem area while implementing a supply chain strategy is *context-related,* in other word, it is the area that considers the circumstances that form the setting for healthcare. (Lillrank et al, 2011; Drupsteen *et al*., 2013; Aronsson *et al*., 2011; Converso *et al.,* 2015; Kreindler, 2017).The second problem area is *strategy-related,* many literature have demonstrated that ambiguous strategy for employees is one of the major inhibiting factor can face the implementation of the adopted strategy many literature (Rechel *et al.*, 2010; D'Andreamatteo *et al.*, 2015; Roemeling, Land and Ahaus, 2017), the second perspective is a debatable definition of waste in service sector, (see e.g.

Grove *et al.*, 2010; Radnor and Holweg, 2012; Ahmed, Abd Manaf and Islam, 2018). The third problem area is *human-related*, four observed issues in this area are to be discussed. Firstly, the lack of leadership and communication (see more Grove *et al.*, 2010; Al-Hyari *et al.*, 2016; Dobrzykowski *et al.*, 2016). A second challenge facing lean application in hospitals is the lack of employee engagement and training (see e.g. Meijboom *et al.* , 2011; van Rossum *et al.*, 2016; Schonberger, 2018). The third challenge is organisational culture resistant to change, Kollberg *et al.*, (2006) specifically human- related issue regarding the embedding of change and blame culture are quite prevalent across healthcare sector which prevents lean strategy from being utilized in a systematic manner (compare Timmons *et al.* , 2014; Lot *et al.*, 2018).

The following in figure 6 is a summary of thematic findings represented in an archetype of supply chain strategies is healthcare context.

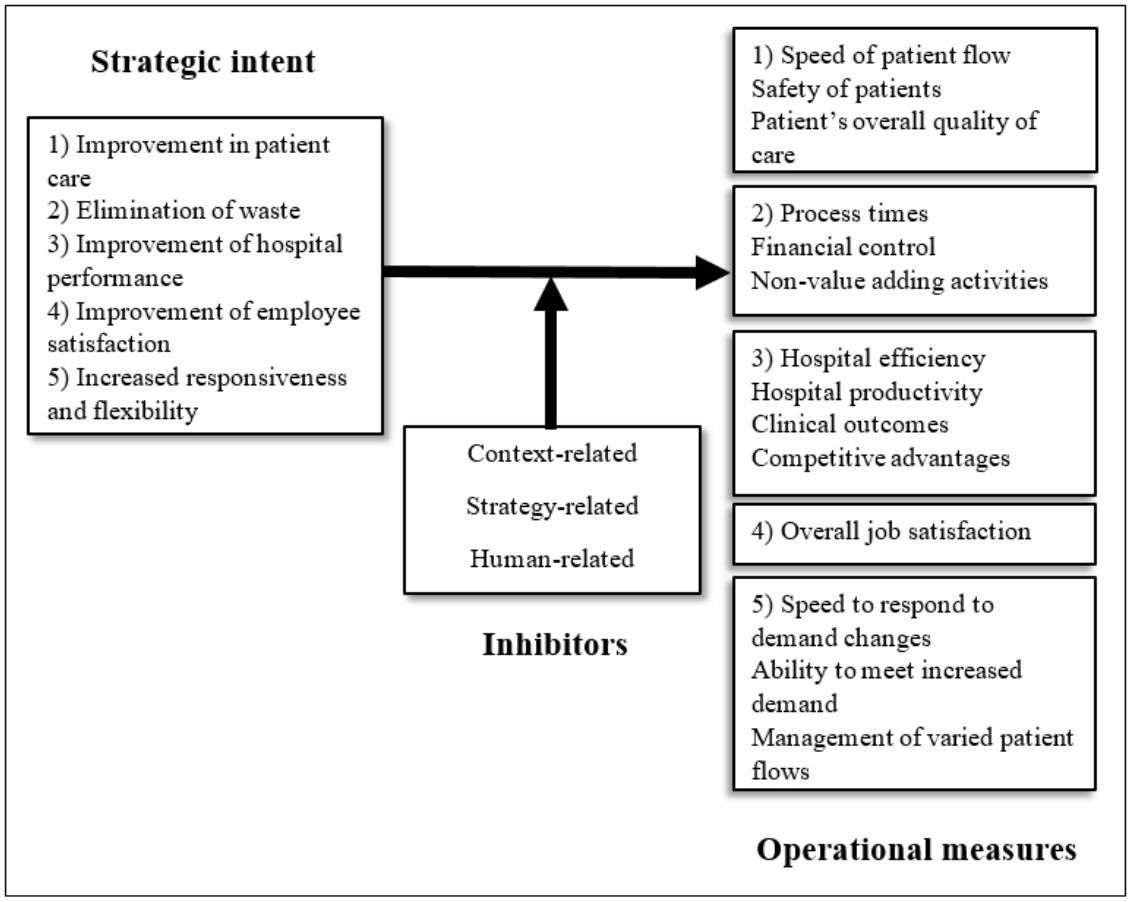

Figure 6: Archetype of supply chain strategies in healthcare

Conclusion:

By conducting SLR a holistic view is presented beyond reviewing individual papers, we will contribute to both the academic and professional communities. For researchers, the synthesised architype introduced is a further step in developing the understanding relating to the role of supply chain strategies in managing healthcare processes in the lens of patients flow. In the literature, lean supply chain implementation in healthcare has been discussed extensively while both agile and hybrid thinking have received little academic attention. Further research is needed to empirically test the implementation of hybrid

supply chain in healthcare, moreover, research assessing the properness of each strategy for managing patients flow is recommended which indicate the shift from the use of lean strategy as a topic of research to use agile as well as the combination of the two (i.e. hybrid).

For professionals, we will provide some managerial guidelines regarding the impact of supply chain strategies practices which should be of particular interest to hospitals' managers, in order to tackle hospitals' dilemma and how they can create and sustain competitive advantages in a complex and turbulent healthcare setting in addition to advice on how they can be implemented. The inhibitors factors can be used as a checklist to overcome the complexity of the hospital processes and to identify the appropriate strategy for improving performance regarding patients flow.

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Healthcare and the Economies of Sharing Economy

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Abstract

Leveraging the shared economy concept of ‘access’ instead of ‘ownership’ in healthcare would facilitate in tapping latent capacity of idle medical devices, reaching to patients

without access to quality health care and higher economic savings from reduced operational inefficiencies. In our model, a hospital can either take a high-quality capacity constrained device on share from another hospital or can buy a lower quality one from the manufacturer. We study analytically when quality sharing happens and when it leads to demand cannibalisation for hospitals. We analyse the impact of price sensitivity, the quality on the socially optimal outcome and patient's welfare.

Keywords: Shared economy, Healthcare, Stackelberg Game

Introduction

Global medical device industry is changing the face of the healthcare system with its highly innovative and technology-driven medical devices. The Indian government's 2017 National Health Policy envisions equitable health and well-being for all sections of the society (skpgroup, 2017). Around 69% of the Indian population lives in rural areas. Most of the region in rural areas are underserved with regards to quality medical devices. There exists an opportunity in the transformation of the Indian healthcare system, where there is a low level of penetration and adoption of advanced medical equipment. Increasing the accessibility of medical technology to improve national healthcare poises as a promising task.

In the financially stretched healthcare market, medical technology is often perceived as an expensive luxury (Davies, 2013). The high and rising prices of medical devices causes a reduction in consumers' welfare which ultimately reduces total welfare in the

economy (Pauly, 2008) . The reasons for medical equipment unavailability are mainly high capital cost and lack of financing options. Low-profit margin, low-income patients mainly contribute to the high capital cost. One of the solutions is getting low-cost equipment from low-cost manufacturers, for e.g. manufacturers in SE Asia offer low-cost products targeted at Africa, which is cheaper than US OEM alternatives. However, there are cons associated like poor product fit, non-standardized parts.

Sharing economy is sharing underutilised assets to improve efficiency and sustainability. There has been a surge of sharing economy in every industry which is changing the landscape of traditional operations like, transportation (Zipcar, Lyft), entertainment (Pandora, SoundCloud), logistics (Instacart, Uber Rush), hospitality (LeftoverSwap, Feastly), consumer goods (Nichol, 2016). There's a high demand for the collaborative economy, especially in emerging markets where it provides consumers access to services, they couldn't traditionally afford (French, 2015). Over 1 year, 25% of UK adults used internet technologies to share resources, according to research on the collaborative economy by NESTA in 2014 (Ahmed, 2017). The sharing economy's rise to prominence is due to the associated operational efficiencies and economic savings it introduces. Currently, two things are happening in the healthcare industry, that is actually positioning it for sharing. The number one is that the medical service providers are shifting their focus on consolidation and economies of scale because of the changes to how and how much they are paid for the provided services and the second can be attributed to the advancement in technology that is actually making sharing feasible (Mohamed, 2017). Medical surplus i.e. the usable supplies that hospitals throw out mainly accounts for the higher health care costs. Medical equipment's like ultrasound machine (about $25,000), Infant Warmer (about $3,995), Miltex Hegar Uterine Dilators (about $40 each), Airflow Manual

Resuscitator/Ventilator (about $26) and Covidien HET Bipolar Forceps (about $299), etc accounts for $20 million worth of medical equipment in a warehouse in Portland (Mirza, 2017). Often, healthcare providers are faced with situations where they have to operate under capacity due to the purchase of advanced and expensive medical devices. Applying sharing economy to healthcare sector would facilitate in leveraging technology for 'access instead of ownership' and reducing the potential inefficiencies associated with ownership and underutilization. Sharing brings back revenue back to the hospital by lowering overall operating costs.

Comparing with conventional supply and demand models, collaborative models are more resilient, accelerating consumption frequency, minimizing the latent capacity of medical devices, providing a higher return on investment for the healthcare units (hospitals) and improving patient outcomes. Hospitals use any given machine only about 42% of the time, at most, according to a GE healthcare study (Mohamed, 2017). Surgical and medical devices like infusion pumps and ultrasound scanners are traditionally viewed as fixed assets belonging to a specific hospital facility. Consider an example, where one Hospital, say PHU (Primary Healthcare Unit) owns a $250,000 mobile medical asset whose utilization rate is once per week which is quite a small fraction of the time and on the other hand, another Hospital, say SHU (Secondary Healthcare Unit) has also a need of the same medical device. The hyper-consumerism economic model encourages both the hospitals to buy the medical equipment in need at an exorbitant price. Moreover, if SHU comparatively is more financially constrained, then such a model doesn't make sense at all. So, PHU instead of letting the equipment go underutilized, he can actually generate additional revenue by monetizing the time the medical equipment is not in use. The peer-to-peer or collaborative consumption economic model would actually enable PHU to share it out

to SHU. Thus, creating affordable accessibility of medical equipment to lower end-hospital along with better utilization of equipment's latent capacity. Cohealo, a start-up in Boston uses this kind of collaborative consumption model instead of the traditional economic model of hyper-consumerism in healthcare. By using sharing economy, the healthcare organization can thus achieve the triple aim, a reduction of 30-40% in healthcare cost (Luisetto, 2016) and rental expenses (Reed, 2018) also support expanding care and an increased revenue capture (Crampton, 2018).

In our model, OEM sells differentiated versions of the same equipment and charge different prices to different hospitals based on the included features. In our proposed methodology, we say that the reduced price of the medical equipment provided by OEM to SHU is associated with reduced features of the medical device. So, if the SHU takes the machine on share from PHU, then it gets a higher quality machine than if it buys directly from the manufacturer. However, given the capacity constraint of the machine and the demand structure of the market of PHU, there is always uncertainty associated with the availability of the device. There isn't enough literature dealing with such models where the quality of the medical device is being shared under capacity constraints. So, we study under what situations, it is optimal for SHU to actually take the high-quality machine on share from PHU than opting for a non-share strategy, where it buys the low-quality device from the manufacturer and vice-versa. We also study how the market size of both the parties (PHU and SHU), price sensitivity and the quality of the device would affect the equilibrium price as well as the profitability of the healthcare units and also on the socially optimal outcome and consumer welfare. Also, we analyse that whether the existence of such a sharing environment, would lead to cannibalisation of demand for PHU. Thus, we study analytically, how leveraging the underlying notion of shared economy in turning the 'world of scarcity' into a

'world of abundance' would facilitate in tapping the excess capacity of the idle machines, reaching to patients without access to quality health care, a decrease in associated operational inefficiencies and higher economic savings (and consumer surpluses) in healthcare along with the scenarios where the sharing environment won't be beneficial for the parties involved.

Model and Assumptions

In our model, PHU is already in possession of the equipment and has bought from OEM at a price P. PHU is a monopolist investor-owned for-profit hospital and SHU is a monopolist not-for-profit hospital run by a private, for-profit firm. Both are profit maximizers. SHU can either buy from OEM at a discounted price or can take it on share from PHU at a rental price. As shown in (Figure 1), PHU acts as the platform owner and is the Stackelberg leader. In the first stage, PHU decides the rental price p_r to be charged to SHU, if SHU takes on share and the price p_A^B (Non-share Scenario) or p_A^R (Share Scenario) for medical services provided to its patients. We have assumed the discount d provided by OEM to SHU to be pre-decided by the OEM and the capacity of the equipment to be the sum of market sizes of PHU and SHU. In the second stage, SHU decides whether to buy the device with reduced features from OEM or to take the higher quality device on share from PHU and also decide the price p_K^B (Non-share Scenario) or p_K^R (Share Scenario) to charge to its patients. We have taken the price of the equipment as a proxy for the quality of the device. The demand equations for the base model are given by equation (1) and equation (2). In the secondary model, we take into consideration of demand cannibalisation for PHU due to the presence of the sharing market.

$D_A = \alpha_A - \beta_A p_A + \gamma_A P$, under both the scenario (share and non-share) (1)

$$D_K = \begin{cases} \alpha_K - \beta_K p_K + \gamma_K (P - d), & \text{if SHU buys from the manufacturer} \\ \alpha_K - \beta_K p_K + \gamma_K P, & \text{if SHU takes on share from PHU} \end{cases} \quad (2)$$

Where, α_K and α_A represent the market size of SHU and PHU respectively. The impact of the quality of device on demand generation for SHU and PHU are captured by parameters γ_K and γ_A respectively, whereas β_K and β_A captures the price sensitivity of SHU and PHU markets. The optimization models are described in Table 1.

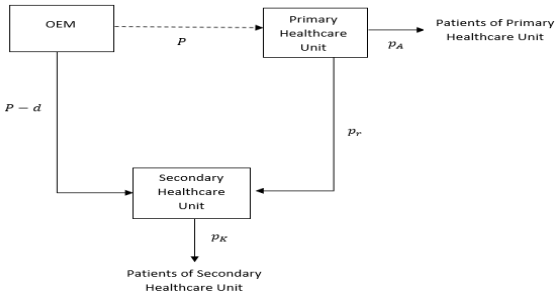

Figure 1- The proposed methodology

Assuming the game to be a complete information game and the parties to be completely rational, we solve the optimization problems (constrained and unconstrained). Table 2 gives the equilibrium profit and prices.

Table 1- Profit functions for Non-Share and Share Scenario

Unit	Non-Share Scenario	Share Scenario
SHU	$\pi_K^B = \left(p_K - c_K - \frac{P-d}{D_K}\right)(\alpha_K - \beta_K p_K + \gamma_K (P-d))$	$\pi_K^R = (p_K - c_K - p_r)(\alpha_K - \beta_K p_K + \gamma_K P)$
PHU	$\pi_A^B = \left(p_A - c_A - \frac{P}{D_A}\right)(\alpha_A - \beta_A p_A + \gamma_A P)$	$\pi_A^R = \left(p_A - c_A - \frac{P}{D_A}\right)(\alpha_A - \beta_A p_A + \gamma_A P) + p_r(\alpha_K - \beta_K p_K + \gamma_K P)$ Such that $\alpha_K + (\gamma_K + \gamma_A)\, P \leq \beta_K p_K + \beta_A p_A$

Findings and Contribution

We observe that the profit of SHU under both the scenarios (share and non-share) decreases with increase in price sensitivity of SHU market. Below and above threshold values of price sensitivity of SHU, PHU's and socially optimal strategy coordinates. Between the two extremes, there exists a conflicting zone. The profit of SHU under non-share scenario decreases with increase in the ratio of PHU to SHU market size. The profit of SHU under sharing scenario increases with increase in the ratio. The switching decision of SHU from "non-sharing" to "sharing" strategy is governed by a particular ratio value. Moreover, using this ratio and the price sensitivity of the SHU market, the strategies of the players can be categorised into coordinating and non-coordinating zones, depending on the interaction between HU's and socially optimal strategies. The rental price charged by PHU to SHU is more than the price charged by PHU under "no-share" scenario when the quality factor is taken into consideration whereas the relationship reverses otherwise.

Table 2- Base Model: Optimal profits and prices

Unit	Scenario	Optimal Price	Optimal Profit
PHU	**Non-Share**	$p_A^B = \frac{\alpha_A + \beta_A c_A + \gamma_A P}{2\beta_A}$	$\pi_A^B = \frac{(\alpha_A - \beta_A c_A + \gamma_A P)^2}{4\beta_A} - P$
SHU		$p_K^B = \frac{\alpha_A + \beta_K c_K + \gamma_K (P-d)}{2\beta_K}$	$\pi_K^B = \frac{(\alpha_A - \beta_A c_A + \gamma_A P)^2}{4\beta_A} - (P-d)$
PHU	**Share**	$p_A^R = \frac{\alpha_A + \beta_A c_A + \gamma_A P}{2\beta_A}$ $p_r = \frac{\beta_A(\alpha_K - \beta_K(c_K + c_A) + \gamma_K P) + \beta_K((\alpha_K - \alpha_A) - \beta_K c_K + (\gamma_A + \gamma_K)P)}{\beta_K(2\beta_A + \beta_K)}$	$\pi_A^R = \frac{[\beta_A(\alpha_K - \beta_K c_K + \gamma_K P) + \beta_K(\alpha_A + \beta_A c_A - \gamma_A P)]^2 + 4\alpha_A\beta_K(\gamma_A P - \beta_A c_A)(\beta_K + 2\beta_A)}{4\beta_A\beta_K(2\beta_A + \beta_K)} - P$
SHU		$p_K^R = \frac{\beta_A(\alpha_K + \beta_K c_K + \gamma_K P) - \beta_K(\alpha_A + \beta_A c_A - \gamma_A P) + 2(\beta_K + \beta_A)(\alpha_K + \gamma_K P)}{2\beta_K(2\beta_A + \beta_K)}$	$\pi_K^R = \frac{[\beta_A(\alpha_K - \beta_K c_K + \gamma_K P) + \beta_K(\alpha_A + \beta_A c_A - \gamma_A P)]}{4\beta_k(2\beta_A + \beta_K)^2}$

Proposition 1: For $A < \gamma_K < B$, where A and B are functions of $\alpha_K, \alpha_A, \beta_K, \beta_A, c_K, c_A$ and P, then we have $p_A^R > p_r > p_A^B > p_K^B > p_K^R$.

Proposition 2: There exists a threshold for discount d_c, such that for $d < d_c$, SHU opts for sharing however for $d > d_c$, SHU opts for buying the device from the manufacturer directly.

Proposition 3: When SHU is indifferent between buying the device and taking it on share, then the socially optimal outcome is to share the higher quality device rather than buying the inferior one, whereas when the socially optimal outcome is indifferent between sharing or buying, then SHU opts for buying the inferior medical device.

Limitations

The results are obtained using deterministic demand of the hospitals. Our model does not incorporate any kind of uncertainty of parameters. We assumed that both the parties have complete information about each other's cost structure, which is not always true. In fact, parties have partial information, specifically about the cost structure of the other party involved. In such a case, the cost can be assumed to follow a certain distribution.

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An analysis of strengths and weaknesses of SCM strategies in medical technology OEMs: a perspective from German manufacturers

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Abstract

Original Equipment Manufacturers (OEMs) in the German Medical Technology (MT) sector are facing a strong competition from low-wage countries developing, manufacturing, and distributing high-quality products globally. For this reason, organisations in this sector require orientation in the implementation of SCM policies to reduce operating cost and to create value for their customers. A multiple case study was conducted to identify SCM issues and best practices in this sector. This study contributes to healthcare operations management literature with a tailor-made assessment tool. Its findings offer new priorities for managers, particularly if they are contemplating a re-engineering of their SCM strategies.

Keywords: Supply chain network design and analysis, Collaboration and coordination issues in SCM, Medical technology industry

Introduction

Medical technology is an innovative, fast-growing and promising industry, particularly so in Germany as it is the third largest market in the world behind the US and China (BVMed, 2018). Around 1,200 small and medium-sized enterprises (SMEs) represent the core of this sector (BMBF, 2017). In 2017, the sales volume of MT organisations rose to 29.9 billion euros, with an export rate of 64% (BVMed, 2018).

Despite this remarkable growth, the Medical Technology industry in Germany is faced with a number of challenges. Reportedly, Germany's statutory health insurance fund (gesetzliche Krankenversicherung) has experienced funding difficulties, forcing administrators to reduce fees and thus expenditures on Medical Technology (Hartford, 2014; Focus, 2016). Furthermore, manufacturers rely strongly on new product development to sustain or increase their market share, and with products having lifecycles not longer than 3 years, short development times and regulatory approvals become critical issues (Hempel, 2017; BVMed, 2018). Additionally, Chinese and Indian companies are also lined up to be frontrunners in terms of cost, workforce, and market capture, pressuring German manufacturers to produce and distribute cost-

efficient devices (Marucheck et al, 2011; Hempel, 2017). In this environment, the search for rationalisation potential becomes critical. Studies (J & M, 2010) show that a defined supply chain strategy often falls short in this sector. Major deficiencies reported are the absence of a formulated strategy, the lack of efficient planning and coordination processes, along with unreliable sales forecasts.

In this paper, the authors investigate multiple cases of OEMs involved in Medical Technology Supply Chains (MTSCs) in Germany and use the results of the analysis to identify both areas at which these organisations excel as well as areas of improvement which require addressing during the design and operation of their SCM strategies. This paper builds on previous research conducted by the authors (Garcia-Villarreal et al, 2019) and is organised as follows: first, a review of the literature is reported. Then, the research aim and focus are formulated, followed by the justification of the selected methodology and case study design. Next, the findings are presented and analysed. Finally, this paper concludes by stating the implications for theory and management practice along with research limitations and avenues for further research.

Literature review

Healthcare & Medical Technology Supply Chains

Supply chain management as an area in operations management literature is extremely well served whereas there is a real dearth regarding its focus on medical technology supply chains and their agility as exemplified by recent literature (Gligor, 2014; Mandal, 2017). Mentzer et al (2001, p. 4) define supply chains as a *"set of three or more entities directly involved in the upstream and downstream flow of products, services, finances, and information from a source to the customer"*. There are three major players in the Medical Technology supply chain: producers (product manufacturers), purchasers (group purchasing organisations, or GPOs, and wholesalers/distributors), and healthcare providers (hospital systems and integrated delivery networks, or IDNs) (Burns et al, 2002).

The manufacturers (producers) in the supply chain can be broadly classified into three groups namely, pharmaceutical, medical-surgical, and device manufacturers, the latter being the object of this study. Their products are then purchased by GPOs, wholesalers, distributors and in some cases independent contractors, and then delivered to providers like hospitals, integrated delivery networks (IDNs), physicians (individual clinics) and pharmacies. Customers (payers) in this supply chain are local governments, employers, and individuals. They pay the providers through fiscal intermediaries like insurers, health maintenance organisations (HMOs) and pharmacy-benefit managers. Smith et al (2012) provides a detailed view of the medical devices supply chain, in which the main product flows between the key players are clearly represented (see Figure 1), underlining the heavy influence of intermediaries or third-party players.

Studies by Burns (2000), Dacosta-Claro (2002), J and M Research (2010), and Mayer (2013) indicate that a significant portion of the costs associated with supply chains in the health care sector can be reduced by adopting strategies already deployed by the industry sector (e.g. automotive). For this reason, identifying areas of opportunity and areas managed successfully by these organisations becomes very important.

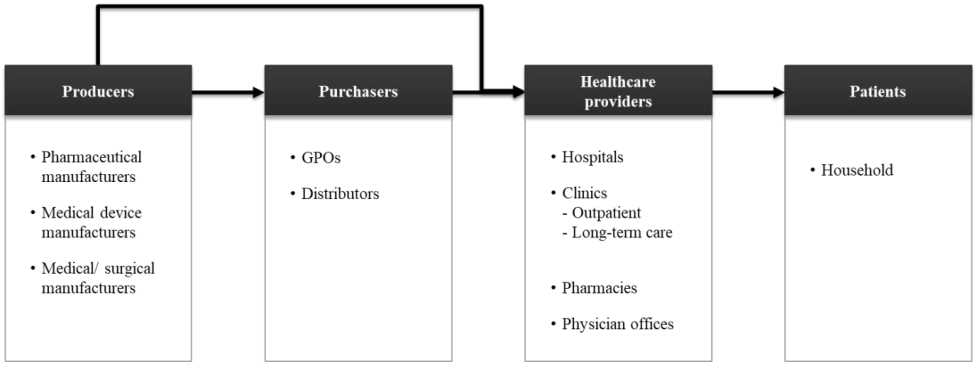

Figure 1: Detailed view of the medical devices supply chain (Smith et al, 2012, p. 3)

Review of SCM assessment tools available in academic literature

The literature review identified a number of tools available for assessing the performance of logistics and manufacturing companies within their supply chains, which are briefly presented and discussed in this section.

Tummala et al (2006) conducted a survey research with top and middle managers within a large enterprise as respondents in order to examine operational issues concerning success factors that are necessary when implementing SCM plans in one large manufacturing firm. Dimensions for evaluation were *'customer-supplier relationship', 'information and communication technology (ICT)', 're-engineering material flow', 'creating corporate culture', and 'performance measurement'.* Their study revealed that resource allocation could be enhanced in areas such as information systems, goal-setting, training personnel, and aligning SCM initiatives with current priorities and committed resources in that particular organisation. Although this assessment tool did focus on many factors related to logistics and SCM, neither *'make'* (e.g. manufacturing issues) nor *'return'* processes (e.g. reverse logistics, green supply chain) were considered in it.

Gunasekaran and Ngai (2003) conducted an interview-based case study on a small third-party logistics (3PL) company in Hong Kong that had been successful in its overall business performance and in satisfying its customers. In this study, they designed a framework for developing an efficient 3PL system. While their assessment tool appeared easy to use, it only included five major dimensions for evaluation (*'strategic planning', 'inventory management'; transportation planning'; capacity planning'; and 'information technology'*). It can be noted that this assessment tool was not intended for manufacturing firms, but rather for 3PL companies, as neither of the dimensions considered any form of evaluation criteria aimed at identifying issues in the development, production, and quality assurance of items (*'make'* processes).

Finally, Thakkar et al (2011) used a case study approach to identify issues in SMEs of Indian origin. The assessment tool developed for this study offered a thorough approach, consisting of the evaluation of Critical Success Factors (CSFs*) 'effective partnership', 'improve communication', 'logistics integration', 'supply chain business strategy', 'buyer-supplier relationship', 'effective planning and control', 'trust among supply chain partners',* and *'availability of performance management tools'.* However, the dimensions under review appear to be too much leaned against the *'source'* side of the business.

Research methodology

The research objective of this study is to explore key areas of improvement of German MT OEMs during the design and operation of their supply chain strategies. Therefore, this study was driven by the following research question:

- *What are the strengths and weaknesses of German MT OEMs in regard to their supply chain strategies?*

In order to answer this question, an exploratory research with a multiple case study approach was selected for three reasons: (1) the literature review revealed limited insights concerning weaknesses and strengths in SCM practices in the MT sector. In such an embryonic research field, a qualitative research provides better means to identify patterns and develop theory (Edmondson and McManus, 2007). (2) As the researchers were able to interact with respondents, perspectives were better understood (Boyer and Swink, 2008). (3) Case studies encourage management involvement, which helped this research to generate managerially relevant knowledge. Established methodological guidelines for case study research were observed (Eisenhardt, 1989; Robson, 2011; Yin, 2009). Fourteen in-depth case studies of manufacturing organisations were conducted to obtain a greater understanding of the main issues of German MTSCs (see Table 1). In order to enrich the results, the selected case study organisations were of different subsectors (e.g. laboratory equipment manufacturing, electromechanical MT, non-active implantable technology, etc.) and sizes, with eight Large Enterprises (LEs) and six SMEs participating.

Table 1: Summary of the respondent demographics

Nr.	Company	Classification according to the GMDN Agency (2012)[1]	Position of respondent	Company size according to IfM (2017)[2]	Number of employees
1	A	Laboratory equipment	Vice President of Supply Chain	Small and Medium Enterprise (SME)	300
2	B	Electromechanical medical technology	Vice President Global Logistics	Large Enterprise (LE)	53 000
3	C	Electromechanical medical technology	Manager of Logistics Planning	Large Enterprise (LE)	12 500
4	D	Non-active implantable technology	Director of Supply Chain Management	Large Enterprise (LE)	3 400
5	E	Electromechanical medical technology	Head of Supply Chain	Large Enterprise (LE)	6 000
6	F	Reusable instruments	Manager of Logistics Planning	Large Enterprise (LE)	4 400
7	G	Hospital hardware	Vice President of Global Logistics	Large Enterprise (LE)	6 300
8	I	Non-active implantable technology	Vice President of Supply Chain	Small and Medium Enterprise (SME)	180
9	J	Electromechanical medical technology	Head of Supply Chain Operations	Small and Medium Enterprise (SME)	400
10	K	Diagnostic and therapeutic radiation technology	Director of Supply Chain Management	Large Enterprise (LE)	49 000
11	L	Single use technology	Director of Supply Chain	Small and Medium Enterprise (SME)	500
12	M	Healthcare facility products and systems adaptations	Head of Supply Chain	Small and Medium Enterprise (SME)	200
13	N	Anesthetic and respiratory technology	Director of Purchasing, Global Supply Chain	Small and Medium Enterprise (SME)	200
14	O	Hospital hardware	Head of Outbound Logistics	Large Enterprise (LE)	15 200

1 = (GMDN-Agency, 2012)
2= (Institut für Mittelstandsforschung (IfM), Bonn, 2017)

A suitable assessment tool was required for this study. The literature review identified and discussed available assessment tools, which were deemed too simplistic, too complex for practitioners to use regularly, missing processes featured in the SCOR-Model (Supply Chain Council, 2008), or not suited for the context of this study. For these reasons, an assessment tool was designed, piloted, and implemented to identify strengths and weaknesses of SCM strategies in the case organisations (see Figure 2). The theoretical foundations of this tool as well as the dimensions under review are based on identified CSFs by the authors in previous research (Garcia-Villarreal et al, 2019).

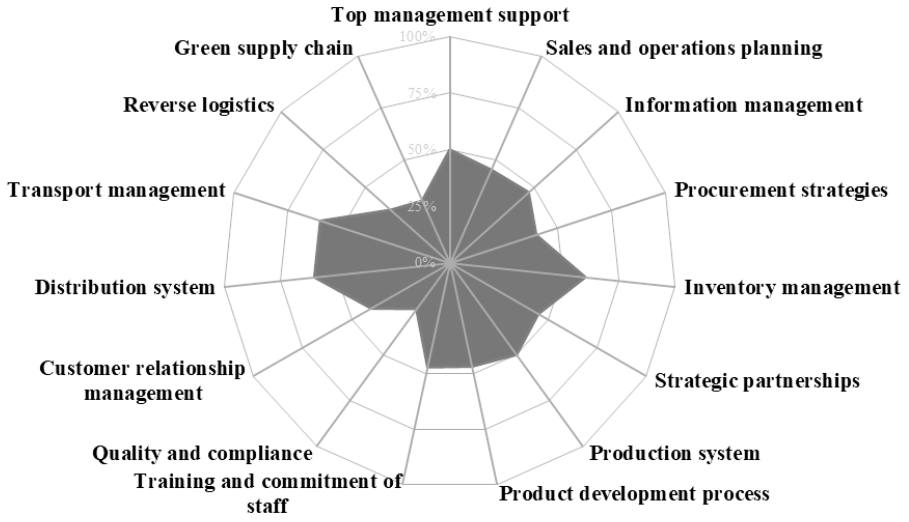

Figure 2. Example of mapping results of Case Organisation L using the assessment tool for this study

Research findings

This study identified areas where case organisations excelled at their SCM strategies as well as areas requiring immediate attention by SCM practitioners. These are reported here.

Strengths in SCM practices of MT organisations

Strengths of MT organisations (predominantly LEs) were found in four areas: (1) the design of OEMs' supply chain capabilities according to their customer value propositions; (2) the deployment of intelligent product design; (3) the use of *'track and trace'* systems to increase supply chain visibility; (4) an expansion of the role of OEMs to deliver more value for their customers.

In terms of the design of the supply chain capabilities according to their customer value propositions, this study identified three fundamental approaches: a flow-oriented approach, a batch-oriented approach, or a combination of both. The flow-oriented supply chain is set up on the basic condition of a quite fixed series of repetitive transactions (material, information, payments). Case Organisations A, E, L, and N had a flow-oriented approach to their supply chains. What these companies had in common is the production of mass articles with a low degree of variation and in high volumes.

These companies strived to reduce costs in their supply chains by improving their standard, repetitive operations. Conversely, Case Organisations D, M, and I had adopted a batch-oriented supply chain strategy for their operations. These companies had three things in common: they produced niche products according to customer specifications, they did not manufacture these products in high volumes, and they sold these items at a high price. The supply chain required to carry these products needed several arrangements: Manufacturers had to interact with a larger number of raw material suppliers; each contract with hospitals or clinics needed to be individually priced and logistics details had to be arranged individually; instead of a continuing number of shipments, there was a limited number of batch deliveries.

The basis for the economic success of German MT is the broad range of innovative products it creates, with about a third of its revenues generated from products that are less than three years old (BMBF, 2015). For this reason, the product development process becomes crucial for the supply of innovative products to their customers (Medina et al. 2013). Case organisations in the study reported a transition from an inwardly-oriented approach to product design (first developing a product then searching for a market) to a more customer-oriented approach (understanding customer needs and developing products thereafter). Involving surgeons in the innovation process proved beneficial to OEMs, as development, product test, and regulatory approval times could be reduced (Lettl, 2013), while increasing product variety to address users' specific needs (Al-Zu'bi & Tsinopoulos, 2012). Given the importance of the role of users in the design of products, Case Organisation D cooperates actively with surgeons in the design of medical devices and names their finished products after the physician that inspired or co-designed them. Activities in product development process have an influence on the performance of other organisational functions, such as procurement, manufacturing, marketing and sales, and service. Case Organisation A launched a project to standardise information flows between sales, product development, and procurement in order to reduce the risk of dependency to niche suppliers. These efforts enhanced their material availability while reducing the risk of material obsolescence. Case Organisation J analysed their product portfolio in an effort to standardise their raw materials and their part numbers, with the effect of decreasing their supplier base and streamlining their purchasing, order picking, and assembly processes. Case Organisation D focused on reducing manufacturing costs (technology, methods, and materials) through a re-examination of their product portfolio. Finally Case Organisation H launched a project to improve their product update services in order to cut manufacturing, procurement, inventory, and after-sales costs.

Several organisations in this study have made supply chain visibility a top priority in their agendas and have made significant investments in this area. One major reason is to fight product counterfeits. Another reason is that their customers require status reports about shipments in real time: hospitals are increasingly under pressure to schedule both patients and surgeries more efficiently, both for humanitarian and economic reasons, as costly hospital equipment (e.g. computer tomographs) cannot afford downtimes. Therefore, the recipients are requiring effective *"track and trace"* instruments to monitor the shipping status in real-time. Clinics expect real-time information, especially for unplanned maintenance work. At Case Organisation K, 30 to 50 per cent of the maintenance services are unplanned. Case Organisation K needs to supply 98 per cent of all spare part orders within 24 hours – and, if possible, in all 132 countries covered by the manufacturer. This poses a challenge for freight forwarders: if the shipment is half an hour too late, it is already considered late. Therefore, Case Organisation K has been working with third party logistic providers to digitalise their distribution chain. In

order to enhance their response rate, Case Organisation K defined milestones with the freight forwarders along the supply chain. Once a milestone had been reached during the transportation of products, it was the freight forwarder's responsibility to deliver a push message to both manufacturers and recipients.

One of the largest cost items for hospitals and clinics, as reported by some case organisations, is the management of products such as endoprosthetics, pacemakers or surgical covers. Some case organisations are reportedly working to improve hospitals' operational procedures in the sterilisation departments, in operating rooms, as well as in the hospitals' internal logistics. Effects of these projects are shorter throughput times for the supply of instrument trays to operating rooms, reduced stocks of instrument trays in storage rooms, and streamlined logistics processes for hospitals. Additionally, Case Organisation K reported working on taking over the repair management functions of hospitals in order to consolidate internal cost and reduce the replacement rates of instruments. In the same context, Case Organisations D and K have been working on expanding their capacities for the repair of used instruments, in order to reduce the hospitals' replacement rates. For this reason, it is expected that OEMs can gain a competitive advantage by working together with their customers to streamline their internal processes and to reduce managerial efforts.

Weaknesses in SCM practices of MT organisations

In terms of the main SCM issues in this sector, this study identified four areas where the severity of SCM issues is critical: (1) a lack of rigour in the deployment of sales and operations planning; (2) poor first-tier integration; (3) distribution networks not set up according to customer needs of product availability; and (4) a strong emphasis on quick wins and quarterly savings hindering change at management level.

Regardless of their products and services or their size, 11 (C, E, F, G, O, A, I, L, J, M, N) of the 15 case organisations in the study have experienced some form of disruption in their respective supply chains that has hindered their ability to harmonise customer demand with production and distribution capacities. Reasons for these disruptions are, among others, a low level of trust, integration, and information sharing between OEMs and both customers and suppliers; and a lack of rigour in the deployment of their existing Sales and Operations Planning (S&OP) process, fostered by conflicting target and performance appraisal systems within the organisations and developing counter-productive behaviours such as silo-thinking within organisational departments. This issue has particularly affected SMEs, which, in the absence of joint planning with customers, has made the position of their supply chains vulnerable.

Several organisations reported having issues related to their current procurement strategies and approaches. Similar patterns were identified for both LEs and SMEs: LEs reported on having adopted select procurement strategies (Kanban, Vendor-Managed Inventory (VMI), Electronic Data Interchange (EDI), Just in Time (JIT)) and have come to expect their supplier base to become JIT suppliers, but in the absence of cross-functional integration within the OEMs, the implementation of these strategies appeared to be disjointed and did not lead to a full utilisation of their systems' capabilities. In addition, approaches to procurement of Case Organisations E, G, and O seemed to be one-sided, apparently seeking no win-win situations with suppliers and thus hindering collaboration. In contrast, issues shared by SMEs range from underprivileged power relationships with suppliers (cases M and L), inaccurate master data hindering an efficient information exchange with suppliers (cases J, A, N), and raw material shortages due to fluctuating prices and an almost exclusive focus on local sourcing (cases I, L, M). Evidence of this disconnect in the relationship with suppliers could be

found in the presence of the high raw material inventories and slow turnover ratios for almost all cases referenced above.

Additionally, Cases B, G, O, A, L, I, J, and I shared that their distribution network was not set up according to customer needs of product availability. Therefore, these companies were forced to ship their products via express delivery at high cost. In the case of Case Organisations I, L, and N, this is partly explained due to the fact that reportedly, the design of efficient logistics structures had not been focus of much work, as before the crisis in 2009, there had not been a need to change. Now these companies are catching up with several concepts well established in the automotive industry. For instance, Case Organisations L, J, M, and N – all SMEs -, are currently embarking on projects of their own seeking to integrate external logistics service provides. They believe that outsourcing distribution will help them focus on their core competencies, access new markets, optimise transport routes, and save them the time and money they would have invested in setting up their own distribution facilities.

Finally, it appeared that several managers have merely added the term 'supply chain' to their jargon without adopting a SCM mind-set. A strong emphasis on quick wins seemed to limit the ability of several case organisations to establish appropriate processes and relationships or to anchor them in the organisational culture. For instance, Case Organisations G and O seemed to have organised all their SCM activities around their logistics and customer service activities, yet these efforts were focused primarily on direct 'A' customers and were reactive in nature, neglecting 'B' customers with the potential to transform into 'A' customers. While all respondents believed that SCM could assist their respective companies to succeed in their marketplace, they did recognise the difficulty to bridge organisational boundaries in their relationship with suppliers. In this sense, the procurement strategies of several case organisations (e.g. Cases E, O, G) appeared to be one-sided, seeking no win-win situation, thus hindering collaboration.

Furthermore, several case organisations seemed willing to invest in technological solutions to solve operational challenges. Respondents I, M, and L made a case for investments on better information technologies hoping that this would provide their supply chains with substantial improvements in terms of efficiency, collaboration, and responsiveness. While this may be partially true, some respondents warned that improving collaboration between stakeholders required more than an enhanced information platform. Therefore, they had been working with core first-tier suppliers and customers to (1) define the boundaries and strength of their relationships; (2) establish communication requirements; and (3) select appropriate technologies based on an analysis of these requirements.

Only a few companies have established a SCM culture that promotes fact-based decision-making. For instance, case organisations such as C and D had been installing common goals in SCM for all departmental functions within their organisation. Furthermore, these organisations have understood that cultures change slowly and that changing long-standing ways of doing things require appropriate strategies and serious commitment from management. Therefore, they have been involving owners, senior managers, and middle management in transformation projects, as they understood that a real change could only occur with direct involvement of stakeholders.

In this context, the middle management seemed to have a key role both as an intermediary between the goals of senior management and the priorities of the operational staff, and as an agent for sustainable changes in operational policies. For these companies, SCM was not seen a project but as a long-term journey.

Conclusion

The objective of this study was to identify strengths and weaknesses of current SCM practices of OEMs in the German MTSC sector. The interactions with fourteen OEMs have helped to identify both areas where these organisations excel and areas where the severity of the issues requires immediate attention.

Areas where MT organisations excel are (1) the design of OEMs' supply chain capabilities according to their customer value propositions; (2) the deployment of intelligent product design to reduce sourcing costs and to build stronger partnerships with physicians; (3) the enhancement of supply chain visibility with *"track and trace"* systems; and (4) designing and implementing individual concepts for supply and management of medical devices for hospitals and clinics.

On the other hand, major issues identified in this sector include: (1) a lack of rigour in the deployment of sales and operations planning; (2) poor first-tier and second-tier integration; (3) misaligned distribution networks; and (4) a strong emphasis on quick wins and quarterly savings hindering change at management level.

This research contributes to knowledge in the form of an assessment tool that identified strengths and weaknesses of SCM strategies in the MT sector. Although a number of tools available for assessing the performance of organisations within their supply chains were identified, these appeared to be either too simplistic, too complex for practitioners, lacking important dimensions for evaluation, or not suited for this research context. In an effort to fill this gap, this study developed its own tool, providing an approach to evaluation that considers the five basic business processes required to satisfy customer demand ('*Plan', 'Source', 'Make', 'Deliver', 'Return'*) (Supply Chain Council, 2008).

Researchers can use it as a means to conduct further research work in other contexts. Additionally, managers of MT OEMs who wish to develop or restructure their organisations' SCM policies can benefit from this tool, as it provides them with an orientation for resource allocation. The main limitation is that this tool is tailor-made for organisations in the MT sector. Although this is a limitation, it does however give evidence to how closely this tool is designed for the sector in focus, as it considered this industry's characteristics. Further research work can use this assessment tool to test its applicability in other contexts other than the German MT sector.

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Achieving engagement by provider and patient in the use of patient portal for standardized care pathways

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Abstract

A digital patient portal is a promising mechanism to support greater patient engagement. Yet questions remain about how adoption of these portals can be encouraged since patients and providers still face a lot of resistance. This paper examines, by building on the MOA framework, if and how usage behavior is influenced. With action research in an innovation project at Ghent University Hospital we collected data (interviews, observations, log data, questionnaires) of involved parties. Preliminary results showed higher use of the portal by implementing changes. The role of intrinsic and extrinsic motivation of all included parties needs to be further investigated.

Keywords: action research; eHealth; motivation, opportunity and ability framework (MOA); patient portal.

Introduction

In the last decades, day surgery has steadily and significantly grown in countries with established stable economies (Jarret et al., 2006). Advances in surgery and analgesia, changes in clinical practice and in the attitude of the surgical team, as well as the establishment of dedicated day-surgery facilities with dedicated staff and well-defined care pathways, together with financial incentives have made this development possible (Leroy et al., 2017). Ambulatory surgery becomes more important and will be further promoted by the government; it is safe and cost-efficient but quality must be guaranteed. As more complex operative procedures will be performed on a day care basis, patient follow-up has to be intensified. This increase in day surgery entails some challenges,

mainly in the continuity of care and in patient follow-up after day surgery unit discharge. Persisting postoperative pain, post-discharge nausea and vomiting, and wound problems remain critical symptoms that necessitate continuous monitoring (Apfel et al., 2012; Goldfarb et al., 2017; Odom-Forren, 2013). Systematic e-assessment can increase patients' quality of recovery and identify key areas for improvement in peri- en post-operative care. As such, an eHealth solution could be the answer to some of these challenges.

The implementation of technology in the health sector, popularly known as eHealth, is emerging as one of the most rapidly growing areas in healthcare today (Srivastava et al., 2015), with the potential to provide innovative solutions to health problems. The emergence of the Internet and the electronic health record has brought new opportunities for patients to play a more active role in his/her care. The implementation of a *digital patient platform* could provide in the requirements that an ambulatory surgery center needs (Ammenwerth et al., 2012).

An active integration of the patient in his/her treatment bears multiple potential benefits. Certainly as we notice a change in the patient's role from a patronized patient to an informed patient, and further to a responsible, autonomous and competent partner in his or her own care (Bravo et al., 2015). A patient portal is an online platform that provides patients with access to their health record, improves the patient-provider communication, and enables patients to take control of their condition(s) (Otte-Trojel et al., 2015). So a patient portal is a promising mechanism to support greater patient engagement. However, the expected benefits of the implementation of such an eHealth technology under the form of a digital patient platform are not always a match with the actual outcomes (Van Gemert-Pijnen, et al., 2011).

EHealth technology must be developed as a user-friendly digital tool with benefits for the different users. . Therefore different stakeholders have to work together to develop and implement the application in everyday practice. Although new technologies can offer the new opportunities and benefits, stakeholders don't always seem to appreciate it (Hee-Woong & Kankanhalli, 2009). There is often a mismatch between the expected benefits eHealth technology can offer to the users and the actual outcomes in practice (Van Gemert-Pijnen, et al., 2011). In addition, healthcare professionals often have a sceptical view on the digital transformation and do not see the potential benefits for themselves and their patients. Van Gemert-Pijnen et al. (2011) demonstrated possible explanations of this mismatch: (1) the absence of a pre-defined scope and clear objectives that cover the requirements of all stakeholders; (2) the lack of coordination and communication between the relevant stakeholders; (3) the position of the user and the level of their involvement during implementation. If users do not see the benefits in using technology, they will resist using it as it looks to be time consuming and frustrating. Above that, there are situations where the innovation of eHealth technologies is not enough reimbursed because of a lack of financial trust by investors. Further, it could also be that the implementation of eHealth is not supported by legislation, which slows down the development process (Gemert-Pijpen et al., 2011).

In an effort to understand usage or non-usage of technology, researchers have frequently turned to technology acceptance models. The Technology Acceptance Model (TAM and TAM2) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) are the dominant approaches in the technology acceptance research. The models suggests that when users are presented with a new technology, a number of factors influence their decision about how and when they will use it (i.e. 'perceived usefulness' and 'perceived ease of use'). These models

however, are not always fulfilling (Peek et al., 2016) and further research is needed. Agarwal et al. (2010) stress out the importance of further research in the field of Health IT as following: "*The healthcare industry faces the same challenges as other industries while integrating IT. At the same time, however, the healthcare industry has its unique features and attributes.*" Questions remain about how adoption of patient portals can be encouraged since patients and providers still face a lot of resistance (Irizarry, 2015).
We investigate the actual use of a patient portal peri-operatively in ambulatory surgery and how this is perceived by patients and healthcare workers. Secondary we try to identify and remediate reasons for non-use.

Framework

Motivation–opportunity–ability (MOA) framework

The integrative motivation–opportunity–ability (MOA) model proposed by Ölander and Thøgersen (1995) was constructed to explain customer actions. The MOA framework uses information on the targeted stakeholders' motivation, opportunity and ability to undertake the preferred behaviour (Rothschild, 1999). A deeper understanding of these three key aspects would allow programme developers to formulate effective behavioural change strategies. In this model, "Motivation" influences "Behaviour" with "Ability" and "Opportunity" as moderating influencing factors (Figure 1).

Some theoretical models used in information system research may lack explanatory power and consistency because of their failure to provide an adequate means of accounting for contextual and situational factors which influence behaviour. The motivation-opportunity-ability (MOA) framework addresses these problems for important new areas of information system research by theorizing two of the most critical factors, ability and opportunity, on the link between motivation and behaviour. The MOA framework has been used in many studies in different areas of research. For example, MOA was used to discuss the public health and social issue behaviours (Rotschild et al., 1999) and consumer behaviour (Ölander & Thøgersen, 1995).

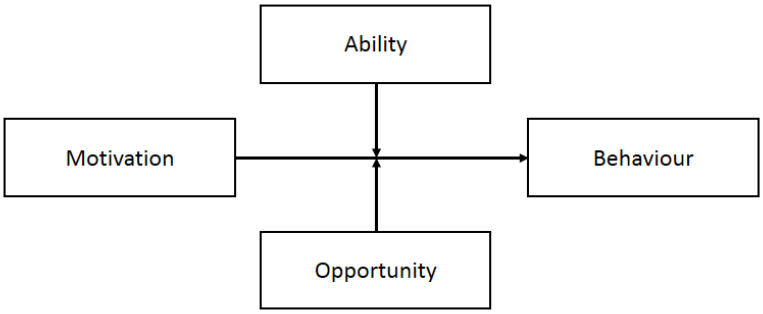

Figure 1 – Ability, Motivation, and Opportunity Theory (Hughes, 2007)

Building on the MOA framework "Motivation", "Opportunity" and Ability", are defined as patients' motivation, opportunity and ability to adopt the digital patient portal. MOA theory is used as a foundation because it is believed that in the context of patient portal adoption "Motivation" is considered as the drives, urges, wishes or desires which initiate the patient's intention to use the patient portal. "Ability" can facilitate patients in adopting the patient portal and "Opportunity" is interpreted as situational factors that encourage patient in the adoption of digital patient platform. "Behaviour" reflects the "adoption" of the digital patient portal.

Methods

This study presents preliminary data of the innovation project in Ghent University Hospital, Ghent. The ambulatory surgery unit at Ghent University hospital aims at electronic communication with both patient and caregivers involved in ambulatory care (e.g., in-hospital, out of hospital, general practitioner, physiotherapist, home nursing). In cooperation with CoZo (Collaboratief Zorgplatform), an electronic hub which allows safe and efficient multidisciplinary communication, a digital patient platform was developed.

Design

To conduct the study we opted for action research. Action research involves actively participating in a change situation, often via an existing organization, whilst simultaneously conducting research (Cordeiro & Soares, 2018). Researchers who believe that existing practise or issue can be improved or refined can attempt to develop and implement new approaches through action research (Kaplan et al., 1988). As such, we had to develop a coherent process, posit a theoretical framework and align these with the research aims and procedures, and local transformation needs. As stated by Denscombe (2010, p. 6) our action research strategy's purpose is to solve a particular problem and to produce guidelines for effective practices. In this case best practise could increase the adoption of a digital patient portal.

Setting

We included two care pathways to measure the adoption of the digital patient platform. Patients planned for knee arthroscopy or sinus surgery.

The patient platform includes (1) an informative part: visualization of the individualized care path (different steps can be chosen for each patient which makes the pathway customized), provision of reliable information about the diagnosis and the treatment, links to relevant websites, contact details of the treatment team, and (2) an active part with the possibility to have secure conversations with the treatment team, self-registration of complaints and other problems in diaries and other questionnaires, and a question prompt list (Figure 2).

Data collection

We conduct a longitudinal study with different phases. In each phase we implemented, according to the action research strategy, new insights learned from the former phase. A pilot study started in September 2017 introducing the digital patient platform to the participating care processes and the stakeholders. The first phase of the study started in August 2018 and was recently finalized. Meanwhile, a second phase is initiated (see further). In each phase data is collected, analyzed and conclusions are taking into account to be able to evolve to the next phase.

A multimethod approach, combining qualitative and quantitative data, was chosen because of the nature of the research. Collection of both qualitative and quantitative data bolsters the findings by combining the strengths of each method. Data was collected through interviews (with patients, involved caregivers and physicians), observations (first introduction to patient with platform, team meetings), log data collected from the patient platform, clinical outcome measures and a patient questionnaire (see Table 1).

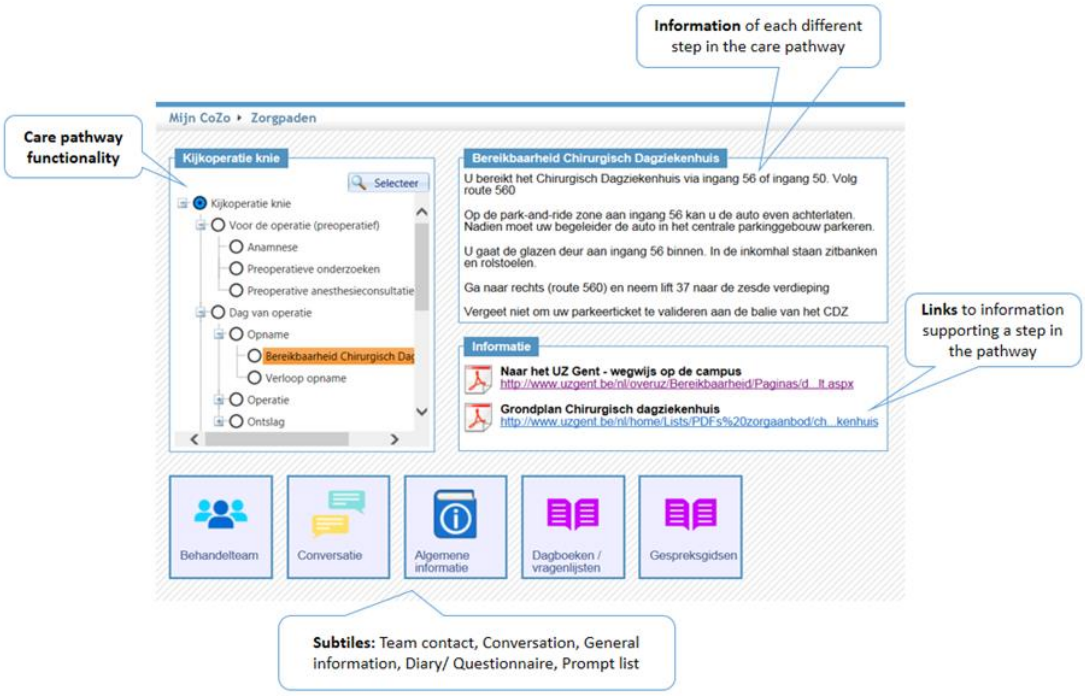

Figure 2 – The Digital Patient Platform

Semi-structured interviews were held with patients and involved care providers to gain deeper insight into the user-friendliness and applicability of the portal. We explicitly included patient who did not use the patient portal as well to understand why the portal was not used and what factors could trigger patients to use the portal.

Additionally, patients received a validated survey. This survey, based on the questionnaire of Bakken et al., 2006, assessed the user-friendliness and satisfaction with the patient portal. The original scales were translated in Dutch using the standard back-translation technique. A fourteen-item scale for user-friendliness was used. We used eight items for the satisfaction scale. The usability of the eight different sections of the system was also asked (see Figure 2). Reponses were provided on a five-point Likert scale, with anchors ranging from 1 (strongly disagree) to 5 (strongly agree), and for usability from 1 (not at all useful) to 5 (very useful). Previous research provides evidence of high reliability and validity evidence regarding perceptions on eHealth (Demiris, Speedie, & Finkelstein, 2000).

Similarly, system-related log data were tracked; namely the number of logins on the system (patient and caregiver), the number of times the various sections were consulted, number of messages sent and number of completed diaries and questionnaires. Demographic, tech savviness, satisfaction and clinical variables were also collected from patients (users and not-users). To compare the baseline need of the patient in information support we calculated the profile of the patient at the start of the study. This data will be used to compare groups with different needs.

Sample

All patients from the selected care pathways willing to participate were included, this results in a convenience sample. As we noticed in the pilot study that only few patients willing to use the patient platform actually used the platform (17%), we opted not to randomize to have sufficient data in this project. Also, we described the reasons why patients did not participated in the study.

Patients with one of the following criteria (1) not having a computer with an internet connection, (2) not having the Belgian identity, (3) not Dutch speaking, (4) having a cognitive and/ or psychological disorder (as assessed by the research team) and (5) unable to read or write (as judged by the research team) were excluded. All involved caregivers were included. The flow of the use of the patient portal can be found in Figure 3.

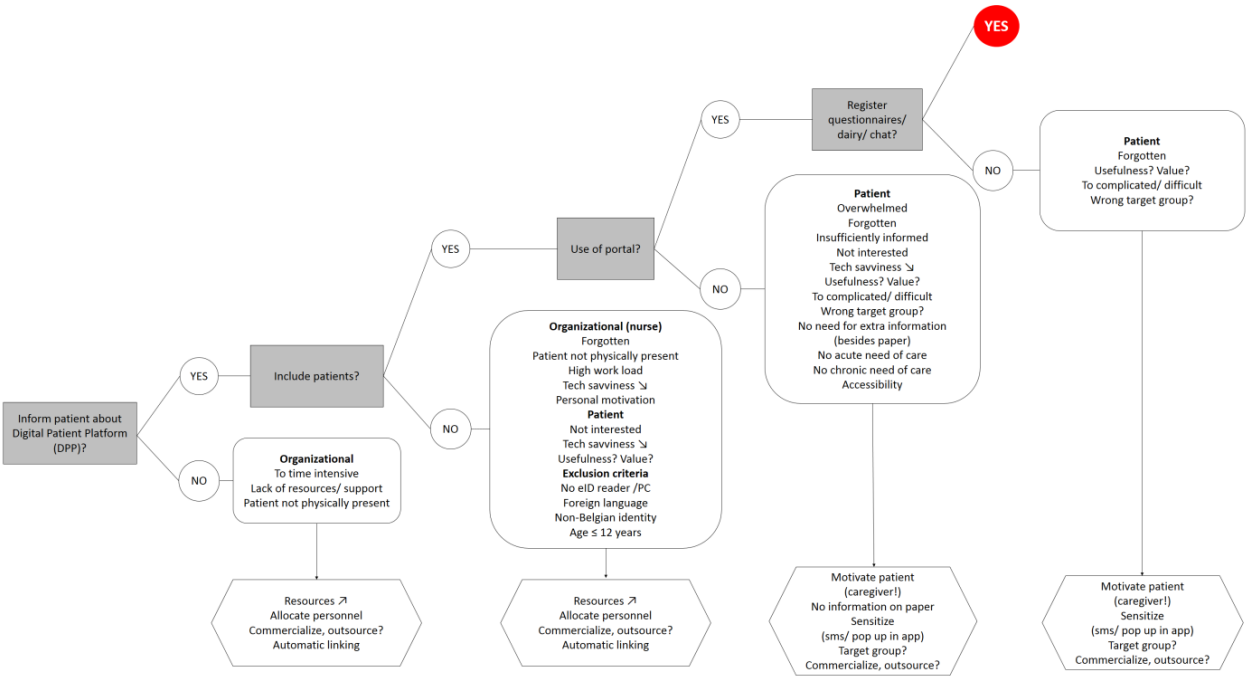

Figure 3 – The flow of use of the Digital Patient Platform

Data analysis

Interviews were conducted both by telephone and face to face with the end users (patients and caregivers) and were recorded on tape. Immediately after the interview, the findings were noted. The interviews were transcribed verbatim. The qualitative data were analyzed through thematic content analysis. The analysis was carried out by two researchers, both experienced in qualitative research.

The sample and study variables of the patients will undergo descriptive statistical analysis. Cronbach alpha reliability scores will be calculated to test the internal consistency of the scales. Variance analysis (Anova) will be used to compare groups.

Ethical considerations

The study protocol was approved by the institutional review board and all participants took part voluntarily. Written informed consent was obtained from all patients.

Phases

Table 1 – Different phases in the innovation project

Phases	Time frame	Main actions	Data collection
Development and implementation of the Digital patient platform (DPP)	2015-2016	See De Regge et al. (2018)	See De Regge et al. (2018)
Pilot study	October 2017- August 2018 Start October 2017 for orthopedics From mid February 2018 for Otorhinolaryngology	o Develop specific care process information for patient platform o Create information folders for caregiver and patient o Education sessions for caregivers o Implementation of mobile app 1.0	o Interviews with caregivers o Meetings o Observations o Log data
Phase 1	September 2018- April 2019	o An automatic email can be coupled to the patient questionnaires reminding patients to fill in these questionnaires o Motivation sessions where organized with care providers who are responsible for presenting the platform during a first consultation o Alternative login for eID reader (Itsme® app) o Platform information was simplified Update mobile app (vs. 2.0) o no longer supply information on paper for specific group	o Interviews with patients (users and non-users) o Observations o Meetings o Questionnaires from patients o Log data
Phase 2	May 2019- currently	o Involve nurses of day surgery center to inform patient with a real life demo of the portal. o Expansion of care pathways in the patient platform.	
Phase 3	To be decided	To be decided	

Results

In phase 0, 252 patients were willing to participate. However, a substantial number of patients were not enrolled (n=51). Main reasons for not enrolling where: not having the Belgian nationality (n=13) or not speaking Dutch (the language used in the portal, n=8); not having an eID reader, PC and/or smartphone (n=24), or patient not feeling digital competent, lack of interest or lack of added value (n=6). The healthcare professionals acknowledged that the technological barrier under the form of the need to use the eID

user (according to the European GDPR guidelines), has a negative influence on the user acceptance.

Some patients were not asked or informed to enroll (exact data incomplete) due to organizational issues (e.g., forgot to ask patient, too busy) indicating a need to automate this process. Within the orthopedic setting this was caused by a turnover in personnel, where at the otorhinolaryngology setting this was rather due to lack of motivation of the nursing staff. In short, in the pilot study we were confronted with a high number of not included patients and low use of the portal by patients who agreed to participate.

Preliminary data of phase 1 (work in progress) included 85 patients (who underwent surgery before April 2018) that enrolled in the study. Fifty one patients did not enroll in the study, this for the same reasons as in phase 0, but notable more number of patients being not interested (n=29). Forty one % of the patients were not asked or not informed. Observations and interviews showed that the nurses allocated to enroll the patients had a major influence on the latter two reasons of non-participating. High work pressure, shortage of staff and lack of interest in the project (from the otorhinolaryngology setting) resulted in low enthusiasm. As such, less effort was made to include patients.

Forty five % (n=38) of the enrolled patients used the patient platform. This suggest that there is interest but patients do not perceive an urge to log in. The majority of the actions taken on the platform where gathering information (n= 1214); while 71% of the patients actively used the platform to register questionnaires or diaries (n= 27). Rarely a conversation with a care provider was started (n=15) and the prompt list was not used. A positive trend of higher use of the patient portal by patients was found in time. This being the results of different measures taken by the innovation team (e.g., prompts to patients by mail, better inform and motivate involved care providers) during the study (see Table 1).

Interviews demonstrated that patients using the portal find the portal a user-friendly tool, mainly for searching new information. Our observations showed that patients who are strongly motivated by the nurse to use the portal (e.g. by explaining the added value of the patient portal) leads to higher use. But we also observed a high lack of involvement of the surgeons who did not inform their patients about the patient portal. Data analysis of the interviews with non-active patients might reveal important insights why they did not use the portal. This will be supplemented with the data from the questionnaires. Also comparisons between the two cases is lacking at this moment in the data analysis.

As previously mentioned, patients have the possibility to use the functionalities of the digital patient platform both on computer and smartphone application. One third (n=13) used the smartphone app.

The profiles of users versus non-users will be compared after analysis of the questionnaires. Next step is to focus on motivating and lowering the threshold by guiding the patient in the first electronic identification in the portal during face-to-face contact preoperatively during preoperative anesthetic consultation (nurse or anesthetist). Additionally, interviews demonstrated that patients do not always see the added value of the portal. Therefore, a patient portal for day surgery involving a more complicated care

process (e.g. in pain experience) will be tested to investigate whether there is a higher perceived usefulness compared to the already included care processes in phase 2.

Discussion

Our study supports Classic Technology Acceptance theories by demonstrating the importance of '*perceived usefulness'* and '*perceived ease of use'* of technology towards the intention to use this technology (i.e., the patient portal). However, we also showed the importance of improving the operational process and applying operational features (such as automatically linking patients to the portal for standardized care processes).

Our findings support the MOA theory. The patient needs the 'ability' to use the patient portal. Patients not equipped with the right (access) resources cannot use the patient portal, substantiated by the high number of patients that not have access to the portal due to technical issues (e.g. no eID, no Belgian identity). Developers should beware of this group that cannot be reached and should not neglect them as they are probably more vulnerable. Another important factor is that the patients must identify the 'opportunity', patients not sensing the usefulness of the portal do not have an urge to use the portal, and thus not find it an opportunity. As such, we must not believe that all care processes are effectual for the use of a patient portal. Patients must see an added value for themselves (intrinsic motivation) when using the patient portal in their care process. Taking into account the opinion of the patients is of major importance in selecting the right care processes. But above all, to achieve patient engagement we highlight how third parties (in this study the physician or nurse who has a direct relation with the patient) are an important asset to extrinsically motivate patients to use the portal. Provider endorsement is one of the most influential factors of impacting patients' adoption (Ross et al., 2016). The theoretical framework will guide us in making the difference in intrinsic and extrinsic motivation of the patient and how these can be empowered resulting in higher use of the portal. Further analysis will provide more insight in why the portal is not used.

Conclusion

The introduction of eHealth has the potential to provide innovative solutions to health problems. However, eHealth technology should be developed so users can't find any reason not to use it. Patients who use the portal are positive and we notice an increase in the use and registration of questionnaires and diaries at the portal. This illustrates that by action research we can implement changes that improve eHealth implementation (i.e. the use of the digital patient portal). However, the development and understanding of the MOA constructs, particularly the important role of intrinsic and extrinsic motivation, might provide the potential to attain a higher use of the portal.

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Process theory applied at a surgery unit

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Abstract

There is a demand from within the professional healthcare organizations that operational and organizational changes must be evidence-based. "Process theory – The principles of operations management" is the closest to evidence-based practice that our research field has come up with to date. The purpose of this article is to operationalize the theory by proposing a design procedure based on it and to test that procedure on the problem of increasing the capacity of a surgery unit at a large hospital. The present state analysis part of the procedure was carried out and has led to new insights for the hospital's management.

Keywords: case study, healthcare, process mapping

Introduction

Hospitals, all around the world, need to increase productivity, in order to meet the increasing demand of an ageing population without increasing the costs. Many hospitals in Sweden have lack of capacity to meet the present demand and there are long queues of patients waiting for access for specialised care (Stiernstedt, 2016).

Sahlgrenska University Hospital is one of the largest hospitals in Sweden and provides emergency and basic care for the inhabitants of the Gothenburg region and highly specialised care for West Sweden and, with about 700.000 and 1,7 million inhabitants respectively (Sahlgrenska University Hospital, 2019). It is also Sweden's centre for certain specialised care, e.g. in paediatrics, and is one of six teaching hospitals with medical education in Sweden. In 2017, the hospital had a turnover of around EUR 1,6 billion and employed almost 17,000 co-workers (Sahlgrenska University Hospital, 2018).

The hospital's top management has initiated an improvement project with the purpose of decreasing the queues to surgical operations by increasing the capacity without increasing the costs. The ambition of the hospital's management is to take a holistic view of the problem and therefore, encompasses several aspects: organization and division of labor, education and staffing, IT and automation, production planning, and work environment and attractiveness as an employer. Further, the improvement project involves managers on all levels from first line managers to the division manager three steps up in the hierarchy. The project started in 2018 and it will finish in 2020. To sum

up, many of the aspects above are related to operations management and thus, there is a need to analyze the problem described above, with long queues and lack of capacity in surgical operations, with an operations management lens.

There are numerous scientific papers about application of operations management principles in healthcare and especially in operating theatres (Guerriero and Guido, 2011). However, as concluded by Holweg et al (2018), there is not a single underlying theory in operations management that can be used to analyse a process, instead there is ambiguity on which theories to use in operations management. Therefore, Holweg et al (2018) proposed the "process theory" and presented the 10 principles of operations management. However, Holweg et al (2018) make a point in the book to not present a comprehensive case or example of application of the complete theory, they refer to empirical evidence of the parts but not of the whole. To make the theory testable and practically applicable on an improvement project, there is a need to re-interpret the process theory to a design model. Therefore, the purpose of this paper is two folded, first to develop a model for re-designing processes based on the principles of operations management presented by Holweg et al (2018) and secondly to increase the understanding on how process design impacts patient queues, capacity utilization and costs in surgical operations.

Process re-design model

The base for the process re-design model are the ten principles of operations management as presented by Holweg et al (2018). The process re-design model is divided into two steps: the first step is to understand the current and the second step is to re-design the process. Further, the re-design part is divided into design, measure, manage and improve (see figure 1) also used by Holweg et al (2018). In the description below, the ten principles are related to the developed mapping rules (MR) and design rules (DR).

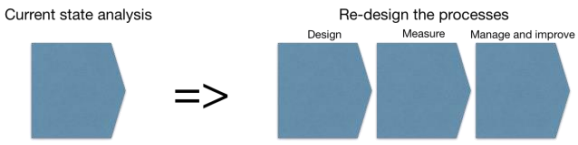

Figure 1 – First current state analysis and second re-design the process

Principles and mapping rules related to current state analysis

In order to improve and re-design a process, it is necessary to have a deep knowledge about current situation. This is done by mapping all processes including the tasks, inputs, outputs, resources and controls. The principles developed by Holweg et al. (2018) related to the developed mapping rules are principle #1, #2, and #3 (see figure 2).

Principle #1 - all operations are composed of processes: In order to improve operations, it is necessary to know the situation and map all processes including the tasks, inputs, outputs, resources and controls. The design mapping rule is:

- *MR1 Map all activities in the processes:* Map all producing, supporting, and overhead processes including tasks, inputs, outputs, resources and controls

Principle #2 - variation is inherent in all process inputs, tasks and outputs: In a process, there will always be variation in quality, quantity and time and these variations can be handled by using extra time, inventory or extra capacity (Holweg et al, 2018). The mapping rules generated from principle #2 are:

- *MR2 Identify customer needs:* Determine the customer needs for quality (minimum level), quantity, and timing for every customer process (averages and variation)

- *MR3 Variation in quality, quantity and time:* Measure averages and variation in quality, quantity and time for every process
- *MR4 Identify buffers (time, inventory, capacity):* Determine what buffering mechanisms that are used for every process

Principle #3 - work in process is determined by throughput-rate and throughput-time: The throughput of the system is controlled by bottlenecks and the throughput-time of a process is stochastic (Holweg et al, 2018). The mapping rule is:

- *MR5 Identify present bottlenecks:* Identify static and dynamic bottlenecks for the present situation

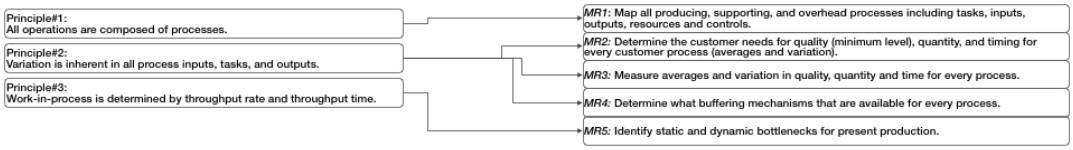

Figure 2 – Relation between principles of operation management and mapping rules

Principles and design rules related to re-designing a process

The principles that can be related to re-designing a process are principles #2 - #10 (see figure 3). Consequently, principle #2 and #3 will be a base for both current state analysis and re-designing the process.

Principle #2 - variation is inherent in all process inputs, tasks and outputs: (description see above). The design rule is:

- *DR7 Dimension buffer sizes (time, inventory, capacity):* Dimension what buffering mechanisms needed to cope with the variation in the processes. Add time, inventory or capacity when demand is high and in critical processes. (also related to principle 3 and 5)

Principle #3 - work in process is determined by throughput-rate and throughput-time (description see above). The design rules are:

- *DR5 Match throughput-times and throughput-rates:* Re-design the processes to get throughput times and work-in-process that matches the needed throughput rates (capacity per time unit) on average over a long period of time (also related to principle 3)
- *DR6 Identify future bottlenecks:* Identify static and dynamic bottlenecks for future production scenarios. If more capacity is needed, run improvement programs that chase the bottlenecks.
- *DR7 Dimensioning the buffer sizes (time, inventory, capacity):* Dimension what buffering mechanisms needed to cope with the variation in the processes. Add time, inventory or capacity when demand is high and in critical processes. (also related to principle 2 and 5)

Principle #4 - complexity in process design amplifies managerial challenges: A simpler solutions will outperform a complicated one and the complexity will be a function of static elements, their heterogeneity and dynamic interactions (Holweg et al, 2018). The design rules related to principle #4 are:

- *DR1 Reduce unnecessary processes:* Reduce complexity by removing unnecessary processes and tasks
- *DR2 Standardize processes and tasks:* Reduce complexity by standardization of processes and tasks
- *DR3 Simplify dynamic interactions:* Reduce complexity by simplifying dynamic interactions

Principle #5 - Process choice requires fit between the task and the external requirements: The possibility to specialized will be depending on the volume and variety of the processes (Holweg et al, 2018). The design rules are:

- *DR4 Specialize when low volume and variety:* If the volume and variety is low, select processes and invest assets that are specialized and dedicated.

- *DR5 Match throughput-times and throughput-rates:* Re-design the processes to get throughput times and work-in-process that matches the needed throughput rates (capacity per time unit) on average over a longer time period. (also related to principle 3)
- *DR7 Dimension buffer sizes (time, inventory, capacity):* Dimension what buffering mechanisms needed to cope with the variation in the processes. Add time, inventory or capacity when demand is high and in critical processes (also related to principle 2 and 3)

Principle #6 - No single measure can capture the performance of a process: It is important to use several performances measures but remember that the metrics are often dependent of each other (Holweg et al, 2018). The design rules are:

- *DR9 Design measures for decisions:* Design measures based on the decision and information need of the organisation
- *DR10 Measure all performance aspects:* Use several measures to capture all aspects of performance
- *DR11 Use absolute measures: Select absolute measures above relative ones*

Principle #7 - Process metrics can drive unintended behaviour: You need to measure in order to manage, but on the same time you will get what you are measure (Holweg et al, 2018). This leads to design rule:

- *DR12 Be aware of dependent metrics and behaviour:* You need to measure, but be aware of the dependences of performance metrics and design metrics to avoid unintended behaviour

Principle #8 - Processes are improved by reductions in throughput time or in un-desired variation: There is a need for ownership of the processes, to work with continuous improvement and root cause analysis (Holweg et al, 2018). The design rules are:

- *DR13 Ownership of all processes:* Make sure that all processes are owned and managed
- *DR14 Continuous improvement resources:* Dedicate resources to work with problem solving and continuous improvement for all process (also related to principle 9)
- *DR15 Reduce throughput-time and undesired variation:* Focus improvement efforts on reduction of throughput-time and undesired variation

Principle #9 - The rate of process improvement is subject to diminishing returns: In high performance processes, there are a trade-off between aspects of process performance, and these cannot be broken (Holweg et al, 2018). The design rules are:

- *DR14 Continuous improvement resources:* Dedicate resources to work with problem solving and continuous improvement for all process (also related to principle 8)
- *DR16 Continuous improvement vs process investment:* Perform continuous improvement until it is economically viable to make process investments
- *DR17 Strategic prioritizing of performance objectives:* In a high-performance production system, a strategic prioritizing between performance objectives need to be made due to trade-offs

Principle #10 - Processes do not operate in isolation: There is always a risk for sub-optimisation in process improvement if you don't take a holistic view (upstream and downstream processes) and focusing too much on one process can drive decisions and behaviours (Holweg et al, 2018). The design rule is:

- *DR 8 Design with a holistic view:* Design with a holistic view of process interactions to avoid sub-optimum solutions

The principles and the design rules have many relations, see figure 3 to get an overview of all these relations.

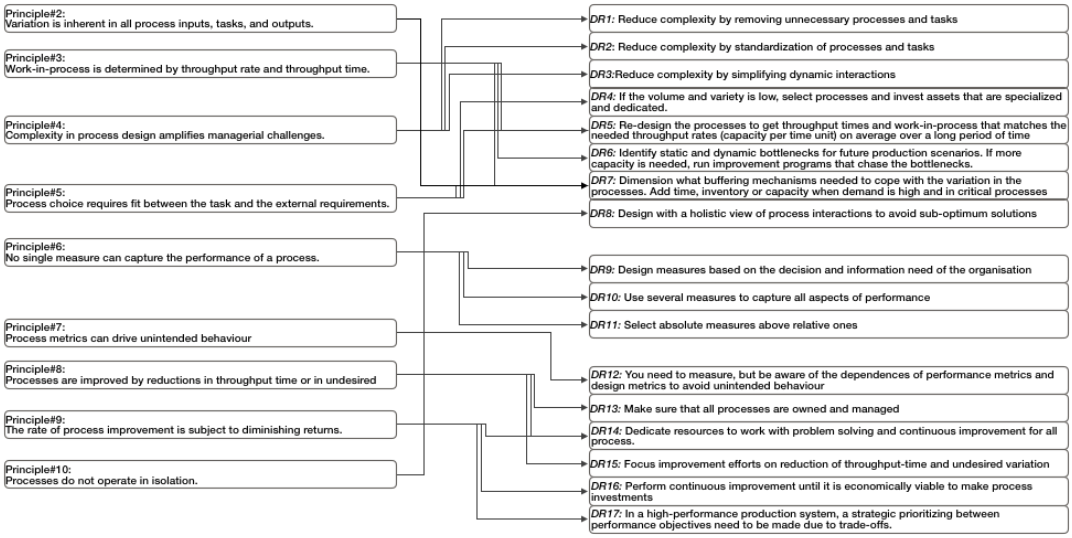

Figure 3 – Principles for operations management relations to the develop design rules

The developed process re-design model

The developed process re-design model (see figure 4) is carried out in two steps: first to understand the current situations, by mapping all activities and their interrelation using the five developed mapping rules and second to re-design the process based on the thirteen design rules. The five mapping rules are group (current state analysis). The thirteen process re-design rules are grouped into design, measure, manage and improve. This is the same used by Holweg et al (2018).

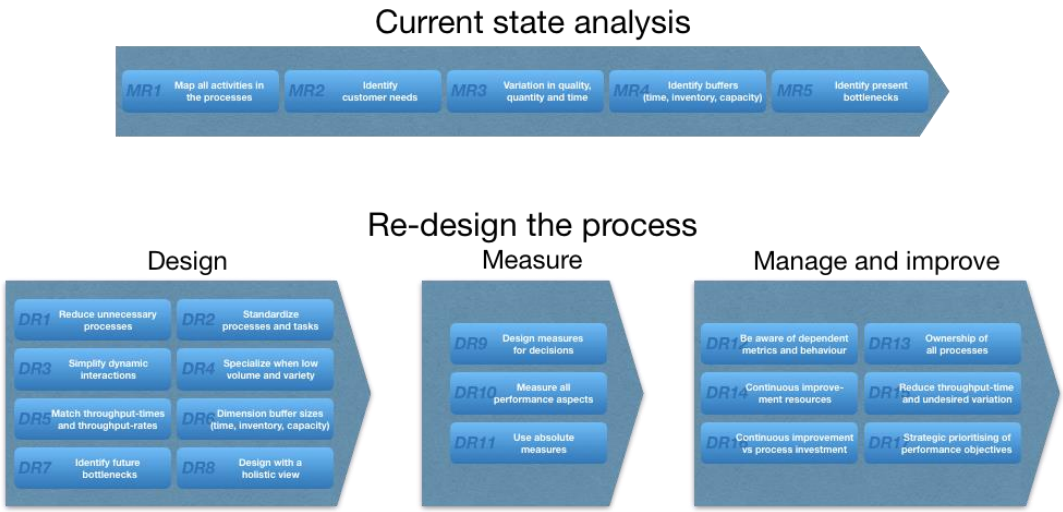

Figure 4 – The developed re-design model, including mapping and design rules

Methodology

The first part of the purpose was to develop a model for re-designing processes based on the principles of operations management presented by Holweg et al (2018). To interpret the principles as design rules, the academic researchers had several meetings and discussions about design methodology based on experiences from application of design methodology in manufacturing settings and in healthcare.

The second part of the purpose is to increase the understanding how process design impacts patient queues, capacity utilization and costs in surgical operations. To answer this, the research team from the university is involved in an operational improvement project, in an action research arrangement, where the researchers are involved in data collection, analysis and in designing improvements. This improvement project following the developed process re-design model.

Activity mapping
The first step of the data collection was two activity mapping workshops where the first line manager together with experienced staff used an activity list developed for ward units and transformed it to a list of some 80 activities valid for the surgery unit. This list was then used as the foundation for both the process mapping and for the work sampling study.

Process mapping
The mapping was led by the research team and was conducted through a series of workshops with personnel responsible for different functions and processes. Between 2 and 6 persons attended each workshop and 8 workshops were conducted, 2 for the main process and 6 for supporting processes. The process maps were analyzed and clarified in a subsequent workshop with hospital staff from the project team and the final version was set after feedback on a meeting with the management. The project team analyzed all identified disturbances and bottlenecks and came up with recommended actions that were summarized in a report.

The process maps were documented using the IDEF0 method (NIST, 1993). It is a standard method that has been extensively used for a wide range of applications. The method has a structured notation with activities in boxes that are connected by inputs, outputs, controls, and resources. An input is something that is transformed by the activity to become the output. The input can be e.g. a sick patient or a dirty instrument that becomes a healed person and a clean instrument respectively. A control determines how and when the activity is carried out. Resources are needed to perform the activities such as people and machines.

Work sampling
The work sampling study (see e.g. Zandin, 2003) was carried out by two master students who were assisted by one assistant nurse that got training in conducting work sampling studies and handle the surf pad with a specific software for the task. A list of 31 activities were selected from the larger activity mapping list. In total were 4055 samples collected in 20 2h sample periods spread over 4 weeks. Only the day shift was measured and only staff belonging to an operations team and employed at the operating unit was included.

Results – current state analysis
A brief case description is followed by the results from the current state analysis which are structured according to the mapping rules (MR 1-5).

The case
The hospital has several surgery units with different specialties. The research case is carried out at a surgery unit specialized in stomach and intestine disorders. Colon cancer is the most common surgical operation at the unit. The unit has around 100 employees, not including the surgeons, and performs around 4000 operations per year. There are 10 operation rooms at the unit, of these are only five available for operations, due to staff shortage. The goal of the operational improvement project is to increase the capacity of

the unit by both open up more rooms and use the rooms for more operations per day, while not increasing the staff. The staff shortage has been worst for surgical specialty nurses, but the bottleneck staff category shifts over time. There are several other bottlenecks as well and the ambition of the project is to keep a systems view and encompass all important bottlenecks.

Each operating room is manned with an operating team consisting of the surgeon, an anesthesiologist, one nurse anesthetist (NA), one surgical nurse (SN) and one assistant nurse (AN). Sometimes, depending on the surgical procedure, one more SN or AN is needed. There are often different types of students present in the operating room, since it is a teaching hospital. The anesthesiologist is usually only present for a short while in the operating room and monitors several patients from another room. The surgeon is not employed at the surgery unit. Therefore, did the work sampling study only include the NAs, the SNs and the ANs in the operating team. There were other persons from the same three worker categories that handled supporting activities, such as production planning and coordination, material and pharmaceutical administration, and sterilization of instruments.

MR1 Map all activities in the processes

The process mapping workshops resulted in process maps documented using IDEF0. In total were 59 pages of IDEF0 process maps produced after some revisions and rationalization, initially there were over 70 pages. The maps include the main inputs to each activity and the output, but they do not in general include resources and controls. The resources are in most cases obvious and the controls were regarded as too time consuming to map in detail at this stage.

The main operating process is divided into:

- Pre-operative support process (activities to prepare for an operation before the patient arrives)
- Pre-operative patient process (activities to prepare the patient)
- Peri-operative process (the actual operation activities)
- Post-operative process (activities after the operation until the patient leaves the unit for post-surgical care)

The mapped supporting processes are the:

- Planning process
- Surgical instrument handling process
- Pharmaceuticals handling process
- Material handling process
- Education process
- Surgical equipment maintenance process

MR2 Identify customer needs

Two stakeholders can be regarded as customers to the operating unit, the patient and the society. The patients are a part of the society, but sometimes there are conflicting goals. The patient want treatment as fast as possible, while the society wants to treat the person with the greatest need first. Since the hospital is tax funded, there is also a focus on utilizing the resources as much as possible, which also can come in to conflict with the individual patient's need. One need that is in common of both stakeholders is to shorten the long waiting lists, which was the background and motivation of the project at the hospital.

MR3 Variation in quality, quantity and time

The operating unit has good records of the quantity and quality the surgical operations performed. The time is planned using "operations cards", which is essentially the process planning where all surgical and anesthesiological activities, and all material and instruments needed, are connected to specific surgical operations. This process planning is used in a production planning software "Orbit". The actual operating time is measured and reported back to Orbit. The variation of operating time for different surgeons is taken into account to some extent in the production planning. Other time categories like preparation times and cleaning times are not measured. There is a planned time in Orbit, but the process mapping revealed that there was no one responsible for updating and maintaining these times. These other times, are sometimes as long as the actual operating time, which means that there is probably a great potential for improvement in the change over time.

The work sampling study was carried out to measure how much work time that was spent on different activities with the purpose of investigating the utilization of different staff categories. In the data collection was 31 activities used, however there were several activities that got none or very few samples. The summary in Table 1 is a reduction of the original list to only 12 activities, where the smallest activities have been joined to form larger activity groups. The activities are further categorized in four categories and ordered by size for each category.

Table 1: Percentage of total work time spent on different activities for Nurse anesthetists (NA), Surgical nurses (SN) and Assistant nurses (AN).

Category	Activity	NA	SN	AN	Total
Direct patient work	Patient activities in the operation room	53,5%	66,1%	55,8%	58,6%
	Talk to and transport patient	8,7%	1,9%	0,4%	3,5%
Indirect patient work	Document and read information about a patient	8,3%	5,3%	7,6%	7,1%
	Prepare operating room	4,7%	6,9%	6,2%	5,9%
	Fetch and leave material, samples and equipment for a specific patient	3,3%	5,1%	6,0%	4,9%
	Communicate about a patient	3,7%	0,7%	1,8%	2,0%
Service work	Handle other information and attend meetings	6,8%	4,4%	3,9%	5,0%
	Cleaning	0,8%	1,6%	5,2%	2,6%
	Other material handling	0,7%	0,7%	5,5%	2,4%
	Tutor students	1,9%	0,1%	0,8%	0,9%
Other	Paid break	5,9%	4,6%	3,8%	4,8%
	Disturbances and waiting	1,6%	2,5%	3,0%	2,4%

The result showed that the staff spend 58,6% of the work time on actual operating activities. This was perceived as a good result, because the management feared that it would be lower. However, there is still potential to increase this time by reducing the time spent on change over activities, documentation and waiting. The paid break time was much lower than we have previously measured on ward units.

MR4 Identify buffers (time, inventory, capacity)

There is obviously a large "inventory" buffer of people waiting for their elective surgical operations. The patients act as buffers on shorter time scale as well. If an operation is cancelled due disturbances, the patient will be put in the buffer again and sent home,

which on a personal level for patient is very inconvenient and prolongs the patient's suffering. From the patient's point-of-view would a capacity buffer been much better.

MR5 Identify present bottlenecks
Bottlenecks were discussed in the process mapping workshops, with focus on disturbances that the staff experienced in the work. These disturbances and their causes were documented on the process map connected to the activities they affected. In total were 36 action points identified that will have impact on the capacity by affecting different bottle-necks.

Results – Process re-design
The process re-design phase has only started up at the time of writing this article. The redesign activities have focused on three areas with potentially large impact on the capacity:

1. The changeover time between surgical operations. A method study of the preparation activities has commenced, a new cart for sorting trash directly in the operating room will be tested and the work of cleaning the operating rooms will be better synchronized to the production schedule.
2. The planning procedures will be revised, and staff schedule data will be used in the planning software, in order to use the optimization functions already available but not used. The changeover times will also be measured and used to update the "operation cards".
3. The most important disturbances will be handled. This includes late changes of the operating schedule due to different reasons. Some reasons are internal but hard to affect (e.g. someone that can't easily be replaced calls in ill the same day), some are internal and easy to affect (e.g. the surgeon hasn't checked all the details of the case in time and decides on late changes). Some causes are internal to the hospital, such as lack of in-patient beds due to staff shortages at care wards, while some causes are external, such as that the patient hasn't followed the instructions and had breakfast when he shouldn't had eaten anything.

The improvement project will continue for another year, and hopefully there will be new culture of continuous improvement focusing on improving capacity by decreasing complexity, shorten lead times and lower variations.

Discussion
When it comes to the improvement actions and re-design of the operations at the unit, there is much to learn from the research literature. For example Meredith et al (2011) have analyzed the changeovers effect on efficiency and Fügener et al (2017) have recognized the importance of single surgeon's behavior on the capacity. As mention in the introduction, is the study of operating units very common in scientific literature. This is probably due to the fact that an operating unit has a very clear production objective with easily measurable inputs and outputs. However, this study has demonstrated the need to go into deeper detail and analyze each activity and all processes to understand the complete problem and the important interactions within the system. There are no single or isolated action that will have any significant impact on the capacity, since there is a multitude of dependencies and interactions.

The methodological approach in this project has been a very traditional work study approach and work studies goes back to the origin of operations management. Even though Holweg et al (2018) don't write about work studies, they point at the need for

detailed information about activities, times and variation. Consequently, in order to achieve a real impact on work places, there is a need to get into the details of the operations and applying the classical work study methods is still a very useful way of doing that.

The developed process re-design model, based on the operations management principles by Holweg et al (2018), has shown its practical use in the improvement project at the hospital. The mapping and design rules helped to structure the improvement project and communicate the need for the different current state analysis steps. So far, we have only begun to follow the re-design phase's 17 rules. The application of those will be the material of forthcoming articles.

Conclusion

There is a demand from within the professional healthcare organizations that operational and organizational changes must be evidence-based. "Process theory – The principles of operations management" is the closest to evidence-based practice that our research field has come up with to date.

This paper contributes to the operations management theory by validating the applicability of the principles of operations management. The process maps and the work sampling result have laid the foundation for the analysis of the problem situation and several improvement areas have been identified. The design model has the potential to be used for all kinds of operational re-design problems in any context.

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The pros and cons of cancer care pathways from the health care professionals' perspective

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Abstract

The purpose of this paper is *to outline pros and cons of cancer care pathway (CCP) components perceived by health care professionals involved in the diagnostic process*. The results are based on a comprehensive national survey. The biggest pros follow from the component of care pathway description, which make cancer diagnostics more process-oriented and standardised and thereby contribute to more timely, safe and patient-centred for the CCP patients. The component of standardised criteria for referral are associated with most cons. The biggest cons are the perceived "crowding out" effects, which imply impaired access and longer waiting times for non-CCP patients.

Keywords: Care pathways, Cancer care, Quality Management in Health Care

Introduction

Improvement of health care structure and management to deliver a high-quality care to acceptable cost is an important priority for health care systems (WHO, 2016). Advances in medicine and technology have helped to make a significant progress in diagnostics and treatment of many diseases, but also contributed to highly fragmented care processes. Due to specialisation, critical tasks in health care delivery are distributed across several care units with its own objectives, responsibilities and capabilities (McDonald et al., 2007, Berwick et al., 2008). Care processes often involve several transitions between primary care and specialist units, and many handoffs between health care professionals. Processes, that if uncoordinated, risks leading to lack of continuity and thereby ineffective and unsafe care with long waiting times (Stiernstedt, 2016, Bodenheimer, 2008).

In order to address these problems, care pathways are increasingly implemented as means to support more organised and efficient care based on evidence (Rotter et al., 2010, Vanhaecht et al., 2009). A care pathway is defined as a care plan that specifies the ideal

sequencing and timing of interventions for patients with a specific clinical condition (Campbell et al., 1998). It guides clinical decisions in the process best suited for managing a particular health problem and increases the certainty of what to do in a given medical situation. Care pathways also help bringing together interdependent health care professional and teams that contribute to a common goal, such as when patients receive care from multiple providers (Singer et al., 2011).

Cancer Care Pathways (CCPs) are implemented in the Swedish health care system since 2015 and are considered crucial for supporting high quality, safe and effective clinical practice (NBHW, 2015). The primary purpose is to shortening the time from cancer suspicion to initiation of first treatment since early diagnosis and treatment are crucial to improve survival chances. In addition to faster diagnostics, CCP also aims to contribute to more equitable cancer care and improved patient satisfaction (Wilkens et al., 2016).

The Swedish health care system is decentralised with 21 independent regions, which implement CCPs for the nationally defined diagnoses. The implementation is based on nationally developed guidelines, but it is the individual region that is responsible for creating an organisation and ensuring resources that enable implementation and sustainable achievement of outcomes. The national follow-up of the implementation efforts show that regions choose different approaches to operationalize the CCPs in their local health care systems (NBHW, 2018). Implementations of care pathways usually include people and principles governing the flow of patients and information and it is supported by a range of measures as standardised communication procedures, clarification of responsibilities, active handovers, decision support tools, clinical information systems, coordinator roles and multidisciplinary work (Vanhaecht et al., 2010, Schrijvers et al., 2012).

The core of the CCP development program in Sweden constitutes on five components. *1) Standardised criteria for referral* describe alarm symptoms for well-founded suspicion of cancer for each cancer diagnosis and constitute the entry key to CCP. *2) Coordinator role* were assigned to ensure continuity in the diagnostic process and avoid unnecessary waiting times. *3) Care pathway description* define the sequence of diagnostic activities and maximum waiting times. *4) Pre-scheduled appointments* block time slots for appointments and investigations to ensure that CCP patients can be diagnosed within time limits. *5) Multidisciplinary conferences (MDC)* should be carried out at end of the diagnostics process to evaluate the patient's status and make a multi-professional decision on treatment. Hence, the purpose of this paper is *to outline pros and cons of CCP components perceived by health care professionals involved in the diagnostic process*.

Frame of references

The concept of care pathways has its roots in Total Quality Management, Critical Path Method, Business Process Redesign and Theory of Constraints (Mould et al., 2010, Schrijvers et al., 2012). Health care has typically a functional organisation requiring the patient to move between care providers with waiting times between visits (Bohmer and Lawrence, 2008). Care pathways imply a process-oriented organisation where the different tasks that need to be carried out by health care professionals are defined, sequenced and standardised for a specific group of patients (Mould et al., 2010). Process standardisation is considered a key for quality improvement as it helps achieving consistency, predictability and control over the material and information flow (Deming, 1994). In health care, it facilitates the movement of the patient and information, reduces

ambiguity, and provides more integrated care among health care providers (Bohmer and Lawrence, 2008).

The advantages of care pathways include shortened lead and waiting times, reduced fragmentation of care, improved efficiency, and increased patient satisfaction (Mould et al., 2010, Schrijvers et al., 2012). In Sweden, the goal of the CCP implementation is to improve the quality of cancer care as defined by the six underlying requirements: patient-centred, safe, effective, efficient, timely, and equitable (NBHW, 2006, Institute of Medicine, 2001). The CCP components, *standardised criteria for referral* and *care pathway description* (defining sequence of diagnostic activities) help to deliver more uniform and predictable diagnostics processes and thereby contribute to more safe, effective, efficient, and equitable care. Guaranteeing *pre-scheduled appointments* and setting maximum waiting times aim to assure more timely care. Finally, implementing *coordinator roles* and *multidisciplinary conferences (MDC)* should, among others, extend the communication with the patient, support patient involvement and thereby increase patient-centeredness (Schmidt et al., 2018, NBHW, 2015).

The disadvantages of care pathways comprise decreased flexibility, reduced job satisfaction due to increased time pressure, decreased autonomy and variation in work, and increased costs to manage and control the process (Schrijvers et al., 2012). Standardisation in health care is often also associated with reduced choice autonomy. Physicians are highly trained individuals who are used to act on their own decisions, and standardisation place limits on their freedom to practice as they prefer and to treat patients based on their professional experiences (Timmermans and Berg, 2003).

CCPs are also implemented in other countries such as Denmark, Norway and the United Kingdom (Håland and Melby, 2016, Jensen, 2015, NICE, 2011). One of key concerns surrounding care pathways there is that they are inflexible and insensitive to individual patient variation and needs. The common criticism is that if health care professionals are required to follow care pathways it might imply that patients' individual needs go unmet or are inappropriately addressed (Håland and Melby, 2016). Further, both Swedish and Danish experiences show that the implementation of CCPs may lead to longer waiting times for other patients, which share the same resources as CCP patients (Smeds and Poksinska, 2018, Jensen, 2015).

Design/methodology/approach

This paper is based on a quantitative online survey. The survey is part of the national evaluation of CCP implementation in Sweden and was conducted in cooperation with the National Board of Health and Welfare. Data were gathered in four regions, which vary in size and geographical location and are characterised by different implementation strategies for CCP. In total, Sweden has 21 regions and the four selected regions represent almost one quarter (~23%) of the total Swedish population. The survey was sent out to 981 professionals and resulted in 359 responses, which makes a response rate of 36%.

The survey was directed to professionals working with diagnosing cancer in pre-selected CCPs. Respondents belong to three health care professionals' groups: *doctors from patient care units* (medical, oncological and surgical) (48%), *nurses for support and coordination* (28%), and *doctors from diagnostic units* (e.g. pathology, radiology and colonists and endoscopists) (18%). There was also the possibility to choose "*other*", which included respondents with mixed background as, for example, doctors in combination with the coordinator, specialist dentists, doctors in palliative medicine and nurses at cytostatic reception (6%). The selected respondents received an email with a

request to fill out the survey by the end of April 2018. After sending two reminders the data collection was closed by the end of August 2018.

In most of the questions the respondents received a predefined set of statements and were asked to indicate the degree of agreement based on a Likert scale with five points from 1 (not at all/not important at all) and 5 (to very high extent/very important). The data were analysed with SPSS Statistics 24. Descriptive statistics as well as ANOVA were used. The free text answers were categorised by themes, which were identified in an iterative process during the analysis. When the categories were set all answers were reviewed and categorised by at least two researchers. Some free text answers were long and could belong to several categories.

Results

The survey provides insights into a number of pros and cons of the five CCP components: *Standardised criteria for referral, Coordinator role, Care pathway descriptions, Pre-scheduled appointments,* and *Multidisciplinary conferences (MDC)*. Respondents were asked to grade the importance of the components for achieving better cancer care processes. The result shows that they are quite equally important, see Table 1. Standardised criteria for referral and multidisciplinary conferences were considered somewhat more important.

Table 1 - The importance of the CCP components

	Not at all important (1)	**(2)**	**(3)**	**(4)**	**Very important (5)**
Standardised criteria for referral	*2%*	*2%*	*6%*	*13%*	*76%*
Coordinator role	*3%*	*5%*	*13%*	*22%*	*58%*
Care pathway description	*3%*	*3%*	*11%*	*24%*	*59%*
Pre-scheduled appointments	*6%*	*4%*	*12%*	*20%*	*59%*
Multidisciplinary conferences (MDC)	*2%*	*3%*	*8%*	*21%*	*67%*

Pros of CCPs

The pros of CCPs were, among others, captured by the evaluation of CCP's improvements as perceived by health care professionals. Respondents were asked to evaluate to what extent they believe that CCPs have contributed to a number of improvements, see Table 2. The respondents found that CCPs make the biggest contribution to a *more efficient diagnostic process* with significant differences between contact nurses being most positive and doctors from care units being least positive. *More satisfied patients* and *shorter waiting times* are equally ranked on the second place followed by *increased collaboration within specialist care* and *more equal cancer care*. CCP´s contribution to *increased collaboration between primary care and specialist care* is judged somewhat lower compared to collaboration within specialist care. Lowest ranked by the professions is the CCP's contribution *to more individualised cancer diagnostics*.

Table 2 - CCP's contribution to improvements

Predefined improvements	***Mean***	***SD***
More efficient diagnostic process	4,1	1,1
More satisfied patients	3,8	1,1
Shorter waiting times	3,8	1,2
Increased collaboration within specialist care	3,7	1,2
More equal cancer care	3,6	1,3
Increased collaboration between primary care and specialist care	3,3	1,3
More individualised cancer diagnostics	3,0	1,3

The table shows the mean value on scale 1-5, where 5 = to a large extent and 1 = not at all

The analysis of the free text answers provides valuable insights into the quantitative evaluation of the CCP's contribution to improvements. Table 3 presents the pros of CCP sorted by the number of free text answers included in the different pros' categories. The mostly commented aspect was *promptitude*, describing the positive effects related to access, waiting times and lead times for CCP patients. Standardised sequence of diagnostic activities and increased coordination are considered to reduce the number of visits and thereby reduce the lead times. CCP patients benefit from prioritisation and pre-scheduled appointments as the waiting times for investigations are shorter and diagnostic process goes faster. Next category, s*table and predictable* processes contribute to more efficient and safer care for CCP patients. The responsibilities become clearer and improved coordination and collaboration, which is believed to reduce the risk of patients falling between the chairs.

The increased *process orientation*, which was implied in the CCP implementation, was recognised as useful to redesign the current working practices and achieve more structured and predictable diagnostic processes. This initiated also process work at various levels of the health care system. Further, the prioritisation of the CCP patients is believed to contribute to more equitable cancer diagnostics. *Equity* does not necessarily mean that all patients have the right to receive care equally quickly. Rather, it means that all patients receive assessments and care of equal quality at the right time based on their needs. Another example provided on improved equitability is that the diagnostic processes became clearer and unified across the regional health care systems. Respondents also commented on the *increased awareness* of different problems as waiting times, shortcomings in routines and bottlenecks in the system. This has led to many discussions and several improvement projects.

Next category of comments describes better conditions for increased *cooperation* around patients, see Table 3. All competencies within different specialties can be involved and can contribute to the investigation through MDC and cross-professional collaboration. The process work contributed to better communication and collaboration between clinics and hospitals, but not between primary care and hospital care. The contact between primary care and hospital care takes primarily place through referrals which were often not sent according to the CCP standard and commented by several as a development area.

The last category includes free answers that describe different aspects contributing to increased *patient satisfaction.* The perception is that the patients appreciate both faster and more coordinated care, which reduces potential anxieties for patients.

Table 3 – The pros of CCPs based free text answers

Categories	Number	Examples of quotes
Promptitude	109	*"Rapid care of the patient" "Good that there are reserved times at the X-ray clinic for CCP. This speeds up the diagnostic time." "Shorter waiting times" "More efficient use of time"*
Stable and predictable	60	*"A faster standard care for the majority of tumour patients" "Clear guidelines, clarity in investigation"*
Process orientation	46	*"Better organisation and flow, we have in a useful way revalued routines" "Increased thinking about flows and why we do what we do - what can be changed"*
Increased awareness	32	*"A thorough review of the diagnostic process that also improved the work with other processes" "That more people in health care are informed about the importance of shortening all lead times"*
Equity	29	*"More uniform treatment" "Clarified differences nationally and locally for the same cancer diagnosis." "Prerequisites for more equal care and reasonable investigation times. Clearer referral pathways."*
Cooperation	15	*"Learned to participate in the whole process and not just one part" "Improved communication between different units and with university hospitals"*
Patient satisfaction	8	*"Standardisation of the care process is an advantage for both employees and patients" "Of course, all patients will be grateful for quick treatment, which they often say."*

Cons of CCPs

There are also several cons identified from the questionnaire, which are presented in Table 4. The *crowding out/impaired access* for both non-CCP cancer patients and other patient groups stands out significantly more than other cons. In questions about disadvantages and associated impacts for other care areas or patient groups, 38 percent of all comments (193 out of 504 part comments) deal with "crowding out" effects. As CCP patients received priority, but share resources with other patient groups, the perception is that non-CCP patients have impaired access and longer waiting times for care. The "crowding out" also emerge because of the *increased number of cancer diagnostics*, which is the second mostly mentioned negative effect. Too broad criteria for referral are considered to contribute to that. The perception is that the number of cancer diagnostics has significantly increased, but not the number of cancer diagnoses. CCP is therefore considered to be resource-intensive in relation to the benefits generated. The criteria for referral form a large funnel that also captures quite healthy patients who don't need cancer diagnostic and are unnecessarily anxious about cancer suspicion.

Excessive administration is the next category of cons associated with the requirement for coding and follow-up of lead times. Changed referral routines are also described as an aspect that contributes to administrative hassle and takes unnecessary time. Several respondents point out that CCP involves extra administration since the IT-systems are not compatible with process-oriented way of working. It all causes stress for the staff and takes time from the patients.

Increased workload is also a recurring theme in the free text answers since the introduction of CCP is considered to increase production levels. Too broad criteria for referral are perceived to increase patient flows and unnecessary tests and examinations.

Even though shorter lead times are mentioned as something positive several also comment that there is far too much focus on shorting lead times. The diagnostics process is shortened, but then patients need to wait longer for treatment. It is also considered that the diagnostic process may go *too quick* so patients have not been able to reflect on the situation and are not always mentally ready for the next step.

The last category is *faulty referrals*. It is mentioned that there are both incorrect and incomplete referrals due to uncertainty in how the criteria should be interpreted and that CCP can be used as a quick path for patients who do not fulfil the criteria.

Table 4 - The cons of CCPs based free text answers

Categories	Number	Examples of quotes
Crowding out / Impaired access	193	*"The "regular" patients must wait for their examination. CCP takes huge place at our unit. It is not fair to other patients. Clearer and better criteria??" "There is so much focus on single diagnoses that what is not cancer becomes unimportant"*
Increased number of diagnostics	60	*"An increased flow of referral to visits. Workload moved from primary care to inpatient care. Primary care does not consider if pat can handle CCP or not" "inflexible system which implies many unnecessary investigations"*
Excessive administration	28	*"The coding system is unnecessary, only for administration without significance for health care." "Double work to code correctly. Does not change patient care for the better. Time and energy is used for coding."*
Increased workload	27	*"Highly increased workload for radiologist / X-ray doctor with demands for quick answers and heavy MDC" "Increased working pressure and constant stress due to shorter response times for more and more patients."*
Too quick	19	*"A lot of concern for the patients. Quick investigation and then longer waiting for treatment" "Not at all correlated with medical prognosis, which makes it difficult to defend the rapid course of events, can actually cause more concern for the patient"*
Faulty referrals	17	*"Incorrect referrals made for CCP " "CCP is not always used in primary care"*

Analysis

By the analysis it has established a connection between the CCP components and the pros and cons presented in the findings. However, the empirical material is so comprehensive that it is out of the scope of this paper to describe all examples brought up by the respondents. Anyhow, the purpose of the analysis is to show in what way the CCP components contribute to the perceived pros and cons. The results are presented in Table 5 and described in the following sections.

Table 5– Pros and cons of CCP components from professionals' perspective

	CCP COMPONENTS				
	Standardised criteria for referral	**Care pathway description**	**Pre-scheduled appointments**	**Coordinator role**	**Multidisciplinary conferences (MDC)**

PROS	**Promptitude**		Maximum waiting times	Prioritisation of CCP patients	Patient contact	
	Stable and predictable		Defined sequence of diagnostic activities		Monitoring patient status	
	Process orientation		Knowledge about care pathways		Coordinating handovers	
	Increased awareness		Understanding problems and bottlenecks		Connecting care units	
	Equity	More objective criteria	Equal across hospitals and regions		Navigating weak patients	
	Cooperation		Integration of diagnostic activities		Coordinating health care professionals	Joint meetings
	Patient satisfaction		Predictability of diagnostic activities	Short waiting times	Personal support	Multidisciplinary assessment
CONS	**Crowding out/ Impaired access**	Prioritisation of CCP patients		Lost appointments		Increased need for MCs
	Increased number of diagnostics	Too broad criteria				
	Excessive admin.		Follow-up waiting times	Non compatible IT-systems		
	Increased workload	More investigations			Monitoring patient status	More MCs
	Too quick		Maximum waiting time	CCP patient prioritised		
	Faulty referrals	Uncertainty at referrals	Misuse of CCPs	Misuse of CCPs		

The most important but also the most questioned component of CCP are *standardised criteria for referral*. Alarm symptoms are defined for each cancer type and constitute a basis for referral. The referral criteria are however criticised for being too inflexible and leading to waste of resources. The criteria for several cancer types are considered too broad, which contributes to increased number of cancer investigations and capacity problems in diagnostic units. This implies an increased workload and stress for health care professionals. An advantage of referral criteria is that they contribute to more equitable care, since vulnerable patient groups have higher chances to be referred and benefit from fast-track diagnostics.

The *care pathway descriptions* contribute to the consistency and predictability of work processes and makes the system less dependent on individuals. The diagnostic process is

perceived as more integrated, coordinated and quicker. The pros are enhanced communication, improved collaboration around the patient and more seamless transitions between care units. The care pathway descriptions contribute also to more equitable cancer diagnostics across hospital and regions. Maximum waiting times included in the care pathway descriptions contributes to the pros of promptitude. However, too much focus in the care pathways descriptions is placed on waiting times, which cause several cons. First, a quicker diagnostic process is also not always better. The strong focus on lead times can make that other patient needs go unmet. Second, resources are wasted on following waiting times. The administrative work is considered cumbersome and taking time from patients. Third, CCPs can be misused to push non-CCP patients through quicker diagnostics.

The *pre-scheduled appointments* prioritize CCP patients and contribute to more timely diagnostics. The drawback is that patients cannot always benefit from getting quicker diagnosis as they may need to wait longer for treatment. Some patients may not be mentally ready to go through diagnostics quickly. The pre-scheduled time slots may also cause that appointments are lost for other patients.

Coordinators are perceived as a valuable resource that contributes to more patient-centred care and supports coordination and administrative work. They are an important means for patient contact so that not only patients' medical needs, but also psychological needs are met. Coordinators have also an important role to support weak patients and navigate them through the diagnostic process. An important work assignment is monitoring patient status, which implies a significant workload as the IT systems are not suited for the process-oriented way of working.

Multidisciplinary conferences create opportunities for different specialists to evaluate individual patient cases and develop a joint recommendation for treatment. MDCs contribute also to an improved cooperation as the involved health care professionals get to know each other and get an increased understanding about the different professional perspectives on cancer care. The cons include increased workload since the preparation for and carrying out MDCs requires extensive resources in terms of time and personnel.

Some pros and cons are difficult to assign to a single component, but they result from CCP implementation as the whole concept. An example is that CCP contributed to better insights into bottlenecks, waiting times and shortcomings in routines and resulted in process improvements at various levels of the system. A perceived negative effect is that the prioritisation of CCP patients and the increased number of diagnostics led to longer waiting times for other patients. This is the most widely discussed negative effect in the survey.

Conclusions

As expresses by one respondent CCPs provide "*more pros than cons but still there is a lot of to improve"*. The biggest pros follow from the description of pathways, which make cancer diagnostics more process-oriented and standardised and thereby contribute to more timely, safe and patient-centred for the CCP patients. The biggest cons are the perceived "crowding out" effects, which imply impaired access and longer waiting times for non-CCP patients. Standardised criteria for referral are associated with most cons, a component that can be a subject for revision and may improve over time.

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Time personalities and the waiting time experience: the case of transportation of hemodialysis patients.

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Abstract

Although a straightforward relationship seems to exist between the 'objective' length of waiting time and the more 'subjective' customer experience it has also been recognized that individuals do have different time perspectives.
In this study we explore the role of time perspectives in order to better understand how hemodialysis patients experience time during a time-laden service, i.c. the process of transportation from home to the hospital and back. In our findings we found a distinction between patients in terms of hurriedness and social orientation while being transported. As such dialysis patients exhibit different timestyles or time personalities.

Keywords: time personalities, waiting time, patient transportation

Introduction

In the field of service operations management, there has been since many years attention for waiting times. A recent article summarizes the strategies to manage queues to reduce the discomfort experienced while waiting: (1) eliminate or reduce the wait through process enhancements, (2) manage expectations through timely and relevant communication with one's customers, and (3) enhance the waiting experience (Weiss and Tucker, 2018). Although these strategies are based on the well-known operations management and psychological approaches for managing waiting times, they do not necessarily take into account the complexity of the time concept. In this study of waiting time in the process of patient transportation, we link the more traditional operations management view on time with the more recent findings on temporal variables in organizational science.

Background

The OM and psychological approaches for managing waiting times are based on the classical distinction between objective and subjective time in the time theory. Objective time or clock time is usually what people answer to a question "what is time?". Shipp and Fried (2014) defined clock time as a view of time that is (a) unidirectional—progressing

from past to present to future, (b) homogeneous—each second is the same as any other second, and (c) absolute—time is the same across all situations and individuals. In contrast to objective time, subjective time (psychological time), is described as "(a) cognitively cyclical—thoughts may move between past, present, and future in any direction; (b) heterogeneous— some moments pass more quickly than others; and (c) interpretive—experiences can only be understood in context" (Shipp and Cole, 2015, p. 239). Subjective time is integral to the experience of being human. It is "merely our word for the movement of events and sensations through us" (Burdick, 2017, p. 369).

Although a straightforward relationship seems to exist between the 'objective' length of waiting time and the more 'subjective' customer experience (Pruyn and Smidts, 1998), it has also been recognized that individuals do have different time perspectives (Shipp et al., 2009), i.e. the overarching view that an individual has towards various aspects of time. These time aspects are defined in terms of different temporal variables such as temporal structure, temporal focus (Shipp et al., 2009), hurriedness (Conte et al., 1998) and others.

In this study we explore the role of time perspectives in order to better understand how hemodialysis patients experience time during a time-laden service, i.c. the process of transportation from home to the hospital and back. One might expect that patients do not want to spend too much time in this supporting process. Nevertheless, how patients do experience this transportation time can be different based on their time perspectives. This study aims to explore what kind of temporal variables can be recognized in this process and how the transportation process can be designed to better fit these personalities.

Methodology

First a literature study on waiting times in healthcare services and time perspectives was conducted. Empirically, we carried out a case study, primarily due to the exploratory nature of the research (Yin, 2014). Multiple sources of data collection have been used such as documentation, archival records, interviews and direct observation. Thanks to these multiple sources, findings and conclusions are likely to be more accurate and in this way the case study will substantially increase in quality (Yin, 2014).

The dialysis center of a general hospital was chosen as case. This center was selected because they were currently investigating how the transportation process of patients could contribute to improvements in the process of hemodialysis treatment. The center was facing an increase in the number of patients having dialysis which can be explained by higher life expectancy and the more successful treatment of cardiovascular morbidity. Most patients have dialysis three times a week. In Flanders, more than half of patients having dialysis in 2013 had an age older than 65 (De Meester, 2013). The main part of the patients comes to the dialysis center with "collective transportation". Both small with less than 5 vehicles and larger taxi firms are involved, offering individual or collective (in group) transportation.

In this research qualitative interviews are held since the focus lays on the interpretation and experience of the respondents. The method used is in accordance with the Consolidated Criteria for Reporting Qualitative Research (COREQ) and will be presented as such (Tong, 2007). Based on a topic list derived from the literature studied, we conducted 75 semi-structured interviews: 50 patients, 11 drivers (from 7 taxi companies), 9 dialysis nurses, 2 assistant head nurses and 2 employees from the hospital's social department. Besides, observations and analyses of documents facilitated a process of triangulation.

The study of contemporary phenomenon in its real-life context obligates several ethical practices such as gaining an informed consent. All respondents were asked to sign an informed consent before the interview to inform them of the nature of the case

study and formally soliciting their willingness to participate in the study. The interaction with human subjects in the study take place through both direct contact (as in interviews) and indirect contact (patient records). For both kinds of data collection permission is obtained by the Ethics Committee of the two hospitals involved in the study.

Results

Results of patients' interviews

At the start of the interviews, patients were asked if they were satisfied or rather unsatisfied with their transport to and from the hospital in general. The opinions were divided equally: 48% of the patients responded to be rather satisfied about their transportation whereas 52% feel unsatisfied. The aim of the remainder of the interview was to clarify this 50/50 relationship and more particularly the role of time.

When asking about the time patients had to wait at home, 33% of the respondents stated that the driver picked them up on time. 45% had to wait in average between 0 and 15 minutes, 18% between 15 and 30 minutes and 2% longer than 30 minutes. Only one patient said that the driver tended to pick her up too early: *"They pick me up too soon at home and too late at the hospital. I'm away from home for 7 hours, that's a long time without having lunch*" (Patient respondent 39). When patients asked the reason of the tardiness they found it difficult to believe the excuses since drivers tended to repeat the same excuses, such as traffic jams or having to drop off another patient first. Several patients mentioned that drivers had already forgotten that they picked them up on an earlier occasion.

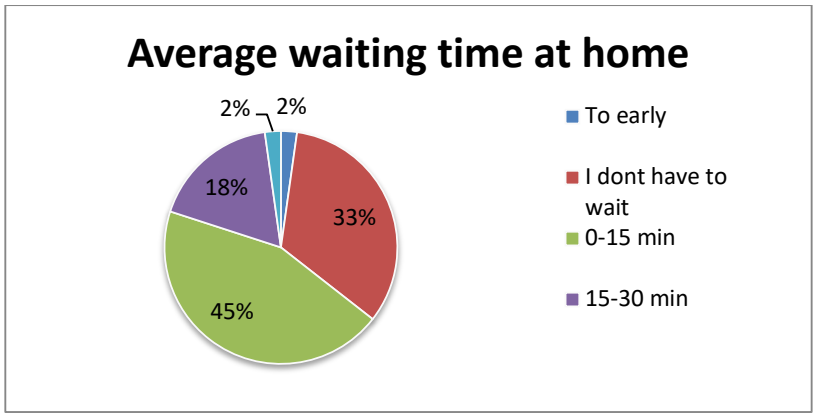

Figure 1: Average waiting time at home

After dialysis, 11% of the patients did not have to wait at all because the driver was already present in the waiting room before they arrived. 34% of the patients had to wait less than 15 minutes, 17% between 15 and 30 minutes, 19% between 30 and 45 minutes, 13% of the patients more than 1 hour. When asking how the respondents experienced this waiting time, 71% responded they found it comfortable: *"We see each other several times a week, it is nice to get to know each other. By spending some time together in the waiting room, we become a kind of family, that's something beautiful*" (Patient respondent 44). After dialysis, 81% found the waiting time normal but only 55% found it acceptable. Many patients had understanding for having to wait for their driver: *"I go home after dialysis, so I do not mind if I have to wait for 15 minutes. I understand that this is different for people who live in a retirement home*" (Patient respondent 48). Patients were sometimes mad on the driver if he was running late, even though this was not always the driver's fault. They never saw the dispatcher (only in case of a small taxi firm with the dispatcher also being the driver), so if they wanted to complain, the driver was the first person to address.

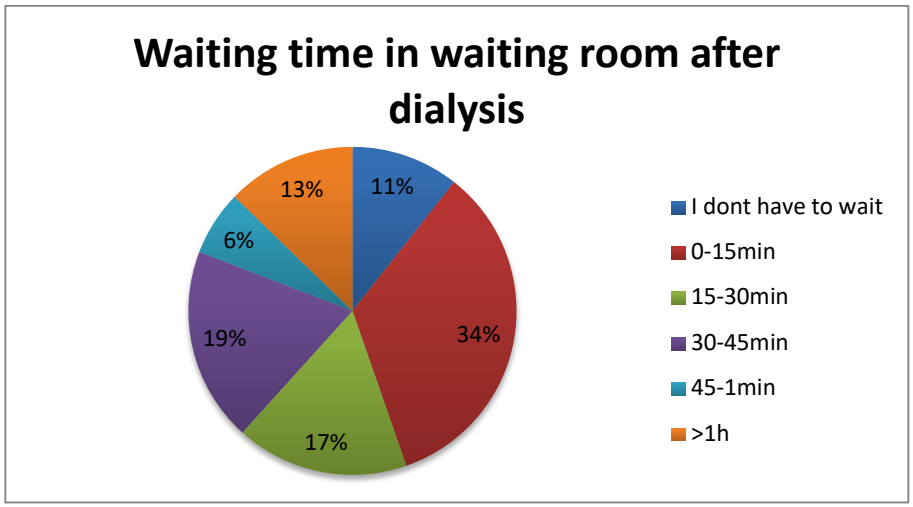

Figure 2: Waiting time in waiting room after dialysis

Furthermore, patients complained about the time they had to spend in the car. Some patients were sharing a taxi with 4 persons so that the time spent in the car (one way) could mount up to 45 minutes: *"They try to put as many patients in one car so it becomes profitable for them, but that is less comfortable for us. They should know their priorities; the patients or the money?"* (Patient respondent 44).

Results of nurses' interviews

Some of the findings of the patients were also confirmed by nurses. Several nurses made the remark that not only time spent in the waiting room but also time spent underway in the car can be very long for a considerable number of patients. *"There are patients who spend more than one hour in the car. Most of the patients are old and are tired after a dialysis treatment. The dialysis days can be very long and exhausting for these patients, and this several times a week. A patient having dialysis can be compared to a person running a half-marathon"* (Nurse respondent 8).

An assistant head nurse remarked that not all patients complained when something went wrong. Several patients just waited patiently while others complained directly: *"Some patients have a strange notion of time; there are patients who are in the waiting room for 5 minutes and start complaining of being there for 30 minutes. Other patients are satisfied about their driver and know him, they don't mind having to wait."*

Results of drivers' interviews

Also drivers recognize the problem of tardiness*: "Sometimes there is a lot of traffic causing delays. The same trajectory I normally do in 15 minutes can take up to 1 hour in that case*" (Driver respondent 7). Multiple drivers also quote that the punctuality of the patients after the treatment depends on the day of the week, on the nurse and on the shift. One driver experienced the biggest tardiness problems when picking up the patients in the morning session. In this respect the drivers of large taxi companies claimed to have an advantage compared to the small firms: "*When a patient isn't ready on time we communicate this to the dispatch. They check with the other drivers who will also drive to the hospital and can pick up that patient later. In this way the patients are moved last minute to another schedule. Also, when we dropped off a patient too late this is communicated. In this way the dispatcher can take into account that this patient will probably finish later as well*" (Driver respondent 4).

Taxi companies could be classified into two main types depending on the number of cars. Small firms tended to have a limited number of dialysis patients. Most of the time, the same driver did the same route with the same patient. Patients that mentioned always having the same driver, all drove with a small company. This type of taxi had several advantageous features, for instance, the fact that driver and patient started to know each other well. This boosted the communication between both parties and created understanding for tardiness. For patients in possession of a phone, the driver had the possibility to contact these patients if he was running late. Several patients and also nurses mentioned that if they knew why the driver is late, they would not worry about whether or not the driver had forgotten about them and this would create an entirely different kind of waiting atmosphere. In this way the communication had an influence on the waiting time experience.

Bigger firms had a large number of dialysis patients and a large number of drivers. As a consequence, patients did not have a fixed driver. 82% of the patients mentioning they had many different drivers, were driven by a large taxi firm. The biggest advantage of these large firms was the opportunity to make last minute changes in the schemes to switch patients from one driver to another. This prevented drivers of having to wait at the hospital. The taxi firms were paid per trip so standing still was a waste of time and money. An unpleasant characteristic of these larger firms was the lack of a relationship between driver and patient. Drivers came to the waiting room of the hospital with only a name of the patients they wanted to pick up, without knowing the conditions or situation of these patients at all. More than half of the patients who had been forgotten to be picked up, were driven by one of the larger companies. Drivers of these larger firms acknowledged his problem and saw last minute changes in schedules as the main cause. If one compares small and large taxi firms on satisfaction, 91% of the patients who were served by a small taxi firm said to be satisfied while this was 64% for larger firms. Furthermore 85% of the patients served by small firms accepted tardiness while this was 77% for the large firms.

Discussion

The interviews show that many patients are rather unsatisfied with the current organisation of the collective transportation to and from the hospital. The main reasons are long waiting times and miscommunication. Patients have complaints primarily about the waiting time after the dialysis. 38% of the patients that use transportation have to wait regularly more than 30 minutes before being picked up by their driver. 13% of the patients even have to wait more than one hour after the dialysis. Regarding communication, the major problem is that the dialysis center and the driver do not communicate enough in case of delays or changes in the schedules.

Our results also show two groups of patients with different characteristics (Table 1). The groups differ in terms of how they look at different aspects of time, more specifically waiting time, time in car or process time and the on-time performance (e.g. tardiness). Durandeau et al. (1999) describe the general attitude towards time as time styles and were one of the first to link the time styles of service customers to their experience of waiting. They conclude (p.183) that “more and more diversity exists in the way people perceive and manage their time, and individual differences in terms of time styles influence a number of time-laden consumer services (such as financial services).”

In this study we find evidence that the transport of patients is also a time-laden service where differences in terms of time styles affect transitional factors when the customer waits for the service. For instance, patients differ in their concern with the passage of time, or are less or more hurried. Hurriedness, as a dimension of timestyles, is the general tempo of an individual’s activities being fast or slow (Shipp et al., 2009). A fit between

the general tempo of an individual and of the group they belong to can create satisfaction (Jansen & Kristof-Brown, 2005).

The studies of Usunier and Valette Florence (2007) and Durrande- Moreau and Usunier (1999) further support the view that people have a general tendency to perceive and use time in a certain way that is characteristic of them. Furthermore, Cotte and Ratneshwar (2001) argued that timestyles are also described by a dimension of social orientation, which indicates the tendencies of preferring to spend time alone or to spend time with others. This social orientation seems to be an important characteristic of dialysis patients. In the present study this social orientation comes down to the distinction between 'talkative' and 'silent' patients. There is some indication that talkative patients who are not in a hurry prefer small taxi companies, allowing them to a create a personal bond with the driver (see table 1)

Table 1: Characteristics of patient groups

Prefer silence		Talkative
Don't care about who drives	↔	Prefer fixed driver
Don't like waiting		Don't mind waiting (= social contact)
No understanding for having to wait		Understanding for having to wait
Don't know the driver	↔	Have personal bond with driver
Like to complain		Optimists
Time in car = short (picked-up last, dropped-off first)	↔	Time in car = long (picked-up first, dropped-off last)
Short time in waiting room		Long time in waiting room

As timestyles seem to be a multi-dimensional construct (Cotte and Ratneshwar 2001, Settle et al. 1978, Usunier and Valette-Florence, 2007), timestyle scales have been developed to capture these multiple dimensions (Usunier and Valette Florence, 2007). In further research these timestyle scales can be adapted and used to better understand the perception of the time dialysis patients spent in a taxi.

Conclusion

In the field of service operations management, there has been attention for waiting times since many years. A recent article summarizes the strategies to manage queues to reduce the discomfort experienced while waiting (Weiss and Tucker, 2018). Although these strategies are being based on the well-known operations management and psychological approaches for managing waiting times, they do not necessarily take into account the complexity of the time concept. Based on a growing body of literature on time personalities and timestyles in organizational science, we can much better understand how patients experience time. These insights can be used to better design services, e.g., patient transportation in line with the needs of the patients.

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Management of complexity in the care system

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Abstract

Managing complexity within care systems is an increasing challenge as levels of comorbidity and frailty grow within the population. This case study research examines, longitudinally, the sources, types and nature of complexity within a care system in the UK. Providing care professionals with a framework on how to categorise and develop approaches to managing complexity within and across professional boundaries.

Keywords: Complexity, Healthcare Management, Care

Introduction

Complexity is a growing area for research in operations, both in terms of its positive contribution as well as dysfunctional attributes. However, it is a poorly investigated area in health and social care. Increasing levels of comorbidities and fragmentation of services are significant sources of complexity faced by healthcare and social service professionals and their ability to deliver quality outputs (Aronsson et al., 2011). The concept of complexity within healthcare was only formally recognized by the U.K. Medical Research Council (MRC) on the production of guidance notes to develop and evaluate complex interventions in 2000. However, this original document, and its subsequent revision in 2008, was criticized for largely avoiding the specific question of what constitutes complexity in healthcare. The lack of clarity on definition has led to complexity being viewed as an abstract concept with limited relevance and fit for what managers need (Cohn et al, 2013). To embrace the opportunity of envisaging complexity at a system level, across multiple interfaces, healthcare and social service professionals have to evolve their comprehension of complexity and its management (Sturmberg et al, 2014).

Recently, manufacturing operations scholars have begun to research a dualistic approach to managing complexity. This envisages complexity in terms of properties, which can be reduced or accomodated to either minimize dysfunctional or embrace strategically important characteristics. A framework for managing this approach has been proposed (Aitken et al, 2016; Turner et al, 2018). Historically, managing complexity in care systems was done through reducing phenomena to constituent variables however, this approach ignores the interactions which are emergent and contingent upon one another as well as those aspects which remain uncertain (Nilsson and Darley,2006).

Differentiating between complexity which has negative or positive consequences, and the approaches to manage these characteristics, is an area that has not been investigated. This paper explores the possibility of this dualistic approach proffering a platform for health and social care professionals to manage an increasing challenging and difficult environment.

Literature

Operations researchers have explored the applicability of manufacturing derived concepts and models in service environments, as an approach to enhance the efficiency and effectiveness of the processes used to deliver customer value. However, within the care sector this approach has proven to be challenging and on occasions unsustainable (Lindsay and Kumar, 2016). The duality of patients being providers of their own inputs into the care system, as well as beneficiaries of its outputs, is viewed as being the most critical and challenging aspect of applying traditional operations management approaches to health care (Sampson, 2000). The patients' dual role limits the care systems ability to build inventory and buffer against variations in arrival demand uncertainty, service process time variability, patients' capability to interact with care being provided as well as capacity constraints (Aitken et al, 2016). Due to budgetary and resource limitations care system capacity, unlike commercial organisations, is not demand-led instead it is "resource-driven" leading to queues and an increased likelihood of service failure (Walley et al, 2013:887). Healthcare organisations attempt to manage non urgent demand on their systems by delaying the arrival of patients through utilising appointments and extending lead-times for scheduled operations and consultant visits.

Against the background of a resource-driven stance the care system is experiencing greater complexity in patient illnesses, treatment processes along with fragmented vertically integration across the organisation (Aronsson et al, 2011; Gehmlich, 2005). Addressing complexity through a reductionist approach has been the historical modus operandi of healthcare practitioners. Segmenting the patients' illnesses into singular components has aligned with a resource-driven perspective which schedules capacity through availability and priorities. Recently, the sector has recognised that patient treatment is more complex than isolating and treating specific components of an illness rather they are "increasingly being forced to evaluate components across a range of different domains – bio-medical, organisational, psychological and social – all at work simultaneously" (Cohn et al, 2013:40). The comorbidity of patients and the need for multi-agent support has increased the complexity faced by care professionals in the delivery of a quality service challenging the resource-driven approach of the sector.

Operations researchers have studied and derived conceptual models to support practitioners in the management of complexity for over twenty years (Wilding, 1998, Bozarth et al, 2009. Turner et al, 2018). The ideas and frameworks which have been developed to categorise and manage complexity, we posit, could provide a basis for addressing the increasing complexity care professionals are experiencing within the confines of a resource-driven environment;

Internal vs external generated complexity: Literature within operations has sought to identify where complexity originates from. Internally complexity can be generated by quality issues, failures to conform to standards, diverse IT systems, poor process controls and organisational structures (Serdarasan, 2012; Manju and Sahin, 2011). Within healthcare these issues are also apparent and challenge care professionals in delivery of a quality service (refs). Externally issues across organisational interfaces such as customer demand variances or unclear specification of requirements (Bozarth et al., 2009). The

duality of a patients' role, in being an input into the system as well as a direct participant in the care process and its performance, has the potential to increase the complexity within and across boundaries.

Detail vs dynamic complexity: Numerousness in a system drives detail complexity. Reflecting the number of customers, suppliers and components that are located within and across interfaces of an organisation (Bozarth et al., 2009). Within a care system this would include patients and their range of illnesses, medical suppliers, multi-care agencies and process interactions. Early research into complexity highlighted uncertainty as a major element of dynamic complexity. The interconnected nature of processes and their wider systems can impact performance at other points in unexpected ways (Bode and Wagner, 2015). For example, the bullwhip effect demonstrates how a small change in demand can be magnified across a system leading to significant changes elsewhere in the system. The concept of detail complexity was recognised in the 2008 MRC guidance that complex patient interventions consisted of several components. However, the guidance failed to identify the interconnectedness of the patient and their treatment to the wider ecosystem and that change in one component can provoke unplanned changes throughout the system (Thompson et al, 2016)

Necessary vs dysfunctional complexity: Recent literature has highlighted the dichotomous nature of complexity as it can be both a positive force for change as well as negative influence on efficiency and effectiveness (Turner et al, 2018; Aitken et al, 2016). For example, within operations management increases in product types or customisation can be of strategic importance when entering new markets yet, can cause inefficiencies within manufacturing as the frequency of changeovers grows. Similar juxtapositions are evident in the care system. Through increases in expertise and knowledge of how to prevent and treat illnesses patients are surviving and living longer. This positive development has led to a greater need for healthcare professionals to consider frailty levels of patients. At the extremes, long term conditions can mask frailty or patients with no precondition are accessed with a minor aliment which result in a rapid decline of health (Turner, 2014). which is challenging the effectiveness and efficiency of the care system

The three themes identified are important to care professionals in the management of their processes and the delivery of a quality service. Comprehending the causes and types of complexity provides a basis for organisations to explore and design their potential responses. Firstly, identifying the source of complexity, internal or external, provides the opportunity for an organisation to determine how to manage the complexity to limit its deleterious impact on care process performance. Secondly, the different types of complexity, dynamic or detail, have differential impacts on operation and performance of processes and require different solutions. Thirdly, recognising whether complexity is dysfunctional and needs to be reduced or necessary, for a patients' health and well-being, can guide care professionals on the appropriate approach to complexity management (Turner et al, 2018).

The operations and healthcare literature are in accord that organisations should focus on reducing complexity to diminish its dysfunctional impacts on processes (Mazzocato et al, 2014; Serdarasan, 2012; Manju and Sahin, 2011; Bozarth et al, 2009). Through a reductionist approach some individual components of a system can be standardised, variability minimised and controls increased (Aitken et al, 2010). However, not all complexity is deemed negative in nature requiring diminution as some aspects may provide differentiation and a competitive advantage in manufacturing (Fisher,1997).

Similarly, the care sector through recognising that patients are part of a wider, interconnected ecosystem are embracing complexity in the management and support of patients. Comprehending that complexity can be important to businesses operation scholars have identified that the creation of slack resources (that can absorb increases in complexity) and investment in information systems or lateral relationships (providing the platform for an organisation to process information more efficiently and effectively) are two options that can be developed (Turner et al, 2018; Aitken et al, 2016; Galbraith 1977). Improving information systems and developing lateral relationships may also provide an opportunity to accommodate complexity across the care system. However, the resource-driven context faced by care professional may restrict the opportunity of developing slack resources.

Understanding the types and nature of complexity that exists within the care system and how it can be addressed and managed by care professionals is the focus of this research. The next section describes the methodology deployed to investigate complexity within a care system in the U.K.

Methodology

This single case study (Jankowicz 2005) employs an exploratory approach, supporting a detailed understanding of areas that are not well documented (Eistenhardt, 1989) and without sufficient theoretical underpinning (Meredith, et al 1989). Understanding context, a strength of the case study methodology, enables a more expansive understanding of operational complexity. . Further, multiple sources of data collection e.g. observation, semi structured interviews, documentation, enable systematic analysis of contemporary activity over time (Yin, 2014; Eistenhardt, 1989) to provide insights which can be evaluated against literature.

The unit of analysis, within this longitudinally case study is the community care system and included participants from GPs (General Practitioners), Acute Hospitals, Community Hospitals, District Nursing and Social Services. The case study provided an opportunity to review the under research domain of community health care systems (Heaney et al, 2006) which is connected to acute hospitals and GP's through the provision of rehabilitation (either in the form of after surgical care or enabling patients to be returned to their normal place of residence). The case study organization treats patients from both urban and rural communities and specifically is in the region where over 65's are the highest in the UK. At the time of the study the health of the population served by the healthcare system is representative of the UK with the exception of weight (marginally higher) and the levels of exercise (marginally lower). Geriatrics average length of stay (LOS) in the acute healthcare setting was the worst in the region (although overall the LOS for all conditions treated in the acute setting was comparable to others in the region). The community care system was therefore selected for a improvement programme seeking to improve the performance (both within the acute hospital by providing earlier rehabilitation and within the case study setting).

The system selection reflects input, process, output proposed as the basis for operational theory development (Boer, et al, 2015). Patients were predominantly referred by either local GP's or were discharged from the acute hospitals. The community hospital, as the system unit of analysis (process) consisted of four ward within a physical hospital boundary. The capacity of the community hospital was used flexibly although the wards were demined as two rehabilitation (28 and 30 beds respectively), one trauma and orthopedic (14 beds) and one stroke (28 beds). A purely clinical flow was rejected (i.e. care pathway) as this would have potentially diluted the observations related to operational complexity. In the system studied,

patients were discharged primarily to their homes, A discharge liaison officer was in post to facilitate this process.
Secondary data collection provided performance date, while semi structure interviews provided multiple actors to express and reflect on perspectives of operational performance versus how it felt to work in the case study environment. Participant observation of improvement workshops provided an opportunity to collect primary data and latterly validate research findings. Triangulation of collected, both qualitative and quantitative, and subsequent verification of derived findings are discussed in the next section.

Case Study
Community care systems typically provide a range of healthcare services where rehabilitation and specialist therapy intervention are most prevenient (Heaney et al 2006). The community care case excludes outpatient activities. The inpatient care provision is predominantly rehabilitation services to return patients to their place of residence and exclude maternity services. As with the acute hospital setting all patients, ideally, have a discharge plan in place at commencement of their episode of care. Discharge plans are designed to understand what treatment/outcomes are anticipated for the patient (internal to the organization) and which activities need to be initiated for the patient outside the organistion (down stream). The internal process flow of patient treatment is a function of different professional interventions and outcome of treatment(s). All patients referred to physiotherapist but not all were referred to occupational therapist. . The medical team assess patients on alternate days.

Findings
GP admissions to the community hospital were predominantly arriving between 12-6, with admissions from acute hospitals arriving from 3-6 in the afternoon. Performance data showed that patients age range in the period studied is 10% are 65 or below, 50% are 81 or below, 80% are 89 or below.

Where patients where admitted with preexisting mental health conditions an additional member of staff was required to support their care. In the period studied 7% of admissions were coded to require this care package and a further 7% with a secondary coding of this nature.

Sixty-nine percent of patients were discharged, 14% were readmitted to an acute hospital, 11% died and the remainder were transferred to other community hospital. Of the total patient group 14% were discharged to nurse led care homes with just over 11% of these patients being determined as delayed transfers of care (DTOC).

Length of stay statistics for the period of study reveal that 7% of patient leave within 5 days, 20% of patient leave within 15 days, 50% of patients within 40 days, 80% of patients within 88 days. Length of stay is not a function of age with DTOC including patients from 50 and upwards

At conclusion of the research 13 patients had been at the community hospital for the year of study. There was variation in length of stay for all the different medical conditions. There was no real pattern in admissions and discharges, although activity dips at weekend.

Medical team ward rounds were alternate days and therefore may not pick up on rehabilitation patients at suitable time (potentially 2 days could be lost) because of the time of admission to the community. Further complexity could be highlighted at the medical team ward round related to co-morbidities, which would mean involvement of other professionals. Once the requirement for an occupational therapist was confirmed the lead time for an assessment was 7-10 days for OT assessment.

Specialist therapy's reported delay in patients getting x-rays (up to 4 days) and computed tomography scan (up to 4 weeks) to aid decision making about treatment and recovery progress.

Internal vs external generated complexity

The case study revealed the level of internal complexity in the community care setting particularly around the discharge process, which rather than being a type of 'standard operating procedure' or checklist for good practice was moderated by the frequency of the medical ward round (equivalent to a set up in manufacturing) where the treatment plan was confirmed.

It was found that patients from the acute setting (upstream) could have provided input into the discharge plan at the community case as part of the hand over documentation for the patient. However professional standards require that an individual is professional liable for patient diagnosis and treatment and thus each professional will individually review the previous assessment.

The frequency of medical ward rounds becomes a feature of internal operational complexity. This complexity is then amplified as a consequence of arrival variation (from the acute setting) and discharge variation (external variation). The community care hospital worked to align capacity and demand to improve the flow and therefore reduce time routine patients needed to stay on the wards.

The finding from the case study was that 14% of patients were discharge back to the acute hospitals. This could be construed as a deviation against the discharge standard upstream. However a patient condition is not homogeneous and the management of technical quality need to be more akin to the repair and overhaul process within industry. The continual assessment of professionals is therefore an important part of quality. The proportion of patients returning to the acute hospitals suggested that there is also process quality issues i.e. what is a discharge standard upstream, where nurses reported 'Inappropriate transfer of patients to free up beds in acute'.

Detail vs dynamic complexity

The different professional groups undertaking tests and investigations, therapies and clinical assessments means there are many differing voices in the assessment and discharge process. These different voices mean that variation is not just across professions but down to the individuals working at a point in time. The compounded with uncertainty regarding timing of discharge from the acute hospitals, the management of ambulance transfers and the readiness for the community hospital

to take patients is a function of uncertainty in operational capacity across the supply chain. and the overlapping of professional and personal standards.

Further complexity is then added if there are social considerations In this case study 14% of the patients were discharged to a care home and sixty nine to their own homes. In the first instance a social services package may either need to be invoked (for patients moving to a care home for the first time) or restored (for patients needing to return to a care home for the same or an increased level of care). In the second instance it may be deemed that, while the patient may return to their own home, they may require enhancements to the property (stair rails, etc) to improve safety.

Coordination across several organizations, involving many professionals and across a number of different medical conditions, was initially not recognized by those involved in the case study. There was no means to resolve conundrums although the different groups coming together did enable a better understanding of each others role. Whil change was adopted in the case study, management of DTOC still provide a level of complexity that is a challenge, because of the extra level of professional involvement with local authorities and different financial constraints and rules for social care.

Necessary vs dysfunctional complexity

While the professional complexity for treatment is deemed as necessary complexity the setting for the delivery of services is not. The ability to rehabilitate some of the patients in their own home (known as reablement) had been recognized by social services. Provision of a service package to avoid admission to the community care system had been made. Therapies been considered a necessary complexity for patient recovery i.e. therapies can only be offered in a community hospital setting. Breaking this view provided the potential for dysfunctional complexity to be removed. However as a consequence of the different groups of professionals housed in different functional entities this enhancement of service had not been well communicated. Since the research period and as a consequence of the improvement programme patients there has been a steep increase of those patients being referred from acute hospitals to the reabilement service. Approximately 20% of patients can be diverted from the community setting to their own homes for rehabilitation.

Through examining the care system, over the period of a year, both reductionist and absorptive approaches were identified. Health and social care professionals migrated from a fragmented approach to supporting patients to develop a structure and processes that provide an integrated service. Recognizing complex and emergent conditions required the capacity and ability of the entire system to absorb unexpected and unplanned patient changes. This led to a focus on demand management, structured communication between different disciplines and shortening discharge times. Overall the length of stay for patients in hospital, requiring in community support after hospital care, reduced from 38 days to an average of 27.5 days

The absorption of increased levels of complexity in care was achieved through the lowering of professional boundaries, sharing risk and improving ownership of patient discharge. By developing standard operating procedures that aligned across the system (process complexity), agreeing discharge protocols (information complexity), reconfiguring wards (range of illness complexity) and removing territorial boundaries (organisational complexity) participants were able to reduce dysfunctional complexity (including the costs of duplication of resources and long discharge times). Through these changes the capacity to absorb increased levels of patient and service provision complexity was found (see figure 1).

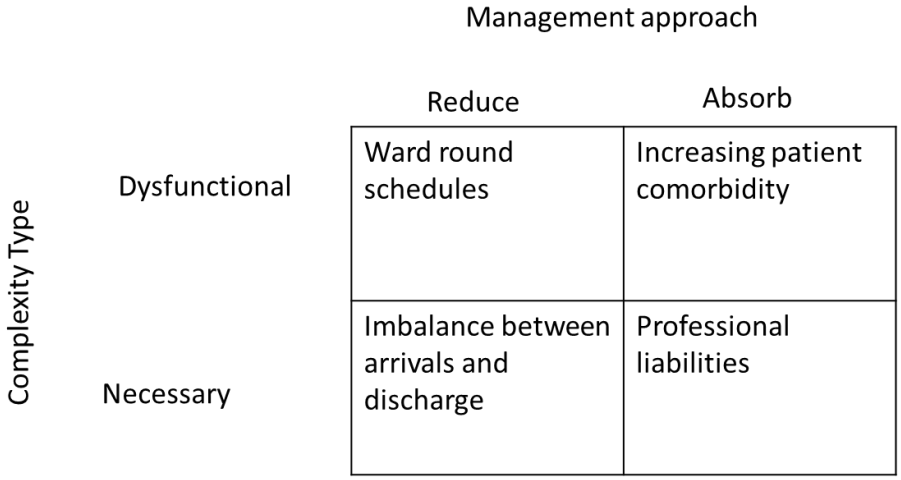

Figure 1: *Complexity types and management approaches*

Conclusion

After a year of changes in the care system, both reductionist and absorbing approaches to managing complexity were found. For routinized processes standard operating procedures, which already existed, were realigned across the system. This helped to minimize complexity arising from the multiple components which, constitute the treatment route for patients. In contrast, for more complex comorbidity illnesses, often associated with an aging population, an array of factors created uncertainty and unknowns requiring capacity to absorb problems as they emerged. Understanding the characteristics of the complexity within the care system as well as, the consequences of its impact on its operation is an important first step for care professionals and managers. Recognizing the type of complexity proffers the opportunity to develop and select an appropriate response to drive down waste whilst, improving service.

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INTERFACES IN COMPLEX MODULAR CARE SETTINGS

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Abstract
The objective of this study was to investigate a complex modular service offering, with a focus on interfaces, from the perspective of the service provider as well as the customer. Case research is conducted in four hospitals, where patients with a complex condition, receive care in a multidisciplinary team. The results show a wide variety of interfaces before, during and after healthcare provision. These interfaces can be categorized based on four purposes: identifying needs & wishes of customers, coordinating services, co-creating services, and increasing transparency of services. We find that interfaces are essential for managing *complexity* and *customization* through modularity.

Keywords: Service modularity, Interfaces, Customer involvement

Introduction

Modularity involves building a complex product or service from smaller subsystems that can be designed independently yet function together as a whole (Baldwin & Clark, 2000). Each of these subsystems must be coordinated to fit the overall goal of the complex service. Coordination of services can be achieved by interfaces, as they take care of the interaction between components, modules and providers (Voss & Hsuan, 2009). In health services, coordination is of utmost importance as these services are typically produced by multiple providers and organizations over a long period of time.

For effective treatment of patients with complex conditions, like Down Syndrome (DS), coordination of professionals and care provision is challenging as this context is characterized by complementary and specialized health services. This type of complex care typically consists of professionals from different disciplines, who often represent different organizations (Meijboom, Schmidt-Bakx & Westert, 2011). Moreover, identification of the customer's needs should be an important part of service provision (Duray et al., 2000). Including the needs and wishes of customers in service provision is necessary to deal with heterogeneous and extensive demands of customers. This indicates that not only professional- and organizational-, but also customer-related challenges complicate the coordination of services in complex care settings. Conceptually, interfaces in service modularity have the potential to alleviate these challenges as they make sure that combined, but independent, modular parts form a functional whole (De Blok et al., 2014; Peters et al., 2018a).

However, the above-mentioned challenges related to interfaces continue to be a rather unexploited perspective (Vähätalo, 2012). Few studies provided evidence on how to manage interfaces, especially the customer ones (Pekkarinen & Ulkuniemi, 2008; De Blok et al., 2014; Peters et al., 2018b). These studies need further elaboration to get a better understanding of interfaces in complex service offerings. We extend the discussion by underlining the role of the customer during modular service provision. The aim of this study is to investigate a complex service offering, with a focus on interfaces, from the perspective of the service provider as well as the customer.

In order to understand interfaces in (healthcare) modularity a literature review was performed. A generic framework was derived from this study in order to describe and analyze complex care provision with specific attention for the dimension of interfaces. Insights from this literature review were used in an exploratory case study on care provision for children with DS. This resulted in a multiple in-depth case study in four hospitals in the Netherlands. The results of this study are discussed and improve our understanding of interfaces in complex modular care provision.

Theoretical background and framework

Modular interfaces have a major role as linkages in the configuration of a complex service offering. They ensure the formation of a functional, coherent whole as they manage the interactions and connections of components when they are combined into the final service offering (Peters et al., 2018a). We use the definition of de Blok et al. (2014) as they developed the most recent and comprehensive healthcare-specific definition of interfaces in service modularity: "*the set of rules and guidelines governing the flexible arrangement, interconnections, and interdependence of service components and service providers*" (p. 186).

Interfaces

Only few interface classifications can be recognized in the service modularity literature (Peters et al., 2018a). First, de Blok et al. (2014) distinguished four different types of

interfaces: closed-customer (C-C), open-customer (O-C), open-information (O-I) and closed-information (C-I) interfaces. Second, Spring and Santos (2014) distinguish two types of interfaces: structural and procedural interfaces. Last, Broekhuis et al. (2017) make a distinction between functional interfaces and organizational interfaces. We (Peters et al. 2018a) recently argued that these conceptualizations can be aligned. The C-C and O-C interfaces, structural interfaces and functional interfaces focus on the outcome dimension of a service offering and refer to the content part of the service offering, i.e. interactions between components or modules. We described them as *customer-flow* interfaces that enable patients to flow smoothly through the system, which is necessary to provide continuity of care. Additionally, C-I and O-I interfaces, procedural interfaces and organisational interfaces focus on the process dimension of the service offering and provide linkages between service providers. They refer to the 'people' part of the service offering, i.e. interactions between service providers. We describe them as *information-flow* interfaces that guide the exchange of information and stimulate information transfer about the (changed) patient situation between the different modules involved in the healthcare provision. The flow of information is achieved through collaboration and coordination of activities between service providers (Soffers et al., 2014). However, in service provision, the customer has a more active role (Duray et al., 2000). In order to ensure their active participation, interfaces between providers and customers are needed. This can enable customer involvement before, during and after the service provision.

Customer involvement

Traditionally, customers have been viewed as having a relatively passive role, essentially as recipients of what an organization does for them (Voss et al., 2008). In service provision such as healthcare, the customer could assume a more critical and active role. This means that customers (patients) could be more actively involved by contributing information and knowledge, as they could have an important role in co-creation of a service. However, the service provider could also effectively involve patients in order to get a better understanding of the customer preferences. This requires more active participation during service provision from both the service provider and the customer. In complex service offerings, this is complicated by the substantial diversity in customers' needs. This is reflected in the various types of providers and organizations involved. Therefore, a better understanding about customer preferences, customer needs, mechanisms of collaboration and coordination, and co-creation is necessary (de Mattos, Fettermann & Cauchick-Miguel, 2019).

The need to better understand the customer perspective in modular services has been pointed out in earlier literature (e.g. Pekkarinen and Ulkuniemi, 2008). However, few studies explicitly focus on modular interfaces, especially interfaces between service provider and customer (Peters et al., 2018a). The way interfaces with customers, i.e. customer need recognition and service co-creation, are handled in a service offering have not received much attention in the previous studies of modularity (Pekkarinen & Ulkuniemi, 2008), despite the attributed importance of customer involvement in modularity (Brax et al., 2017). A few approaches have been identified to discover interfaces with customers (Pekkarinen & Ulkuniemi, 2008; Silander et al., 2017): 1) identification of the customer's needs, 2) management of relationships with customers and 3) co-creation of services. When service providers engage in these approaches, the role of the customer in the whole service provision becomes (more) visible. This helps the customer to take into account what is required from them during service provision (Duray et al., 2000). Also, it assists service providers in identifying customer preferences and customer needs. Thus, customer involvement in modularized services is a relevant

aspect (Pekkarinen and Ulkuniemi, 2008) that should be possible during the service process (Silander et al., 2017). In sum, interfaces are essential for both service providers and customers in managing *complexity* and *customization* through modularity. Therefore, it is essential to truly delve into the customer perspective and form an understanding of the customer's involvement in modular services.

An implicit assumption in this literature is that the modular service architecture of a service offering needs to be completely specified a priori (Baldwin and Clark, 2000) to understand the functioning of interfaces. Only with such a complete representation of the service offering it is possible to identify coordination and/or communication mechanisms between components and/or service providers. Therefore, we build further on our work presented at the 8th international modularity seminar (Peters et al. 2019). In this study, we applied modular decomposition logic to gain a better understanding of the organization of multidisciplinary Down syndrome healthcare provision. In other words, we created a complete representation of a complex service offering.

Methodology

This study aimed to improve the understanding of interfaces by focusing on relationships in the provision of modular care provision for children with DS. A case study research design was chosen since this method is recommended as the most appropriate when, among others, contextual conditions are believed to be highly pertinent to the phenomenon of study (Eisenhardt 1989; Yin, 2003). The case study research was conducted in the field of chronic care provision for children with DS, specifically healthcare provision by multidisciplinary teams in hospitals in the Netherlands. This type of care serves as an example of complex service provision by its wide range of health care professionals/organizations involved and largely heterogeneous patient group. In the Netherlands, pediatric outpatient clinics organize multidisciplinary team appointments for children with DS, including a visit to medical, paramedical, and non-medical specialists, all on the same day (van den Driessen Mareeuw et al., 2017).

Our sample consisted of four multidisciplinary teams (Downteams) from four hospitals in the Netherlands that are geographically dispersed and well-known in the field. To our knowledge, these teams provided a good representation of the overall teams in the Netherlands. By means of purposive sampling we conducted 74 semi-structured interviews with parents of children with DS (N=21), representing the demand-side and members of the multidisciplinary team, representing the supply-side (N=53). Interviews lasted approximately one hour and questions were based on (healthcare) modularity literature. Because the interviewees were not familiar with the vocabulary of modularity, questions were adapted to topics relevant for care provision by Downteams. Moreover, we conducted 12 unstructured observations, 3 at each case, which lasted half a day, during consultations of children with DS. The Ethics Review Board of Tilburg University approved the study. To enable triangulation of information, the data was collected from multiple sources within each hospital: semi-structured interviews, observations and documentation.

The data analysis was conducted during two stages: within-case analysis and cross-case analysis (Barrat, Choi & Li, 2011). A thematic analysis of the content was carried out in each stage, using the three steps methodology developed by Miles and Huberman (1994): 1) data reduction, 2) data display, and 3) drawing and verifying conclusions. By making use of this methodology we provided rigor in our research, as we are open to the data and thorough in our data collection. To evaluate the present study, we used the consolidated COREQ criteria list for qualitative research developed by Tong, Sainsbury & Craig (2007). This list made sure that our research adheres to the standard of good

qualitative research, as we report the important aspects of the research team, study methods, context of the study, findings, analysis and interpretations.

Findings

We present results of the healthcare provision for children with DS by multidisciplinary teams in the Netherlands. We apply modular composition logic and build on previous research in this context (Peters et al., 2018b; Peters et al., 2019).

Within-case analysis

The within-case analysis of interfaces served to identify the interfaces used in each of the separate cases. While describing the interfaces from the four cases, there appeared to be consistency among the cases, so we decided to condense the within-case findings. However, some interfaces were only found in a single case. We found a total of 26 interfaces. We present an illustrative sample of the identified interfaces in Table 1.

Table 1 – Sample of identified interfaces

Interface	Description	Involved parties	Cases
Care coordinator	A person who is in charge of coordinating the care for the patient. He/she is up to date with the current health of the patient.	Specialized nurse	B
Electronic patient file	The electronic file stores all information at one place and makes it possible that almost every specialist can access the information of a patient	All healthcare professionals	All
Information letter	Each patient receives a letter prior to the visit showing what the visit to the Downteam looks like	Patient, secretary, general practitioner	All
Information folder for parents	A folder in which the parents can find an overview of what they can expect during the visit to the Downteam. This helps to ask the right questions at the right specialist	Parent	C
Information folder for patient	A folder in which the patient can find an overview of what he can expect during the visit to the Downteam. This eases the visit	Patient	C
Multidisciplinary team meeting (afterwards)	A multidisciplinary meeting in which the healthcare professionals discuss the individual results of their consultations and together discuss the follow-up program for the patient	Subset of healthcare professionals	All
Multidisciplinary team meeting (in advance)	A multidisciplinary meeting prior to the start of the Downteam in which the involved healthcare professionals discuss the medical history of the patient and any particularities	Subset of healthcare professionals	A
Summary letter from primary care	A summary letter from healthcare professionals in primary care	Primary care, Downteam	All
Patient letter	Each patient receives a patient letter after the visit to the Downteam. This includes a summary of the results of each specialist and the follow-up (if necessary)	Patient	All
Patient portal	Website on which the patient can access his appointments and his personal care dossier	Patient, parent	B,C
Private communication lines	The parents have the private mobile number/e-mail contact of a specialist	Parent, pediatrician	A,C,D
Questionnaire	Each patient receives a questionnaire prior to the visit to the Downteam in which he can indicate what his preferences are	Patient	D
Referral letter	Referral to healthcare specialists that are not part of the Downteam	Pediatrician	All
Small talk	Conversation with patients and parents to learn about the patients' situation	Patient, healthcare professional	All
Telephone contact (Afterwards)	Explaining the results of the visit to the Downteam, the patient letter and whether there are any unanswered questions	Parent, pediatrician	All
Telephone contact (In advance)	Discovering the critical questions of parents before the visit to the Downteam	Parent, secretary	B

Cross-case analysis

From the data presented in the within-case analysis, it appeared that the identified interfaces in each of the cases do not have the same purpose. We therefore re-examined

the data, looking for similar patterns across the cases by analyzing multiple interface types simultaneously. We revealed four different purposes of the previously identified interfaces. See Table 2 for an overview of these interfaces, their purposes and when they are in play for service provision.

Table 2 - Interface purposes

Purpose	Sample of interfaces	Before	During	After
Identification of heterogeneous customer requests	Multidisciplinary meeting (in advance)	☑		
	Care coordinator		☑	
	Information letter	☑		
	Questionnaire	☑		
	Telephone contact (in advance)	☑		
Coordinating services	Multidisciplinary meeting (in advance)	☑		
	Multidisciplinary meeting (afterwards)			☑
	Electronic patient file	☑	☑	
	Care coordinator	☑	☑	
	Summary letter from primary care	☑		
	Referral letter		☑	☑
	Information letter	☑		
	Patient letter			☑
Co-creating services	Questionnaire	☑		
	Patient portal	☑		
	Small talk		☑	
Increasing transparency of services	Information letter	☑		
	Patient letter			☑
	Telephone contact (afterwards)			☑
	Patient portal	☑		☑
	Private communication lines	☑		☑
	Information folder for parents	☑		
	Information folder for patients	☑		

Identification of (heterogeneous) customer requests

Various interfaces (e.g. telephone contact (in advance), information letter) have been identified as interfaces that were aimed at discovering patients' needs and wishes. For example, the phone call is made a few weeks in advance of the visit to the Downteam. The secretary or specialized nurse asks whether the patient has any specific requests or needs for their visit. Those requests can be medical issues, but also organizational issues like a convenient planning scheme of consultations. For example: "*For my last visit to the Downteam, I did not want to visit the ENT-doctor and speech therapist, because I did not need them. The Downteam arranged this and made sure that I had a convenient visit*" [Parent]. The healthcare professionals endorsed this expression: "*If parents inform us in advance about their requests, either medical or non-medical, we can both use this to our advantage*" [Secretary]. By doing this, the Downteams can identify the needs and wishes of their patients and improve their care provision.

Coordinating services

Most interfaces (e.g. multidisciplinary team meeting, referral letter, care coordinator) have been identified as interfaces that enabled coordination and collaboration during care provision. The multidisciplinary team meeting ensures that all professionals come together. In this meeting, all the gathered information of all the professionals involved in one patient is discussed and a follow-up meeting is planned (if necessary). We discovered two separate multidisciplinary meetings with different purposes: the meeting in advance of the patients' visit is used to adjust care provision based on the medical history of the patient and identification of the patient's needs. The meeting after the Downteam took place is used to discuss and combine the outcomes of each professional. This ensures that any follow-up treatments are provided in a coherent way and underlines the multidisciplinary nature of the care provision. Remarkably, the care coordinator is only used in one case, but seems to be very important to parents, mainly for non-medical

related questions: "*The specialized nurse guides us through the maze of our healthcare system. She is pro-active in her way of working and makes sure our problems are being answered before, after or during our visit to the Downteam*" [Parent].

Co-creating services

Only a few interfaces (e.g. patient portal, questionnaire) have been identified as interfaces that were used to co-create services in care provision. The patient portal allows patients to access their personal medical file and makes sure that the patient can pose questions before their visit to the Downteam. To illustrate: "*The patient portal gives me the opportunity to look at the medical history of my child and give input for the next visit. But, I feel we could do way more with this added service*" [Parent]. This provides healthcare professionals with the possibility to make adjustments to their consultation in a way that matches the requests of the patient. Providing information before their visit allows for co-creation of care provision.

Increasing transparency of services

Several interfaces (e.g. information folders, patient letter) have been identified as interfaces that were used to increase transparency of care provision. The information folder makes sure that patients and parents are acknowledgeable about each healthcare professional that is part of the Downteam. It also makes sure that patients feel more at ease in the hospital, since the folder contains a photograph of each healthcare professional, including pictures of the most important care elements of each professional. To clarify: "…*Since we only visit the Downteam once a year, my son has no clue what we will be doing in the hospital. The folder helps us to prepare for the visit, as he sees some pictures of the care elements and a photograph of the doctor. Children with DS are very visual, so this is really of added value*…" [Parent].

Discussion

Building on modular theory on interfaces (Peters et al., 2018a) and customer involvement (Pekkarinen & Ulkuniemi, 2008), we have examined whether and how Downteams share information and interact with customers before, during and after care provision. Our empirics showed a wide variety of interfaces. We found that these interfaces served four different purposes. First, we observed interfaces that focus on the identification of (heterogeneous) customer requests. Their purpose is to identify customer preferences and customer needs in order to adjust the service offering. Second, we identified interfaces that focus on coordinating services. Their purpose is to serve as mechanisms that improve the collaboration and coordination in a service offering. Third, we discovered interfaces that focus on the co-creation of services with the customer. Their purpose is to allow for co-creation in a service offering in order to match the needs and wishes of customers. Last, we identified interfaces that focus on enhancing transparency of services. Their purpose is to manage and reduce the complexity in a service offering by increased transparency of the service offering.

In modular service offerings, the role of the customer becomes more important if certain activities are transferred to the customer, e.g. self-service regarding the information about the offerings. In our case, the patients' understanding of the available treatments and their own medical needs and medical wants becomes essential in care provision. Both literature (Pekkarinen & Ulkuniemi, 2008; Brax et al., 2017; Oertzen et al., 2018) and our empirics show that it is essential to identify and find out the customers' service needs: the ones that are expressed explicitly but also the needs that are still unconscious/unknown ("under the surface". Therefore, supporting customer involvement

in service provision is especially important in the context of healthcare, as the patient is at the center of the core service process regarding treatment, arriving at appointments as scheduled, providing sensitive information about themselves, and following treatment instructions at home. This indicates that the service provider should actively search for those unconscious/unknown customer needs and the patient should actively provide relevant information. Our empirics show that some cases (B, C) are more active in this regard than others (A). The more active cases try to determine customer needs and wants by providing patients and parents with relevant and up-to-date information and knowledge by means of information folders and access to a patient portal. For co-creation to take place, both customer and service provider must be involved, engaged and participating constructively and actively (Oertzen et al., 2018).

Furthermore, we observed a relatively small number of interfaces focusing on the co-creation of service. This could be due to the fact that the complexity of Down syndrome care provision leaves little room for co-creation. Moreover, co-creation of services also depends on the extent to which customers share relevant information and knowledge with their service providers. The active role of customers should not only be reflected during service provision, but they should also, (pro) actively share information between involved service providers. However, there appeared to be a contradiction in our empirics. On the one hand customers were expected to participate in information transfer, while at the same time some of them were criticized of interfering with care provision too much. In this study, the minor role of customer involvement in the co-creation of services may be linked to the steep information asymmetry between healthcare professional and the patient, an essential characteristic of hospital services (Berry & Bendapudi, 2007). Also, in the context of co-creation of services that operate in increasingly networked environments (e.g. construction services, health services), it becomes harder to develop interfaces a-priori due to the involvement of various stakeholders (Alexander, Jaakkola & Hollebeek, 2018; Peters et al., 2018a).

Contribution

We address the call to conduct studies with interfaces as the central unit of analysis, instead of interfaces being just one theme among many (Voss & Hsuan, 2009). In our study, we explore how interfaces manifest themselves in a multi-provider context (Vähätalo, 2012), with special reference to customer involvement. We build on the proposition posed by Peters et al. (2018a) who argue that interfaces in complex modular services improve coordination of decomposed tasks within service provision not only across professional boundaries, but also organisational boundaries (p. 6604). Our cases indicate that modular interfaces help customers to better manage a comprehensive and complex service in its entirety. It is in this sense that interfaces improve coordination of tasks and information across professional boundaries, organisational boundaries.

Furthermore, few studies provided evidence on how to manage interfaces, especially the customer ones (Pekkarinen & Ulkuniemi, 2008; De Blok et al., 2014). These studies need further elaboration to get a better understanding of interfaces in complex service offerings. We build on existing work in this field, but we differ from de Blok et al. (2014) because we underline the role of the customer before, during and after service provision. The interfaces found by de Blok et al. (2014) make sure that the catalogue of a service provider becomes more explicit, i.e. how to connect the available care and service components, whereas our study adds new sections to the catalogue, i.e. what does the customer need and how can we (re)arrange care and service components. It is in this sense that interfaces can provide more added value during service specification (de Blok et al., 2010).

From a managerial perspective, practitioners can find our interface purposes very helpful. These purposes provide a starting point for other healthcare professionals to identify interfaces in their own situation. In this way, interfaces can be made visible, for example in modular service architectures, in the same way modules and components can be visualized. This allows care providers to not only focus on care provision itself, but also make explicit how the various parts of a modular service are connected. It gives insights in the interfaces being used, but also the one not being used. If a care provider observes that there are hardly any interfaces that focus on identifying customer requests or co-creation of services, it might be that his patients are not being heard.

Conclusion

The findings of our multiple in-depth case study increase our knowledge on modular interfaces (with customers) within a service offering in the context of a complex hospital modular care setting. We discovered a wide variety of interfaces and found that these interfaces can be categorized based on four purposes: identifying needs & wishes of customers, coordinating services, co-creating services, and increasing transparency of services. They are essential for both service providers and customers in managing *complexity* and *customization* through modularity. With respect to managing complexity, our study showed that as the tasks and care elements included in, and related to, the service are made more visible, the role of the customer in the whole service process also becomes more visible. This helps the customer to take into account what is required from them during the service, which increases awareness of the complex service offering. With respect to customization, our study showed that identifying customer preferences and customer needs is essential in order to co-create services. This helps the service provider to take into account what is necessary to deliver a customized service offering.

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Visualising complexity: using visual tools to facilitate co-production of complex system design in healthcare settings

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Abstract

This paper reports on an empirical study evaluating the use of visual tools in an NHS Clinical Commissioning Group, City CCG. UK CCGs commission most of the community and hospital health care services, these are wide ranging and include emergency care, community health services, and rehabilitative care. Consequently, the need to communicate and design complex systems with staff and service users is common. This paper specifically focuses on how visual tools impacted on this challenging process - to communicate and co-produce complex operational systems. It finds the approach used widened participation and facilitated depth of conceptualisation of the underlying systems.

Keywords: Visual, healthcare, co-production

Introduction

The use of visual tools is well established in Operations Management (Tezel, Koskela, and Tzortzopoulos, 2016), general management (Meyer, Höllerer, Jancsary and van Leeuwen 2013). strategic decision making (Paroutis, Franco, and Papadopoulos, 2015) and healthcare (IHI 2018). This paper seeks to extend and explore the type of visual tools used in healthcare beyond status boards and dashboards (IHI 2019 and Jeffs, Beswick,, Lo, Lai, Chhun, and Campbell, 2014.), to engage with aspects of co-production of operational designs. This is significant because the multi-stakeholder environment in which most healthcare settings operate are such that they need to engage with clinical staff, managerial staff, social care, patients and their families.

The subject organisation City CCG had been using visual communication to engage staff and service users in the co-production of the services they commission for a number of years, specifically using the tool graphicing. In graphicing, complex messages are streamlined into visual images that perform a similar function to process diagrams such as value stream maps (Rother and Shook 2003) but with a more accessible presentation for healthcare. The general perception across the CCG was that the graphicing method was a useful tool that allowed staff and service users to gain a more informed and holistic understanding of services. This research seeks to explore the extent to which the graphicing approach supports the co-production of operational system designs. In order to provide a robust evidence based on which the CCG could base decisions for the use of the graphicing method, the empirical study set out to evaluate the efficacy of the graphicing method by asking the following research questions:

1. How are the graphicing images produced and used?
2. How are the graphicing images perceived by stakeholders?

Methods

To answer the research questions the project focused on the use of images produced through graphicing in two commissioning areas: the system of care provided for frail older patients and the redesign of patient pathways in the renal, cardiology and respiratory service area (Figure 1 and 2). In both cases the images had been co-produced using a range of engagement activities and were drawn by the Head of Engagement and Communication using tailored software.

A qualitative approach to exploring the use of graphicing in these areas was chosen in order to gain an in-depth understanding of its use. This involved the use of both participant observation and semi-structured interviews.

The researchers attended a range of engagement workshops to observe the co-produced nature of the images and their use in practice, and carried out 26 semi-structured interviews with key stakeholders, including: healthcare professionals such as consultants, nurses, and pharmacists; managerial staff; and admin staff. Some interviews were with individuals and others were in small groups. This was format directed by the way people arrived for the workshops - either as individuals or in groups.

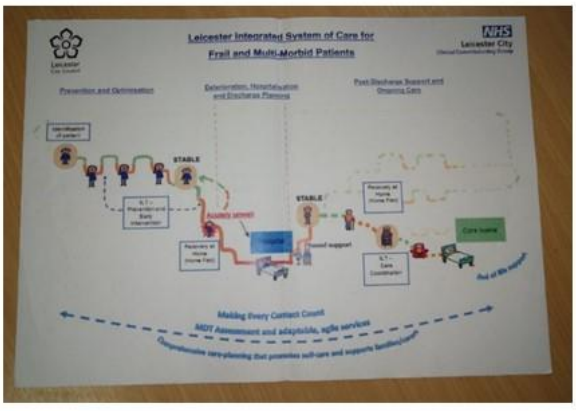

Figure 1: Graphicing images produced by City CCG – Frailty care

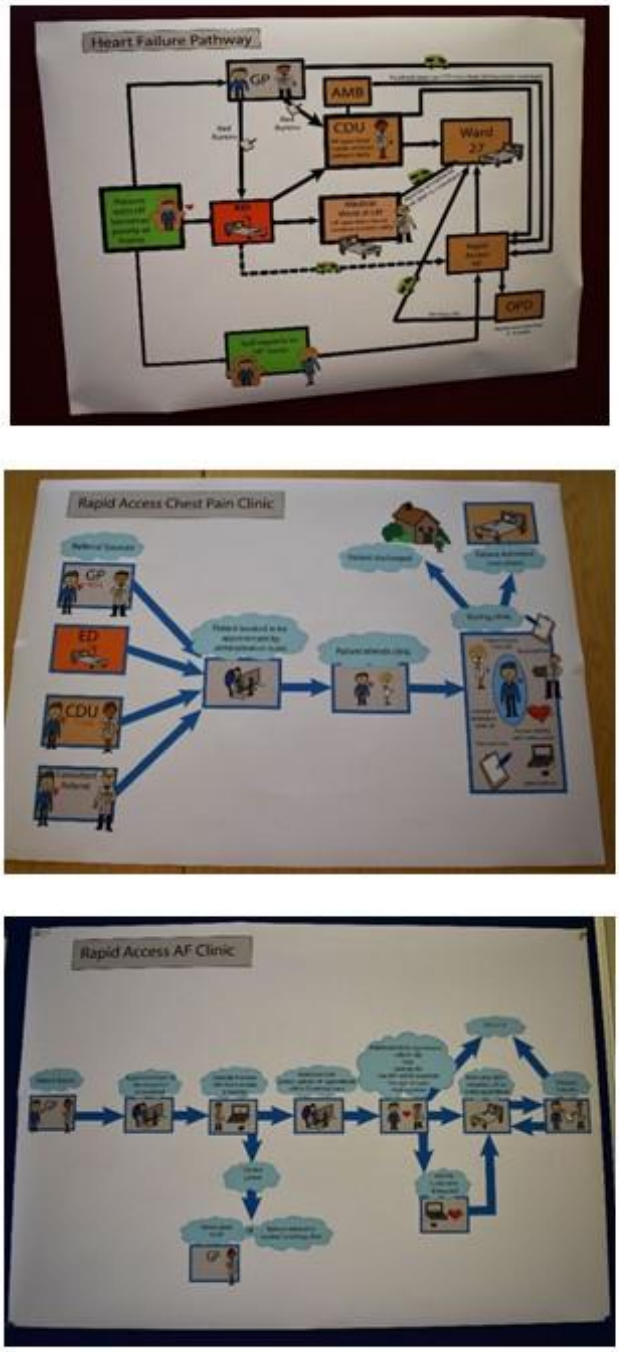

Figure 2: Graphicing images produced by City CCG – care pathways for renal cardiology and respiratory care services

The interview recordings were transcribed and coded using thematic analysis (Braun and Clarke 2006). The question style followed the SHOWeD framework advocated in the photovoice method (Wang 1999). SHOWeD aims to facilitate in depth talk about images and recommends questions such as What do you See here? What is really Happening? How does this relate to Our lives? Why does this problem or strength really exist? What

can we Do about it? While these questions were originally designed for use in participatory action research in order to facilitate bottom up social change, they also worked well in this setting whereby the focus was stakeholder inclusion in pathway redesign. The project was granted ethical approval from the University of Leicester and written consent was obtained from all involved.

The interview transcripts were analysed using thematic analysis; this iterative process that identifies patterns of meaning across the data. The themes that emerge are closely related to the data, allowing an in-depth focus on the data corpus (Guest et al 2012). Braun and Clarke's (2006) adaptable six-step guide was used in order to thematically analyse the interviews. This involved: familiarisation with the data; coding; the identification of themes within, between and across codes; review of the themes; formalisation of the themes; and write up. In accordance with Braun and Clarke (2006) data was initially organised into 29 codes using Nvivo 12 Pro. A preliminary coding framework based on the interview guide was refined iteratively between both researchers. An open approach to coding allowed additional code identification and all revisions to the coding framework were applied to the transcripts that had been previously coded.

Results

From the coding process four themes emerged from the 29 codes, these are: co-creation facilitation; facilitated insight; data density; and design. Each of the themes are illustrated and discussed in the sections that follow, focusing particularly on stakeholder perception. Generally the images were overwhelmingly well received and with participants broadly supportive of their use:

P2: I quite like the simple way that the pathway is shown on there, and it is quite easy to understand. It's not just data so that helps.

P21: Yes, it's basic but straightforward and easy to understand, so you can take it in pretty quickly, so it's quite a good point of view and understand very quickly.

P3: There is nothing more powerful than displaying in a visual format. It seems to flow a lot better for people that aren't clinically minded or have that background, but in layman's terms it's very easy to understand.

Co-creation facilitation: This theme relates to the extent to which graphicing facilitates the range of stake holders in producing the graphing images. This theme has two aspects, capacity for shared understanding and then this enables participation in the adaption of the image. This stage - that of understanding is a logical precursor to participants feeling they can participate in adapting the images. This first stage of understanding is illustrated by:

P20 : So, for me, as much as anything it's really helped me to get to understand the patient journey through all of these specialities….it's helped me personally get a better understanding of all of the pathways.

P6-9: It's self explanatory and I think it would be quite easy for anybody to look at it and understand it at whatever level. … That on a board in a staff room really is a good

way of communicating and sending out a message, and so people can see oh that's going to happen, and that's going to happen.

In terms of participating in the development of the graphicing image and design of the underlying system, participants commented:

P15: What was helpful was that when we discussed it with other people at the LIA event, obviously getting their perceptions in terms of things that needed adding in, because you have one very narrow perspective of a service in terms of a pathway that you directly deal with, but other people have other experiences that need adding in as well.

P20: So this is probably at least the second or third, if not fourth iteration of how they actually started and then we've used them in consultation process, and also in design workshops so these pathways show us what the journey of the patient is now, and we've been able to scribble on them and actually get different key people involved to actually say how we want the pathway to look in the future.

P16: I think it's just been a team effort and getting lots of different people's opinions on how they think things flow through the Department, and the best way of doing that, it has given quite a lot of insight into how different the team work and trying to bring that together.

These quotes demonstrate the iterative (P20) and team based approach (P15 and P16) enabled by graphicing. They highlight the benefits of having several viewpoints (P15) in developing the design of the underlying system. The iterative approach allows nuance to be added to develop both the design and the image that conveys the system design (P16).

Facilitated insight: This theme addresses the potential of the visual image to allow the viewer an additional insight or understanding of the system they are viewing. This was particularly prominent in participants who were involved in the production of the more abstract frailty image (Figure 1):

P22 I think it's useful to have complexity on the page, so people can instantly see that looks a bit ridiculous, what can we do to improve it, but she's taken … it actually this heart failure one and improved this, because the flow is not necessarily right, where these things land on the page, is probably because you can fit them there, but as I say, the referral routes, the GP, the patient at home and this self-report, HF, probably all could happen at the same point, so they're aligned.

P4: And, actually what you find is, your own thinking is enriched and developed by talking that way because you're getting around that 'camp fire' if you like, of a basic image or a metaphor…… it's been really helpful for me to help me conceptualise how we bring about change and the further change within this system in the future... as a commissioner, it helps you to think about the whole board. So chess players talk about seeing the whole board and I think this helps you, from a strategic point of view, to say, "This is a system within a system."

P1: So it helps people to think a bit more creatively about how we can use that resource, rather than saying, "This is health, this is social care." Do you know what I mean? It's almost impossible to completely separate the two and we certainly do debate whether something is health or social care on a daily basis. But actually if we're doing this integration right and we are truly person-centred, some of that is irrelevant.

The respondents here highlight the advantage of having the system shown visually (P4). This allows the viewers to see excessive complexity of the system or to see the 'whole picture'(P22). It also overcomes artificial barriers in the care system created by having separate systems for health and social care (P1).

Data density: This highlights the participants' ongoing negotiation between detail and simplicity. Overall, the participants welcomed the accessibility of the images but often found it challenging to decide what information to include and exclude.

P23: So it's a difficult balance, I think, between overcomplicating the image and putting lots of words on there, because I think then it would lose its impact of the actual image itself.

P24 & 25: Yes, you might be able to come up with something that's a bit more condensed there, you absolutely don't want to make it too complicated.

P21: I think pathways can get a bit over-complicated. So this one is bordering on getting over-complicated and some of them get much more complicated than that, but it is useful for specific conditions.

P4: So you can overcompensate and make it a too cluttered image and at the same time you want to give enough information there that you're not answering 50 questions about why 'x, w and z' isn't in there. So it's a bit of a delicate balance between too cluttered, on one hand, and not enough information on the other.

From these comments the respondents (e.g. P23) are acknowledging the need to balance the complexity of the image – thus reflecting the design of the underlying system - with the need to be comprehensible to the viewer (P4).

Design: The final theme of design is united by participants' comments on specific aspects of the design of graphicing images, for example use of colour or icons. We specifically asked about flow and use of colour but comments on the icons and how they did or did not represent different groups emerged from the data.

P2: I think the way the arrows go from left to right and it's quite simple. I think sometimes when you get something in the middle of a big piece of paper and all the arrows go off, and it just looks like a bit of spaghetti, it's a bit hard to understand sometimes and it takes a lot of energy to try and get your head round it. And instantly I could see the things that I would think, 'Oh! I might want to just tweak that a little bit.'

P3: So I think seeing it with the images and looking at the flow, it makes you question, it makes you stop and it makes you have a look at the individual processes and pathways

and making sure that there is nothing missing. So it does make it a lot easier to see that particular pathway and the processes.

P2 comments that the design of having the flow from left to right helps understanding and thus design "I would instantly see….I might want to just tweak that a little bit". P3 states the flow helps the viewer understand the detailed processes and make sure nothing is missing.

The representation of specific roles by images of people was problematic; respondents reported a tension between who actually filled the roles and how they were represented on the images. As P2 states:

P2: … we've got some female faces, which is good, but it's a little bit stereotypical isn't it?

The use of icons of people, participants commented, made the images more accessible, to 'humanise' the service. Participants said things like:

P3: just putting pictures of people on it just makes it feel a little bit more real, doesn't it?

Interviewer: What aspects of the visuals have people liked?

P19: The use of characters. I think the great thing about it is that it sort of humanises the process in a way.

The use of colour was also commented upon:

P1: Possibly some use of different colours, like the arrows all being the same colour, whether that would break it up a bit. Not so much on the Rapid Access one but on the AF Referrals, there's a lot going on at the end there and it might just make that a bit clearer.

P6-9: The thing that is slightly bothering me is that heart failure is different, it's not done as a flow in blue, it's ….I think I prefer the blue to the black lines though….

P3: Good colour coordination and it displays the message which you are trying to portray really.

The respondents did not have single clear view on how colour should be used - some liked the use of colour P3, but the focus group with respondents P6-9 had some issues with how colour was used.

Discussion

The four themes clearly overlap and each have differing levels of support in the evidence. Co-creation facilitation had the most substantial body of evidence, with the speed and accessibility frequently cited as broadening the number of people who were prepared to engage with the images and also how quickly they were able to assimilate the message. For the images relating to renal cardiology and respiratory care there were several design

iterations and many comments from participants written on the images that were later incorporated. This indicates that the participants felt they were empowered to change the designs – indicating a lower level of perceived finishedness (Bresciani et al. 2008). This ability to sanction viewers to modify the image with their own insights is key part of the co-design part of co-creation

In terms of the next theme, facilitated insight, the first stage of co-creation facilitation - that of quick and easy understanding of the images - also supports facilitated insight. However, facilitated insight goes beyond understanding and allows viewers to gain insight into the underlying system that they might not have been able to obtain via other mediums. Bresciani et al. (2008) outline the related ideas of inference support, discourse management and directed focus and these constructs support this theme of facilitated insight. Inference support and directed focus allow viewers of the images to make connections between data to come to useful conclusions. Discourse management allows groups to have productive discussions, this is particularly useful in group decision making environment. This ability, to provide an in depth overview, is documented by Meyer, et al.(2013 p 493) who state "visual representation can objectify social arrangements and socially constructed realities through the absence of predication, explicit logical conjunction, and grammatical mood, and through its capacity for accurate and detailed depiction."

The data density theme reflects a tension between including detail and simplicity of the message. In the field of graphic design and use of data Tufte (2001) states that "data rich designs give a context and credibility" and extorts to "maximise data density and the size of data matrix within reason". This is balanced by McCandless (2014) who highlights the need for story should be combined, but not overwhelmed, with information, function and visual form. He suggests that these aspects should be carefully combined for a successful visualisation and data without a story is dull; if the visual has no function it is "useless" and deficiency in visual form renders the image lacking structure and harmony.

The design theme pulls together a wide range of comments regarding the design of the images and the underlying system. The results have suggested a number of recommendations for designers of graphicing visuals:

1. The use of icons – develop a neutral set of appealing icons
2. Standardisation – including colour and icons
3. Management of data density to balance detail and accessibility
4. Consideration of flow in terms of both representation and underlying system design.

The development of this approach could support the future facilitation of graphicing images and co-production of images. It could also lay the foundations for its more systemic use in other CCGs.

In terms of the role of these visual tools, they echo the role of value stream mapping (Rother and Shook, 2003) in non-healthcare applications but emphasising the role of human actors in the system design. As such they develop the use of visual tools in healthcare from daily operations management in the form of dashboards to the design of the underlying system of operations also known as the operating model (Bateman 2018).

Conclusions

Consistently the participants liked the images and found them accessible - this enhanced the number of people prepared to engage with them. In addition the findings showed that the use of visual tools greatly increased understanding and accessibility of the two projects observed, both in terms of the number of people who understood the design of the projects and also their depth of understanding. In terms of the two research questions:

1. How are the graphicing images produced and used?
2. How are the graphicing images perceived by stakeholders?

The graphicing images are produced by an iterative process of co-production involving a wide range of stakeholders. The images are positively perceived by the stakeholders both in terms of liking the images, but also valuing their underlying utility in terms of system design.

The co-production of the system design was improved by the wide level of consultation and this was facilitated by the use of visual tools. The graphicing method also aided the reconceptualization of the underlying systems and processes for those people with detailed knowledge of the systems.

This approach represents an extension to the type of visual tools used in healthcare from day to day operations management extensively used in status boards and dashboards to a strategic approach that addresses operations system design. This approach was particularly useful for spanning the artificial boundaries between health and social care. In terms of the type of visual research conducted here it addresses the area of "practice" as defined by Meyer et al. (2013) and has the characteristics typified by the category of research e.g. examining visuals that are socially meaningful and produced by the field actors. With the focus of the research on the use and development of the visual artefacts.

In summary the use of graphicing had a marked positive impact on stakeholder understanding, involvement and engagement and significantly allowed a step change in the ability to design healthcare systems. This reflects the need to develop Operations Management approaches that take greater account of the context (Radnor, Holweg, and Waring .2012) - in this case a more human centred, public service environment.

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Process improvement in healthcare – an interrupted time series analysis

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Abstract
Healthcare organisations continue to invest in process redesign as a way to improve quality using continuous improvement and Lean approaches. An Interrupted Time Series (ITS) evaluated the outcomes of a Rapid Process Improvement Workshop (RPIW) at a National Health Service (NHS) mental health hospital Trust. The ITS analysis was unable to confirm that the RPIW was successful. The limitations of conducting an ITS using routinely collected data needs to be recognised. It is important to appreciate the social and cultural context in which the intervention is embedded to effectively evaluate improvements, which implies the need for a mixed-methods approach.

Keywords: Healthcare, Process Improvement, Rapid Process Improvement Workshops (RPIWs), Evaluation

Introduction
Healthcare systems face many challenges, such as population aging, rising costs (OECD, 2017), inflation, and cost of new technologies (Silander *et al.*, 2017). In response healthcare organisations throughout the world continue to make large investments in process redesign with the goal of treating patients more effectively without incurring additional costs (Berwick *et al.*, 2008). Process redesign aims to reduce variation, delays, errors and eliminate redundant processes (Locock, 2003). Healthcare indicators are often used to assess the operational effectiveness of healthcare systems (OECD, 2017). The use of metrics may help healthcare systems become more efficient and effective whilst improving the quality of care (Boaden *et al.*, 2008).

At the level of the process, however, there is a need to understand the link between process improvement, human resource management and how these impact on outcomes and the quality of patient care offered (Leggat *et al.*, 2015). It is important, therefore, to evaluate process improvements in healthcare. Evaluating the outcomes to see if process improvements are achieved is an important area of research for two reasons. Firstly, it is important to evaluate: i) the intervention process, so that it can be improved; and ii) the change in performance achieved by the intervention, which can be measured using healthcare indicators (metrics). This paper evaluates the use of a Rapid Process

Improvement Workshop (RPIW) applied at a National Health Service (NHS) Hospital Trust in the North East of England UK, which aimed to improve the referral process on a psychosis care pathway.

Literature Review

Continuous improvement and Lean aim to improve the effectiveness and efficiency of healthcare delivery (Brandao de Souza, 2009). Understanding what is meant by 'Lean' can be difficult as the term 'Lean' has been used as a label to describe the majority of process improvements initiatives in healthcare (Matthias and Brown, 2016). The approach adopted is often similar to the Master Class (Pullin, 1998; Bateman and SMMT Industry Forum, 2001) that seeks to provide a structured approach to process improvement. Rapid Improvement Events (RIE) (e.g., Papadopoulos *et al.*, 2011), Rapid Process Improvement Workshops (RPIWs) (Plsek, 2014) and Kaizen Events (Glover *et al.*, 2014) are examples of such structured improvement programmes. These events/workshops have been used in healthcare for achieving process improvement in targeted areas but are not Lean in its truest form. Whilst these criticisms may be acknowledged, RPIWs and RIEs are still a popular method of bringing about process improvement, therefore, understanding if these events 'work' is of interest to both the academic and practitioner communities.

The North East Transformation System (NETS)

In the North East of England, the NHS North East (NHS NE) performs well in terms of meeting governmental targets and achieving performance measures (NHS North East., 2008). The population of the region, however, has poor health possibly resulting from the industrial heritage of the area and other socio-economic factors (NHS North East., 2008). This presents a paradox in terms of a good healthcare system (employing 77,000 staff) but poor health of the population of the region (2.4 million people). Graham (2009) commented that this paradox could result from factors that lie outside of the healthcare system. Marmot *et al's.* (2010) work addressed this by demonstrating that social and economic circumstances, how people choose to live and work impacts upon their health. NHS NE, however, believed the healthcare system could perform much better by adopting a system wide approach to change that focused on quality and safety (Erskine *et al.*, 2009). Up until that point, the implementation of quality improvement methods in the NHS NE had involved relatively small-scale interventions confined to particular hospital departments and support services (Fillingham, 2007).

The North East Transformation System (NETS) was launched in 2007 and was a unique experiment in the adoption of transformational change in a complex system, namely the NHS in North East England (NHS North East., 2008). NHS North East received support from the Virginia Mason Medical Center in Seattle, which developed the Virginia Mason Production System (https://www.virginiamason.org/VMPS). This was derived from the Toyota Production System (TPS). The NETS comprised an ambitious regional vision 'to put the patient at the heart of everything we do', a 'compact' (a psychological contract between staff and the organisation which specified mutual expectations) and the 'method' (the VMPS) which adopted Rapid Process Improvement Workshops (RPIWs) (Erskine *et al.*, 2009).

Rapid Process Improvement Workshops (RPIWs)

A Rapid Process Improvement Workshop (RPIW) could be described using Locock's (2003) terminology of healthcare "redesign". Locock (2003) described redesign as looking at the best process from the bottom up as a complete redesign to achieve quick

and efficient care; the removal of all delays and additional steps; and identifying and eradicating where errors can occur. Rapid Process Improvement Workshops (RPIWs) adopted Lean problem solving tools, value stream mapping, 5S, visual control; Kanban; streamlining flow; and standard operations (Bohmer and Ferlins, 2006). The team members involved in a 5-day RPIW are set out below in Table 1.

Table 1- The roles and responsibilities that make up an RPIW

Role	Responsibility
Sponsor	Responsible for setting the direction, scope, goals and targets.
Process Owner	Approved project goals and targets, negotiated scope and boundaries, identified a local process expert to assist with data collection, communicates to employees and is responsible for planning follow-up actions.
Workshop Leader	Negotiates the direction and scope with the Sponsor and Process Owner, got approval for goals and targets, developed value stream maps, led the workshop, and scheduled reviews 30, 60, and 90 days after the RPIW with the Sponsor and Process Owner.
Team Leader	Responsible for planning, logistics and documentation, the collection and analysis of data, leading the team and acting as a facilitator.
Sub-Team Leader	Assists the Team Leader.
Participants	Team members representing a range of stakeholders and disciplines.
Advisory Group	Arranges appropriate resources for the Team Leader to conduct the workshop.

Each RPIW had a mid-week and final report-out where all RPIW team members jointly presented progress and the outcome of the intervention. These were based upon a framework that included: an overview – team members, current situation, process flow, TAKT time (Miltenburg, 2001), targets and boundaries; an analysis of standard work; a progress report that measured prior performance and targets (for space, inventory, staff walking distance, parts travel distance, lead-time, quality, productivity, 5S and set-up reduction). The report-outs included a value stream map, TAKT time calculations and work flow diagrams that showed the status before and after the intervention as well as through 30, 60 and 90 day follow-ups (which formed part of the RPIW process).

Evaluating Process Improvement Events

Chavez *et al.* (2013) argued that the Lean literature is biased in terms of the effectiveness of Lean that is reported, as well as the improvement in measured metrics that are an outcome of the intervention. Dickson *et al.* (2009, p. 508) elaborated that there is a reporting bias because organisations that fail to meet their objectives, or do not achieve the intended outcomes, are unlikely to report the interventions or the reasons for failure. Young and McClean (2009, p. 384) commented that the evidence whether "*Lean can systematically and dramatically improve a sector as significant as healthcare is still a matter of belief, rather than proof*". Leggat *et al.* (2015, p. 161) conducted a systematic review and commented "*while the academic literature contains a large and growing number of papers that suggest positive outcomes of process redesign in hospitals, reviews of the impact of process redesign are largely inconclusive with unsatisfactory methodologies limiting conclusions*".

This study attempts to address these concerns by adopting an Interrupted Time Series (ITS) analysis. An ITS could be described as quasi-experimental in design, and can provide greater internal validity in terms of the hierarchy of evidence (Hansen, 2014). The ITS was used to evaluate the outcomes of a Rapid Process Improvement Workshop as a method to improve the quality of care on a psychosis care pathway. This study seeks to address if RPIWs can be an effective way to enact process improvement and increase quality of care of patients?

Methodology

A National Health Service (NHS) mental health Trust psychosis pathway was the unit of analysis that comprised three sequential processes: referral, assessment and discharge. This paper focuses on the referral process of the pathway specifically. The RPIW was conducted at three intervention sites. The training was conducted off-site at a training centre and was attended by 43 individuals from the three sites including Trust employees, carers and family members and supported by the Certified Workshop Leaders and the Trusts Kaizen Promotion Office (KPO). The RPIW was set up to address a range of problems identified on the psychosis pathway including:

- No standard approach to developing a care plan;
- No standard approach to involving other disciplines;
- No standard assessment pathway and lack of clarity when assessment stops and treatment starts;
- No standard information sent to service users/carers;
- Time taken to input patient treatment assessment data on the information system was variable.

The aims and targets set out by the sponsor on day 1 of the RPIW were:

- To effect a complete redesign of the patient pathway;
- To address patient needs and the needs of carers;
- To demonstrate quality of service and value for money;
- To reduce waiting times for the ‘customers’ (patients, carers, GPs, family members);
- To increase face-to-face contact time by 50%.

A primary objective of the RPIW was to increase the proportion of the referrals assessed on the same day and to reduce the time taken from referral-to-assessment for those not assessed on the same day. By referring and starting a patient’s treatment quicker, it was believed would increase the quality of care offered. The hypotheses, used to measure the RPIW, therefore, can be stated as:

- The number of patients assessed on the day-of-referral would increase;

- The time from referral-to-assessment would decrease.

Data Collection and analysis

Data were extracted from the Trust’s electronic patient record system covering a two and a half year period that included one-year pre-RPIW and 18 months post RPIW. The design included three intervention sites (localities within the Trust) with five control localities. A multiple Interrupted Time Series (ITS) analysis was used to analyse the

data as multiple observations were available pre- and post-intervention. A random effects logistic regression model was adopted because the dependent variable (the number of patients assessed on the day-of-referral) is a Boolean variable (i.e., has one of two values only). The random effects negative binomial regression model was appropriate given the count nature of the variable time from referral-to-assessment (Winkelmann, 1995). In both cases, the clustering was on the site.

Results

The descriptive statistics associated with the intervention, controls and frequency of patients treated are set out in Table 2 below.

Table 2- Intervention and Control Sites

Site Number	Frequency	Percent	Intervention/Control
1	166	8.5	Intervention
2	199	10.2	Control
3	307	15.8	Control
4	213	10.9	Control
5	341	17.5	Control
6	217	11.1	Intervention
7	214	11	Control
8	292	15	Intervention
Total	**1949**	**100**	

The time from referral received to first allocation was highly skewed with a mean 4.1 days and the standard deviation was 10.3 days as demonstrated in Figure 1.

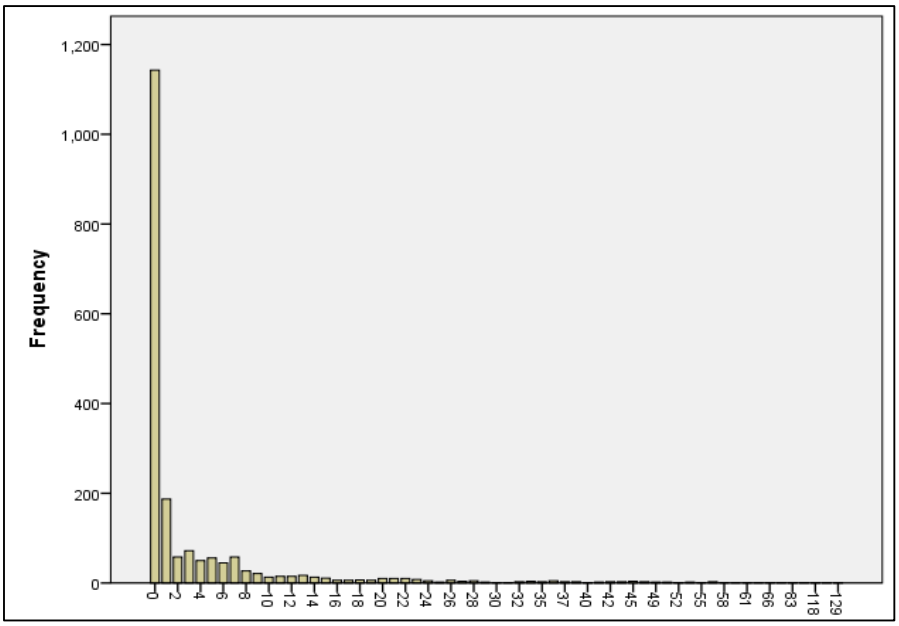

Figure 1- Time in days to first allocation from receipt of referral

For most patients, 59% (95% CI: 56%, 61%), the date of first allocation was the same as the date that the referral was received. Initial exploration suggested that the most appropriate way to model the data was to fit a zero inflated negative binomial regression model. Using this procedure the likelihood of being allocated on the date that the

referral is received and the length of time spent waiting for other patients (that is those for whom the date of allocation was not the same as the date of referral) are modelled simultaneously. Summary data corresponding to these variables are plotted by calendar month in Figures 2 and 3.

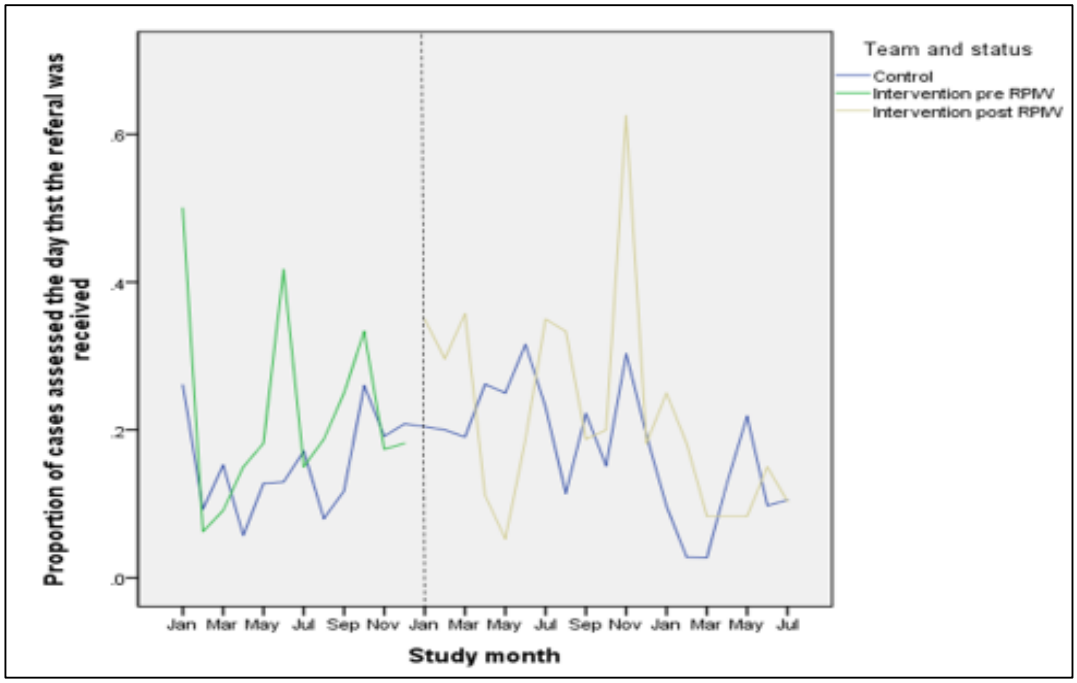

Figure 2 – Proportion of patients allocated on the day that the referral was received

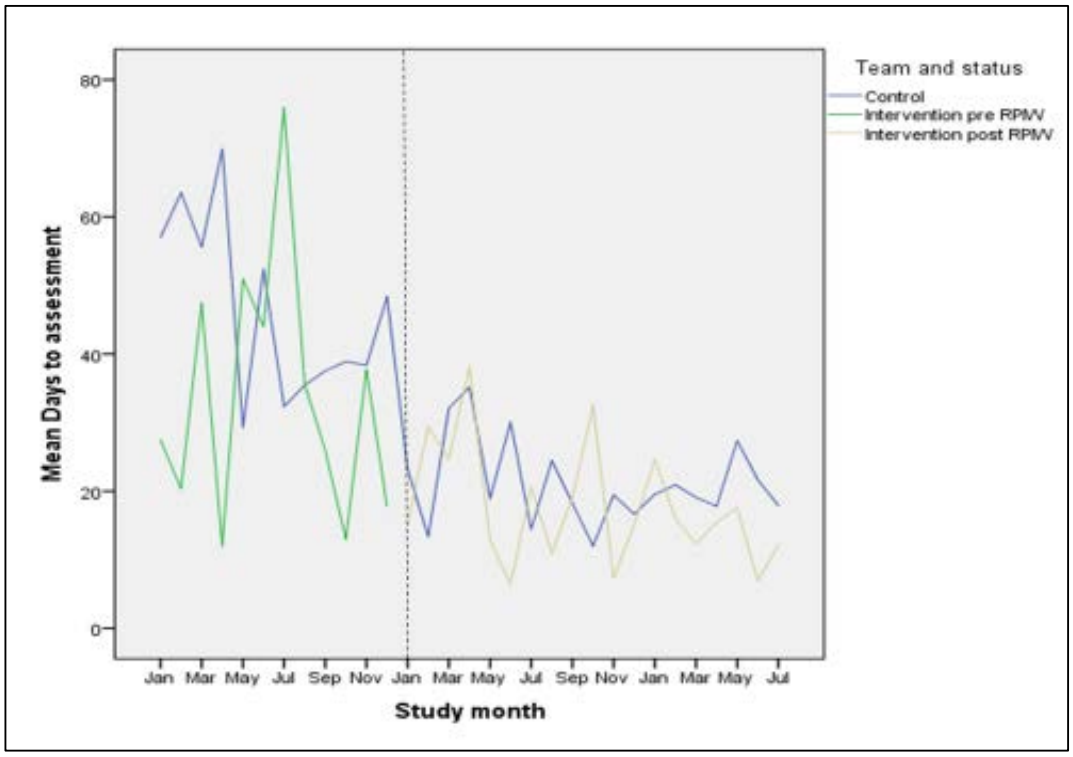

Figure 3 – Mean time to allocation for those patients who did not receive an allocation on the day that the referral was received

Any effect of the RPIW would appear to be in hypothesised direction. There appears to be a higher proportion of patients allocated the day that the referral was received in intervention sites following the RPIW and the mean time to allocation for the remaining patients appears to be lower than in control sites following the intervention. The hypothesis that the number of patients assessed on the day-of-referral would increase due to the RPIW intervention was not supported. The time from referral-to-assessment was reduced at both the intervention and control sites.

The hypothesis that the time from referral-to-assessment would reduce due to the intervention was also not supported. Time to allocation fell more in control sites but this can primarily be attributed to the fact that time to allocation has already fallen considerably in intervention sites six months prior to the intervention. There was much less room for improvement in intervention sites which may explain the modest reduction in time to allocation observed in those sites. It is very difficult to explain the very large reduction observed in control sites.

Discussion

A rigorous multiple interrupted design has been used to evaluate process improvement in healthcare. The ITS analysis concluded that the impact of this RPIW was not statistically significant on the duration from referral to first assessment and the duration from referral to diagnostic formulation for patients (in terms of either the number of patients assessed on the day-of-referral, or the time taken between referral and assessment for those not treated on the day-of-referral). The evidence demonstrated that there was a step change in the time to assessment at both the intervention and control sites, particularly after the process improvement. If the research failed to include the controls, the evaluation would have indicated improvements at the intervention sites. These outcomes would have been supported by the previous literature in terms of reporting positive process improvement outcomes.

It is somewhat coincidental that there were improvements at both the intervention and control sites after the process improvements were implemented. There is unfortunately no data to understand why. This puts into conflict the advocates of evidence-based decision making who propose decision makers should adopt approaches that scientific inquiry has evaluated as more effective (McDaniel Jr and Lanham, 2009). It is possible that the improvements were a result of a number of factors that the ITS could not detect. One consideration could be the sampling selection of the intervention and control sites themselves being within the same hospital Trust and geographical region. This highlights a limitation of the sampling approach and the ITS method in general. For example, the ITS drew on routinely collected data in order to adopt a standardised experimental design.

It is argued that process improvement interventions can only be successfully evaluated if the content, context, and application are clearly understood (Walshe, 2007; Boaden *et al.*, 2008). In this case study, the ITS analysis only addressed one of the five objectives that the RPIW set out to accomplish: to reduce waiting times for the patients, carers, GPs, family members. The ITS was not a suitable method for measuring whether the RPIW achieved the other four objectives (to affect a complete redesign of the patient pathway; to address patient needs and the needs of carers; to demonstrate quality of service and value for money; to increase face-to-face contact time by 50%) which were qualitative in nature and required different research methods to measure the impact. For example, a number of positive changes were directly attributable to having standardised processes supported by common documentation (see Hunter *et al.*, 2014). Acceptance of standard work had highlighted gaps in the structures of the multi-disciplinary teams in different locations, but had also empowered staff to make requests for – and obtain – team members

with the professional skills to fill those gaps. From a human resource management perspective, psychosis team care co-ordinators were now better equipped to deal with their workload and staff sickness absenteeism had reduced. This supports the argument set out by Leggat *et al.* (2015) from their systematic review of process redesign methods in hospitals. It was identified that there needs to be more focus on the linkages between process redesign, the people involved and how this combines to improve patient care (Leggat *et al.*, 2015).

These inconclusive results suggest that it is important to do further research to evaluate process improvement interventions in a range of healthcare contexts. As Øvretveit and Gustafson (2002) argued, that just looking at the measured outcomes of any intervention does not mean there has not been improvement in process or the process improvement approach is not suitable. An ITS analysis reports on outcomes not process. Qualitative research methodologies would be appropriate for evaluating context, content and application elements of an intervention (Walshe, 2007), where the objective is to generate hypotheses. This might sit uncomfortably with advocates of evidence-based decision making who argue that decision makers and managers should only adopt practices that scientific inquiry has demonstrated to be effective (McDaniel Jr and Lanham, 2009). Quasi-experimental designs such as multiple interrupted time series rate highly on the hierarchies of evidence and are appropriate for establishing causality (Barends *et al.*, 2014), but may be limited in interpreting a number of outcomes resulting from process improvement interventions. Research should adopt a pragmatic approach (qualitative, quantitative, or both) to healthcare process improvement interventions.

Conclusion

Healthcare organisations are continuing to support process redesigns in order to treat patients more effectively. Process improvements that utilise a structured approach are frequently reported in the literature. Evaluating if the outcomes of structured process improvement events are achieved is an important area of research. The North East Transformation system adopted the Virginia Mason Production System (VMPS) which utilises Rapid Process Improvement Workshops (RPIWs) as a structured approach to bring about process improvements. This paper evaluated an RPIW conducted on a psychosis pathway that was part of a NHS mental health Trust. The evaluation concentrated on the referral process of the pathway specifically.

The ITS analysis concluded that the impact of this RPIW was not statistically significant on the duration from referral to first assessment and the duration from referral to diagnostic formulation for patients. This would imply that RPIWs are not a successful mechanism for implementing process improvements in healthcare. The limitations of conducting an ITS using routinely collected data, however, needs to be recognised. What is required is an appreciation of the social and cultural context in which the intervention is embedded.

The research had a number of limitations. The geographical proximity of the control and intervention sites could have led to interactions that undermined the internal validity of the quasi-experimental design. Further work could consider intervention and control sites in locations where interactions are minimised. The ITS analysis drew upon routinely collected data which limited the performance criteria that could be assessed. It is important to understand the metrics and healthcare indicators identified, and their limitations when evaluating process improvements.

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From experiential patient feedback to achieving highly reliable healthcare processes

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Abstract

This paper aims to evaluate how healthcare providers make use of unsolicited and real-time patient feedback, posted on online website called Care Opinion (CO), to improve the delivery of care and thereby embrace the characteristics of highly reliable organisations (HRO). The five characteristics of HRO – pre-occupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise, is tested in the selected English NHS Trust that has Care Opinion subscription. Semi-structured interviews with CO and NHS employees revealed that staff reaction and response to online patient stories is faster and positively influences NHS service delivery processes.

Keywords: Healthcare, Highly Reliable Organisations, Patient Feedback

Introduction

W. Edwards Deming the Quality guru stated, *"Quality is everyone's responsibility and we never have to stop getting better"* and the statement beautifully equates to the context of healthcare and patient safety. Despite of two decades of efforts to make healthcare safer and highly reliable the search for perfection continues with a big gap to be filled (Woods-Hill and Bird, 2019; Babyar, 2019). The key issue for studies of safer healthcare systems is therefore the understanding of how social and technical systems combine to generate a reliable healthcare organisation with just culture that promote staff pre-reporting and encourage learning (Weick and Sutcliffe, 2007).

The principles of highly reliable organizations (HRO) focuses on developing organization's ability to pre-empt failure, deliver and sustain almost error-free performance over long time period, resulting in improved patient safety and creating a culture and environment that promotes safety (Weick and Sutcliffe, 2007; Chassin and Loeb, 2013). The principles of HRO has been successfully implemented in the Air Traffic control system, nuclear power stations, Navy nuclear aircrafts, parks and other industries. Researchers have argued that every organization need to identify and

understand the characteristics and behaviours of individuals and beyond, to create conditions to achieve highly reliable performance (Weick and Sutcliffe, 2007; Martin et al., 2015).

In an era where usage of social media has become a cultural norm in the western countries, healthcare organisations can benefit a lot from usage of such data to transform their organisational culture from provider-focused to patient- centred (Rozenblum et al., 2017). The application of HRO principles in providing error-free healthcare services can be realized by going beyond accessing the patient feedback through the hospital system to learning from experiential feedback provided by patients and/or their relatives on social media and other feedback websites. Asking patients to share their experience of care received at the hospitals is realized to be a widespread way of generating useful knowledge for improving service delivery (Ziewitz, 2017; Sheard et al. 2017). The readily available crowdsourcing data from social media platform or dedicated patient stories webpages are being used by proactive hospitals to conduct problem-solving, quality control, and organizational learning (Adams, 2011; Rozenblum et al. 2017). Care Opinion (CO) is one of the online websites that provides a platform for patients to share their experiences of care which helps the other patients and the NHS to receive and deliver good quality of care.

The aim of this paper is to evaluate how healthcare providers make use of unsolicited and real-time patient feedback to learn and improve their service delivery process by engaging with patient stories posted on a social media platform called 'Care Opinion'. In an attempt to understand the relationship between using experiential feedback and exhibiting HRO characteristics (see table 1), authors apply the five characteristics of HRO (Weick and Sutcliffe, 2007; Hopkins, 2007) – pre-occupation with failure, reluctance to simplify, sensitivity to operations, commitment to resilience, and deference to expertise, to analyse how a selected NHS Trust in England make changes in their processes and practices to have a holistic approach towards patient-centred care. Semi-structured interviews with Care Opinion and the selected NHS Trust revealed the greater benefits of integrating social media feedback with traditional methods used in hospital for collection of patient feedback. The unsolicited real-time feedback results in quick response and action in majority of the cases and it has helped to improve the accountability and empowerment to conduct improvement at the source – one of the key principles of HRO, i.e. deference to expertise.

Literature review

HRO and its characteristics

Adverse events and preventable harms still continue to pose threat to patients since it was first highlighted in the Institute of Medicines (IOM) report "To Err is human (1999). The year 2000 brought a big storm in the field of patient safety in Healthcare after the publication of IOM's report "To Err is human" (1999). Its assertion that nearly 100,000 people were harmed each year in United Sated alone due to several medical errors brought into attention the need of looking at healthcare from different lenses. Since then, several healthcare incidents globally and the shocking performance of the Mid-Staffordshire NHS trust in the UK where 1200 patients nearly died over a decade demanded for developing high reliability healthcare processes. There is great opportunity for healthcare to learn from organisations operating in high risks environment but consistently performing safely and reliably such as airline and nuclear industry (Woods-Hill and Bird, 2019). HRO can be defined as developing resilient and flexible processes and practices in an organization to achieve and sustain highest levels of reliability (Hopkins, 2007).

The design features or guiding principles of the HRO are presented in the table 1.

Table 1- Characteristics and Challenges of HRO (Adapted from: Hopkins, 2007; Weick and Sutcliffe, 2007)

HRO Characteristics	**Description of characteristics**	**HRO role**	**Challenges to achieve HRO characteristics**
Pre-occupation with failure rather than success	Organisations need to identify early warning signs or signals, analyse them and act on them	Manage the unexpected in future	Finding signals from noise
Reluctance to simplify	Organisation need to simplify data to take better decisions; simplification may sometime lead to ignorance or loss of data	HRO have specialised people or department to pick warning sounds from background noise	Cost cutting organisation regard such dept./people as redundant and redundancy is enemy of efficiency
Sensitivity to operations	The front-line operators are most aware of current state of operations	Mangers must encourage to report the experiences	People refusing to speak the reality due to fear culture- this results in loss of rich data that remains as a tacit knowledge
Commitment to resilience	HRO is not error free but that error doesn't disable it	Commitment to learn from failures	Lack of integrated system to identify failures, learn quickly from it, and share across the organization
Deference to expertise	In difficult situations, bottom-up decision making is required	Highly trained people at low hierarchy to take quick and informed decisions	At low hierarchy employees are sometimes unaware of implications of their decisions

Researchers have argued that every organization need to identify and understand the characteristics and behaviours to create conditions to achieve highly reliable performance (Weick and Sutcliffe, 2007; Martin et al., 2015). Table 1 summarises the key characteristics exhibited by HRO and challenges faced by organizations to embed those practices. The next sub-section focuses on literature linked to use of experiential patient feedback from social media for improving quality of care.

Social Media and Experiential Patient Feedback

Healthcare previously has been managed by interpersonal communication between the patient and their healthcare providers typically by one to one and face to face arrangements. However, this traditional method of garnering patient feedback are costly to administer and suffer from response bias (Greaves et al., 2012), and it may take few months to get a response to a patient feedback or complaint (Rozenblum et al. 2017). Patient Feedback is one of the core aspects in improving the healthcare service delivery at the hospitals (Rozenblum et al., 2017; Sheard et al., 2017). Feedback through on-line platform including social media and other sources has gained tractions in the last one decade (Adams, 2011; Griffiths and Leaver, 2018). More and more patients have been increasingly active online since 2004, utilising social media platforms and websites to engage and communicate with their healthcare providers (Hamm et al., 2013). Nowadays

patient find it easy to report their healthcare experience using platforms such as blogs, social media, wikis and on health care rating websites (Greaves et al., 2012; Rozenblum et al., 2017). Platforms such as Twitter and Facebook have now become an easy and less expensive source for collecting unsolicited and real-time feedback from patients/ their families, which not possible by the traditional feedback systems (Hawkins et al., 2015).

Access to readily available feedback on micro blogging website such as Twitter or social media platform such as Facebook needs to be carefully interpreted and used beyond its face value (King et al., 2013). The limitations of data generated from Twitter and other online feedback systems can be manifold – validity of story (Lague and Greaves, 2015); not representative of entire population (King et al., 2013); biased opinions, retweets, misrepresentation, confidentiality issues, and limited regulations (King et al., 2013; Rozenblum et al., 2017). Other alternative web platforms such as kiesBeter.nl (Choose Better) in Netherland or NHS choice, and Care Opinion in the UK, provide an online space to patients so that health services can be reviewed (Adams 2011). Such websites provide a platform to patients and family where they share their experience about healthcare professionals, organisation, treatment or service they receive. The growing number of 'share your experience websites' for collective benefits provide patients with opportunity to compare the information online and leave feedback at right places. Such information by the online websites are than repackaged for the use of different stakeholders like hospitals (Adams, 2011; Rozenblum et al., 2017; Sheard et al., 2017).

In spite of certain limitations highlighted in the use of online feedback stories, several benefits have been reported by researchers from the use of real-time and unsolicited feedback (Baines et al., 2018). The benefits can be varied from improvement in the service delivery of healthcare provider (Gibbons and Greaves, 2017) to patient taking informed decision about their choices based on the online feedback and provides relevant information about healthcare quality (Greaves et al., 2012). Acknowledging the ambivalence of feedback and integrating it as a part of care will offer useful sensibility for executing feedback schemes in practise and sharing the same can be productive (Ziewitz 2017). Rozenblum et al. (2017) reported that learning from patient experience feedback such as the Care Opinion Website in UK helps in determining the ways in which the organisation can improve patient engagement. This shift from provider focused to patient centric will inculcate continuous improvement in the services thereby enabling them to embed the culture of learning using patient feedback into their organisation (Rozenblum et al. 2017).

The relationship between using data from social media platform to make informed changes in healthcare processes and practices, and its impact on transitioning towards HRO is a research gap that will be addressed in this paper. Authors will analyse the findings from the semi-structured interview, conducted with Care Opinion and the selected English NHS Trust, by using the guiding characteristics of HRO presented in table 1.

Methodology

The exploratory nature of the research questions leads to an adoption of an exploratory case study design (Barratt et al., 2011). The case study was conducted in the Care Opinion and a selected Hospital in the English NHS Trust that can be considered as active user and responder to patient feedback received from CO website. The selected hospital was one among 23 hospitals in England that was deemed as 'adequate' by Care Quality Commission (CQC), an organisation responsible for ensuring the quality of healthcare in England by aggregating large number of quantitative measures to identify risks in the quality of care. The case hospital still remains under special measures of

CQC. The 'special measure' tag forced the selected hospital to subscribe to CO services to become more patient-centric and be quick in responding to patient feedback, thereby making necessary and safe changes to their practices and processes. In less than three years of their journey with CO subscription, they have made significant changes in the way feedback is managed in the hospital for improvement and learning.

A mixed-method approach to the data collection was adopted for this study. Seven semi-structured interviews with clinical staff were triangulated with crowdsourcing data linked to the hospital and documentary evidence provided by participating hospital. Interviewees included members from all three levels of the hospital such as Patient Safety Director, Consultant, Improvement Specialists, Matron and Nurses. Each interview lasted from thirty minutes to sixty minutes. Authors also conducted interview with two executives of CO including CEO and moderation expert. Both interviews lasted for approximately one hour. The interviews were transcribed and analysed with systematic, iterative coding of verbal data for rich findings (Khan, 2014). The interview data was analysed based on common patterns and insights given by the interviewees. The codes generated were divided into common categories (Miles et al., 2013) linked to outcomes from experiential patient feedback and were mapped against the five characteristics of HRO to have a meaningful analysis and explore relationship between experiential patient feedback and HRO characteristics. Ethical considerations were crucial and were discussed openly with all staff involved prior to the study. The staff was selected based on their willingness to participate in the study. All the data was pseudo anonymised and all the identifiable for the participants are removed and stored as per Data Protection Act 2018.

Findings

Care Opinion is an online platform where patients can share their stories and experience which is then prioritised, moderated and packaged back to different stakeholders like patients, healthcare providers and regulators. In the UK, currently 550 organisations use CO out of which 100 have paid subscription. The hospital response rate in Scotland was found to be 96%, for England its 80% and 40-50% for Wales. The selected hospital has taken subscription service for over 18 months, since it came under special CQC measure, and believes it as a great tool to get unsolicited and real-time feedback from patients and their families. CO also combine stories from NHS Choices, another feedback platform used by NHS England to get patient feedback, and pass it to hospitals in a similar fashion.

The *CEO of Care Opinion* explained the two types of subscription model to receive online feedback – *basic subscription* is free for any hospitals in the UK, but a paid subscription service will give valuable access and advantage to the participant hospital including directly sharing the feedback with right department involved in the posted story. The *Associate Chief Nurse* (ACN) quoted that the benefit of paid subscription was that feedback reaches to the right level of organisation in real-time. The senior management and clinical team supported the use of CO services by staff members.

The *Associate Chief Nurse* confirmed that 90% of their feedback is of positive nature and other 10% are mixed. All interviewees concurred that they receive more positive feedback, which is morale booster in a highly pressurised and busy environment. Positive stories get shared via intranet and Twitter, celebrated with everyone and staff gets appreciation and a certificate of recognition. In case of negative stories, they are also looked on immediate basis. An email from central team is sent requesting an urgent response to critical stories from the relevant department which can later be followed if there is a change made. The response is monitored and the staff is reminded that they need to respond in case they forget in their busy schedule. The author of the story is

informed of any changes made in the system as a result of their feedback.

There was strong opinion in general from all the interviewees that online patients can be more open and honest as they can remain anonymous. Hospital staff believes that online presence changed the perspective and the way they interact and communicate with the patients. The *Service Improvement Leader* (SIL) in the hospital quoted *"happy patient means happy staff"* and explained that patient mostly share honest feedback which is very valuable for the team to understand and address the issue. The *Deputy Complaint Manager (DCM)* of the hospital reported that it is much easier to give online feedback as traditional method of collecting patient feedback can be cumbersome and time taking. More importantly, those feedbacks were dealt centrally first before it can reach right department after significant time delay. After subscription was gained, staffs from relevant department can now respond to their own feedback directly. This is crucial as the feedback comes from the department directly accountable for the issue reported. This further helps in resolving the issue more quickly and efficiently. However, *Service Improvement Leader* felt that there is a limit to a response which a staff can post online as sometimes the information can be misconceived and there are issues which can be dealt in a better way if done face to face.

The stories posted can be seen by anyone from staff in an email alert but because it is tagged with the relevant department, it becomes their responsibility to respond to it. This is in accordance with 'accountability' and 'empowerment' theme under *'deference to expertise'* characteristics of HRO (see table 2). In this way, staff members have engaged more by listening to stories and responding to them to close the loop. Training was provided by the central team and patient experience team to all subscribing members on how to respond to different types of feedback. The central team encourages the staff to respond however do provide support in responding to a negative feedback. The *Ward Clerk* (WC) suggested they feel good about senior management team promoting individual in each ward to improve quality of care and encourage them to always follow up a negative feedback and close the loop. This also assures that an action is being taken or changes are being made to address the paitent's feedback. Discussions revealed that staff can sometimes feel anxious and worried about not only receiving a negative feedback but also responding to it publicly on an open platform. Also *Service Improvement Lead* is wary about negative feedbacks as some feedbacks can be *"really nasty and exaggerated, responding them with a thank you for feedback can sometimes be really difficult especially when they are misrepresented"*.

Table 2 – Findings reported from the case analysis

HRO Characteristics	**Common themes**	**Quotes***
Pre-occupation with failure rather than success	Communication	*"The subscription to CO gives staff quick access to listen and respond to stories" - ACN*
	Teamwork	*"Improvement done by team in one ward gets spread to other wards and then to the whole hospital"* - WC
Reluctance to simplify	Leadership	*"Our Matron comes and makes us aware when she receives positive feedback…..she encourages us to take ownership"* -WC *"In my clinical cabinet all senior staff comes to focus on a story that*

		hasn't got well… what learning has come out.. share Trust wide for learning" - DN
	Systems Thinking	*"We did make a policy change by allowing fathers to stay overnight"*- MM *"Different Ward managers meet on monthly basis to identify any common pattern or themes across wards "*- HA
Sensitivity to operations	Reporting	*"traditionally we report any problem to service manager and wait for action….through Care Opinion we get the story to the right person or department quickly"* - SIL
	Feedback	*"We can now point out to people whats being said, and especially good feedbacks about their services"* - ACN *"90% positive feedback stories and 10% mixed"*- DCM
Commitment to resilience	Safety Culture	*"Once staff gets used to improvement from feedback, it becomes ingrained in the culture"* - WC
	Robust process improvement	*"We introduced a red tray system to take care of elderly patient at a risk of malnutrition and dehydration"* – WC
Deference to expertise	Training	*"Central team and patient engagement team train individual on how to respond to patient stories"* - ACN *"Training on following SOPs and checklists to avoid errors"* -DCM
	Accountability	*"Subscription allows feedback to be passed to right person quickly and then he/she is responsible for closing the feedback"* - ACN
	Empowerment	*"Individual are trained and empowered to respond to feedback after making improvements in their process"* - DCM

**ACN- Assistant Chief Nurse; DCM – Deputy Complaint Manager; SIL – Service Improvement Lead; MM- Maternity Matron; WC – Ward Clerk; DN- Director of Nursing; HA-Head of Audiology*

There are many examples given by NHS staff about changes made following patient's feedback, either received through traditional method or CO. The *Ward Clerk* provided an example where an idea of introducing a colour coded tray came from a nurse in the care ward, after receiving complaints from patients and their families, to provide extra

assistance to older patients that are at the risk of dehydration or malnutrition. Another example of improvement was provided by Deputy Complaint Manager who received complaint from CO about conflicting information given to mothers' breastfeeding their babies. This was immediately rectified by dedicating a special team and providing extra training to all the staff in that ward. Hospital staff remain optimistic that such changes in hospital not only make them better but also instil confidence amongst patient and their family about the high standard of safety culture in the hospital.

The brokerage firm such as CO has an important role in enhancing patient safety as it allows hospitals to use the patient feedback data for making improvement in the quality of care and thereby exhibiting characteristics of HRO, i.e. engaged leadership, enhanced safety culture, effective communication, teamwork, empowerment, accountability, effective reporting and feedback, and robust process improvement (see table 2). From the interviews, it is understood that patient experience has drawn a great deal of importance in terms of improving the healthcare service delivery. The patient stories are being heard and is considered to be important for the hospitals in their journey to embed the culture of learning with strong patient safety culture thereby exhibiting characteristics of HRO. The case analysis facilitated in identifying examples and methods on how selected case hospital used patient feedback for making informed changes at all levels in order to aspire to operate as error-free highly reliable healthcare organization. The process of implementing a change in the organization is undoubtedly a difficult task to perform but by utilizing this case study a direction for improvement in the quality of care can be obtained.

Discussion and conclusion

Literature highlighted an increasing organisation awareness in the importance of listening to stories of patient experience posted on different online platforms (Ziewitz, 2017; Sheard et al., 2017; Franceet et al., 2011; Frank, 2013). The results from the findings are similar and suggests that patient feedback holds immense value for NHS in their improvement journey. The spread of new technologies is ever growing and in this era of digitalisation, there is a dramatic increase in patients using online and social media platforms to share their experience. Findings are in line with the literature - stories are more visible online and hospital staff engagement with public has improved as a result of such visibility (Hamm et al., 2013; Rozenblum et al., 2017; Griffiths and Leaver, 2018). Nonetheless, there was element of anxiety and discomfort among staff members initially when dealing with negative feedback as it brings them or their ward into centre of attraction and discussion. Similar to literature findings, the CO staff also expressed their concern about confidentiality issues and misrepresentation, even after high quality moderation process, that may cause discomfort at patient or hospital end (Lagu and Greaves, 2015; King et al., 2013).

The CO platform provides an opportunity for patient and family to share *"truth based personal experiences"* Borkman (1976), and majority of the interviewees conceded this statement by stating online patients can be more open and honest about their experience and interactions with providers as they can remain anonymous. Interviewees from both CO and NHS also concur with findings reported by Greaves et al. (2012), that online feedback is easy and less time consuming for patient's than traditional methods. It also ensures quick and timely response without the requirement to fill length forms. Similar findings were reported in literature (Rozenblum et al., 2017; Hawkins et al., 2015)- approaching hospitals directly may involve filling up lengthy forms and giving out

personal information which can demotivate users. In contrast, one of the participants contradicted this and revealed that some issues are better dealt face to face.

Does increased number of subscription and listening to CO stories leads to exhibiting HRO characteristics? The selected case hospital from England demonstrated significant improvement in their care process and practices by proactively listening and responding to patient feedback posted on the CO website. Majority of the staff in the selected hospitals are active on Twitter. As a result, Twitter is used as a real-time communication mechanism for sharing any learning from improvements or mistakes (i.e. exhibiting *'sensitivity to operations'* and *'preoccupation with failure'* characteristics) and recognising an individual or team for enhancing safety culture and conducting improvement, aligning with findings from Adam (2011) and Rozenblum et al (2017). The subscription services also brought structural changes in the way feedback was managed – moving the control from the central team to local ward and employees who are now accountable for responding to feedback and take actions for improvement. This is aligned with *'deference to expertise'* and *'sensitivity to operations'* characteristics of HRO (Chassin and Loeb, 2013; Hopkins, 2007).

There were few feedbacks that cut across organisational boundaries and required systems thinking approach to problem solving. This was achieved by active coordination and teamwork between different wards managers and clinical staff to implement improvement actions and close the loop (Martin et al., 2015; Sheard et al., 2017). This is a good example where *'reluctance to simplify'* and *'commitment to resilience'* characteristics were met. Adams (2011) questioned the transparency and reflexivity of online feedback, and our study identified that staff were concerned about patient's sometimes exaggerating their issues online and warning other users to avoid consuming such service. However, these feedbacks are based on individual perception and their encounter which may not be representative of the services offered by the ward or hospital. In spite of the anxiety and discomfort, interviewees revealed that patient's stories help them to identify common themes and patterns and improvements made from listening to feedbacks are on rise recently. It also prompts for cross-functional team work for problem solving and reflection. Thus, exhibiting such practice and behaviour helps staff members to embrace HRO characteristics of '*reluctance to simplify'*, *'sensitivity to operations'* and *'commitment to resilience'*.

The ability to use patient and family members' perspective can be a useful tool for both patients and health care workers (Greaves, 2012). It has been demonstrated from this case study that if experiential patient feedback data is implemented in practice and treated as an integral part of care, then patient-centered changes can be implemented across the organization which can lead to high quality of care provision and less errors. The subject of patient safety is of vital importance as is HRO and healthcare processes/organisations. This study has taken an organisational perspective to close the gap in knowledge concerning the design of relevant and reliable models of care.

Time and resource constraints led to reliance on a single case study to conduct the research project. Focusing on a single case study has obvious limitations. However, the data collected via interviews with the key participants from different hierarchical levels from two organisations helped to achieve the aim of the study. This case study can be considered as a pilot study. There is a scope in future where data from multiple hospital can be compared and contrasted to conduct in depth analysis in order to evaluate the impact of patient's feedback on overall improvement of service delivery. A large sample size will provide more reliable data for analysis. Further research can focus on understanding the level of engagement of different healthcare departments in rolling out the patient feedback for organizational learning. This study includes the staff's viewpoint

on patient's story, further research can also be carried out by involving patients and relatives who are actual authors of the feedbacks to understand how they are impacted as a result of feedbacks they share.

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Improving productivity of hospital operating rooms (ORs): the case of a public hospital

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Abstract

The purpose of this study is to develop an improved scheduling methodology to increase productivity by reducing idle time and over time. At present, the hospital utilizes the methodology of allocating fixed blocks of ORs for a given clinical department on a yearly plan based on surgery types forecasting. The recommended approach (Modified blocks) allocates just a given percentage of ORs time (e.g. 75%) as fixed blocks and the remaining hours are flexible allocated. The improved scheduling model used 80% of the capacity. It resulted with an improvement of 87% in regards to over time and with no idle time.

Keywords: Operating room, Productivity, Public hospital

Introduction

Operating rooms (ORs) are resource intensive and costly hospital units. Since ORs are the hospital's largest cost and revenue center, maximizing its productivity is essential to maintaining an economical viable institution (Guanlian, et al., 2018). Increased healthcare costs are pushing hospitals to reduce costs and increase the quality of care. Operating rooms are the most important source of income and expense for hospitals. Therefore, the hospital management focuses on the effectiveness of schedules and plans (Gur and Eren, 2018). Managing the operating theatre, however, is hard due to the conflicting priorities and the preferences of its stakeholders, but also due to the scarcity of costly resources. Moreover, health managers have to anticipate the increasing demand for surgical services caused by the aging population. These factors clearly stress the need for efficiency and necessitate the development of adequate planning and scheduling procedures (Cardoen et al., 2016). Numerous factors constrain OR productivity including, infrastructure, human resource management issues, scheduling variation, process flow, technology issues and information management limitations. One common methodology of ORs capacity allocation is booking block of days/hours to a given clinical department in the hospital. This booking procedure frequently results in idle time or over time, thus increasing costs and patients waiting time. Other problematic issues are the variability of operating hours (even for the same type of surgery) and the set up periods needed between two operating procedures (Gauthier and Legrain, 2016). Many hospitals allocate blocks of OR time to individual or groups of surgeons as guaranteed allocation, who book surgeries one at a time in their blocks. The booking procedure frequently results in

unused time between surgeries (Li et al., 2016). Realizing that this presents an opportunity to improve OR utilization, hospitals manually reschedule surgery start times one or two days before each day of surgical operations. A rescheduling problem was developed as a variant of the bin-packing problem with interrelated items, which are the surgeries performed by the same surgeon. A lower bound (LB) construction algorithm was developed and proved that the LB is at least (2/3) of the optimal staffing cost. (Li et al., 2016), implemented a discrete-event simulation model to understand how changes to the Master Surgery Scheduling (MSS) would affect bed occupancy, thereby providing business intelligence for short- and long-term hospital planning. A decision tool was subsequently developed for hospital managers to test different scenarios. Simulation results showed that significant bed occupancy levelling could be achieved through small and practicable changes to the MSS. Optimisation routines conducted using the simulation model then gave additional insights into how the schedule should be revamped for the long term.

In the literature, there is unanimous consensus that OR performance depends strongly on how surgical activities are scheduled (Litvak and Long, 2000), There is also consensus that the scheduling process comprises three sequential stages (Beliën and Demeulemeester, (2007). (i) case-mix planning, (ii) master surgical scheduling (MSS) and (iii) patient selection and sequencing. The aim of the first stage is to establish the total amount of OR time to be assigned to each surgical specialty, usually on a yearly basis. The second stage involves determining the specialty (or specialties) to assign to each OR for each day of the planning horizon (e.g. two weeks or one month) and, sometimes, the number and types of surgery to be performed each day. Finally, the third stage involves selecting and sequencing patients to undergo surgery in the coming week. The study suggests that creating an effective operating room scheduler requires clustering patients in homogeneous surgery groups and developing a flexible tool that allows: scheduling surgery groups instead of actual patients, easily adding/removing constraints, changing the objective function(s) and adjusting the planning horizon (Yip, et al., 2018),

Visintin et al., (2017) and Samudra et al., (2017) found that it is important to model non-elective arrivals and to include elective rescheduling decisions made on surgery day itself. Rescheduling ensures that OR related performance measures, such as overtime, will only loosely depend on the chosen patient scheduling method. They also found that capacity considerations should guide actions performed before the surgery day such as patient scheduling and patient re-planning. The common practice in hospitals is to use mean arrival and processing times for OR planning .However, in a highly stochastic health care system, it is necessary to account for variations in patient arrivals and processing times. Gunna et al., (2017) deal with the dynamics in processing times and patient arrivals. They propose an optimization model for OR block scheduling by using the portfolio selection (PS) technique to maximize patient flow and benefit.

Vali-Siar et al., (2018) investigated a multi-period and multi-resource operating room integrated planning and scheduling problem under uncertainty. To this end, a mixed integer linear programming model has been developed for minimizing the tardiness in surgeries, overtime and idle time. Constraints related to human resources, equipment, as well as beds in pre-operative holding unit, recovery unit, ward and intensive care unit are taken into consideration.

Al-Refaie et al., (2018), propose optimization models for multiple-period scheduling of patients in ORs as well as for sequencing of patients in the operating theatre. The first model considers scheduling at a minimal total cost, comprising

hospitalization, under-time, overtime, and cancelation costs. The second model involves patient sequencing in the operating theatre at a minimal total overtime cost. The research results are expected to improve patient satisfaction and resource efficiency as well as reduce hospital expenses by minimizing overtime, under-time, hospitalization costs, and cancelation costs. Emergencies occur frequently in hospitals, and the number of lives saved should be maximized. Because emergency patients disrupt established schedules of hospital operating room, proactive techniques should be employed to save as many lives as possible. Al-Refaie et al., (2018) developed three optimization models for optimizing OR scheduling during unexpected events and accommodating emergency patient surgeries in the established schedule. Molina-Pariente et al., (2018) address a stochastic operating room scheduling problem which consists of assigning an intervention date and operating room to surgeries on the waiting list, minimizing the under- and overtime costs of the operating rooms, and the cost of exceeding the capacity constraints of the system. Uncertainties in surgeries duration, in the arrivals of emergency surgeries and in surgeons' capacity are considered. The study proposes a Monte Carlo optimization method based on the sample average approximation method, which combines an iterative greedy local search method and Monte Carlo simulation.

Block scheduling is a combination of surgery types that can be performed in the same operating room on the same day of the planning horizon. Benchof, et al., (2017), report on the development and implementation of an integer programming model to generate a near-optimal block schedule. The approach differs from many in the literature because it considers both direct nursing costs and patient-related costs, and can accommodate a variety of practical constraints. Three major benefits of the schedule are that it: (1) satisfies almost all of the monthly block requirements in only four weeks, thereby releasing capacity to reduce the surgical backlog; (2) eliminates days with excess admissions, which would have required additional nursing staff; and (3) reduces the number of surgeries cancelled due to an insufficient number of available beds.

The allocation of surgeries to ORs is a challenging combinatorial optimization problem. There is also significant uncertainty in the duration of surgical procedures, which further complicates assignment decisions. Denton et al., (2010) presented stochastic optimization models for the assignment of surgeries to ORs on a given day of surgery. The objective includes a fixed cost of opening ORs and a variable cost of overtime relative to a fixed length-of-day.

Yahia et al., (2016) generated an optimal case-mix plan of surgery patients with uncertain surgery operations, which includes uncertainty in surgery durations, length of stay, surgery demand and the availability of nurses. In order to obtain an optimal case-mix plan, a stochastic optimization model was proposed and the sample average approximation method is applied. The model is used to determine the number of surgery cases to be weekly served the amount of operating rooms' time dedicated to each specialty and the number of ward beds dedicated to each specialty. The optimal case-mix selection criterion is based upon a weighted score taking into account both the waiting list and the historical demand of each patient category. The score aims to maximizing the service level of the operating rooms by increasing the total number of surgery cases that could be served. The results show that the stochastic model solution outperforms the expected value problem solution.

In general, multiple surgeries are carried out in the same OR every day. Each surgery may have a random duration, which results in room idle time and patient waiting time. One of the major factors affecting the idle and waiting times is the

schedule of surgeries in the OR. To better sequence multiple surgeries to reduce idle and waiting time, an effective performance evaluation method is needed. Zeng, et al., (2018) introduced an analytical model to evaluate the performance of OR schedules. First, closed formulas to evaluate the case of two surgeries are developed and used as a building block in subsequent studies. Then, an iteration procedure is presented by aggregating every two surgeries into one using the two surgeries formula, and continuing to approach the next one, until all surgeries are aggregated into one. Using such a model, the expected idle time and waiting time for a given surgery schedule can be calculated quickly and accurately.

Methodology

The public hospital

The medical centre under study serves a population of about one million children, adults and elderly people. It manages 800 beds in various clinical departments and 21 operating rooms. In 2017, there were 160,000 visits to the emergency room, 21,000 surgeries were conducted, 64,000 were hospitalized and delivered 9,000 new borns. The medical centre is approved to the JCI (Joint Commission International) standard.

The operating rooms division

The division performs three types of surgeries: Emergency/unplanned surgeries, elective/planned surgeries and ambulatory surgeries where the patient is discharged when the procedure is completed. The ORs operate as follows: elective and ambulatory procedures are performed five days weekly during the first shift between 07:00-15:00. Other procedures are conducted upon demand during the second (15:00-23:00) and the third (23:00-07:00) shifts. Figure 1 illustrates the 2017 operations distribution per department.

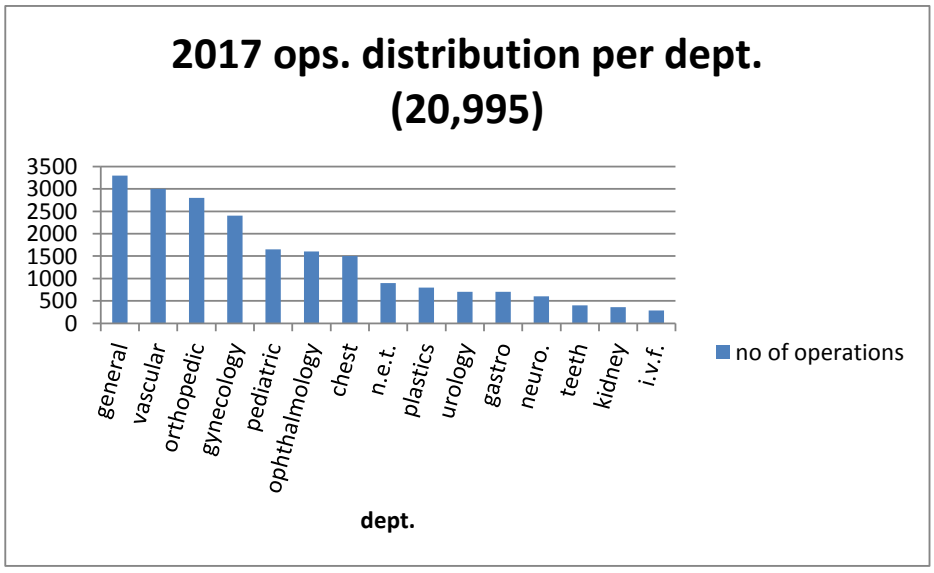

Figure 1 – 2107 operations distribution per department

A Pareto analysis reviles that general/vascular/orthopaedic/gynaecology/paediatric surgeries are about 70% of all the operations performed. General surgeries department

is the most users of the ORs with 16% of the operations. Table 1 presents the weekly allocation of ORs per department.

Table 1 – Weekly allocation of ORs per department

day / room	Sunday	Monday	Tuesday	Wednesday	Thursday
1	general	general	general	general	general
2	orthopaedic	orthopaedic	orthopaedic	orthopaedic	orthopaedic
3		neuro.	neuro.		chest
4	vascular	vascular	vascular	vascular	vascular
5	chest	chest	chest	chest	chest
6			general		
7	teeth	gastro	teeth	gastro	gastro
8					
9	vascular			vascular	
10	urology	kidney	urology	kidney	urology
11	orthopaedic	orthopaedic	orthopaedic	orthopaedic	orthopaedic
12	vascular	vascular	vascular	vascular	vascular
13	general	general	general	general	general
14	gynaecology	gynaecology	gynaecology	gynaecology	gynaecology
15	gynaecology	gynaecology	gynaecology	gynaecology	gynaecology
16	i.v.f.	i.v.f.	i.v.f.	i.v.f.	i.v.f.
17	paediatric	plastics	paediatric	plastics	paediatric
18	n.e.t.	paediatric	plastics	n.e.t.	n.e.t.
19	paediatric	n.e.t.	paediatric	paediatric	plastics
20	ophthalmology	ophthalmology	ophthalmology	ophthalmology	ophthalmology
21	ophthalmology	ophthalmology	ophthalmology	ophthalmology	ophthalmology

It should be noticed that room number 8 is available during the week for emergency/unplanned operations. Figure 2 illustrates the weekly hourly plan.

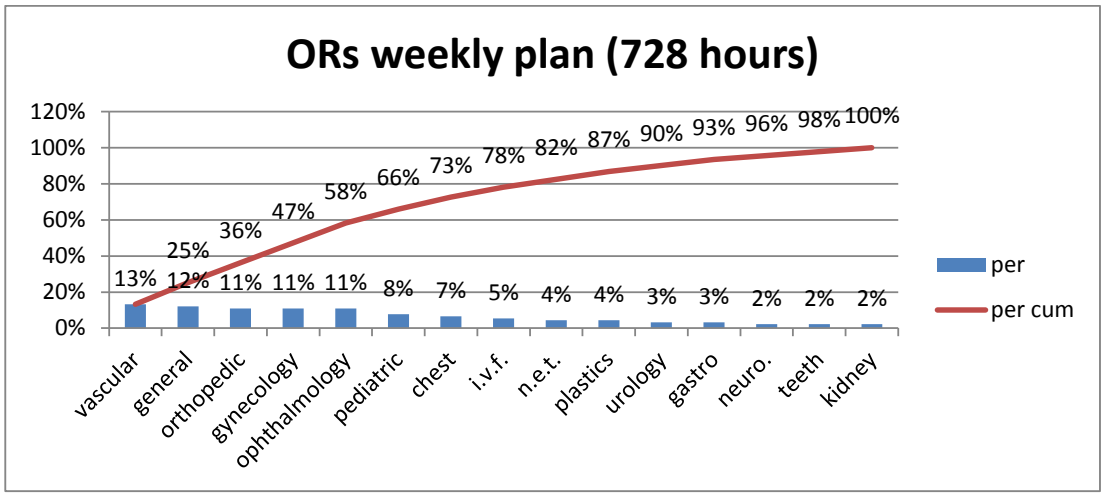

Figure 2 – ORs weekly hourly plan

Weekly allocation of ORs is conducted on a yearly basis according to past demand and future forecast. The *Block Scheduling Strategy* is used. The allocation algorithm is based on a weighted average index contains a set of parameters for each department. Figure 3 presents the set of parameters and the related weight.

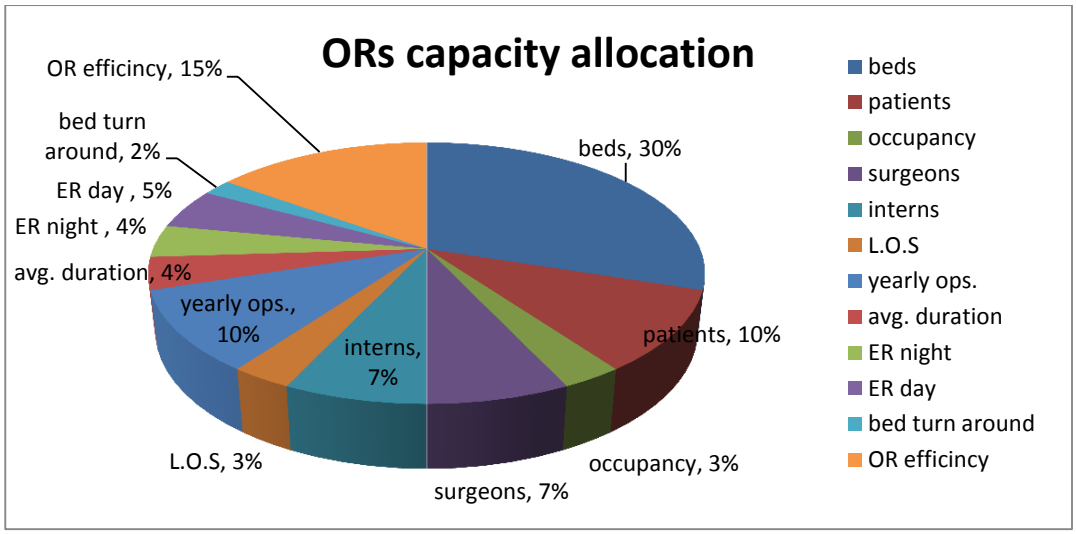

Figure 3– Allocation parameters weights

This methodology of fixed allocation per department creates two problematic issues: a. demand for over time for some departments and b. low efficiency/idle times for other departments. Figures 4, 5 present actual versus planning hours for general surgery and neurosurgery departments accordingly.

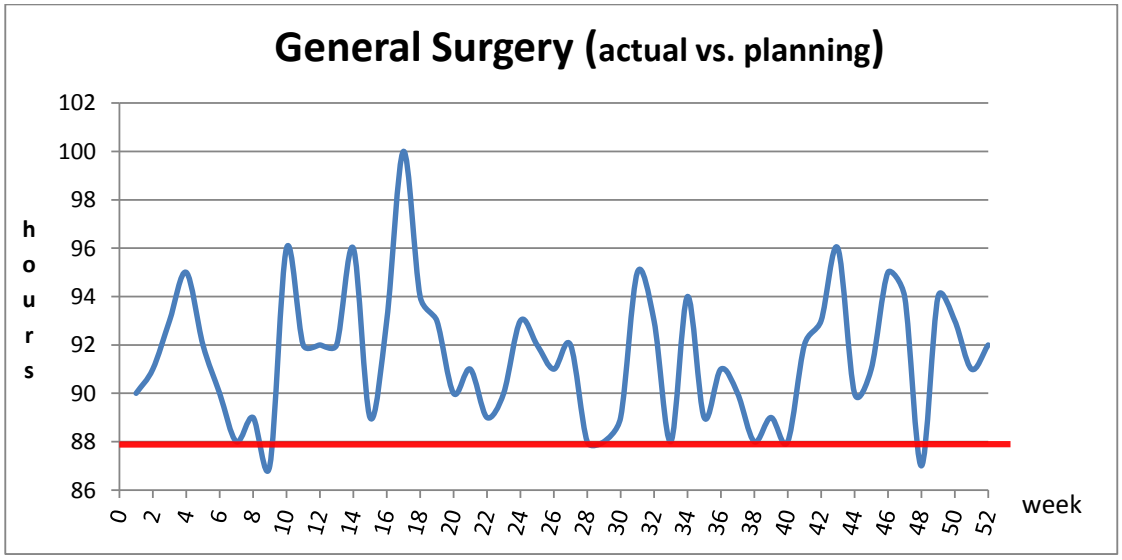

Figure 4 – General surgery actual vs. planning hours

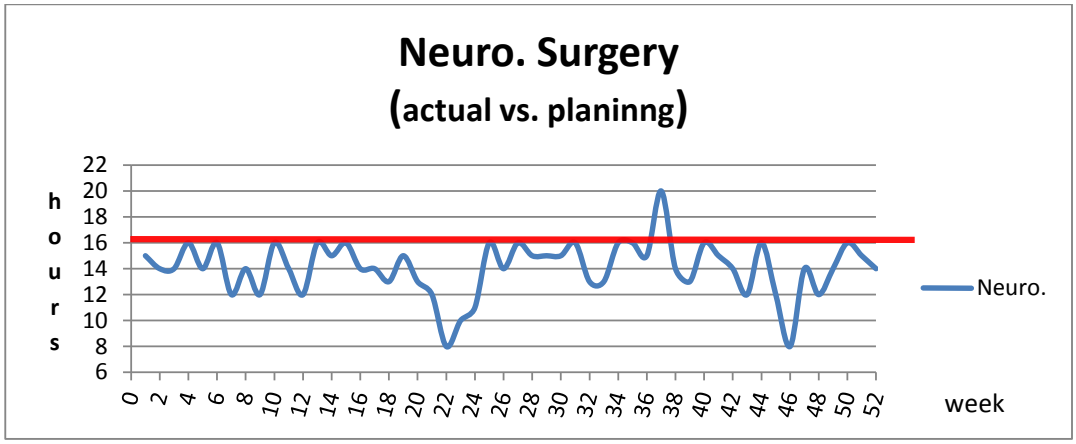

Figure 5 – Neuro surgery actual vs. planning hours

Observing the above figures demonstrate the problematic issues where regarding general surgery the allocation method creates over time while for the neurosurgery it creates idle time.

The improved scheduling methodology

There are three common strategies to schedule ORs in hospitals: a. *Open scheduling*- allocate the first available room; b. *Block scheduling*- allocate fixed blocks for a given department and c. *Modified block strategy*- Integration of strategies a and b. Allocation is conducted in two steps. 1. Decide upon a fixed percentage for the block scheduling and 2. Using the open scheduling strategy for the remaining ORs hours (Fei et al., 2010). Figure 6 presents simulation results for the best percentage in regards to over time to be 80%.

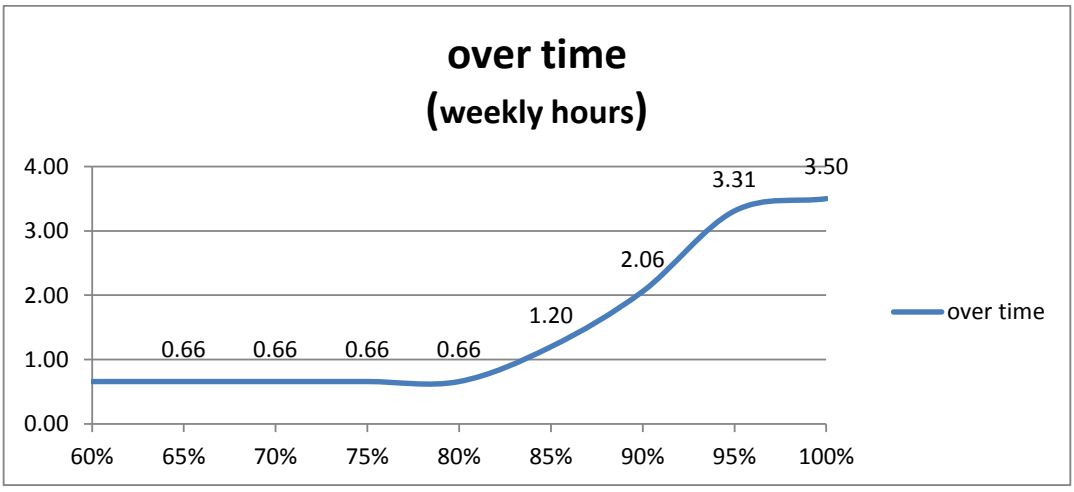

Figure 6 – Percentage for fixed blocks

The improved methodology is conducted in two steps: 1. each department gets 80% of the present weekly plan and is responsible to define the sequence of surgeries in its assigned ORs. The Longest Process Time (LPT) heuristics was used and 2. An independent person will get seven days in advance the rest of needed ORs of all the departments and will perform allocation to minimize over time. In order to optimize

these 20% of ORs hours, the Mixed Integer Nonlinear Programming (MINLP) was used to minimize the number of overtime hours (Zhaoxia and Xueping, 2014).

The recommended Modified Block Strategy was tested and showed an improvement of 87% in regarding overtime with no idle time.

Summary and Conclusions

In many post-industrial societies, health care industry is one of the largest industries in the service sector. Health care expenditures have been increasing rapidly for the last few decades, and will reach 19.5% of the US GDP by 2019. ORs are usually the most critical resources in hospitals. In some hospitals, more than 40% of the total revenue comes from ORs, and the ORs consist of a large proportion of the total expenses. Research indicates that in some situations, the ORs have not reached the target utilization, and a better surgery-to-OR scheduling strategy is needed to improve the utilization level and thus achieve cost savings.

As mentioned above, ORs are resource intensive and costly hospital units. Since ORs are the hospital's largest cost and revenue centre, maximizing its productivity is essential to maintaining an economical viable institution**.**

The medical centre under study serves a population of about one million children, adults and elderly people. It manages 800 beds in various clinical departments and 21 operating rooms. In 2017, there were 160,000 visits to the emergency room, 21,000 surgeries were conducted, 64,000 were hospitalized and delivered 9,000 new-borns. The medical centre is approved to the JCI (Joint Commission International) standard.

Weekly allocation of ORs is conducted on a yearly basis according to past demand and future forecast. The *Block Scheduling Strategy* is used. This methodology of fixed allocation per department creates two problematic issues: a. demand for over time for some departments and b. low efficiency/idle times for other departments.

An improved scheduling methodology was developed based on the *Modified block strategy*. The improved methodology is conducted in two steps: 1. each department gets 80% of the present weekly plan and is responsible to define the sequence of surgeries in its assigned ORs. The Longest Process Time (LPT) heuristics was used and 2. An independent person will get seven days in advance the rest of needed ORs of all the departments and will perform allocation to minimize over time. In order to optimize these 20% of ORs hours, the Mixed Integer Nonlinear Programming (MINLP) was used to minimize the number of overtime hours. The recommended Modified Block Strategy was tested and showed an improvement of 87% in regarding overtime with no idle time.

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A Deadly Flu Season in the US: a Strong Virus or a Supply Chain Problem?

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Abstract
2017-2018 was the worst US flu season since the 2009 H1N1 pandemic. However, the mortality rate of hospitalization cases in 2017-2018 was almost doubled than what it was during the pandemic. A hospital case is used to illustrate unexpected strong relationships and outcomes of how the disruption in the IV-bags supply chain during hurricane Maria in Puerto Rico, 2017 may have affected the number of deaths in 2017-2018 U.S. flu season. This event showed how the American healthcare system may have significant high public health risk caused by supply chain disruption, especially due to the location of pharmaceutical plants.

Keywords: Keywords: Hurricane Maria, Flu season, Risk Management, Supply Chain

Introduction

In September 20, 2017, Puerto Rico was slammed by a category four storm with violent winds and screeching rains that terrified the island population for 72 hours and was later known as Hurricane Maria. It caused $90 billion in damage and a reported death toll of 2,975. It was about 11 months until power was finally fully reestablished in the island. Transportation of people and goods that has always been a challenge in Puerto Rico, became almost impossible after Hurricane Maria. To the point that, a year later Maria's landfall, when asked where more recovery resources should be put on, 93 percent of Puerto Ricans point to the island's crumbled roads and busted highways, outranking other major priorities, such as the repair of damaged houses, hospitals, the power grids, and the fact the island had to permanently close 283 public schools. "We got more craters here than the moon" (Hernandez, 2018; Kaiser Family Foundation, 2018; CENTROPR, 2018).

Despite all the island precarious infrastructure, it has a long-lasting relationship with American health care companies. U.S. relies on Puerto Rico for many key medical products. Almost 10% of pharmaceutical expenditures by Americans are for products manufactured in Puerto Rico; with many important drug categories including oncology drugs, HIV drugs, and blood fraction products. Puerto Rico produces more pharmaceutical products for the U.S. ($40 billion) than any part of the world (Dooren, 2017). The next largest producer is Ireland, from where it imports nearly $20 billion. Puerto Rico also produces more pharmaceuticals than any American state (by dollar value). The next largest producers are Indiana and California, but Puerto Rico produces more pharmaceuticals than both of these states combined (Dooren, 2017).

One of these critical pharmaceutical products that is mainly just produced in Puerto Rico is a bag containing a saline solution in a diluent form (0.9% sodium carbonate) used to deliver a variety of parenteral medications called IV bag. This a critical medication for any patient under hospitalization. The United States gets almost the totality of its saline supply from just three companies: Baxter International, B. Braun Medical, and ICU Medical. One of these companies, Baxter, located in Puerto Rico, supplies almost 50% of all US Hospitals (Mazer-Amirshahi & Fox, 2018). The inventory level for the IV bags has been a constant challenge since 2013 for healthcare providers. The shortage of saline solutions has worsened, and its supply chain has not been fully recovered when a severe rupture in saline manufacturers supply chains occurred after Hurricane Maria (E. Fox, 2018; Loftus, 2017). The saline components delivered through the IV-Bags are basic drug required by virtually all hospitalized patients, either as a component of a medication infusion or as hydration, resuscitation, or irrigation fluid (Azghandi et al., 2018; Mazer-Amirshahi & Fox, 2018). The lack of an IV bag presents risks to the patient's health as a result of non-treatment, under-treatment and possible medication errors due to attempts to replace missing drugs (WHO, 2016), which can eventually impact in the increase of death rates.

The U.S. Center for Disease Control and Prevention (CDC) estimates that the 2017-2018 was one of the worse flu seasons in the American history. The number of cases of people who got sick was the highest (48.8 million) since the 2009 H1N1 pandemic (60 million). Even though official reports by the CDC do not consider anything related to the shortage of IV bags as possible causes for a particularly deadly flu season, it was not rare to witness media outlets featuring that possibility during the peak of the problem. "If we can't support patients coming in emergency rooms who have the flu, more people are going to die," predicts Deborah Pasko, director of medication safety and quality at the American Society of Health System Pharmacists, a professional group. "I see it as a crisis." (Johnson 2018). Different supply chain problems were also exposed. "Most IV saline bags used in U.S. hospitals are made in Puerto Rico. Hurricane Maria has shown how troubling it can be to rely on one producer" (Wendelbo and Blackburn, 2018).

Considering the relevance and complexity of supply chain management in the pharmaceutical industry and the possibility that the lack of IV bags may have contributed to the deaths from influenza in the severe 2017-2018 flu season in the United States, we pose the following research question**: How the disruption in the IV-bags supply chain during hurricane Maria in Puerto Rico, 2017, affected the number of deaths caused by the 2017/2018 flu season in the U.S.?** Historical data on influenza deaths in recent decades, news, government agency documents, and other documents are considered in our analysis. We also used a large not-for-profit hospital in the Midwest to illustrate the relationship between the shortage of IV bags and deaths from influenza related illness.

Literature Review

Pharmaceutical supply is composed of four main levels: chemical plants, pharmaceutical plants, distribution affiliates, and healthcare facilities (Burns, 2002; E. R. Fox et al., 2009). Pharmaceutical shortage can be addressed through varying strategies introduced in each of these levels. Drug shortages in any the four pharmaceutical supply chain levels affected directly patients causing significant safety concerns (Saedi, Kundakcioglu, & Henry, 2016). They result in inconvenience and/or profit losses and pose a health risk to patients due to inadequate, interrupted, or lack of treatment (WHO, 2016).

In general, the research of pharmaceutical supply chains has been approached from managerial analysis or quantitative modeling (Azghandi et al., 2018; Saedi et al., 2016). Managerial approaches include vendor managed inventory (VMI), outsourcing, supply chain integration, and risk management in pharmaceutical supply chains (Saedi et al., 2016). Studies on disruption mitigation in pharmaceutical supply chain management are related in the scope of the types of disruptions, mathematical modeling supply chain and response strategies has been conducted for other industries (Azghandi et al., 2018). There are many different approaches for mitigation of disruption risks that have been examined. Common tactics for alleviating the effects of disruptions are financial mitigation, operation mitigation, and operational contingencies (Brian Tomlin, 2006). Mitigation tactics are those in which the firm takes an action in advance of a disruption and correspondingly incurs the cost of the action regardless of a disruption's occurrence. Operational tactics, such as inventory management, multiple sourcing, and flexibility in production are also studied in the literature of supply chain disruptions.

There have been many works regarding supply chain risks in general, and disruption uncertainty in particular. Researchers from the supply chain rupture area demonstrate that an optimal strategy to implement when dealing with a rupture varies based on the characteristics of the interruption (Chopra, Reinhardt, & Mohan, 2007). Tomlin (2006) suggests inventory strategies, dual sourcing, and acceptance to deal with disruptions, and demonstrates that the optimal strategy changes as the disruptions become longer or more frequent. Chapman et al. (2002) discuss supply chain vulnerabilities by enumerating sources of disruptions and analyzing the impacts of each. Mitroff and Alpasan (2014) provide strategic tools to help identify stress causes and their impact on a firm's preparedness towards disruptive events. Kleindorfer and Saad (2005) chart a conceptual framework that trades off risk mitigating investments potential losses caused by supply disruption. Ritchie and Brindley (2007) also build an empirical framework that addresses the question of choosing a set of suppliers that minimizes loss caused by deviation, disruption, and disaster risks. Atan et al. (2016) present hybrid strategies to deal with supply uncertainty or demand uncertainty in multi-segment supply chains. They consider the interruptions that occur at a specific location and demonstrate that an optimal policy to deal with an interruption in supply uncertainty is not the same as the optimal policy to deal with an interruption in demand uncertainty.

Puerto Rico and the Life Science Industry

Puerto Rico, officially the Commonwealth of Puerto Rico, is an island territory of the United States, located in the northeast Caribbean Sea (Rodríguez-Díaz, 2018). Puerto Rico's pharmaceutical and medical device manufacturing industries are integral to the Island's economy. In 2016, approximately 30% of Puerto Rico's GDP was composed of pharmaceuticals and medical devices manufactured on the Island and these products were two of Puerto Rico's largest exports (Dooren, 2017). Medical product manufacturing help support a highly skilled workforce in Puerto Rico. Residents employed in the drug and medical device industries collectively earn approximately $800 millions in wages in one year and this industry employs about 90,000 people, which represents about 30% of all manufacturing employees in Puerto Rico (Dooren, 2017). An important fact to consider and understand the even greater importance of this industry to Puerto Rico economy is to look at Puerto Rico's wealth. Puerto Ricans, despite being considered American Citizens, make way less money than their counter parties in the US mainland– Puerto Rico household annual income (20,078) is 65% lower than the US median household income ($57,617) (DATAUSA, 2019). A combination of more affordable labor, still keeping the production as being "made in

America", plus an attractive tax incentive package (Reeves, 2017) may have contributed to make Puerto Rico one of the top destinations for Pharmaceuticals and Medical Devices manufacturing companies.

There are more than 1,000 individual drug products that are registered to be manufactured in Puerto Rico; of which several hundred are considered by the Food and Drugs Administration department (FDA) to be medically important (Dooren, 2017). Puerto Rico manufactures 30 drug products and approximately ten biological devices that are of critical importance. For these, Puerto Rico is a primary for all of them and the sole manufacturing site for at least 14 of them. These drugs do not have clear therapeutic alternatives (Dooren, 2017). The FDA acknowledges the risks related to that and FDA Drug Shortage Teams are carefully monitoring all 40 of these products.

There are more than 80 pharmaceutical and medical facilities owned by companies like Amgen Inc. AMGN, Baxter International Inc., Mylan NV, Johnson & Johnson Inc., Medtronic, and Abbott Laboratories residing on the island (Meagher, 2017). Puerto Rico is home to top multinational pharmaceutical companies operating in more than one site on the island. According the Government of Puerto Rico (2017), two dozen different kinds pharmaceutical products are manufactured in Puerto Rico: antihypertensive drugs, tranquilizers, laxatives, anti-diabetic drugs, vasodilators, antibiotics and contraceptives, among many others. Additionally, 12 of the top 20 pharmaceutical companies have presence on the island (See Figure 1).

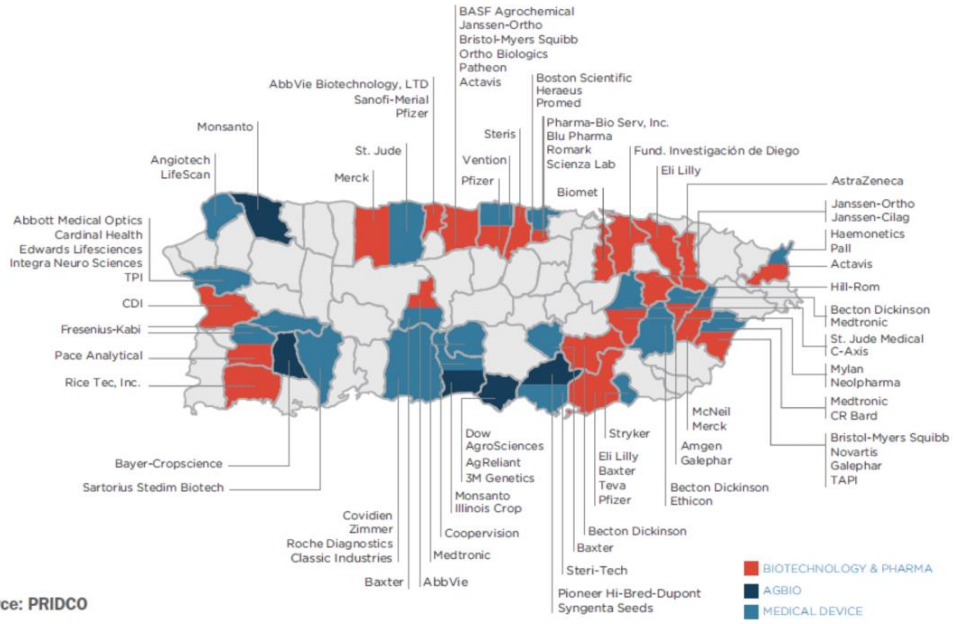

Figure 1 – Map of Puerto Rico's pharmaceutical manufacturing facilities

Hurricane Maria's Effect on IV bag shortages

Hurricane Maria made landfall in Puerto Rico on September 20, 2017, as a Category 4 hurricane, with sustained wind speeds just below 155 mph, gusts of 175-195 mph, and rainfall of up to 38 inches in some areas (NHC, 2017). Drug shortages and medical device shortfalls abounded as pharmaceutical companies scrambled to find enough diesel to run their factories, deal with power outages, locate and ensure their employees' safety, and figure out how to transport people to work on obstructed roads (Weber, 2018). While the island lived its worst blackout in history that contributed to loss of

many lives due to power outage in hospitals all over the island, hospitals in the US started to feel those consequences in a different kind of outage.

The devastation caused by the hurricane Maria in Puerto Rico amplified the IV bag shortage in the U.S. hospitals. In particular, sodium chloride 0.9% injection bags, which are ubiquitous in medical facilities and hospitals (Azghandi et al., 2018). Most drug shortages occur with older, generic, injectable medications that are produced by typically three supplier (Mazer-Amirshahi & Fox, 2018). As mentioned before, the U.S. gets its saline from just three companies: Baxter International, B. Braun Medical, and ICU Medical, and about 50% of this supply come from Baxter, which manufacturing sites are located in Puerto Rico. In the past, some shortages were caused by a quality or production problem at the manufacturing facility (E. R. Fox et al., 2009; Mazer-Amirshahi & Fox, 2018). Also, when one supplier experiences a shortage, other suppliers often do not have sufficient manufacturing capacity to make up the difference. Drug manufacturers are not required to have redundancy in their facilities or even a business contingency plan in case of a disaster, no matter how essential or lifesaving the medication they are producing (Mazer-Amirshahi & Fox, 2018).

After Baxter's Puerto Rico manufacturing plant was hit by Hurricane Maria, the shortage of small-volume saline bags became more intensive and critical. Baxter had no redundancy in manufacturing capacity for saline bags. The other two IV bags suppliers have not been able to increase their production enough to make up for the shortage either. Saline produced by B. Braun was already in short supply before the hurricane, as the company worked to correct manufacturing-quality problems. The IV bag shortage had begun in 2014, affecting large- as well as small-volume products (Mazer-Amirshahi & Fox, 2018). Large-volume saline products (>500 ml) are typically used as maintenance or resuscitation fluids or for irrigation. Though some shortages of large volume saline solutions are attributable to problems at manufacturing facilities, increased demand for intravenous fluids due to a severe influenza season has also contributed to the current short supply (Mazer-Amirshahi & Fox, 2018).

Unavailable medicines broadly affect the treatment and prevention of diseases. Saline shortages can affect patient care in various ways (Mazer-Amirshahi & Fox, 2018). Medication errors and adverse drug events can result when medications that are typically administered as short infusions are given by intravenous push or when providers choose less familiar but more readily available products as substitutes. Increased ad hoc compounding of drugs may result in dilution errors or microbial contamination, and eventually contribute to increase in death rates.

Background of influenza in the U.S.: *2017-18 influenza season*

According the Centers for Disease Control and Prevention (CDC), the United States 2017–18 influenza season was a high severity season with high levels of outpatient clinic, and emergency department visits influenza-like illnesses (ILI), high influenza-related hospitalization rates, and high and geographically widespread influenza activity for an extended period (Garten et al., 2018). ILI activity during the 2017-2018 season began to increase in November, reaching a period of high activity during January and February nationwide and remaining high until the end of March. ILI reached a peak of 7.5% weekly outpatient consultations to health service providers participating in the U.S, which was the highest percentage since the 2009 H1N1 flu pandemic (7.7%). Outpatient Influenza-like Illness Surveillance Network (ILINet) was equal to or greater than the national reference level of 2.2% for 19 consecutive weeks (weeks 47-13) during the 2017-18 season.

CDC reports its data in four levels to understand the seriousness of a flu season: number of people who got sick, number of people who seek a health care provider, number of people who were hospitalized, and number of deaths for influenza related illness. CDC believes that the high number of influenza cases in the 2017-2018 was due to a particular strong virus. That theory is reinforced by the fact that a large number of people who got sick (48.8 M) where then hospitalized (959,000), which represented about two percent of all sick cases. The strength of that virus is particular impressive when compared to the pandemic numbers, when 0.45 percent of the people who got sick (60.8 M) had to be hospitalized (274,304). Moreover, another number becomes even more impressive. During the 2009 H1N1 pandemic, 4.5% (12,469) of all people who were hospitalized due to influenza related illness (274,304), died. During the 2017-2018 flu season, this number jumped dramatically, increasing 82% from 4.5% to 8.3% of deaths (10,300) of people who were hospitalized (79,400). When just the number of deaths is compared among the two seasons, the 2017-2018 had almost 700% more deaths in absolute numbers than the 2009 H1N1 pandemic. The number of working adults (18-64 years) who died for influenza related illness was also higher in the 2017-2018 season than it was in the 2009 pandemic. For that reason, the 2017-2018 may be considered the worst flu season in the U.S. history. (Table 1)

Table 1 – Comparison of 2009 H1N1 Pandemic and 2017-2018 Flu Season

	2009-2010*			2017-2017**			Season comparison 2009 to 2017	
Got sick	60,800,000			48,800,000			-19.74%	
Got hospitalized	274,304	**0.45%**		959,000	**2.0%**		249.61%	
Died	12,469	**4.5%**	**0.02%**	79,400	**8.3%**	**0.16%**	82.14%	693.4%
Working adults dead	**9,565**			**10,300**			7.68%	

Source: * https://academic.oup.com/cid/article/52/suppl_1/S75/499147
** https://www.cdc.gov/flu/about/burden/2017-2018.htm

As illustrated on Table 1, this paper argues that the 2017-2018 flu season can be considered the worst flu season in the US history. That is also based in the death rate. According to Sundar et al (2011), a death rate due to influenza related illness should range from 1.5% to 6% of the hospitalizations, as illustrated on Figure 2. However, the death rate for all age ranges hospitalized during due to ILI in the 2017-2018 flu season was higher than that, at an 8.3% average. A rate 82 percent higher than the worst record season (2009 pandemic). When compared to the number of sick people, this number is alarming. During the 2009 pandemic, 0.02% of the population who got sick, died from ILI. On the other hand, during the 2017-2018 flu season, this rate was 0.16%, an increase of almost 700%.

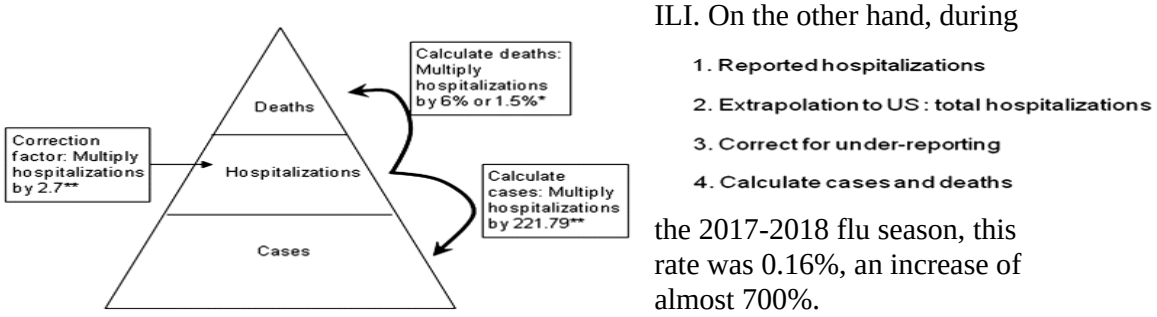

Figure 2. An illustration of the methodology used to extrapolate death from reported laboratory-confirmed, based on 2009 pandemic
Source: Sundar et al (2011)

It is well know that children and the elderly are usually the most susceptible to suffer from the flu. However, if we considered the number of working adults (18-64 years) who died for influenza related illness during the 2017-2018 season, that was also higher than those who lost their lives during the 2009 pandemic, we may find another hidden cost of the flu season: the lost income of these working adults during their possible life time. To calculate what that could be, we used the US life expectancy in 2017 (80.1 years of age), the average American individual income ($57,652), and the distribution of age range in current US population (US CENSUS, 2018). Considering these data, ignoring other related tangible and intangible costs, those working adults whose lives were lost due to the flu season in 2017-2018, cost the American society, at least $24.2 billion (Table 2)

Table 2 – Working adults' income loss due to death on 2017-2018 Flu Season

	Median Age	% of the working adults	Years to live (LE=80.1)	Expected income (Avg $57.652)	Individual Income Loss	Proportion of Death Toll (10,300)	Total Income Loss
18 to 19 years	19	9.88%	61.6	$ 57,652.00	$ 3,551,363.20	1,018	$ 3,614,757,122.30
20 to 24 years	22	10.34%	58.1	$ 57,652.00	$ 3,349,581.20	1,065	$ 3,568,611,329.00
25 to 29 years	27	10.93%	53.1	$ 57,652.00	$ 3,061,321.20	1,126	$ 3,446,089,696.25
30 to 34 years	32	10.28%	48.1	$ 57,652.00	$ 2,773,061.20	1,058	$ 2,934,834,748.91
35 to 39 years	37	9.93%	43.1	$ 57,652.00	$ 2,484,801.20	1,023	$ 2,541,165,261.76
40 to 44 years	42	9.19%	38.1	$ 57,652.00	$ 2,196,541.20	946	$ 2,078,288,500.20
45 to 49 years	47	9.81%	33.1	$ 57,652.00	$ 1,908,281.20	1,010	$ 1,927,840,557.51
50 to 54 years	52	10.01%	28.1	$ 57,652.00	$ 1,620,021.20	1,031	$ 1,669,963,926.76
55 to 59 years	57	10.29%	23.1	$ 57,652.00	$ 1,331,761.20	1,060	$ 1,411,745,735.40
60 to 64 years	62	9.35%	18.1	$ 57,652.00	$ 1,043,501.20	963	$ 1,004,630,216.07
TOTAL						10,300	**$ 24,197,927,094.16**

Source: Organized by the authors with data pulled from https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk and https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

There is not much that can be done to treat the flu, and that once the patient is hospitalized, the most important part of his or her treatment involves to keep them hydrated (Ellis, n.d.). Thus, it is possible to see a possible correlation between the problem with the IV-bags supply due to the closure of manufacturing plants during Hurricane Irma in Puerto Rico and the increase of death rates of hospitalized patients to ILI. To test that hypothesis, we performed a case analysis.

Hospital Case Analysis

To illustrate a possible relationship between IV bag shortage and influenza deaths, we used the case of one of the largest US hospitals, located in the Midwest. Among the pharmaceutical supply chain levels, the hospital (healthcare facility) is most affected by shortages because it is in direct contact with patients. We took data from a not-for-profit academic medical hospital for our analysis. The hospital established in 1883, is one of the oldest and most distinguished pediatric hospitals in the United States. It is home to the country's busiest pediatric emergency department, performs the second largest number of surgical procedures at a children's hospital in the nation and offer comprehensive clinical services, from treatments for rare and complex conditions to well-child care.

Data analysis and treatment used 262 weeks as a research sample, from week 40 in 2009 to week 8 in 2018. We used multiple regression as a statistical technique to evaluate the association coefficient between the independent variables on the dependent variable, in other words, the degree of alteration of the dependent variable as a response

to the independent variables (Hair et al., 2009). Therefore, this technique enables an analysis to be made of what contribution each independent variable to the influenza deaths (see Table 3). We considered that there was no variation in vaccination coverage and because that it was used in our model.

Table 3 – Variables used in this study

Variable	Description
Independent variable	
• Hospitalization week rate	Indicates the rate of internalization by week
• Week	The position of week in the calendar
• IV shortage hospital	Categorical variable classifying the type of degree of shortage of IV bags in the hospital: (0) no shortage reported, (1) low shortage, (2) medium shortage, (3) high shortage, and (4) very high shortage
Dependent variable	
• Influenza Deaths	Number of deaths in the hospital

The descriptive analysis of data gives the means, standard deviation and minimum and maximum. The existence of standard deviation and a high dispersion of the minimum and maximum values are important because they show the variability of the variables when using regression model. In our model, the variables prove to have a normal distribution. We analyzed the correlation between the research variables using the significant test at the 0.05 level. Hospitalization and IV bag shortage are variables that are positively correlated with influenza deaths, while week indicates a negative and statistically significant correlation. The fact that there is no correlation between the variables is evidence of the absence of a dimensional relationship, in other words, when a variable is interlinked with another. The discovery of these correlations is relevant evidence for the regression analysis. Analysis were then carried out using the multiple regression technique, which shows the causal relationship between variables.

Table 4 – Multiple regression

Independent variables	t
Week	-6.632***
Hospitalization week rate	17.872***
IV bag shortage	5.544***
Constant	5.667***
R^2	.861
R^2 adjust.	.860

****P*-value < 0.00

The regression test is shown in the Table 4, the results indicate that there was positive relation between the number of deaths and the IV bag shortages.

Discussion

Hurricane Maria have heavily compromised pharmaceutical manufacturing in Puerto Rico and sit the U.S. healthcare system on the brink of a significant public health crisis (Mazer-Amirshahi & Fox, 2018). Saline solutions are used in every healthcare setting that administers intravenous medications in the United States. Larger institutions use hundreds of these bags per day. Hospitals and other healthcare settings have reported critically low on product and unclear as to when their supplies will be replenished, and

the storm exacerbated the situation. Baxter's central manufacturing plants for its IV-bags had its capabilities going down due to hurricane damage, the saline bags — already limited after an issue with quality at a B. Braun factory and a record flu season — were in even shorter supply (Weber, 2018). Hospitals and medical establishments across the country dealt with what they could get their hands on. Other hospitals implemented conservation tactics, using replacements and alternatives when necessary and available, but a severe threat to the safety and quality of patient care still looms (Mazer-Amirshahi & Fox, 2018). In response to the shortage, hospitals throughout the country have adopted strategies to ensure patients were getting the medications and care while minimizing the use of IV bags. For instance Curt Passafume, VP for pharmacy services at OhioHealth, said, "We have gone into the aggressive shortage-management mode." He continued, "I've never seen anything like this before. It's challenging us to think differently than we thought in the past, because we have to.

Given the small number of producers, this situation will not be resolved quickly. Most pharmaceutical companies have not shared detailed status about their products, potential shortages, or availability/release dates. Baxter is one of the few companies that we are aware of that has had contact with the FDA, which prompted the FDA to allow importation of small-volume IV solutions from Ireland and Australia (Mazer-Amirshahi & Fox, 2018; Scott Gottlieb, 2018). However, this importation met only 10–15% of hospital and health system demand (Mazer-Amirshahi & Fox, 2018).

Immediate action is needed to ensure patients can get the care they need. But beyond the immediate need to rectify the emergency, US government should examine how the pharmaceutical industry communicates information about what drugs are manufactured at which plants and where those plants are located. There is no state or federal law requires that this information is disclosed. This lack of transparency puts healthcare systems at a significant disadvantage when trying to take a proactive approach to handle a potential drug shortage (E. Fox, 2018). The current system results in a reactive approach, which is usually short-notice and has a rapid downstream effect, leaving hospitals at a loss to meet patient needs. Furthermore, the current pharmaceutical infrastructure allows for a significant number of manufacturers to be geographically located in an area that is at high risk for natural disasters.

Conclusion

Puerto Rico manufacturing plants are critical supplies of IV bags to hospitals which are used in most of treatments of diseases (Mazer-Amirshahi & Fox, 2018). Despite evidences of need, Baxter has no redundancy in manufacturing capacity for small-volume saline bags. The other two saline suppliers have not been able to increase their production enough to make up for the shortage (Langreth & Coons, 2017; Scott Gottlieb, 2018). Moreover, saline produced by one of the other suppliers was already in short supply before the hurricane, as the company worked to correct manufacturing-quality problems (Langreth & Coons, 2017).

Although critical, this episode of natural disaster is not new. Hurricane Georges in 1998, for example, was only a category 1 storm, but its path across the entirety of the island and its torrential rainfall make it one of the worst natural disasters in Puerto Rico's history (Fritz, 2017). The hurricane caused no direct fatalities, but the damage to infrastructure was almost total.

A strong virus led to a lot of hospitalizations during the 2017-2018 flu season. However, we have enough evidence to believe that the fact that there was a massive problem in the IV-bags supply chain caused by the closure of plants in Puerto Rico during the Hurricane Maria, directly contributed to the high death rate of the 2017-2018

flu season. This sheds new light on how the US health care system should manage its supply chain risk and avoid costs to the system and to the society. The fact that so many critical medical and pharmaceutical components are sole produced in a single island with not enough infrastructure is concerning and, as seeing in the 2017-2017 flu season, can be life threatening. Given the possibility of new natural disasters, public managers need to rethink locations of pharmaceutical plants in addition to ensuring that backup systems can quickly accommodate needs in the event of a disaster.

Even without using the specific terms, the importance of looking at supply chain risks, had been acknowledged in a letter sent to congress and signed by the American Hospital Association, the American Society of Anesthesiologists, the American Society of Clinical Oncology, the American Society of Parenteral and Enteral Nutrition, and the Institute for Safe Medication Practices. In the letter, they raise six questions and call for a comprehensive strategy to manage drug shortages. All six questions are related to risk management in the supply chain (ASHP, 2018).

Many critically important medical products—which includes sophisticated drugs, biologics, and medical devices —are manufactured in Puerto Rico. The combination of a severe flu season and reduced supplies of intravenous (IV) fluid bags after Hurricane Maria devastated manufacturing plants in Puerto Rico put hospitals in critical situation. This event showed how the U.S. healthcare system can have a significant public health difficulty because the location of pharmaceutical plants. Even though manufacturing redundancies may not change the course of the current saline shortage, they are important actions for preventing future shortages, avoiding unwanted costs, and saving lives.

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Teething or terminally ill? How communities of practice in healthcare get started and survive (or not).

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Abstract

Communities of Practice (CoPs) are increasingly being used to facilitate knowledge sharing across organisational and professional boundaries. This study aims to refine our understanding of processes of knowledge mobilisation in CoPs. It does so by describing identity reconciliation practices during the early stages of a mandated 'CoP' set up to mobilise process improvement knowledge in healthcare. Our findings reveal three modes of member engagement - 'identification', 'distancing', and 'peripheral lurking' - showing how meanings associated with a 'CoP' and the knowledge being mobilised may play a role in determining how members make sense of their identity in relation to CoPs.

Key words: Community of Practice, Healthcare, Knowledge Mobilisation

Introduction

Healthcare settings around the world are under pressure to increase efficiency whilst improving service quality and patient safety (Poksinska, 2010; Fillingham, 2007; Radnor & Johnston, 2012). One significant response to these pressures has been attempts by policy-makers, healthcare managers and some improvement-focussed clinicians, to promote the use of service redesign methods and techniques proven to be effective in other industries (e.g. Lean thinking and related approaches) (Ben-Tovim et al., 2008; Radnor & Boaden, 2008). However, attempts to mobilise externally derived redesign and process improvement knowledge in healthcare has faced many barriers and challenges associated with a somewhat more complex, multi-stakeholder setting and its associated organisational, occupational and professional boundaries (Kislov, 2018; McNulty & Ferlie, 2002; Oborn et al., 2013). These issues have led to a growing interest in promoting collaborative approaches to bring stakeholders together and to enable knowledge to mobilise across boundaries. One approach which has provided a focus of attention is the idea of 'Communities of Practice' (CoPs) (Li et al., 2009).

However, contradictory accounts of how CoPs form exist in the literature. In seminal works (E.g. Lave & Wenger 1991; Brown & Duguid, 1991), the concept was deployed as an *analytic* tool to understand social learning, identity-formation, meaning and practice in 'organic', uni-professional CoPs. In this view, CoPs must 'emerge' organically. In

more *instrumental* views, CoPs can and should be deliberately established to manage the flow of knowledge and to enhance knowledge-sharing (E.g. Wenger, McDermott & Snyder, 2002). Exploring the tensions between analytical and instrumental views of CoPs is of significant importance due to the growing popularity of promoting knowledge mobilisation through CoPs (Bunger & Lengnick-Hall, 2018; Ferlie et al., 2010). In particular, it raises the question of whether CoPs can in some way be 'mandated' in settings such as healthcare where collaboration is increasingly seen as central to knowledge mobilisation (Ferlie et al., 2012; Nicolini et al., 2016).

Drawing on the analytic approach to CoPs, we sought to investigate the processes by which actors negotiate their simultaneous membership in existing organic CoPs (E.g. professional disciplines) with their 'membership' in new, mandated 'CoPs'. To do so, we undertook a longitudinal qualitative case study of the early stages (first 12 months) of a mandated multidisciplinary, multi-organisational 'CoP', established by policymakers with the aim of mobilising process improvement knowledge across the public healthcare system of an Australian jurisdiction.

The remainder of this paper progresses as follows: First, we define CoPs and discuss their instrumental use in healthcare, highlighting some of the empirical challenges. Next, we introduce our theoretical approach which draws on analytic perspectives of CoPs and focusses on *identity reconciliation* and related *knowledge translation practices* of actors. We then briefly outline the case and our methodological approach before presenting our findings in terms of 3 modes of engagement. Finally, we return to the literature in light of our findings and conclude with practical implications of our findings.

Defining CoPs, and CoPs in healthcare

Lave & Wenger (1991) coined the term 'CoP' in their situated theory of learning. The concept was used to show how newcomers are socialised into professions and crafts by learning *how to be* as much as *what to do*, through legitimate peripheral participation - 'a continuous, active, engaged, situated and identity-forming process' (Cox, 2005). In this view CoPs are highly institutionalised, and professionals automatically belong by virtue of being part of a specific discipline (E.g. doctors, nurses) (Ferlie et al., 2005). They are organic, emergent and cannot be purposefully formed by organisations (Kislov, 2012).

Notwithstanding the origins of CoPs as an analytical device, policy-makers and practitioners have embraced these ideas in more instrumental terms as a means of promoting knowledge sharing (Ferlie et al. 2010; Li et al., 2009). This is particularly so where attempts have been made to mobilise forms of knowledge from outside the sector, such as service redesign and process improvement knowledge (Nicolini et al., 2016).

However, bringing together actors with partially incompatible 'epistemic cultures' (Knorr-Cetina, 1999) is likely to result in members of mandated 'CoPs' facing sticky boundaries in their interactions with actors from other disciplines. Consequent processes of negotiation have implications for how knowledge is mobilised (Ferlie et al., 2010; Kislov et al., 2011; Kislov et al., 2012). In particular, previous research suggests that mobilising redesign and process improvement knowledge is likely to be most challenging in the case of clinicians, especially senior medical clinicians, as a result of strong professional boundaries, their dominant status and the potential for 'epistemic clashes' (Albert et al., 2008; McGivern & Dopson, 2010; McGivern et al., 2016).

While more recent studies have expanded our understanding of the processes involved in the formation of CoPs (E.g. Gabbay et al., 2003; Ferlie et al., 2005; Kislov et al., 2012; Kislov, 2013; Kislov, 2014), most studies of CoPs in healthcare have tended to be analysed in terms of the extent to which they facilitate their intended outcome - the smooth 'transfer' of knowledge (Li et al., 2009; Swan et al., 2016). Relatively little

empirical research has focussed on the specific *processes* that take place when multiprofessional, multi-organisational 'CoPs' are mandated (Kislov, 2012; Pyrko, Dorfler & Eden, 2017). Moreover, most studies of CoPs in healthcare have focussed on clinical rather than management knowledge (McGivern et al., 2016; Swan et al., 2016).

Tracing translation practices

Returning to the tradition of analytic perspectives on CoPs - with *practice* as the starting point, this paper takes the tools of the CoP approach, and practice studies more generally, as a useful lens through which to explore the *knowledge translation practices* actors engage in when brought together in a mandated multi-professional, multi-organisational 'CoP'. This view assumes knowledge to be social, contextual and political and cannot be unproblematically 'transferred' among individuals (Swan et al., 2016). Instead, ideas are assumed to be transformed as they spread (Andersen & Røvik, 2015), and we are led to contemplate why different actors engage with certain forms of knowledge differently under different conditions (Duguid, 2005; Ferlie et al., 2005; Swan et al., 2016).

In Wenger's (1998) account of learning as social participation, it is the negotiation of meanings and identities, in practice, that results in the formation of CoPs as locally negotiated 'regimes of competence' (p. 137). Viewed in social terms, identities are constantly formed and reformed through social participation – both a process of *transforming knowledge*, and a *place* where new ways of knowing are realised in the form of identity. Becoming a CoP member means taking on an identity, and negotiating it through practice, with others.

Competent membership in a CoP involves: 1) the ability to *mutually engage* with other members in interaction that leads to shared meanings, 2) the ability to understand and take responsibility for negotiating the community's *joint enterprise*, and 3) the ability to make use of the community's *shared repertoire* of common resources and language to engage in, and therefore negotiate, practice (Wenger, 1998). To become even a peripheral member, one must be both *able* and *willing* to engage with all three dimensions.

However, politics of participation exist, and the negotiated experience of the self in the context of a 'nexus of multi-membership' in various CoPs involves complex 'reconciliation work', necessary to maintain a livable identity across boundaries (Wenger, 1998). Despite its significance, identity reconciliation happens privately, may not be consciously acknowledged, and is rarely viewed as part of a CoP's enterprise. Thus, it usually remains hidden (Wenger, 1998, 2010) and has rarely been investigated.

Yet processes of identity reconciliation are likely to have significant implications for how knowledge is translated across boundaries. In the healthcare context, with its strong pre-existing professional and epistemic boundaries and complex broader structures of knowledge and power, this 'reconciliation work' is likely to be especially challenging for actors. In particular, clinicians must negotiate their way through a transition which allows them to reconcile their pre-existing clinical identity (in the case of senior medical clinicians, strongly associated with status, autonomy and a host of deeply-held assumptions about care and best practice) with a new non-clinical identity, and maintain both simultaneously. This transition has implications for how knowledge is mobilised and translated in the process (e.g. McGivern et al, 2015), and is likely especially challenging when a 'CoP' is mandated to facilitate the ability of a 'non-profession' (process improvement practitioners) to mobilise 'outside' knowledge and incorporate it into the practice of dominant professional players.

Research design and methods

A longitudinal case study methodology was employed to follow in real-time the 'setting up' of a multi-professional and multi-organisational knowledge mobilisation initiative -

henceforth the 'Emergency CoP'. The CoP was the brainchild of policymakers responsible for healthcare innovation and improvement in the public system of an Australian jurisdiction in which process improvement had been promoted over a number of years, and a cadre of funded and trained improvement practitioners was active within individual health service organisations. In the face of problems spreading and scaling process improvement knowledge, policymakers sought ways to encourage cross-organisational learning with an initial focus on improving access and flow in emergency care.

To this end, the jurisdiction provided administrative support for 12 months, established an online forum, and funded one consultative and three substantive workshops. Policymakers chose improvement practitioners as their primary point of contact with health services, some of whose roles were either currently being funded or had previously been funded by the jurisdiction. They were encouraged to attend alongside frontline clinical staff selected by participating healthcare organisations, mostly ED clinicians from medical and nursing disciplines, usually with some level of managerial responsibility and an interest in the application of process improvement knowledge. Thus, the mandated CoP brought together two types of actor: 'improvement practitioners' with specific responsibility for and expertise in process improvement and 'improvement-oriented clinicians'.

We undertook a qualitative case study which facilitated our exploration of how improvement practitioners and improvement-oriented clinicians worked to reconcile their existing identities with 'membership' in the Emergency CoP, and how in the process they understood, negotiated and translated the service redesign and process improvement knowledge the policymakers aimed to mobilise. Nineteen semi-structured interviews (7 clinicians, 12 improvement practitioners), and observation of the four workshops between May and December 2018 allowed "doings and sayings" (practices) (Nicolini & Monteiro, 2017, p 110) to be captured. We outline our findings under the headings 'identification practices', distancing practices', and 'peripheral lurking practices'.

Findings

Identification Practices

Improvement practitioners who were new to the overall program in the sector or new to improvement roles, and nurses in hybrid nursing/management roles (E.g. Nurse Unit Managers), were most 'hungry' for both the knowledge content and the contacts that participation in the Emergency CoP provided. This group easily reconciled their existing identities with their new membership in the Emergency CoP. In terms of reconciliation practices, they undertook the following. First, they emphasised the lack of community related to process improvement within their home organisations:

If there is anything in the hospital where it's a big meeting for change, I don't know about it. It's not a thing. Maybe that's what government need to mandate. You need to have a department to specifically focus on improvement strategies, pathways, flow. (Participant 9, ANUM)

It's hard to imagine, to rewind two years ago prior to all this collaboration, I can't imagine what it would have been like to work at [my health service] without all of this. Actually, I can imagine because I did spend four months here in 2016, 2015 doing an internship project. (Participant 24, improvement practitioner)

Secondly, they easily articulated the benefits of the CoP and their desire to belong:

I think for me the biggest benefit has been getting to meet my counterparts in all of the other organisations, and then hearing... Yeah just having the opportunity to look

around and see what everyone's doing, what's working, what problems are they facing (Participant 24, improvement practitioner)

That's exactly what this is all about. We can learn from each other… The initiative is fantastic, by the way… and I will be involved with it from here on, I can tell you that. (Participant 9, ANUM)

Finally, they sought to identify with the policymakers' brand, as this had perceived benefits for their own practice of improvement within their organisations:

Maybe I'm wrong but I think that having [the jurisdiction] behind it lends more credence. So therefore other people listen to it more... if we wanted to start this... to get our flow going, having it under the umbrella of [the jurisdiction] gives it more credence. So we can say, "This has come from [the jurisdiction], not from me, not from anywhere else." (Participant 18, NUM)

Distancing Practices

Many improvement practitioners in the CoP had been in the improvement game for an extended period, either as veterans of the jurisdiction's own capability-building program or in outside industries prior to moving into healthcare. They were highly experienced service redesign and process improvement practitioners. Counter-intuitively, this group had the most difficulty reconciling their existing identities as improvement experts with their membership in the new Emergency CoP. This played out in the following ways. First, while they attended CoP meetings and contributed to discussion, 'backstage' they emphasised their membership in existing CoPs of improvement practitioners:

Well, I knew [improvement practitioner from another health service] from my time at department, but ... I don't know that that's just because of that. I think I would have known [him] anyway. I think there's maybe like a mutual respect. I respect that they're doing something. They respect that we're doing something and that forces us to talk. I've got the same relationship with [improvement practitioner at another health service]. Same relationship with [improvement practitioner]. (Participant 27, improvement practitioner)

They also described these existing CoPs as where the 'real' knowledge mobilisation happens, 'backstage' of the Emergency CoP and its formal meetings:

And I was comfortable to say, "I have no idea mate, but I'll try and find out for you." And then my boss and [colleague] were comfortable just to have a chat to [colleague at another health service] over the phone. That's the real Community of Practice. (Participant 27, improvement practitioner)

Second, this group felt under pressure from policymakers. For them, involvement in the Emergency CoP was yet another obligation over which they had little choice:

I am feeling more and more owned and directed by them in a way that's not necessarily of any benefit to me. It's gone from having no interest three years ago and no direction and support to almost, the pendulum swung way too far. Way, way too far... and I think there's more and more of my role in the sector who are feeling exactly the same way... Under pressure and being micromanaged. (Participant 11, improvement practitioner)

Furthermore, they interpreted policymakers' activities as concerned with achieving their own targets rather than genuinely helping to facilitate knowledge mobilisation:

My impression is that they're very KPI driven… it sounds like there's KPIs regarding how many workshops they hold and how many times people go on [the online forum]. (Participant 12, improvement practitioner)

Finally, the 'distancing' engaged in by these improvement practitioners involved simultaneously diminishing the value of the CoP for themselves as competent improvement professionals, and promoting the value of the knowledge for others:

I just don't think it should be geared at me. It needs to be geared at people at the ground... heavily involved in that practice. Because I've heard that guy from [health service] speak several times before. Like I've heard it all before. (Participant 10, improvement practitioner)

Peripheral Lurking Practices

Policymakers expected that senior medical clinicians would be the most difficult to engage. Our findings show, however, that like the improvement veterans, senior clinicians also engaged in contradictory 'frontstage' performances of engagement and 'backstage' distancing. However, our data suggest the underlying motivations of these clinicians differed. In terms of negotiating their existing identities with their membership in the Emergency CoP, they worked to preserve their clinical identities and simultaneously maintain a position as genuinely interested participants in the CoP.

First, whereas the 'veteran' improvement practitioners regarded the increasing levels of improvement activity organised by policymakers to be a hindrance, senior doctors publicly identified with the policymakers' endeavours to mobilise process improvement knowledge in the hope it would improve the operational efficiency of the busy emergency departments they struggled in day to day:

Comparing 5 years ago to today, arriving at work is very different. It feels like we are all in it together. (Senior ED doctor, quoted in field)

Furthermore, while improvement practitioners had 'heard it all before', senior doctors valued the opportunity to hear what was happening in other services and engage with policymakers:

It was interesting to hear how much variability there was and how frustrating it was … and a lot of people saying what we really want from the Department of Health is to say "This is the requirement, so do it." (Participant 19, senior doctor)

Second, while 'veteran' improvement practitioners justified disinterest in the CoP by highlighting their existing expertise and involvement in a community of experts, senior doctors sought to maintain distance from process improvement in their everyday practice:

I think I still haven't really got the hang of PDSA cycles and quality improvement processes and so forth and I'll leave it to others probably. I was going to appoint someone else to run those projects. (Participant 19, senior doctor)

Finally, while senior doctors attended the CoP and engaged actively, 'backstage' they sought to maintain their distance from other disciplinary groups:

In the CoP when I'm asking for advice... sometimes how things are phrased at the exec level is not work as done, they've misinterpreted, or how they imagine how my job

works isn't quite correct. So if I know I'm talking to someone on the shop floor… it adds a bit more authenticity to the advice. (Participant 4, senior doctor)

Discussion

As we have outlined, research to date suggests that mobilising improvement knowledge in healthcare is likely to be most challenging when changes to clinicians' practice are at stake (Currie, Koteyko & Nerlich, 2009; Jorm, 2016; Radnor et al., 2012), especially during top-down intervention (Waring & Currie, 2009). This has been attributed to strong professional boundaries, their dominant status and the potential for 'epistemic clashes' with this outside knowledge and its proponents (Albert et al., 2008; McGivern & Dopson, 2010; McGivern et al., 2016).

In contrast, we found that it was improvement practitioners with 'veteran' experience were the least genuinely engaged in attempting to further mobilise improvement knowledge through a mandated CoP. Less counter-intuitively, improvement 'novices' (newer improvement practitioners and lower status improvement-oriented clinicians) tended to be highly engaged and able to reconcile membership in the Emergency CoP with their existing identities, and no dissonance was observed in their 'frontstage' and 'backstage' performances of 'identification practices'. In contrast, the 'distancing practices' of improvement 'veterans' and 'peripheral lurking practices' of senior doctors were both marked by significant differences in what was said and done within the public forums of the CoP, and what was said and done outwit of this mandated community. We suggest that this pattern can be explained as follows:

First, those relatively new to the world of healthcare improvement were most likely to seek *mutual engagement* with others on the *joint enterprise* of improving access and flow in emergency departments, and to willingly be part of developing the *shared repertoire* of the 'CoP' (Wenger, 1998). As process improvement knowledge suffers legitimacy issues in healthcare, 'CoPs' mandated at the jurisdiction level could be expected to bolster the legitimacy of this type of knowledge and practice, and thus the 'subject position' of those who practice it (Lockett et al., 2012). For improvement novices and lower status clinicians, this top-down support provided them an entry point into the 'regime of competence' of process improvement that they otherwise had little ability to access and negotiate (Wenger, 1998).

As a result, improvement novices emerged as a sub-community for whom the invitation to participate in the 'CoP' was a clear opportunity - a perceived window to *legitimate peripheral participation* (Lave & Wenger, 1991) and an identity which was easily reconciled with their existing one, and would bring them a shared future with those they considered *"leaders in the field" (Participant 22, ANUM)* (Wenger, 1998; Wenger, 2000). Their identification practices set them on an 'inbound' trajectory (Wenger, 1998, p. 154), because the prospect of fuller participation represented a valued future identity. As such, their 'public performances' and 'backstage' accounts were consistent. These already 'willing' participants felt they would be made more 'able' to practice service redesign and process improvement by belonging to the Emergency CoP.

Second, and by contrast, the improvement 'veterans' displayed a contradictory and unexpected set of distancing practices. As was the case with improvement novices, the kind of knowledge being mobilised fit their 'epistemic culture' (Knorr-Cetina, 1999; McGivern et al., 2016). We could expect that support from the jurisdiction in the form of direct 'mandated' support for this type of practice, and the jurisdiction's concerted effort to engage medical clinicians, would make their core day to day work of knowledge brokering easier by also enhancing their 'subject position' and legitimacy (Lockett et al., 2012). We might also expect that they would automatically form the core of the emerging

'CoP' as 'masters' of the practice, and be enthusiastic about socialising newcomers into it (Lave & Wenger, 1991).

However, the 'veterans' diminished the learning value of the Emergency CoP for themselves. They were already the generators and custodians of the 'tacit dimensions' of process improvement knowledge - accordingly, they asserted that they had 'heard it all before' and promoted the value of participation in the Emergency CoP for less experienced 'others' - constructing their own 'expert' identity at the boundary with non-experts (Jenkins, 2000; Lamont & Molnar, 2002). This could be interpreted as an assertion of their jurisdictional claim to ownership over improvement expertise, and therefore epistemic authority (E.g. Kislov, 2014). Furthermore, in the Emergency CoP, the 'ownership of meaning' and thus the ability to negotiate the regime of practice, its meanings, and their position within it was concentrated with the policymakers who the 'veterans' already felt wished to exert control over them. Thus, in negotiating a coherent identity that could incorporate this mandated 'CoP' within their existing 'nexus of multi-membership' in other CoPs, their identity reconciliation work appeared to set them on an 'outbound trajectory' (Wenger, 1998, pp. 155). While policymakers hoped that the CoP might improve this group's *ability* to broker their expert knowledge, the 'mandated' nature of the CoP made improvement practitioners less *willing* to engage in this practice in this setting.

Third, senior medical clinicians were expected by policymakers to be the most challenging group to engage with service redesign and improvement knowledge, but they were surprised at the apparent level of clinical engagement in the Emergency CoP. Despite this, we found that, like the 'veterans', senior clinicians also undertook contradictory 'public' engagement and 'backstage' distancing, unseen by the policymakers. Publicly, senior clinicians presented a 'unified front' with their organisations' improvement team - in itself, unsurprising given that clinicians attending the Emergency CoP were likely open to external ideas. However, they took their 'epistemic stances' (McGivern et al., 2016) backstage. Here, they enacted their attitudes toward management knowledge and practice, and displayed their conviction (and justifications for it) that these were not worthwhile engaging with and developing (McGivern et al., 2016).

The central proposition of Lave and Wenger's (1991) theory of situated learning and legitimate peripheral participation is that learning is about identity change; through peripheral participation, one learns to *be* a member and to participate in a social activity system, which involves being able to mobilise and translate knowledge in ways that make sense to others in that system. Rather than seeking an inbound trajectory to full participation through identification practices as the improvement 'novices' did, or an outbound trajectory through distancing practices as the improvement 'veterans' did in their quest for epistemic authority and autonomy, the senior doctors in this study sought a 'peripheral trajectory'; to maintain their professional autonomy and epistemic boundaries by *lurking at the periphery* (Wenger, 1998, p. 154). As others have found, 'efficiency' discourses implicitly challenge professional discourses, since integrating them potentially allies professionals to managers and in this case, policy-makers (Sanders & Harrison 2008). This has the potential to undermine the traditional autonomy of the medical profession (Cox, 1991; Dent, 1993). Maintaining a peripheral position enabled them to participate in the CoP and keep a finger on the pulse with regard to policymakers' intentions concerning the improvement of emergency care across the jurisdiction, and at the same time protect their highly valued professional autonomy.

Conclusion

Drawing on the analytical CoP approach, we have brought into focus the private and usually hidden work of meaning-making and identity reconciliation, and politics of practice (Wenger, 1998; Nicolini, 2009). We have shown that the meanings different participants attribute to a mandated 'CoP' and the type of knowledge it aims to mobilise may play a key part in determining their modes of engagement, and 'inbound', 'outbound' or 'peripheral' trajectories (Wenger, 1998). Future research might focus on refining the modes of engagement suggested in this study and exploring others (for example using Wenger's (1998) other trajectory types – 'insider' and 'boundary').

In conclusion, if CoPs are to be created to enhance knowledge mobilisation, an element of 'mandatedness' is inescapable. However, the risks associated with formalising knowledge mobilisation may be offset if those who create them anticipate the politics of participation that will inevitably emerge as people work to reconcile their existence in a 'nexus of multi-membership' in various CoPs.

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Alleviating service fragmentation with inter-organizational interfaces

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Abstract

Service integration is considered essential in order to provide efficient and customer oriented health and social services. However, particularly inter-organizational integration is found to be challenging due to e.g. the diverse aims of different organizations. Interfaces in modularity are elements that ensure fluent compatibility of service components and collaboration between people. The aim of this study is to analyze whether interfaces can support the inter-organizational integration. Interviews were conducted from the service process for Down syndrome children in the Netherlands and elderly care from Finland. Although, inter-organizational interfaces were found, they seem to be scant and problematic.

Keywords: Integration, Interfaces, Healthcare

Introduction

Development requirements in healthcare are increasing due to the e.g. decline of public economy and customers' rising expectations. The public sector has been accused of being fragmented (Kodner, 2009) and thus inefficient (Nolte et al., 2012). In order to provide value for money, healthcare providers are expected to increase the cost effectiveness of their services. Furthermore, customers are increasingly expecting more customer orientation and patient-centered care (Singer et al., 2011). One solution to decrease inefficiency and enhance customer orientation is argued to be service integration. Despite

the consensus that service integration supports e.g. effective use of resources, high quality outcome and patient satisfaction (Berwick et al., 2008; Suter et al., 2009), service integration has been challenging to achieve in practice (Busetto et al., 2016; Kodner, 2009). This has been particularly the case for complex health problems in which services are produced over longer period of time by multiple providers from different organizations.

Modularity has the potential to support integration as it is said to bring better manageability, and thus better efficiency to complex systems (Bask et al., 2010). From the customer perspective, modularity is said to bring variety and possibility to flexibly combine customized service packages (Pekkarinen & Ulkuniemi, 2008). Interfaces in modularity are key elements to enable flexible compatibility of components (Bask et al., 2010; De Blok et al., 2014). The extant literature does describe some classifications for framing interfaces (see e.g. De Blok et al., 2014; Broekhuis et al., 2017; Spring & Santos, 2014) while the literature still remains scarce. For example, the inter-organizational challenges related to interfaces, pointed out by Vähätalo (2012), continue to be a rather unexploited perspective (Peters et al., 2018a). Thus, more research is needed to recognize and analyze interfaces in inter-organizational settings as well as to analyze whether interfaces can alleviate the challenges of fragmented services and support service integration.

In our paper, we build on the work of de Blok et al. (2014). Moreover, we bring the inter-organizational perspective in the interface discourse in the healthcare setting. We base our empirical findings in data collected from Down syndrome care in Netherlands and homecare for elderly in Finland.

Theoretical background

Interfaces in service modularity

The concept of modularity and our understanding of modules can be underpinned thought three design principles, namely 1) specific function, 2) relative independence, and 3) standardized interfaces (e.g. Rajahonka et al., 2013; Peters et al., 2018a). Since services are mostly consumed over a longer period of time and customers' needs and requirements might change frequently (Voss & Hsuan, 2009) it is important to enable rearrangement of services. Interfaces have an important role in compatibility of modules and (re)configuring the service. Because the main focus of this study lies upon health services, we use the definition of interfaces provided by De Blok et al. (2014). They defined interfaces as: "The set of rules and guidelines governing the flexible arrangement, interconnections, and interdependence of service components and service providers" (p. 186).

Although the literature concerning interfaces is scarce, some classifications can be recognized from the extant literature (Peters et al., 2018a) e.g. Broekhuis et al.'s (2017) and Spring and Santos (2014). The most comprehensive classification is presented by De Blok et al. (2014) and applied, for example, by Soffers et al. (2014). The typology by De Blok et al. (2014) is based on two dimensions, interface entity and interface aim. The interface entity refers to the decomposition level – components and services providers – while the interface aim can be either providing coherence or variance (De Blok et al. 2014). Broekhuis et al. (2017) go one step further and point out the way in which the interface design process is affected by the heterogeneous nature of different disciplines and professions they represent. However, the inter-organizational perspective remains unexploited in these studies. Furthermore, there is no studies analysing what possible links exists between the concepts of healthcare integration and interfaces described in operation management literature.

Integrated patient care

Social and health services have been accused of being fragmented (Nolte et al., 2012). Fragmentation causes ineffectiveness, and thus expenses resulting in low customer satisfaction and low outcome quality (Kodner, 2009). Integration of services is often is often put forward as the opposite of service fragmentation (see WHO 2016). Depending on the discourse and discipline, integrated services can be called synonymously as seamless care or coordinated care, among others (WHO, 2016; Zonneveld et al., 2018). Similarly, there are multiple definitions for integrated care depending on the context and purpose of the studies (WHO, 2016; Singer et al., 2011; Kodner, 2009; Kodner & Spreeuwenberg, 2002). Since we address the fact that health services are typically produced by multiple providers over a long period of time, we follow Singer et al. (2011) and define that in integrated services, patient care should be "coordinated across professionals and facilities, tailored to the patients' needs and preferences and based on a shared responsibility between patient and caregivers for optimizing health continuous over time" (p. 113).

The extant literature recognizes integration at different levels. For example, Valentijn et al. (2013) identify integration at system, organizational, professional and clinical level. The extant literature reports challenges at different levels. For example, challenges related to divergent organization culture (Kodner & Spreeuwenberg, 2002), bureaucratic structures, funding mechanisms (Browne et al., 2004), information transfer (Manser et al., 2010) and contractual relations (Valentijn et al., 2013) can complicate the integration at organization level, whereas challenges at the professional level are likely to be related to lack of shared language and divergent healing paradigms (Valentijn et al. 2013; see also Broekhuis et al., 2017). Care processes in complex health problems typically consist of professionals from different disciplines representing different organizations (Valentijn et al., 2013). To conclude, not only professional but also organizational related challenges complicate the service integration in complex care settings.

Interfaces in integrated patient care

This section creates a conceptual synthesis and explicates the link between the definition of integrated care (Singer et al., 2011) with the interface typology presented by De Blok et al. (2014) (table 1). In doing so, we address the theoretical linkage between these two discourses and create a background for our empirical data analysis.

Coordination across professionals and facilities. According to Singer et al.'s (2011) coordination refers to the interaction across professionals or across organizations with the aim to deliver consistent and informed patient care. They mention that the coordination of care often seeks to achieve automation, efficiency and simplicity. Moreover, coordination aims to deliver consistent and informed care (Singer et al., 2011). This definition brings coordination close to the concepts of coherence applied by De Blok et al. (2014). Based on Singer et al.'s (2011) definition of coordination and the interface types introduced by De Blok et al. (2014), a link towards two types of interfaces can be recognized: C-I interfaces and C-C interfaces. C-I interfaces are interfaces that support coherence and unity among people (De Blok, 2010), while C-C interfaces support coherence in a service package among components (De Blok, 2010). Both types of interfaces diminish the amount of information exchanges needed, since the interactions between people or components can be prescribed via these types of interfaces (De Blok, 2010). Based on the ability of both interface types to provide predictability and coherence a link towards coordination can be recognized.

Tailored to the patients' needs and preferences. Tailored to the patients' needs and preferences' is supported by a good communication between the service provider and the patient (AHRQ, 2011). Taking the patient's preferences into account refers to personalization (De Blok et al., 2013) of the services and thus describes the process of the services. When a good relationship can be developed or is built the assessment level linked to customer needs and requirements will increase, which could effectuate customization (De Blok et al., 2013). An interface type that can support this process is an O-I interface, since these interfaces allows for the recognition of (changes in) patients' needs and makes requirements possible (De Blok et al., 2014).

Shared responsibility between patient and caregivers for optimizing health. Shared responsibility can be supported by O-C interfaces (Peters et al., 2018a). A service provider together with, for instance a customer, may indicate some desired changes. When the desired changes are indicated, O-C interfaces can support this adaption process, since these interfaces provide a structure that enables the combination and recombination of component variations (De Blok, 2010). In the end, this structure can support the extent to which the customer, his/her family members, and other caregivers are obtaining information and are involved in, for instance, making healthcare decisions.

Table 1. Interfaces in integrated patient care

Interface type (De Blok et al., 2014)	**Between**	**Integration (Singer et al., 2011)**
O-I	Provider	Tailored to patients' needs and preferences
C-I	Provider	Coordination across professionals
O-C	Component	Shared responsibility between patient and caregiver
C-C	Component	Coordination across facilities

It can be concluded that more research is needed to recognize and analyze interfaces in inter-organizational setting in health and social services as well as to analyze whether interfaces can alleviate the challenges of fragmented services and support their integration. Our study builds on the comprehensive conceptualization by De Blok et al. (2014), and supports the work of Peters et al. (2018b) to address the inter-organizational perspective with regard to interfaces in service modularity. Therefore, the research questions are as follows:

1. How can we describe the interfaces in the provision of multidisciplinary care context?
2. How can interfaces be improved in order to support service inter-organizational integration of services?

Methodology

This study examines interfaces in two different case contexts, home care for elderly (Finland) and children with complex disease, Down Syndrome, (Netherlands). Data is collected by interviewing multidisciplinary teams/networks (i.e. public, private and NGO providers) operating in these contexts as well as the end users. The data from Netherlands (N=15) was collected during 2018 and from Finland (N=20) spring 2019. Due to the scheduling, only tentative findings from comparative analysis is presented. Comparative case study provides wide perspective to interfaces in diverse contexts and different service systems.

A semi-structured interview approach was applied which enabled a combination of addressing topics that have to be covered while leaving room for respondents to tell their

own story (Boeije, 2006). The interviews were based on the theoretical framework of this research. First, network analysis was conducted based on the interviews. Second, deductive content analysis were used to identify de Blok et al.'s (2014) classification and third, data were analysed to find suggestions to improve integration.

Results

Interfaces

We present results of the multidisciplinary healthcare provision for children with DS in the Netherlands and elderly care from Finland. Implicitly, we take a modular perspective and build on previous research in this context (Peters et al., 2018b). Various examples of interfaces were recognized and, as mentioned in the theoretical background section, we classify them according to the typology developed by de Blok et al. (2014) (Table 2).

Table 2 Interfaces in case context

	Down syndrome	Elderly care
Open-information interfaces	Continuous need, preference, value, and capability assessment • Coordination of information between healthcare professionals within the Downteam by the pediatrician and the orthoptist • Electronic patient file • Multidisciplinary team meetings • Medical history • Short communication lines between healthcare professionals of the Downteam • Warm transfer of information between the pediatrician and intellectual disability physician	Continuous need, preference, value, and capability assessment • Multidisciplinary team meetings (within public providers) • Electronic patient file (within public providers) • Phone calls among providers • Unformal progress book in customers' home
Closed-information interfaces	• Electronic patient file • Dedicated specialists • Work schedule • Work division	• Care plan (each provider their own) • Work schedule • ERP system (public provider) • Structured data entry (public provider) • Unformal progress book in customers' home • Structured evaluation practices (MMSE, ADL etc.)
Open-customer interfaces	• Protocols (e.g. protocol for children with DS, protocol of the audiology assistant with a focus on children with a disability)	• lists of different professionals within organization, • lists of providers from private/NGO sector • associations providing voluntary services/help

Closed-customer interfaces	• Planning rules/scheme	• Work scheme • Process describtions (within public sector)

To illustrate the interfaces found from DS and home care for elderly and to illustrate the table 2, we next provide some examples.

Closed-customer interfaces (coordination across the facilities). In Down Syndrome care C-C interfaces enable the arrangement of components, to ensure that components work together in a predictable way and overall coordination of services is covered. The planning scheme leading to a convenient order of the modules and the consultation scheme for a particular day are clear examples of C-C interfaces. These schedules are structured in such a way that a continuous flow of patient is created by matching the agreements of the various healthcare professionals involved: "For the eye drops to kick in, it takes about three quarters of an hour. In the meanwhile, another member could provide his consultation, making sure that the patient doesn't have to wait" (Opthalmologist). This ensures that the patient 'flows' smoothly through the system.

In elderly home care customers' had an individual care plan that guided the care. Care plan was highly structured and well established among public provider and less so among private and NGO providers. Public providers also had process descriptions that concerned all home care teams in the city. These C-C interfaces aimed for standardization and predictability of care.

Open-information interfaces (Tailored to patients' needs and preferences). O-I interfaces create a structure so that the healthcare professionals are brought together. The multidisciplinary team meeting serves as an example of this type of interface, as it allows the professionals to discuss the outcomes of their individual consultations. The gathered information of all the disciplines involved is discussed and leads to a joint outcome. Moreover, O-I interfaces were identified by means of the request for help that is asked at the start of every consultation: "I naturally start asking how things are going and if there are any questions" [Pediatrician]. Within the elderly home care multidisciplinary team meetings were organized typically within public providers. Information transfer was mainly organized via EPR within public provider and by phone calls across the organizations.

Inter-organizational integration

We recognized and analyzed interfaces in an inter-organizational setting in health and social services. Our empirics show that interfaces were at play at different levels: 1) between providers within the same organization (intra-organizational) and 2) between providers across organizations (inter-organizational) and 3) interaction between providers and customers. Despite the importance of interfaces between providers within the same organization as well as interfaces between providers and customers introduced e.g. by Springer and Santos (2014), we focused on integration between providers across organizations and the interfaces related to it. Next, we will elaborate examples of challenges related coherence and variety of services across organizations and how these challenges influence integration.

Integration between professionals from different organization refers to the interaction between service providers across organizations in order to deliver consistent and informed patient care. In this setting, it is especially of importance to focus on retrieval and exchange of information, as this is often lacking (Dobrzykowski and Tarafdar, 2015). The respondents of our study mentioned a number of situations were inter-organizational integration were jeopardized by poor collaboration and information transfer. We

classified these situations under the typology of De Blok et al (2014) and pointed out interfaces that could possibly enhance the integration of services (Table 3).

Improvements linked to the coordination between professionals from different organizations. Inter-organizational interfaces recognized in this study were, for example, achieved by means of face-to-face contact, a formal letter, mail contact, or a phone call. First, a C-I interface like mail contact is applied between the pediatrician and general practitioner (GP), when information is necessary about the medical history of the patient. Hence, this information is not readily accessible, since the EPF of the GP is not accessible for the pediatrician. One way of addressing this is by means of delivering the service by the same service provider, each and every time. We identified this as a C-I interface. This interface leads to a continuous caring relationship between a service provider and a patient. It can be achieved by concentrating the yearly consultation in the hands of preferably one or a few service providers. Due to this concentration, a service provider can be more effective in managing the chronic and complex conditions and monitor the (long-term) development of the patient (Cabana & Lee, 2004). In the end, this will lead to more familiarity with the medical history of the patient.

Similar challenge related to medical history occured in elderly care where only public sector providers had access to EPF. Private providers or voluntary workers had no access to medical history. Furthermore, inside the public sector data entered by social workers was classified and not accessible for healthcare workers.

Improvements linked to tailoring services according to patients' preferences. Related to DS case the interactions between the service providers of the multidisciplinary team and the service providers from primary care (e.g. physiotherapist, speech therapist) was considered poor. However, by means of the creation of an O-I interface, a situation can be created in which the needs, preferences, and capabilities of the patient are known prior to the consultation in DS case. Communication tools such as email formats can constitute these O-I interfaces. Although for this type of exchange of information, a secure transfer of information is compulsory and no specific consent from parents is required. This is based on the main rule of the Medical Treatment Contracts Act (WGBO) in the Netherlands: "Doctors must have permission from the patient for providing information to third parties. This explicit permission does not apply to care providers who are directly involved in the execution of the treatment agreement. They may receive relevant information from the treating physician with the patient's 'supposed consent'" (KNMG, 2018). If these interfaces are arranged, more stable and well-arranged communication lines can be achieved. In elderly care all providers were mainly responsible for re-configuring the services package of their own while the coordination of entire service entity was elderly's duty. If changes in customers' needs were detected by provider (that weren't related to provider's own service) it was on provider's to consider whether they informed other providers. Furthermore, formal care plans were conducted particularly by home care providers from public sector. These care plans were not, however, communicated e.g. with third sector provider who organized day care for elderly once or twice a week. Thus there were missing goal-orientation across the providers.

Improvements linked to the coordination between services offered by different organizations. Based on the analysis it seemed that interactions between service providers take place on the basis of professionals' work experiences, but not substantively on the basis of protocols or guidelines. As a result, service providers have expectations about obtaining certain information of other service providers that is incorrect. This can lead to incomplete information. Therefore, it should be clear what every service provider is doing, when he is doing it and why is doing it. One way of addressing this issue is incorporating planning rules and planning schemes (C-C interfaces) among service

providers. In elderly care service discription were not shared across the organization and thus overlapping and confusion about service content occurred.

Improvements linked to shared responsibility. With regard to O-C interfaces, a situation exists where interactions between healthcare professionals take place on the basis of professionals' work experience, but not substantively on the basis of a clear C-C interface. This shows that professionals can have expectations about obtaining certain information of other professionals that are incorrect: "You are not aware of the kind of activities that other disciplines perform" [ENT-doctor]. Next, there is little interaction between the members of the DS multidisciplinary team and the specialists from primary care (e.g. physiotherapist, speech therapist). This could lead to situations where the needs, preferences, and capabilities of the patient are unknown prior to the consultation. Both the healthcare professionals as well as parents express this: "There is actually no contact between our own speech therapist and the speech therapist of the Downteam. When we visit the various disciplines of the Downteam, we have to explain what our own speech therapist is working on" [Parent] and "I often only hear during the consultation whether the child has had speech therapy and if there is any possible information available from this speech therapist" [Speech therapist]. If the medical history is known in advance, healthcare professionals are able to prepare their consultation even better. In elderly care providers had not enough knowledge about services available. For example, loneliness was a common challenge among elderly while care workers had not knowledge about all the services alleviating loneliness.

Table 3 Examples of observed challenge and potential interfaces

Interface	**Observed challenge in integration**	**Potential interface supporting integration**
C-I	No tools to pass information to providers across the organization	• National protocol for information sharing • Limited number of workers for each customer
C-C	Interactions between service providers take place on the basis of experiences, not on the basis of protocols	• Planning rules • Planning scheme
	Not enough knowledge about other providers services -> causing overlapping	• Clear description of service content from each provider
O-I	No common goal for care across the providers	• Multidisciplinary care meeting • One care plan available for each providers
	Little to no information exchange with primary care service providers	• Well-arranged communication lines between the primary care service providers and the service providers of the multidisciplinary team
O-C	Poor variability of services/Not enough information about providers and their services available	• List of providers and their services available
	Missing service architecture	• The provision of a service architecture in which the modules

		and components of the involved service providers are shown

Conclusion

Based on our findings, we assume that interfaces can enhance integration on three levels: integration between professionals within the same organization (intra-organizational), integration between professionals from different organizations (inter-organizational). Although the typology by de Blok et al. (2014) provided a useful framework to scrutiny the interfaces in healthcare, it does not entirely capture the different levels that are in play in the type of health and social services that we were examining. In this study, we mainly concentrated on inter-organizational challenges which seem to be more severe than others. We point out that by improving inter-organizational interfaces, integration in healthcare can be improved.

Barriers to integration at service provider levels are recognized previously e.g. by Valentijn et al. (2013). Similarly, challenges related to interface design process are studied by Broekhuis et al. (2017). However, based on the results of this study, additional challenges in integration are likely to occur if providers represent different organization. This finding is in line with previous studies (Valentijn et al., 2013), who reported challenges in integration related to inter-organizational settings. Since most care paths cross organizational boundaries, it is important to study inter-organizational integration and how it can be inproved.

Similarly as in previous studies, we recognized interfaces related to components and providers (e.g. de Blok et al., 2014; Spring and Santos, 2014). However, unlike previous studies we argue that, simultaneously, interfaces can be separated to exist both within and across organizations. This study bridged two discourses from different disciplines, namely integrated care and interfaces as a part of the service architecture. We pointed out the connection and the way in which well-defined interfaces can support service integration. Inter-organizational interfaces have the potential to support not only efficiency of the service process, but also customer orientation of the services.

In inter-organizational settings, coordination of service providers and service components is challenging (Dobrzykowski & Tarafdar, 2015) as the number of components is relatively high and responsibilities are shared between several autonomous providers. Furthermore, different organizations might have e.g. different resources and practices (Valentijn et al., 2013). Therefore, as a practical contribution we suggest to pay attention to inter-organizational interfaces in order to enhance the integration at the organizational level. To conlude, we suggest that interfaces can be seen as means to improve inter-organizational integration in the context of complex services..

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Inter-firm relationships in supply chains in health care. Evidence from an extensive survey

Keywords: Satisfaction; Mediation model; Health care supply chain

Topics: Healthcare Operations Management; Managing Inter-firm Relationships in Supply Chains; Operations in the Public Sector

Word count: 995

Purpose

Improving hospital supply chain performance has become increasingly important to improve operational efficiency and to reduce cost, particularly in public systems. Hospital supply chains are unique and different from the typical industrial supply chains in many aspects; nonetheless there is still a lack of theories developed with specific considerations of this sector (Chen et al 2013). This paper aims to investigate SC inter-organizational relationship, identifying the determinants that mostly impacting on customer satisfaction in health care.

Research design and methodology

Literature deeply investigated the link between relationship quality, that is *a relational outcome and an overall means of assessing the strength of a relationship between two firms* (Caceres and Paparoidamis (2007)), and service quality. In particular, relationship quality may be influenced by service quality, even though service quality can be considered a necessary but not sufficient, condition for relationship quality (Crosby 1990). Given this premise, the first hypothesis tested is the following:

H1: Service quality has a positive impact on relationship quality.

A great body of literature has focused on the determinants of customer satisfaction, and in particular, some scholars have analysed the relationship between service quality and customer satisfaction (Caceres and Paparoidamis (2007)). Although this relationship has been investigated in both directions, the majority of findings showed how service quality can be considered as an antecedent of customer satisfaction (Dick and Basu (1994); Cronin and Taylor (1992)). In fact, […] *quality is one dimension on which satisfaction is based* (Rust and Oliver, 2000). Therefore, our second hypothesis is the following:

H2: Service quality has a positive impact on overall customer satisfaction.

Wulf et al. (2001) suggested how an improvement in relationship quality generates a higher level of satisfaction, trust, and commitment. Therefore, considering the first two hypotheses

and the potential impact of relationship quality on overall customer satisfaction, we propose the following third hypothesis:

H3: Overall customer satisfaction is influenced by service quality and relationship quality, even though relationship quality plays the main role.

The analysis has been performed in a large Italian region (Tuscany) where a unique single public organisation (Estar) is in charge to provide integrated supply chain services to all the hospitals of the in the Tuscan healthcare system.

Following the suggestion proposed by Terpend et al. (2008) and Ulaga and Eggert (2005), we conducted the analysis for intermediary and end-users.

Estar customers can be divided in two groups: those who have direct contacts with Estar in managing SC related activity (intermediaries), and those who use the product provided by Estar (the end users).

In fact, there may be that customers, with different needs, and engaging in different kinds of relationships with the supplier, evaluate and weight differently the dimensions that determine the overall customer satisfaction. In particular, we tested for the presence of a moderation effect played by the customer typology on the impact of service and relationship quality on the overall customer satisfaction.

Then, a mediation model has been applied, testing the aforementioned hypotheses, investigating which dimension, among service and relationship quality, mostly impacts on the overall customer satisfaction with supplier performance.

The analysis is based on a survey administered via CAWI (Computer Assisted Web Interviewing) to all professionals of the Tuscan health system who directly or indirectly interact with the supplier in their daily work activities (in total 2,154 health professionals). The response rate was 31%.

Findings

The moderation model showed how different customers perceive relationship quality as differently influencing (in magnitude) their overall satisfaction. This result was also confirmed by the mediation analysis, that showed how for intermediaries, both relationship quality (OR 7.52) and service quality (OR 1.53) are relevant for the determination of their overall satisfaction with supplier performance, even though relational aspects are more significant, compared to service aspects. Whereas, end users' overall satisfaction is fully mediated by relationship quality aspects (OR 24.51), and service quality dimension (OR 1.51) is not statistically significant in determining overall satisfaction.

Relevance/contribution

This study contributes to the literature because it deals with an under-investigated topic in the inter-organizational research field, that is the determinants of business customer satisfaction (Mustak et al. 2013) in a dyadic public sector context. Indeed, differently from previous public sector studies that focused on network relationships, our paper proposes an empirical analysis on a dyadic supplier-customer relationship in the health care supply chain context.

1. Introduction

Since 90s customer orientation has become one of the main priorities in the public sector. In particular, the customer perspective started to be considered in the designing and provisioning of the service (among others Diefenbach (2009); Dunleavy et al. (2006); Kaboolian (1998); Pollitt (1993); Pollitt & Dan (2011)). In fact, the customer voice (even internal) was deemed fundamental in order to improve the service quality provided by the public entity (Pollitt and Dan (2011). Also in governance networks scholars deeply investigated how to detect and measure the user experience with the service provided by the public organisation remains a key aspect (Klijn, 2008; Klassen, Cepiku and Lah, 2017). Moreover, in the inter-organizational context how to measure and use the customer voice is an issue both in public and private sector where customer voice is considered as a proxy of the value created during the relational exchange between the two parties (Mustak et al. 2016).

Value is a key construct that since 90s has been at the centre of the marketing debate among researchers and practitioners. Scholars have investigated this concept both in business-to-consumers and business-to-business contexts. Irrespectively of the specific context of investigation, scholars agree on the utilitarian nature of value, meaning that the value for customer is the results from an evaluation between benefits and sacrifices. For example, Anderson et al. (1992) defined value in business-to-business contexts as *the perceived worth in monetary units of the set of economic, technical, service and social benefits received by a customer firm in exchange for the price paid for a product offering, taking into consideration the available alternative suppliers offerings and prices*. More generally, we can say that customers derive value according to the difference between the 'utility' provided by attributes of a product and the 'disutility' represented not only by the price paid, but also by time, effort and search experienced by the parties (Sánchez-Fernández and Iniesta-Bonillo, 2007).

Very close to the concept of value is the one of *perceived value*, that is the worth for customers, as a result of an evaluation of what they give compared to what they receive. Hence, perceived

value implies a relational exchange between two parties, where each party gives up something of value in return for something of greater value (Holbrook, 1999).

Several studies investigated the conceptual differences between perceived value and customer satisfaction (among others Boksberger and Melsen (2011); Eggert and Ulaga (2002); McDougall and Levesque (2000)). What scholars agreed upon is that perceived value is a cognitive construct, that may arise both during the pre and the post-purchase phase, both for the actual and the potential customer, who evaluate either the actual supplier offering or the potential one. On the other hand, customer satisfaction is an affective construct, that arises during the post-purchase phase only, and consists in an evaluation of actual supplier's offerings (Eggert and Ulaga, 2002).

Since 90s, traditional marketing faced the emergence of a new paradigm, i.e. the relationship marketing (Ravald and Grönroos, 1996). *The core of relationship marketing is relations, […], and the idea is first to create customer loyalty so that a stable, mutually profitable and long-term relationship is enhanced.* In this new reference framework, *value is considered to be an important constituent of relationships*, […] and o*ne recent research stream in marketing is related to customer perception of value created in on-going relationships. In transaction marketing, this solution is a product in the form of a physical good or a core service. In relationship marketing the solution is the relationship itself and how it functions and leads to value creation and need satisfaction for the customer* (Grönroos, 2004).

In the last 20 years, a consistent body of research in the marketing field has investigated the relationships between perceived value, customer satisfaction, relationship quality, and performance. For example, McDougall and Levesque (2000) analysed the factors influencing customer satisfaction, identifying relational quality and perceived value as determinants of satisfaction. Lam et al. (2004) built a model investigating the relationships between customer value, customer satisfaction, switching costs and customer loyalty.

Another stream of research studied how to evaluate the performance of inter-organisational relationships, often stressing the importance of the relational dimension as a key determinant of the overall relationship performance. Giannakis (2007) proposed a framework for the assessment of the performance of supplier relationships, applicable both to the manufacturing and services contexts. This model took into consideration both the supplier and the customer perspectives, measuring their perceptions related to the nature of the relationship, the relational performance of the other party and their own relational performance. Provan and Sydow (2008) provided an overview of how inter-organisational relationships have been evaluated by scholars. They concluded that inter-organisational performance may be measured according to three different levels, i.e. structure, process and outcome. Moreover, they found out how the majority of studies took into consideration either the organizational level or the inter-organisational network as unit of analysis. In the public sector, few attempts have been made to investigate the performance of inter-organisational relationships in the supply chain context (McKone-Sweet et al. (2008); Lai et al. (2002)). One of these is the work proposed by Lega et al. (2013) who developed a framework for the evaluation of the supply-chain performance in the healthcare sector. This was a multi-dimensional framework that considered operational cost, financial benefits and organisational benefits as levels of measurement. The organisational benefits comprehended the evaluation of supplier relationships. Similarly, Ulaga and Eggert (2006) identified benefits and costs building the relationship value dimensions. Among the benefits, they mentioned service support and personal interaction as dimensions characterising the relational aspect, in addition to more traditional dimensions characterising the service quality aspect (product quality and delivery performance).

Therefore, performance evaluation of B-to-B relationships should consider not only service quality aspects, but also customers' and suppliers' mutual perceptions related to the quality of the relationship. Indeed. as stated by Cannon and Perreault (1999), *customer evaluations of*

supplier performance and satisfaction with relationship represent important outcomes in business exchange. Benton and Maloni (2005) investigated the relationships between service outcomes, relationship quality, supplier satisfaction and relationship performance, both from the customer and the supplier perspective in the automobile sector. They discovered how the positive effect of service quality outcome on supplier satisfaction was completely mediated by the effect of supplier-buyer quality of relationship. This finding implies that in assessing overall performance of a relationship, what is most important is the relational dimensions, rather than the service outcome.

In this paper, we will investigate the relationship between service quality, relationship quality and overall satisfaction with the supplier performance, as perceived by the customer in a public context. To the best of our knowledge, scholars have mainly focused on performance evaluation of relationships in the private sector. Whereas, studies on the public sector moved away from a dyadic perspective, taking into consideration the performance of the network, especially through a collaborative governance approach (Cepiku (2017); Montoya et al. (2015); Provan and Milward (1995)). As an attempt to start filling this gap, our work will focus on a B-to-B dyadic supplier-customer relationship in the healthcare sector. Moreover, in this paper, we acknowledge that different typologies of customers may experience different perceptions on the relationship performance with the supplier, since different customers have different needs and different expectations. Therefore, we will conduct the analysis considering that the supplier establishes different relationships with different customers. This distinction also answers to the call of Ulaga and Eggert (2005) and Terpend et al. (2008) to consider contextual dimensions (such as the type of industry, the nature and intensity of the relationship, and the category of product or service under consideration), when analysing the B-to-B relationships.

Hence, in this article we first analysed whether or not service and relationship quality have a different impact on the overall customer satisfaction, also by taking into account the typology

of customer. Finally, through a mediation model, we investigated the relationship between service quality, relationship quality and overall satisfaction with the supplier.

2. Research design

2.1 Hypotheses

Relationship and service quality are constructs deeply investigated by scholars as key determinants for the overall customer satisfaction, along with trust, commitment, loyalty long-term orientation and power (among others Giannakis (2007); McDougall and Levesque (2000); Brown et al. (1995); Michie and Sibley (1985)). Therefore, we investigate B-to-B relationships between the healthcare supplier and the health professional customers, focusing on a public context, the Tuscan healthcare sector, rather than on a private one, as analysed in the work by Benton and Maloni (2005). In particular, we focused on the customer perspective, trying to understand what aspect is more relevant when the customer evaluates supplier performance. In other words, we investigated what determinant is mostly impacting on overall customer satisfaction.

Researchers in relationship marketing, deeply investigated the relationship between relationship quality, that is *a relational outcome and an overall means of assessing the strength of a relationship between two firms* (Caceres and Paparoidamis (2007)), and service quality. In particular, relationship quality may be influenced by service quality, even though service quality can be considered a necessary but not sufficient, condition for relationship quality (Crosby 1990). Given this premise, the first hypothesis we tested is the following:

H1: Service quality has a positive impact on relationship quality.

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satisfaction (Caceres and Paparoidamis (2007)). Although this relationship has been investigated in both directions, the majority of findings showed how service quality can be considered as an antecedent of customer satisfaction (Dick and Basu (1994); Anderson at al. (1994); Cronin and Taylor (1992)). In fact, […] *quality is one dimension on which satisfaction is based* (Rust and Oliver, 2000). Therefore, our second hypothesis is the following:

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Wulf et al. (2001) suggested how an improvement in relationship quality generates a higher level of satisfaction, trust, and commitment. Therefore, considering the first two hypotheses and the potential impact of relationship quality on overall customer satisfaction, we propose the following third hypothesis:

H3: Overall customer satisfaction is influenced by service quality and relationship quality, even though relationship quality plays the main role.

Moreover, following the suggestion proposed by Terpend et al. (2008) and Ulaga and Eggert (2005), we separately explored this model for intermediary and end users. In fact, there may be that customers, with different needs, and engaging in different kinds of relationships with the supplier, evaluate and weight differently the dimensions that determine the overall customer satisfaction.

2.2 The supply chain in the Tuscan healthcare system

In this paper, the focus of analysis will be the relationship between the public organisation that is in charge of the logistic service provisioning in the healthcare system of the Tuscany region, and health professionals who relate with it. Since 2015, all the logistic activities in the Tuscan healthcare system are carried out by a single organisation, called Estar, that has its own

independence on administrative affairs, legal personality, management and accounting. Estar represents a unique experience in the Italian panorama, since it is not only in charge of the purchasing activities, but it has also to guarantee an integrated supply chain in the Tuscan healthcare system (CERGAS 2017). In addition to the logistic activity, Estar is also responsible for the organisation and fulfilment of the personnel recruitment and payment, public tendering, and information and communication technologies (ICT).

As regards the logistic activity, Estar is in charge of the provisioning of several products, such as medical drugs, medical diagnostic devices, personal protection devices and administrative stuff and it became the unique supplier for all the healthcare authorities for the majority of products. Among the customers we find a plethora of different subjects (nurses, physicians, pharmacists, administrative staff, other health professionals, engineers, etc.), that can be divided in two groups, i.e. one composed by those subjects who have direct contacts with Estar, and those subjects who use the product provided by Estar, even if not interfacing directly with it. These two groups can be defined as the intermediaries and the end users, respectively. More specifically, intermediaries are in charge of the product ordering, whereas the end users are those who only use the products in their daily work activities. In the provisioning of the products, Estar has to guarantee not only service and product quality, but also support in managing the ordering procedure, in case the intermediator needs it. The latter aspect may be defined as the relational dimension, i.e. Estar has to be able to establish a good relationship with its customers, which entails being available when needed by the customer, and provide adequate answers to the customers' requests.

2.3 Sample and data collection

The questionnaire was developed in collaboration with experts of Tuscany Region Health System as well as Health Authorities (HAs) and Estar professionals. The questionnaire was aimed at collecting and analysing the customers' experiences (HAs) with the services provided

by the supplier (Estar). In particular, in this article we will focus on a specific service: the logistic. The logistic section consists of 12 questions aimed at understanding the customer satisfaction in relation to both the service and the relationship quality.

The questionnaire was tested with some HAs' professionals in October 2017, and then administered in November 2017, via CAWI (Computer Assisted Web Interviewing) to all professionals who directly or indirectly (see in the paragraph 3.1 the details) interact with the supplier (Estar) in their daily work activities for a total of 2154 health professionals. The survey was opened for one month and a half to fill in the questionnaire. During this time period, two remainders were sent. Results were collected through the web-based software "LimeSurvey", and were then analysed in aggregated form using Stata 12.

The overall response rate was about 31%, that is coherent with response rates of other online surveys (Cook and Thompson (2000)). In particular, among the total number of respondents, we took into consideration only those health professionals who, during the last year, utilised, directly or indirectly, the services provided by Estar. Therefore, the respondents' population we were interested in consisted in 494 health professionals. In particular, 137 out of 494 were the end users group, whereas 357 out of 494 were the intermediaries group.

2.4 Variables

In this article, we will analyse specifically three constructs: customer satisfaction with regards to service quality and relationship quality, and overall customer satisfaction with the supplier performance. The overall customer satisfaction with supplier performance was measured through a 1-5 Likert scale item, that asked the respondents to express the level of coherence between the overall service provided by the supplier and their expectations.

The other two constructs were measured through two different groups of questions, that are reported in *Table 1* of the Appendix.

In the statistical model, we also considered the typology of customer, the intensity of needs, measured through the frequency of contacts that in the last year the customer had with the supplier, and the gender of respondents. A complete description of the variables is reported in *Table 2* of the Appendix.

We tested for the reliability of the constructs used to measure service quality and relationship quality through the Cronbach's alpha. For the service quality and the relationship quality dimensions (described in Table 1) the Cronbach's alpha were 0,79 and 0,82, respectively, showing a more than acceptable internal consistency (Peterson (1994)). Moreover, we conducted an explorative factor analysis to identify the two underlying factors related to the different aspect of the consumer service quality and relationship quality. As we would expect, two factors were extracted from the analysis (eigenvalues >1), i.e. the service quality and the relationship quality factors, which accounted for about 55% and 66% of the total variance of the data.

2.5 Regression analyses

As mentioned in section 2.1, our research hypotheses aimed at investigating the relationship between service quality, relationship quality and overall customer satisfaction with supplier performance. As suggested by Ulaga and Eggert (2008) and Terpend et al. (2008), relationship construct in B-to-B contexts, should be analysed considering also contextual factors that might moderate or mediate the relationship quality evaluation. Following this suggestion, we first

checked for the presence of a differentiated effects of service and relationship quality on overall customer satisfaction, according to the typology of customer. In particular, we tested for the presence of a moderation effect played by the customer typology on the impact of service and relationship quality on the overall customer satisfaction. In fact,

Then, we applied a mediation model, where we investigated which dimension, among service and relationship quality, mostly impacts on the overall customer satisfaction with supplier performance. In other words, we were interested in understanding whether the customer is mostly influenced by the relationship quality, rather than by the service quality, for the determination of her/his overall satisfaction with the supplier.

For the data analyses, we considered the two customer typologies, i.e. the intermediaries and the end-users. In particular, the intermediaries include the following health professional figures: nurses, health assistants[1], pharmacists, and laboratory technicians. All these professional figures are responsible for directly interacting and communicating with the supplier, since they have to make the product orders and have access to the whole tracking process. Whereas, physicians, biologists, physicists, speech therapists, psychologists and veterinarians are the end users, who do not directly engage with Estar, rather they make their requests to the intermediaries, and then use the products, that the intermediary has ordered.

To test the three hypotheses and the mediation effect of relationship quality on overall customer satisfaction, we conducted a regression analysis drawing from Baron and Kenny's (1986) mediation model. The following three conditions must hold in order to have a mediation effect:

1. The independent variable (service quality) should be significantly related to the mediator (relationship quality).
2. The independent variable (service quality) should be significantly related to the dependent variable (overall customer satisfaction).

[1] Operatori socio-sanitari (oss) in italian.

3. The mediator should be related to the dependent variable when the independent variable is also included in the model. In order to establish a mediation effect, the relationship between the independent variable (service quality) and the dependent variable should be reduced (partial mediation) or should not be no longer statistically significant (full mediation), when controlling for the mediator (relationship quality).

The general mediation model we tested is the following:

$$H_1: relationship\ quality_i = \beta_0 + \beta_{1i} service\ quality_i + \beta_{3i} frequency_i + \beta_{4i} gender_i + \varepsilon_i$$

$$H_2: overall\ satisfaction_i = \beta_0 + \beta_{1i} service\ quality_i + \beta_{3i} frequency_i + \beta_{4i} gender_i + \varepsilon_i$$

$$H_3: overall\ satisfaction_i = \beta_0 + \beta_{1i} service\ quality_i + \beta_{2i} relationship\ quality_i + + \beta_{3i} frequency_i + \beta_{4i} gender_i + \varepsilon_i$$

A complete description of the variables included in the mediation model is provided in Table 1 of the Appendix. For the regression analyses, the respondents declaring they were not able to provide an assessment to the overall satisfaction with the supplier services were discarded and considered as missing values. That means the 8% of the end users and the 3% of intermediaries did want (or were not able) to evaluate the overall performance of the supplier (satisfaction with Estar).

The second and the third equations have been estimated through an ordered logit regression model, since the dependent variable, i.e. the overall satisfaction with the supplier performance, is an ordinal variable, where 1 represents the lowest level of satisfaction and 5 the highest one.

3. Results

As regards the intensity of needs of the customers (measured through the frequencies of requests made in 2017) showed how the majority of respondents (60%) made a request to the supplier

more than once a month, 19% less than once a month, 21% less than once a semester. Finally, women represented 64% of total respondents.

First of all, we analysed whether or not the customer typology moderated the relationship between service and relationship quality (the independent variables) on the overall customer satisfaction with the customer. By doing so, we created two interaction terms, one composed by the typology of user and the service quality dimension, and the other one composed by the typology of user and the relationship quality dimension. Then, we performed an ordered logistic regression, where the dependent variable was the overall customer satisfaction, the independent variables were service and relationship quality, the typology of user and the two interaction terms, whereas gender and intensity of relationship were included as control variables.

$$overall\ satisfaction_i = \beta_0 + \beta_{1i} service\ quality_i + \beta_{2i} relationship\ quality_i + \beta_{3i} user_i + \beta_{4i} service_user_i + \beta_{5i} relationship_user_i + \beta_{5i} frequency_i + \beta_{6i} gender_i + \varepsilon_i$$

Results in *Table 3* reported in the Appendix show how the customer typology moderates the effect of relationship quality on the overall satisfaction. In particular, even if both end-users and intermediaries perceive relationship quality as an important dimension influencing their overall satisfaction (OR for *relationship quality* is positive and statistically significant), end-users consider relationship quality as two times more important in determining their overall satisfaction with the supplier, as compared to intermediaries. Whereas, this moderation effect does not hold for the service quality dimension, meaning that the influence of service quality on the overall satisfaction is relevant (the OR for *service quality* is positive and statistically significant) even though almost equal among different customers. Finally, neither the gender nor the intensity of relationship seem to influence overall customer satisfaction.

Subsequently, we tested a mediation model hypothesising that the effect of service quality on overall customer satisfaction is mediated by the relationship quality dimension.

Therefore, we performed a mediation analysis through three sets of regression as reported in section 2.5. The regression models were run separately by the customer typology, i.e. intermediaries and end-users to control for the above mentioned moderation effect.

As regards the intermediaries, we accepted the three hypotheses, hence results reported in *Table 4* of the Appendix show that relationship quality positively but only partially affects the impact of service quality on overall customer satisfaction with supplier performance (Model 3). Findings suggest that both relationship and service quality are relevant for the customer in determining the overall satisfaction with the supplier, even though relationship quality has a higher impact on the outcome, compared to service quality. However, even though relationship quality plays the main role in determining the overall satisfaction, intermediaries still perceive service quality as a significant dimension of evaluation. This finding may be explained by the fact that intermediaries are those customers who deeply know the entire provisioning process, including delivery times, typologies of products requested, quantities and quality ordered. Hence, they can properly evaluate the service quality provided by Estar, and they are more sensitive to the supplier performance related to the service offered.

Finally, we estimated the mediation model for the end-users, for whom results show a different dynamic. In fact, relationship quality for end-users seems to completely and positively mediate the relationship between service quality and overall satisfaction, since the OR for service quality is not statistically significant (*Table 5* - Model 3 of the Appendix). In other words, in determining end-users' overall satisfaction with Estar performance, relationship quality, rather than service quality, plays a significant role. This is an interesting result, since it seems to indicate that the end-user, who is not aware about the proper provisioning process functioning, considers only relationship quality aspects as relevant for her/his overall satisfaction with the supplier. For example, in the determination of the overall satisfaction, since end-users do not engage in direct relationships with the supplier, they may be entirely influenced by the reported

dissatisfaction expressed by intermediaries. Therefore, they do not evaluate service quality dimension as relevant in the determination of their overall satisfaction (since they do not know the service process and its details), rather they perceive the relational aspect as the most significant one.

Comparing the odds ratios (ORs) of relationship quality for intermediaries and end-users (Model 3), we can see how the OR for end-users is significantly higher than the one for intermediaries. Whereas, as regards the ORs of service quality, they do not significantly differ among the customer typologies. These findings are coherent with the results coming from the moderation model (*Table 3* of the Appendix), that showed how for end-users the relationship quality dimension is more crucial, compared to intermediaries, for determining their overall satisfaction with the supplier. On the other hand, the two groups of customers consider service quality as an equally important determinant of satisfaction.

Finally, as regards the variables controlling for the frequency of relationships and the gender, their ORs are not statistically significant neither for intermediaries nor for end users.

4. Discussion

This paper was aimed at understanding the role played by relationship quality in the analysis of service quality and overall satisfaction. Relationship quality is perceived by users as mostly relevant for determining their overall satisfaction with supplier performance. In particular, following the suggestion by Garbarino and Johnson (1999) about the different role of relationship intensity on overall satisfaction, commitment and trust, we first analysed the

moderation effect played by customer typology on the relationship between service and relationship quality on overall customer satisfaction with the supplier services. Then, given the presence of the moderation effect, we performed a mediation analysis, differentiating among the two typologies of customers, i.e. the intermediaries (who have direct contact with the supplier) and the end-users (who have indirect contact with the supplier). We noticed a positive and significant effect played by service quality on relationship quality; the positive influence played separately by service quality and relationship quality on overall satisfaction and that, when both service and relationship quality are included in the model, the significant and positive impact of service quality on overall satisfaction is partially mediated by the impact of relationship quality for intermediaries and totally mediated for end-users. These findings may be explained by the fact that intermediaries are perfectly aware of the entire process of provisioning and they directly engage with the supplier, hence service quality aspects, such as delivery times, quantitative and qualitative appropriateness of the products with the orders, and so on, are perceived as important features composing their overall satisfaction. However, they seem to attribute more significance to relational quality aspects, such as the ability of the supplier to promptly and effectively respond and satisfy any additional requests of support. To conclude, for intermediaries, relationship quality, rather than service quality, seems to be the dimension that mostly impacts on their overall satisfaction with supplier performance, and this occurs regardless of the product category, the frequency of relationships, or the gender.

Whereas, as regards the end-users, the mediation is complete, meaning that relationship quality dimension totally mediates the effect of service quality on overall customer satisfaction. In other words, end users' overall satisfaction seems to be influenced by relationship quality characteristics only, rather than a combination of relationship and service quality aspects. This finding may be explained by the fact that end users do not have direct contacts with the supplier, and consequently the worth of mouth took the advantage of the real service quality outcome.

Hence, the overall satisfaction with supplier is not influenced by an evaluation on service quality, rather it is affected by relational aspects only. Coherently with this argumentation, also for end users, this result is not dependent on the product category or the frequency of relationships. Moreover, another interesting finding has emerged from the descriptive statistics. Moreover, about one third of the end users are not able to express an evaluation on the overall performance of the supplier. This reinforces the hypothesis that end users are not completely aware of the provisioning functioning, and hence they are not always able to evaluate the overall supplier performance, those who did are often based on the worth of mouth opinions which are particularly important when the assessment is negative (Soderlund 1998).

From one side we expected that relationship quality had had a higher mediation effect between overall satisfaction and service quality in the case of intermediaries because of the intensity of contacts (see for instance the case of Garbarino and Johnson 1999). From the other side the high role played by relationship quality in the case of end-users who do not have a direct contact with the supplier, the word of mouth seems to have played a very important role totally mediating the perception of the service quality.

5. Conclusions and limitations

This study contributes to the literature because it deals with an under-investigated topic in the inter-organizational analyses that is the determinants of business customer satisfaction (Mustak et al. 2013) in a dyadic public sector context. Indeed, differently from previous public sector studies that focused on network relationships, our paper proposes an empirical analysis on a dyadic supplier-customer relationship in the healthcare logistic context. More specifically, we

investigated which dimension, among service quality and relationship quality, has the main impact on overall customer satisfaction with supplier performance. Given this research objective, the empirical analysis has been conducted on the basis of the results of a survey addressed to all potential customers of the supplier (Estar) that were analysed through a mediation model.

Following the suggestion coming from Ulaga and Eggert (2008) and Terpend et al. (2008), according to which relationships dynamics should consider, among others the nature of the relationship, we checked for a moderation effect driven by the customer typology, and then conducted a mediation analysis separately for the two customer groups identified in this context: intermediaries who have a direct contact with supplier and the end users who have an indirect contact with supplier.

Findings from the moderation model showed how different customers perceive relationship quality as differently influencing (in magnitude) their overall satisfaction. This result was also confirmed by the mediation analysis, that showed how for intermediaries, both relationship quality and service quality are relevant for the determination of their overall satisfaction with supplier performance, even though relational aspects are more significant, compared to service aspects. Whereas, end users' overall satisfaction is influenced by characteristics concerning relationship quality only, suggesting that service quality dimension is not relevant in determining overall satisfaction. Although both users' typology are important, empirical evidence suggests that suppliers have to put in place different strategies to enhance users perception about the overall performance.

Future research should investigate these relationships also considering other aspects analysed in the literature such as trust, power, cooperation and long term orientation (Abdallah et al. (2017); Chumpitaz Caceres and Paparoidamis (2007); Lam et al. (2004); Ganesan (1994);

Skinner at el. (1992)). Even though there is the need to confirm this evidence also in other context and sector to generalize the results, to the best of our knowledge, this study represents the first explorative attempt to analyse B-to-B relationships in the logistic service of the healthcare system.

Appendix

Table 1 – Service and quality items

Service quality items	
Scale adopted: • *0-5%* • *5-10%* • *10-25%*	On a scale from 0% to 100% express the following evaluations:

• *25-50%* • *50-80%* • *80-100%*	**1** % of times when the accompanying documents were not coherent with the order **2** % of times when at least one ordered product was missing **3** % of time when it was necessary to repeat the order **4** % of times when it was necessary to order missing products with urgency **5** % of products not coherent with the order **6** % of products missing
Relationship quality items	
Likert Scale 1-5 adopted: • *1=completely disagree* • *5=completely agree*	The following dimensions are respondent to the expectations: **1** Information on the availability of products in the warehouse **2** Tracking of the orders **3** Knowing who (among the supplier company) to call in case of need **4** Support provided by the supplier in solving problems related to the order management

Table 2 - Variables description

Variable names	***Variable description***
Overall satisfaction	Ordinal variable, taking on values 1-5, where 1 represents the lowest level of satisfaction and 5 the highest one
Service quality	Factor variable resulting from the factor analysis conducted for the group of items measuring service quality

Relationship quality	Factor variable resulting from the factor analysis conducted for the group of items measuring relationship quality
User	Dummy variable, equal to 1 if the customer is an end-user, O otherwise
Service_user	Interaction term, given by the product of *service quality* and *user* variables
Relationship_user	Interaction term, given by the product of *relationship quality* and *user* variables
Frequency	Categorical variable, taking on values 1-, that describes how many times in the last year the customer ordered something: • 1= more than once a month • 2=once or more a month • 3= less than once a semester
Gender	Dummy variable, taking on values equal to 1 if the respondent is a woman, 0 otherwise.

Table 3 - Results of the moderation model

Dependent variable: overall customer satisfaction	
Independent variables	**Odds ratio**
Service quality	**1.67*** **
Relationship quality	**7.56*** **
User	**1.03**
Service_user	**0.78**
Relationship_user	**2.57*** **
Frequency (category=2)	**1.08**

Frequency (category=3)	**0.62**
Gender	**0.85**
***** p-value<0.01**	**n=381**
****p-value<0,05**	
***p-value<0.10**	

Table 4 - Mediation model for intermediaries

Model 1 (H1)		Model 2 (H2)		Model 3 (H3)	
Dependent variable: relationship quality		**Dependent variable: overall customer satisfaction**		**Dependent variable: overall customer satisfaction**	
Independent variables	**Linear regression coefficients**	**Independent variables**	**Odds ratio**	**Independent variables**	**Odds ratio**
Service quality	0.30***	Service quality	2.20***	Service quality	1.63***
Relationship quality	-	Relationship quality	-	Relationship quality	7.52***
Frequency (category=2)	0.099	Frequency (category=2)	1.24	Frequency (category=2)	1,12
Frequency (category=3)	-0.24	Frequency (category=3)	0.53	Frequency (category=3)	0.43*
Gender	-0.03	Gender	0.97	Gender	0.87
*** p-value<0.01	n=299		n=318		n=299
**p-value<0,05					
*p-value<0.10					

Table 5 - Mediation model for end-users

Model 1 (H1)		Model 2 (H2)		Model 3 (H3)	
Dependent variable: relationship quality		**Dependent variable: overall customer satisfaction**		**Dependent variable: overall customer satisfaction**	
Independent variables	**Linear regression coefficients**	**Independent variables**	**Odds ratio**	**Independent variables**	**Odds ratio**
Service quality	0.52***	Service quality	2.7***	Service quality	1.50
Relationship quality	-	Relationship quality	-	Relationship quality	24.51***
Frequency (category=2)	-0.09	Frequency (category=2)	1.13	Frequency (category=2)	1.24
Frequency (category=3)	0.05	Frequency (category=3)	1.27	Frequency (category=3)	0.90
Gender	0.12	Gender	1.14	Gender	0.77
*** p-value<0.01	n=83		n=91		n=82
**p-value<0,05					
*p-value<0.10					

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The role of brokering in healthcare networks: what does it mean for reforms, practitioners and patients?

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Abstract

Well-integrated systems are required to deliver effective healthcare services. Research suggests misaligned organisational and functional boundaries still thwart effective patient care. Using social network theory and knowledge transfer framework we examine two long-term condition health networks where brokering occurs to bridge the gaps in provision or information exchange. The experiences of patients, relatives and healthcare practitioners illustrate where information/knowledge is transferred, translated and transformed across organisational and functional boundaries. We propose brokering is essential to the integrated healthcare system. Areas of further research include power of brokers and the value and cost of brokering.

Keywords: Health, Broker, Networks

Introduction

Early studies on service management consider the interaction between service users and service providers in the process of creating services (Fuchs, 1968). Service operations management continues the focus on service design, particularly the interaction between the professional and the customer/service user. Anecdotally we know that patients and relatives bridge gaps in health care processes, systems and services to ensure relevant information gets to the necessary healthcare professional(s). What is not well understood is the nature of this brokering role, the types of gaps that are brokered, and the brokering strategies used. Much of the previous research has focused on the

relationships between service users and providers. For example, Harvey's (1990) research in social services explains how relationships in professional services influence process (re)design and consequently service outcomes. The level of trust and the balance of power in professional service organizations can also influence the relationships among professionals, service users and managers. In subsequent research, Harvey (1992) recognized that the knowledge gap between the professional and the customer requires attention if services are to be improved.

It is well-recognised that agents (often-termed actors) within a network can help to bridge the knowing-doing gap by acting as conduits for the transfer of resources including advice, social support and information (Moolenaar and Sleegers, 2015). Social network theory (SNT) (Reagans and Zuckerman, 2008) helps to examine connections and information flows between the actors and across two healthcare networks to establish the 'structural holes' that may exist (Li and Choi, 2009) and identify where actors act as brokers to bridge the gap between unconnected agents or organisations in the network.

For a broker the challenge can be to transfer information to an agent who will accept and value it (Burt, 2005). Brokers can connect groups by engaging in "transferring, translating, and transforming" practices (Carlile, 2004) and developing work practices, repositories, specifications, and standards that support communication across boundaries (Fernandez-Mateo 2007). This process facilitates negotiation that allows localized knowledge to be transformed into jointly produced knowledge that transcends each group's local interests (Kellogg, 2014).

We propose brokering is an essential role in the design and delivery of integrated healthcare networks/services. Using social network theory and Carlile's framework this study aims to understand the nature of brokering roles occupied in two chronic long-term health networks. This study addresses the following research questions:

RQ1. What is the nature of the structural holes (gaps) that exist within two chronic long-term condition care networks?

RQ2. What type of brokering roles do healthcare professionals, patients and relatives play in bridging the gaps in the two care networks?

RQ3. What strategies do brokers use to ensure information flows support the effective delivery of care?

A brief review of the social network theory, specifically structural holes, follows this introduction. The next section introduces Carlile's framework and its use in understanding the transfer of knowledge and information. The methodology employed for this study is then discussed along with the results of the study. The paper concludes with a summary of the findings in relation to the research questions posed above, limitations of the study and areas of further research.

Social network theory

Social network theory has a long and distinguished history in the social sciences and psychology where it has been used to investigate human social organisation (see Scott 2000) with its main strengths being the potential to address population-level or cross-population-level problems by building up complex social structures from individual level interactions. However, the appeal of the networks approach goes well beyond sociology and psychology and has widespread technological applications as well. Anything from transport networks (Sen et al. 2003) to communication systems such as

the internet (Tadic 2001) can be considered as a system of interacting components. In biology, the network approach has been used in various areas, as biologists have realised that to better understand complex systems, we need to study interactions between components of the system not in isolation but as part of a network of interactions Kim et al., 2011). This notion of understanding the interactions and connections in the system can be applied to healthcare networks.

Social network theory encapsulates the need to develop an understanding of structural holes (Burt, 1992) and bridging (Obstfeld, 2005) as agents can broker the movement of information and resources (Peng et al, 2010). Agents can operate as conduits for the transfer of resources including advice, social support and information (Moolenaar and Sleegers, 2015). A central position supports the agent in operating as a broker through bridging the structural hole between unconnected agents in the network. Bridging the hole allows the broker to create value where the value of the information presented resides in someone else accepting it not with its provider. The challenge for the broker is to transfer the information to an agent who will accept and value it (Burt, 2005).

For manufacturing, this necessitates the operation of an information decoupling point to bridge and deliver value across two operational approaches (e.g. from forecast-driven to demand-driven approach). Within healthcare the decoupling point occurs at several points, for example the point where patient demand meets A&E plans, or discharge from acute (hospital) care to the community. Clearly, the independent providers are aware of each other's existence but the information flows are not linked.

Brokering structural holes within and across organisations

Previously, brokering in organisations has been linked with Burt's (1992) structural holes theory. He argued that all organisations contain structural holes which can be defined as "non-redundant" relationships between two or more actors. In simple terms, if a hole is redundant this suggests the connections to bridge across are not needed for the effective functioning of an organisation or the necessary information can be provided through other equally effective and efficient routes. However, if they are "non-redundant", new connections are required. Such connections are crucial to ensuring an organisation operates effectively and achieves its objectives. In short, structural holes are places where people are disconnected in an organisation and /or information flows required to make the organisation work effectively are disrupted (Monge and Contractor, 2003). While structural holes disrupt the flow of valuable information in an organisation they provide opportunities to those who can re-make (broker) those connections. In simple terms, by spanning structural holes brokers can perform an "intrapreneurial" role within an organisation, by leveraging social capital from the new non-redundant connections between organisational actors (Kuratko et al., 1990; Heng and Loosemore, 2013). In this case, social capital is the value that can be derived from an actor's relationships in an organisation (Brass, 2003). For example, if a broker sits between two other actors and controls the flow of information between them, then they are in a powerful position.

Baker and Obstfeld (1999) argue that brokers tend to employ two distinct types of strategies in reconnecting organisations: "disunion" and "union" strategies. In the disunion strategy, the broker pursues the active separation of disconnected actors therefore becoming a bridge between two disconnected actors but not allowing them to interact directly. Conversely, in the union strategy, a broker closes the network holes between two disconnected actors enabling them to communicate directly or through a common third party. In reality, a combination of both approaches tends to be adopted. The above ideas have been informed by the social network theory which focuses on the

relationships between actors rather than the attributes of actors in an organisation (Wasserman and Faust, 1994). Social network theory argues that an actor's influence in an organisation is not only a function of their legitimate power but a function of their position in that network. "Central" actors located at the intersection of information flows between other parties command the most powerful positions while those on the periphery of a network command the least powerful positions. These ideas can inform us of the role of healthcare staff and patients/relatives might play in healthcare services. This brokering role may be more prominent due to the current movement towards integrated health and social care services, which seems to be a desire within and outside of the UK health system (e.g. The King's Fund, 2018). Much of the literature, until now, has focused on roles (often managers e.g. Currie et al., 2015) within the organisation – hence reference to it being an "intrapreneurial" role (Heng and Loosemore, 2013). Here we investigate the roles of healthcare professionals within the two healthcare networks as brokers, which can include primary and secondary care organisations. We also consider the brokering roles assumed by patients and their relatives, which could be described as an "entrepreneurial" role.

Transfer of knowledge and information

We are interested to see how the structural holes are bridged in relation to managing information flows. Specifically we draw on Carlile's framework which is used to help understand how the exchange of knowledge at a boundary is managed. In the literature distinctions are made between three types of boundaries and how these are connected to knowledge. The first is difference in knowledge which refers to a difference in the amount of ***knowledge accumulated*** (e.g. novice and expert). This in turn creates differences in levels of experience, terminologies, tools and incentives. As the difference in the amount of domain-specific knowledge increases between actors/agents, the amount of effort required to adequately share and assess each other's knowledge also increases.

The second ***knowledge difference*** at the boundary is dependence – without dependence, difference is of no consequence (Carlile, 2004). Knowledge can be different in kind and degree, which means managing dependencies requires the capacity to develop an adequate understanding and common knowledge as resources and tasks change. The third difference relates to how ***novel*** the circumstances are. This novelty could relate to actors being asked to share knowledge with others and to access from others. Common knowledge is a boundary object (Carlile, 2002) which actors use to communicate across domains. When novelty is present both the capacity and the ability of the actors to represent the knowledge become important issues (Carlile, 2004).

Carlile's (2004) integrated/3-T framework (see figure 1) for managing knowledge across boundaries draws on Shannon and Weaver's (1949) three levels of communication complexity – syntactic, semantic and pragmatic. The most common phrase used to describe movement of knowledge in organisations is "***knowledge transfer***" (Argote, 1999). This *information processing* (also referred to as ***syntactic***) approach is the most dominant view in organisation design and forms the basis of most technology-based approaches to knowledge management, where the main focus in on storage and retrieval of knowledge (Davenport and Prusak, 1998). This assumes there is sufficient common knowledge; simply transferring knowledge can be problematic when novelty arises as it may be difficult to represent the differences and dependencies that are likely to be present.

A ***semantic*** boundary occurs when novelty makes some differences and dependencies unclear or some meanings ambiguous. This might require ***translating knowledge*** where

mechanisms or roles are developed to help create 'shared meanings' – these might include cross-functional teams, co-location and individuals to operate as brokers and translators (Hargadon and Sutton, 1997). The ability to externalise knowledge – making tacit knowledge explicit is critical to the flow of information. The ability to negotiate varying interests/ agendas of the different actors is also important.

The ***pragmatic*** boundary refers to situations where novelty results in different interests among actors that need to be resolved. This means that domain-specific knowledge and common knowledge will need to be transformed to effectively share and assess knowledge at the boundary. Team working is one mechanism to help transform knowledge along with boundary objects such as drawings and other visuals (Carlile, 2002).

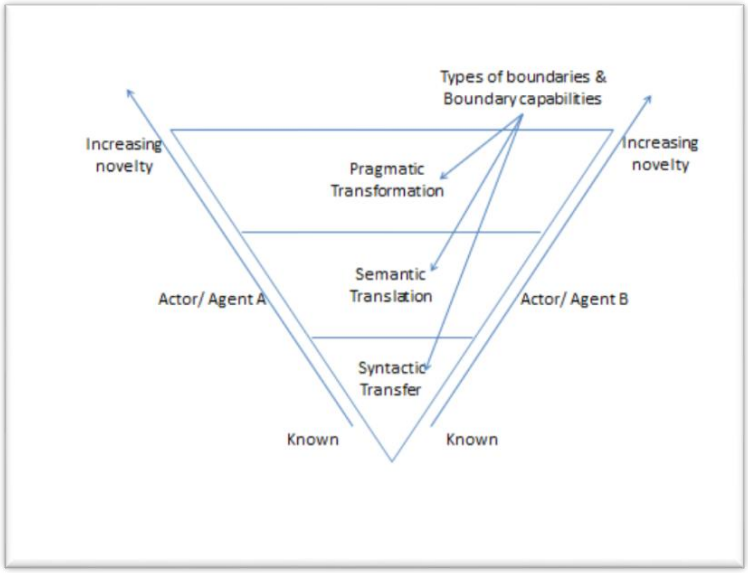

Figure 1. An integrated 3-T Framework for Managing Knowledge across boundaries
Source: Adapted from Carlile 2004:258)

The framework is helpful to categorise and show the relative complexity of a boundary and to identify the different types of processes that exist. The arrows moving from known to increasing novelty indicates new differences and dependencies exist and these need to be identified and understood. Although the line between each type of boundary is clearly demarcated, the transition where one ends and another begins is not often easily identified by the actors/agents involved. The figure also depicts the hierarchy of increasing complexity, where a more complex boundary requires the capabilities below it. This framework can be used to describe the mismatches that can occur between the type of boundary and the capacity/process used to share knowledge. In this study, we employ the framework to help to understand the gaps and boundaries between patients, relatives and staff within two patient networks.

Methodology

This qualitative study was conducted within two healthcare networks for the delivery of services for two long-term conditions in the UK, respiratory and Huntington's disease (HD). Experienced-based interviews were conducted with 45 healthcare practitioners, patients and relatives (see table 1) from the two pathways, which included secondary (hospital) and primary (GPs) care. NHS ethical approval was obtained and consent

sought from participants. The inclusion and exclusion criteria for selection of participants are shown in table 2.

Table 1. Interview participants

Participants	HD Pathway	COPD Pathway
Healthcare practitioners	5	20
Patients	2	10
Relatives	6	2

Table 2. Inclusion and Exclusion criteria for the selection of research participants

Inclusion criteria	Exclusion criteria
Male or female	Participants who are unable to consent for themselves
18 years of age or older	
Able to consent for themselves	
Care-giver or receiver (including relatives/carer) for the selected conditions	

The semi-structured interviews were conducted either at the participants place of work or, in the case of patients and relatives, at their home. The duration of the interviews was typically between 45 to 90 minutes. The interviews were transcribed verbatim, and manually coded and analysed using King's (2004) thematic framework. This paper reports on the themes that related to the type of boundaries, the processes used to transfer of information and brokering roles operating within and across the two networks. Other themes directly associated with the design of the patient pathway/network are outside the scope of this paper and have been previously reported (Williams, 2017).

Results and Discussion

From the analysis of the interview data, it was evident healthcare practitioners, patients and relatives occupy brokering roles in both pathways. Using SNT and Carlile's (2004) framework, this paper identifies the gaps and structural holes in the network and reports on the activities used by the participants to transfer, translate and transform information across these interfaces. Much of this activity occurred at the interface of professional, functional and organizational boundaries. Patients (and relatives) were asked to describe their journeys prior to and since their diagnosis. Healthcare professionals from both the community and hospital providers were asked to share their understanding of the care network and how it works. Mapping the experiences of participants enabled us to identify the structural holes in the network and classify the activity in terms of the type of brokering undertaken. The results show patients and relatives assume or expect the healthcare network to be connected but in 'reality', they have to pick up a brokering role. For both respiratory and HD patients and relatives this largely required transferring information between healthcare professionals and their organisations. In some instances, particularly for HD patients and relatives due to the rarity of the disease, translation of the information and knowledge of the condition was also required on admission to acute services.

Specialist healthcare practitioners often occupied a brokering role within both networks. These can be located in the hospital (respiratory) or in the community (respiratory and HD) and regularly 'inreach' or 'outreach' to services in order to bridge

the gap between acute and community care and/or health and social care. For example, one respiratory staff participant explained, "If the patient is not known to us on the ward we contact the community respiratory team." Although there is rhetoric to move to integrated care in reality this model of care is not fully implemented in the UK health and social care system and is largely dependent on the informal brokering roles bestowed on practitioners, patients and relatives.

Table 3 provides examples of the main boundary issues experienced by the participants from both networks. The types of boundary are classified according to the 3-T framework. Staff, patient and relative participants were found to engage in all three connecting practices – transferring, translating and transforming information. Similarly, all three types of boundaries were found to exist in one or both of the networks. The extent these practices were effective was influenced by language (ability to translate), 'power' relationships (ability to be heard/respected) and being able to bridge the gap (knowledge of network). Participants shared many examples of syntactic boundaries where they needed to transfer information. Often this was due to poorly integrated information systems across different organisations within the network. The HD network required information to be transformed by the family when interacting with services that had limited or no knowledge of the condition (e.g. hospital or GP practice). The participants from the HD specialist community team provided examples of transforming information to enable their patients and relatives to interact and access public services such as housing, benefits and transport.

Table 3. Boundary issues and capability for actors in two health networks

Boundary Issues	Respiratory (R) network	HD network	Type of boundary	Boundary capability
Patient information accuracy	If outside of GP hours then patient information less likely to be available. Some details may be available if attending local A&E department and/or chest outpatient.	Unlikely data will be available to hospital staff unless previous admission. Majority of care provided in the community – poor integration of information with the acute sector.	Syntactic (R) – need to increase capacity to process information Semantic (HD) – no common/ standard approach available	Transferring information (R) Translating information (HD)
Knowledge of patient conditions	If frequent visitors to hospital clinics/ wards and GP surgeries – knowledge of patient conditions likely to be known by various health care teams. However, information may not be integrated across the various organisations/services. Chronic Obstructive Pulmonary Disease is the second highest reason for unplanned	Rare illness estimated to be 6000-8000 cases in UK. Knowledge held by patient, relative or community specialist team (not present in all areas of UK). Less likely to be known in hospitals.	Syntactic (R) Semantic (HD)	Transferring information (R) Translating information (HD)

	admissions – increasing occurrence			
Information sharing	May occur via in-reach or out-reach specialist nurses or relies on discharge letter or discharge care bundle which instructs GP or specialist nurses on follow up.	Through expert patient (relative) or multi-disciplinary team if in place otherwise unlikely to occur which may lead to the patient being missed or misdiagnosed (unless other family members already known to have condition). Multi-disciplinary specialised HD team link with wider public services – no defined common practice to follow.	Syntactic (R) Pragmatic (HD) – relies on relatives and community team if available within the region	Transferring information (R) Transforming information (HD)

Source: Authors

Many of the issues raised by staff and patient/relative participants refer to gaps and structural holes that exist within the networks. Often these gaps are due to poorly integrated IT systems where information is not transferred across the organisation**al** boundaries e.g. primary and secondary care. Other gaps exist due to the lack of or incomplete common lexicons to translate the information e.g. discharge letter. As Carlile (2004) argues as the novelty increases in relation to the information the greater need for information to be transformed. The HD network provides examples of where healthcare professionals frequently act on behalf of their patients and families to broker the knowledge boundary between health and other services. The rarity of the HD increases the novelty of the information and highlights the need for participatory and relational nature of the actor's role. Previous research has shown that actors can misrecognise novelty as something that is already known (Martins and Kambil, 1999) or discarding what is novel as irrelevant (Perrow, 1994).

In this study, the need for brokering occurred at various points within both networks:

- Patient/relative between healthcare professionals
- Specialist healthcare professional between other healthcare professionals
- Specialist healthcare professional between patients/relatives and other public services.

Where specialist healthcare professionals are brokering across healthcare professionals in their own organisation (e.g. respiratory specialist nurse brokering between the respiratory ward and A&E) this can be described as intrapreneurial role. The role of patients and relatives bridging across organisations can be described as an entrepreneurial.

The structural holes identified from the interviews were largely due to poorly integrated systems and/or misaligned organisational boundaries. None of the participants described or recognised their experiences as bridging gaps in the provision or receipt of care. The brokering activities were largely about connecting (union) actors within the system to aid the flow of information, knowledge and value, which then aids patient flow. No examples were identified in this study where participants undertaking

a brokering role purposely aimed to reinforce the gap and disunion the actors within the network (Baker and Obstfeld, 1999). However, what is not clear from this research is the action taken by the organisations to ensure either the brokering role is formally recognised or steps are taken to bridge the structural hole occupied by the broker. Overlooking the brokering activity can potentially introduce vulnerability into the network. Using a range of brokering strategies and understanding the brokerage behaviour and the impact of information/knowledge brokerage on patient outcomes is an important area for healthcare organisations and networks to consider (Heng and Loosemore, 2013).

Conclusion

Uniquely this paper focuses on providing the experiences of healthcare practitioners, patients and relatives occupying a brokering role within designated long-term condition healthcare networks. Using SNT and a brokering framework, this research provides insight to the types of brokering that occur. This research considers three questions, the first being the nature of the structural holes (gaps) that exist within two networks. Using Carlile's framework the three boundaries types were identified – semantic, syntactic and pragmatic, with union bridging activity being undertaken by staff and patient/relative participants (Baker and Obstfeld, 1999). Our second area of enquiry was the type of brokering roles occupied by healthcare professionals, patients and relatives. The examples provided by the participants suggested most of the bridging (union) activity was connecting poorly-aligned organisations and functions. Building on the bridging activity, knowledge transfer, translation and transformation were all evident from the analysis of the interview data. The final question considered the strategies employed by brokers to ensure information/knowledge flows to support the effective delivery of care. All three examples of knowledge transfer were identified – transfer, translation and transformation.

We propose brokering is essential to the integrated healthcare system sought by the NHS as the future model for the health and care system in England (The King's Fund, 2018) and therefore call for formal recognition and training for those occupying this space to ensure equity across all those delivering and receiving healthcare. Although this research has a UK focus, the move towards integrated health and social care systems is a universal goal. Important areas of research not covered here is the power held by the broker, the value of brokering and the cost of brokering.

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Key strategies to integrated care for older people in Sweden

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Abstract

Care for older people must often be provided across health and community settings. The fragmentation of care processes and lack of continuity are common problems. Better and more efficient care models need to be developed to meet the needs of the growing population of older people. Based on case studies in the Swedish health care system this paper focuses on identifying strategies for achieving integrated care for older people. Five key strategies are described: *integration of care processes, development of targeted care services, establishing home-based care services, coordination of care services,* and *use of technology to streamline care*.

Keywords: Integrated Care, Care for Older People, Logistics and Quality Management in Health Care

Introduction

More people live longer and with age comes diseases. Improving care for older people belongs to the most important development priorities in the Swedish health care system. Many chronic conditions are also strongly related to aging and a high proportion of older persons suffers from simultaneous presence of diseases, and cognitive and physical functional limitations (Marengoni et al., 2011). Care for older people must often be given across primary care centres, specialist units, diagnostic centres, emergency departments, home care agencies and nursing facilities. Care processes then becomes highly complex with diagnostics and treatments requiring input from multiple health care providers (Meijboom et al., 2011). Within each care unit, a patient meets a number of physicians, nurses, medical assistants and other caregivers (Ahgren and Axelsson, 2007). Poor transitions between health care providers, lack of continuity and long waiting times are frequently mentioned problems (Stiernstedt, 2016). Problems as lack of continuity and long waiting times often occur due to communication and coordination deficiencies in the health care system where care units often operate as “silos” without the required integration between them (Coleman, 2003). It indicates that the current health care system is not designed to meet the needs of older people. Consequently, new care models need

to be developed to improve continuity and quality of care for this special group of patient (Berglund et al., 2015).

Integrated care models for older people represent a distinct research stream due to the high specificity of care needs and the requirement to integrate primary, secondary and community care (Berglund et al., 2015). The aspects of care desired by older people include needs for convenient access to caregivers, support from a single coordinator, clear communication of care plans, and informational, management and relational continuity of care. Older people also wish that caregivers acknowledge the fluctuating and unique nature of their needs and have a caring attitude (Bayliss et al., 2008, McCormack et al., 2008). There is a growing evidence that integrated care models have a positive impact on patient outcomes, quality of care and cost savings (WHO, 2016). It is therefore important to have a conceptual understanding of different strategies to integrated care, as well as practical examples of how such strategies can be realised. Hence, the purpose of this paper is *to contribute to the body of knowledge on key strategies for achieving integrated care for older people*.

Frame of references

Integrated care

The current health care system is designed to primarily treat urgent and episodic health problems but does not necessarily serve the needs of a growing population of chronic, multimorbid and older patients (Lillrank, 2018). Care of these patients is characterised by a higher need to collect and respond to more symptom, diagnostic and monitoring information and often implies multiple transitions between health and social care providers (WHO, 2016). Lack of integration often leads to a degraded experience for patients and to a qualitatively poorer health and social care. Further, common shortcomings are increased costs, partly because treatments or examinations need to be repeated unnecessarily or since it drives more resources to coordinate unstructured care processes (Clarke et al., 2016). Additional, the responsibility for care coordination often falls on patients and their relatives who are not always capable to navigate and manage their care process (Bodenheimer, 2008).

Integration and coordination of care across settings and providers are considered as two central approaches to managing and improving patient flows (Singer et al., 2011, Goodwin, 2016, Bodenheimer, 2008). Integrated care is often described as contraposed to fragmented and episodic care (Kodner and Spreeuwenberg, 2002). The goal of integrated care is to enhance quality of care and quality of life for patients and to improve system efficiency by reducing the number of hospital stays, shortening the length of stay in hospital, avoiding unnecessary readmissions, and reducing the need for social care services (Damery et al., 2016, WHO, 2016). However, there is no established definition of integrated care and synonymous concepts such as coordinated care or seamless care are used (WHO, 2016). It is likewise suggested that the conceptual elasticity of integrated care is a result of the polymorphous nature of the practice (RAND, 2012). The definitions of integrated care often reflect perspectives of different stakeholders as for example health care professionals or patients (Goodwin, 2016). In this paper we take the perspective of health and social care providers and adopt the following definition: *"Integration is a coherent set of methods and models on the funding, administrative, organisational, service delivery and clinical levels designed to create connectivity, alignment and collaboration within and between the cure and care sectors"* (Kodner and Spreeuwenberg, 2002).

Strategies to integrated care for older people

A strategy can be defined as the pattern or plan that integrates major goals, policies, and action sequences into a cohesive whole (Lampel et al., 2014). This paper deals with strategies to integrated care for older people who often have multiple chronic conditions and receive care from many different health and social care providers. The strategies focus therefore on organising care around the individual patient's needs and effectively managing collaborations across organisational boundaries (WHO, 2016, Reed et al., 2005). Examples of strategies identified in the literature include changing organisational structures and processes to support integration of strategic, managerial and service delivery levels, working in multidisciplinary and multiprofessional teams, communication and information sharing across care sector systems and health and social care professionals, and case management for identifying patient needs and developing care management plans (Johri et al., 2003, MacAdam, 2008, Reed et al., 2005, Dubuc et al., 2013).

Design/methodology/approach

To identify strategies to integrated care for older people case studies at different levels within the Swedish health care system were conducted. The study design is based on qualitative research with an inductive approach (Patton, 2002). Hence, the key strategies presented in this paper are empirically driven.

Study context

In Sweden, the responsibility for care to older people is divided between regions and municipalities, which are governed by politicians elected by the citizens. The health and community care are publicly funded. Regions and municipalities can contract private providers, but purely privately funded health care is, however, marginal. Compared to other countries, the whole Swedish health care system is highly decentralised. The 21 regions are responsible for providing primary and secondary care services. The 290 municipalities are responsible for the community care and health care providers in the regions need therefore to collaborate with several different municipalities. Table 1 provides an overview of how the responsibility for elderly care is divided between regions and municipalities.

Table 1: Care settings for older people in Sweden

Care level	Responsible provider	Type of services
Community care	290 Municipalities	Nursing homes In-home services, e.g. meals, cleaning Home nursing Home-based health care
Primary care	21 Regions	Health centers
Secondary care	21 Regions	Emergency, acute and elective care provided in outpatient, day care and inpatient settings

However, the main responsibility for health policy on a national level lies on the Swedish government and parliament. One of the major challenges in care provision for older people in Sweden is collaboration and coordination of care across health and social care providers (NBHW, 2017). The development towards more integrated care was actualised with the introduction of new law on collaboration when discharging patients from hospitals in 2018. Different strategies are currently implemented at different care levels

within the Swedish health care system to meet the legal requirements and development needs. Since strategies can take different forms and result in diverse outcomes (Lampel et al., 2014) this paper includes both intended, unrealised, deliberated, emergent, and realised strategies.

Data collection

The results are based on case studies carried out at national, regional, and local levels of the health care system. At national and regional levels, the focus was on identifying policies, guidelines and development plans for quality improvement of elderly care. At local level, three development initiatives were studied in two different regions, which together cover 20% of the Swedish population. The three development initiatives are named as "Hälsostaden", "Future care unit" and "Proactive primary care". "Hälsostaden" ("Health city") is a project co-financed by EU where community, primary and hospital care are integrated and managed through one organisation. "Future care unit" is a pilot project aiming to develop and test a new care unit focusing in the needs of older people. Lastly, "Proactive primary care" predicts older patients with risk of hospitalisation and offers them proactive care services.

The data were collected during year 2017 to 2019 through interviews (n=33), meeting observations (n=10) and document studies (n=59). An overview of data collection is presented in Table 2. The interviews were semi structured and were conducted until reaching the data saturation point. The interviewees were chosen to represent different professions and positions. Each interview took about 1 to 2 hours and was taped and transcribed. Participant observations were carried out of meetings related to planning and evaluating development activities. The meetings were documented by free structured notes. The document reviews included national and regional strategy documents, activity reports, handling plans, documented procedures and meeting minutes.

Table 2 Study design

Overview of studies		**Data collection**
National level		1 interview with national investigator at Ministry of Health and Social Affairs 11 document studied
Regional level	*Region Skåne*	3 interviews with managers responsible for elderly care 17 document studies
	Region Östergötland	2 interviews with managers responsible for elderly care 18 document studies
Local development initiatives	*Case: "Hälsostaden"*	5 interviews with managers responsible for hospital, primary and community care 7 document studies
	Case: "Future care unit"	11 interviews with professionals from day-care unit 10 meeting observations 4 document studies
	Case: "Proactive primary care"	11 interviews with mangers of primary care centres 2 document studies

A case study protocol was also established to secure the reliability of the data (Yin, 2013). It describes the entire set of procedures involved in the data collection and included: list of all documents studied, interview guides, transcribed interviews, and meeting notes.

The collected data was analyzed using qualitative content analysis (Patton, 2002). The analysis implied identifying key concepts as initial coding categories related to strategies to integrated care. Two researchers independently coded the data and then jointly discussed the results to establish code content consensus.

Findings

Based on the analysis of the empirical data five key strategies were identified: *integration of care processes, development of targeted care services, establishing home-based care services, coordination of care services,* and *use of technology to streamline care.*
The five strategies are described below.

Integration of care processes

The first strategy is *integration of care processes* where two types of integration were identified to align the three levels of care: community, primary and secondary care. The first type, *organisational integration*, implies that health and care services are managed within a single organisational structure. For example, the case: "Hälsostaden" integrated primary, community and selected hospital care providers into one organisation with a joint management team. The organisational integration created a common ground for collaboration and development but was not sufficient to achieve greater integration benefits. The legal and regulatory requirements for a code of conduct and professional boundaries required further integration and coordination mechanisms.

The second type of integration focused on managing transitions between care levels to establish coordinated and coherent care processes. This integration type, which can be referred as a *vertical integration* of health and care providers, was observed in all three local development initiatives. Collaboration teams were created to develop working procedures and define responsibilities of providers involved in the care process. A common trigger for development work were discussions around specific patient cases with nonconformities and quality issues. This joint discussion contributed to better understanding of realities that govern different providers and identifying root causes of problems. Hence, from contract to operational everyday problems concerning the patient. The solutions involved defining the course of activities, developing best practices and standardising communication and information exchange, which is illustrated by the following quote:

> *"It can be e.g. about how, in what way we agree to contact each other, contact channels are such a thing. Should we make a phone call, fax or maybe email? It can be such a simple thing. Can we decide on one day of the week when we do individual care plans for our patients? It is more easy then when I meet the patient to know when there is a time next week. I can announce this time to relatives and patients. So, it is very much about who does what and in what order and that we all agreed on this. It is also about telling each other how our organisations work".*

Development of targeted care services

The second strategy contains initiatives that imply the *development of targeted care services* for older people. Since, the current health care system is not designed to fulfil the needs of older people, better and more effective ways of providing care need to be developed to address the problems. One example from the case studies is a *day care unit* opened in a hospital to fill the gap between primary care services and in-patient hospital care. There is a wide range of care services, for example regular blood transfusions, draining away excess fluid, monitoring some chronic diseases that are not provided by primary care, but actually do not require hospitalisation. The day care unit addressed these special needs of older people so emergency visits and hospitalisations can be avoided. The physician working at the unit was part-time employed at the emergency department,

which helped to identify patients who could be cared for in an alternative setting. The day care unit is in a development stage and the range of services extends based on arising needs.

Another example is a *proactive primary care service* targeting patients over 75 that are likely to be hospitalised. Patients identified with digital prediction model are approached by a multidisciplinary care team that evaluates patient's social and medical condition and creates an individual care plan. This proactive approach aims also to reduce hospitalisations and emergency visits as patients are cared for before an urgent care need arises.

One more example is *medication reviews* provided by caregivers to assess multiple medications and identify risks of side effects, medicine interactions and other medicine problems. It is a work method of reviewing all drugs prescribed and used by a patient to ensure a correct and up-to-date drug list.

Establishing home-based care services

The third strategy is *establishing home-based care services* which contains initiatives that aim to reduce the number and length of hospitalisations for older people. One example is *mobile teams* making home visits for both planned and acute medical care. The team may consist of caregivers from primary/secondary and community settings, frequently a physician and a nurse equipped to perform care services at home. The type of care provided varies but, in many cases, there are care services that would require an inpatient hospital stay. The patient needs to fulfil some criteria and make an active choice to be registered as a mobile team patient. One example of admission criteria is that the patient is over 75 years old, has more than three chronic diagnoses, have been admitted to hospital three or more times during the last 12 months, has six or more permanent medications, and has already some home-based health care services. One important service provided by mobile teams is assessing the holistic care needs of the older person and establishing an individual care plan. Mobile teams enable older people to live at home or in other accommodation form with a home-like environment as long as possible and to receive care outside the hospital setting. The anticipated effects are a better quality of life for patients and the reduced number of unplanned hospital admissions and emergency visits.

The other example is *integrated discharge* from hospital care. The main goal is to ensure a safe and effective transition from inpatient care to a home environment. Integrated discharge means providing support to older patients so they can feel comfortable to take over responsibility for their care and life and thus reduce the risk of developing a dependence on care services. Hence, the service aims to develop or regain the individual's previous functional ability and independence as quickly as possible. It is also important from a hospital perspective as new patients cannot be admitted when treated patients occupy beds. Integrated discharge is a time-limited service, which ends when no longer needed or when regular home-based health care takes over. Some municipalities work with dedicated discharge teams while others provide the support within regular home-based health care services. For those patients not connected to the home-based health care services an alternative discharge support is offered through a contact nurse who makes home visits two days after discharge.

Coordination of care services

The fourth identified strategy to integrated care for older people is *coordination of care services* using dedicated roles and/or other coordination mechanisms as standardisation of work and multidisciplinary work. Coordination is needed both between caregivers and with the patient.

Coordination through standardisation means setting rules and procedures specifying what and how different tasks should be done. One of the most frequent examples identified in the empirical material is the *coordinated individual plan* (CIP), which gained attention with the newly established law in Sweden on collaboration on discharge from hospitals. CIP is a plan jointly developed by all involved providers and with the participation of the patient and relatives. The plan should define care services needed by the patient and clarify who does what and when. CIP ensures an effective collaboration and coordination of care services and gives the patient and relatives an understanding of who is in charge of the care, so they don't have to spend time and energy on finding and coordinating the needed services themselves.

A common strategy is also to assign coordinators with the overall goal to ensure informational, management and relational continuity of care. One example is a collaboration coordinator that is not linked to a specific patient but has the primary task to manage handovers and ensure that information is transferred between caregivers. This type of coordinator contributes to informational and management continuity of care. Another example is a coordinator assigned to a specific patient with the task to communicate with the patient, shape the care process according to the patients' needs and support the patient and relatives during hospital care and transition to home. Coordinators with this role are important to ensure the relational continuity of care.

The third example is "elderly pilot" whose role is helping patients and their relatives to navigate and access different care services. It can be about available options depending on where the older person lives and what kind of service is needed. It can also be about practical issues such as safety alarms, food deliveries or personal care.

The last example are coordinators in the community care who support patients after the hospital discharge. This support may for example imply daily telephone contacts to convey a sense of security for patients and check if the recovery progresses as expected. This service is provided to patients who do not have a dedicated home-taking-team, but have granted home-based health care services.

Use of technology to streamline care

The last strategy identified is about *using technology to streamline care*. Several strategies at both a strategic and an operative level as well as intended and emergent strategies are described in the empirical material. Integration of IT systems, use of medical technology, e-solutions to enhance delivery of integrated care are examples of this strategy.

One important barrier to integrated care is the transfer of medical and care *information across organisational settings*. The providers of primary, secondary and community care use different IT systems and register patient records locally. This is due to the requirement of high level of security, secrecy and traceability when information is shared between different organisations, so the patient integrity is not violated. Different solutions are implemented at different levels of the health care system to address the problem. At national level a digital platform called "The National Patient Summary" is implemented to provide authorised health and social care providers with access, with the patient's consent, to medical records documented in other regions, municipalities or private care providers. The platform automatically retrieves information from different IT-systems and an authorised health care provider can share and access their own and other care providers medical records. Another example is "My Plans" which is an IT-support for collaboration and joint planning of patient care processes, for example during the discharge.

Furthermore, a big IT project is in the starting blocks in one of the regions studied. The project aims to develop a joint patient record system, which enables process-oriented communication between caregivers and with the patient itself. It should be *a comprehensive system* shared between all public and private health and social care providers with a single login for employees and only one journal per patient. Relevant information about a patient should be accessible at one place for all caregivers involved in the patient care.

Several *technical aids* for supporting older people in their home were also identified in the empirical material, such as Thumb ECG (to send information on cardiac status instead of doing cardiac examinations in hospitals), digital home alarms instead of analogous, digital diapers (to send information in order to pinpoint help to toilet service), and drug dispenser and drug robot to automate drug handing.

IT is also used for *control and management* of care services, for example, by digital speedometer to see the actual number of inpatient days before home taking by the municipality since the region's statistics are delayed by two months. Other examples are measurement and follow-up of mobile team's activities and results, and a system to notify potential readmissions.

Discussion and conclusions

This paper outlines strategies to integrated care and provides examples of how these strategies can be realised. The strategies identified in the empirical material are compiled into a model presented in figure 1.

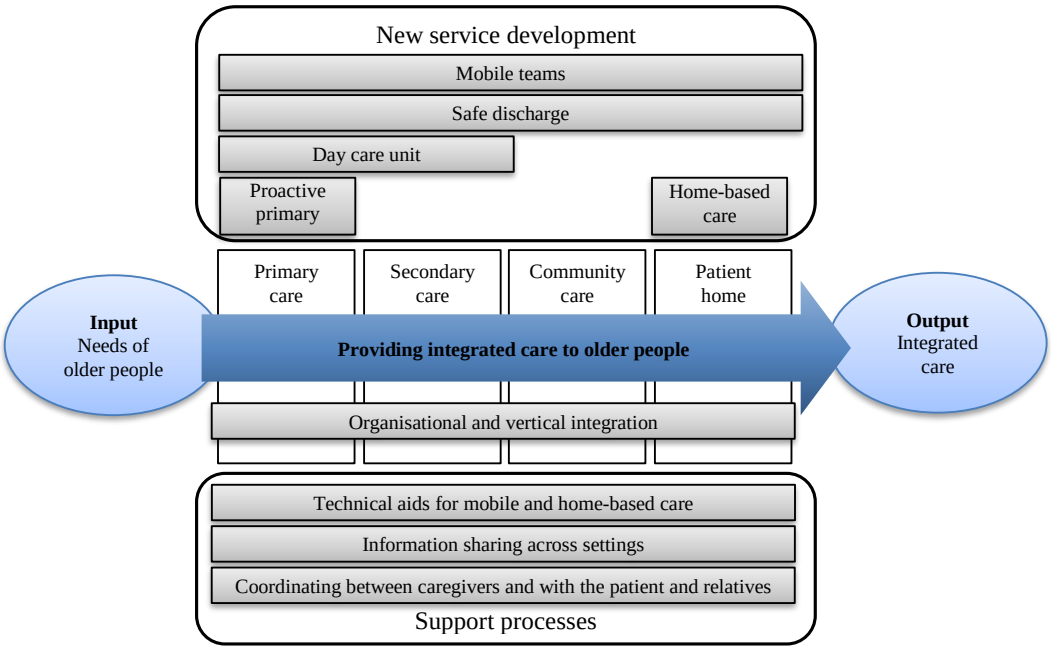

Figure 1: Integrated care model for older people

The model above implies several important implications for the care delivery of older people. First, in order to address the fragmentation and lack of continuity, care for older people needs to be organised in a process-oriented way. The growing specialisation of care has led to strong functional organisation and "silo mentality" with no clear responsibility for patient flows. Care for older people is provided in a complex system with multiple providers that can have different, sometimes conflicting, objectives. The

process orientation in the Swedish care system is weak and is not supported by the management structure, IT system and models for resource allocation (Stiernstedt, 2016). Consequently, the care services provided by single caregivers need to be integrated into a coherent process designed based on the older patient's needs. Two types of integration were identified to align care services provided in different settings: organisational integration where services are managed within a single organisational structure and vertical integration where focus on ensuring smooth transitions between caregivers. A process-oriented way of providing care to older people requires a number of support processes. Caregivers need to communicate with the patient to understand her/his needs and shape the care process according to these needs. Coordinators assigned to patient and joint care planning activities are examples of these support processes. Further, integrated information systems need be developed that ensure an effective information sharing along the patient process.

Second, the previous research focuses on the integration of care in community, primary and hospital settings (WHO, 2016). However, our empirical findings highlight that we need to focus on the integration of one more setting: the older patient's home. In the service management literature, the customer is seen to play an active role in the service creation and delivery processes (Grönroos and Ravald, 2011). According to the school of thought, called Service Dominant Logic (SDL), the customers are perceived as 'co-creators of value' instead of passive consumers (Vargo et al., 2008). This implies that value is not created and delivered by the health care service provider but emerges during the patient's process of value creation (Grönroos and Ravald, 2011). Consequently, the health care providers are not producers of the value, but facilitators of the value creation processes. This perspective on health care delivery is valuable since patient's home becomes a natural setting for providing care services for older people. Hence, health care providers need to facilitate the patient's value creation at home. This was also clearly indicated in the case studies and among the key strategies to integrated care it was identified development of home-based care services and technical aids to support home-based care.

Third, patients' needs change over time and new care services and new ways for health care delivery need to be developed. Traditionally, health care focused on treating acute and episodic illness (Lillrank, 2018). Patients back then experienced health problems more only temporarily and the duration of care provisions were more limited in time and scope (RAND, 2012). Today, health care needs to increasingly care for patients with chronic conditions, where the goals include life-long wellbeing and preventing complications or deterioration rather than curing. In line with this change also the structure, processes and working methods in health care must be renewed and developed. Instead of treating episodic illness in hospitals an increasing emphasis must be put on developing care service for managing chronic disease in outpatient settings. Examples of new services developed by the case organisations are day care unit, mobile teams and safe discharge process.

Summarising, the most important theoretical implications of the paper for achieving integrated care for older people are that fragmented care services need to be provided in a process-oriented way, extended to patient's home and offered by new forms in outpatient settings. The paper provides several practical examples on strategies that have been implemented to provide person-centred and coordinated care delivered at the right time and in the right place.

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Exploring Modularity in Healthcare Service Delivery

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Abstract

This paper explores and assesses modular healthcare service delivery. It follows a survey-based approach and the unit of analysis is specialized hospitals. A model linking constructs of professional competence, technological versatility, clear division of tasks, channelized flow of information, professional autonomy, and modular healthcare service delivery is proposed. Data were collected from 227 doctors and nurses dealing with out-patients services of tertiary care specialized hospitals. Findings will help practitioners in carving out customer involvement during the process, managing heterogeneity of customer request, decomposition of service offerings, standardization of interfaces with design and planning rules, mixing and matching of components.

Keywords: Healthcare, Modularity, Service delivery

Introduction

Healthcare service delivery involves network of participants such as specialised doctors, nurses, support service providers, insurance providers, governments, hospital administrators and end-users. They work in tandem to match the heterogeneous demand and aims to reduce the fragmentation in healthcare service delivery processes. Towards this modularization is expected to enhance flexibility (Bask *et al.,* 2010) through reducing complexity in fragmented systems. Baldwin and Clark (1997) define modularity as configuring complex products or processes from independently designed smaller sub-systems that function together as a whole. This helps in clear division of tasks among the service providers. Modularization enables the simplification of processes as there is a reduction of interdependencies among the interactions (Ethiraj and Levintahl, 2004). Many authors have underscored the role of modularization in healthcare (Meyer *et al.,* 2007; de Blok *et al.,* 2013; Vahatalo and Kallio, 2015; Silander *et al.,* 2017); however, modularization is not explored much in the context of highly specialized healthcare. Healthcare modularity studies have been carried out in areas such as mental care (Chorpita *et al.,* 2005; Soffers *et al.,* 2014), elderly care (de Blok *et al.,* 2010, 2013, 2014) etc. Previous research has identified design aspects of service modularization such as customer involvement during the service process (Pekkarinen

and Ulkuniemi, 2008), managing heterogeneity of customer requests (Rahikka *et al.,* 2011) and standardization of interfaces (Chorpita *et al.,* 2005). This paper aims to explore and assess modular healthcare service delivery. Towards this the paper presents a model which relates the facilitators of modular healthcare service delivery. This model will help service providers to define and operationalise modularity in a more efficient manner.

Literature review

Understanding modularity

Demand for various types of healthcare services are increasing due to increased longevity of people. Healthcare service delivery is complex and place significant demands on providers to know more (knowledge), do more (work), manage more (activity), share more (information), and interact more (coordination among service providers) (IOM, 2001). Modularity involves dimensions such as components, modules, interfaces and packages. Components are parts that perform one clearly defined function in the final product or service offerings and represent a distinct portion of a product or service that function in an autonomous manner (Duray *et al.,* 2000). They are the smallest units in which a product or service can be divided (Pekkarinen and Ulkuniemi, 2008). A module is conceptual grouping of one or more components that provide variants and substitutes that deliver similar functionality (Pekkarinen and Ulkuniemi, 2008). Interfaces are linkages which are shared among components. Interfaces manage interactions and connections between components when they are combined to deliver the service package (Salvador *et al.,* 2002; Voss and Hsuan, 2009). Interfaces enable the mixing and matching of components and achieving a functional service package (Fixson, 2005). In healthcare, components can be grouped into modules such as care services, welfare services, safety services and housing services. Similarly, protocols, procedures, information aids, planning rules and standard lines of communication might all function as interfaces between components.

The challenge of modular healthcare

Healthcare involves heterogeneity that consists of distinct service fields which react to managerial methods in different ways (Lillrank *et al.,* 2015). Patients need vary and require customised as well as standard services. Moreover, healthcare services are often categorized under different medical specialty departments (Porter and Lee, 2013). Division of tasks deter setting of common goals and at times different units operate in an independent manner. Traditionally complexity and high variety of patient needs have been managed within the patient-physician relationship. Consequently, tightly coupled service architecture has evolved within fragmented healthcare units which are characterized by strong professionalism, autonomy, and hierarchical levels. Where individual specialist's discretion and experience play an important role in the decision making. Although some services are mass-produced, professionalism and autonomy are still strongly associated with the delivery of specialized hospital services, which leads to a conflicting co-existence of mass and professional services (McLaughlin and Kaluzny, 2000). This is further compounded by information asymmetry between professionals and patients (Lanseng and Andreassen, 2007). This asymmetry constrains the co-creation of services because patients may not be able to distinguish between their medical wants and needs (Berry and Bendapudi, 2007). Lack of patient involvement may act as inhibitor of healthcare modularity (de Blok *et al.,* 2010). Evidence is discordant regarding the benefits of modularization in healthcare as studies show that modularization can be used both to increase customization in care (de Blok *et al.,* 2013)

as well as to restrain it (Vahatalo and Kallio, 2015). Standardization is a prerequisite of effective modularization but can also challenge it by restraining customization, competition, and new service and technological innovations (Vahatalo and Kallio, 2015). Nonetheless, modularization and the modular service architecture can be used as a means to reduce costs, streamline information flow and enhance care coordination (Soffers *et al.,* 2014).

Conceptual model and research hypotheses

Linkage between professional competence and division of tasks

In an organizational setting, professional competency describes excellence in performance. Professional competence involves number of competencies which are used to perform various occupational roles. Professional competence is a means by which organizations communicate which behaviours are required, valued, recognized and rewarded with respect to specific occupational roles (Fernandez *et al.,* 2012). Professional competence ensures that service providers have a common understanding of the organization's values and expected performance behaviours (Forsten-Astikainen and Heilmann, 2018). Such understanding will be better developed if the competencies are channelized through clear division of roles and responsibilities (Forsten-Astikainen *et al.,* 2017). Clear division of tasks between professionals and the standardization of service components enable increased replaceability among professionals. Formally stated:

H_1: Professional competence positively influences clear division of tasks.

Linkage between technological versatility and division of tasks

Technological versatility reflects the extent to which healthcare processes are facilitated through technological solutions. Adequate technological infrastructure helps in elimination of constraints, streamlining of processes (van Hoof *et al.,* 2014) and management of heterogenous demand. Versatile use of technology enables channelized flow and effective distribution of tasks and responsibilities. Coordinated care supported by technological infrastructure enables the care providers in managing the heterogeneous demands of patients (Vahatalo and Kallio, 2014). Formally stated:

H_2: Technological versatility positively influences clear division of tasks.

Linkage between clear division of tasks and channelized flow of information

Various professionals work together to deliver healthcare services. Clear division of tasks enable faster and timely scheduling of care delivery processes (Erickkson *et al.,* 2017). Clear division of tasks result in improved level of information dissemination. This results in elimination of non-value adding activities and reduction in waiting times (Griffith, 2009; de Blok *et al.,* 2014). In the out-patient care unit context, specified roles and responsibilities among service providers result in enhanced level of service delivery (Lavender *et al.,* 2017). Formally stated:

H_3: Clear division of tasks positively influences channelized flow of information.

Linkage between clear division of tasks and professional autonomy

In an organizational context, division of tasks set the course in which organizational and unit level decisions take place (Hickson *et al.,* 1971). Professional competence of service providers determines their influence on organizational decision making (Connor, 1992). In healthcare service context, professional autonomy reflects delegation of power to make decisions while delivering care processes without being constrained by organizational procedures, financial concerns, performance measurement systems and

managerial control (Salvatore *et al.,* 2018). The way professional autonomy is exercised depends on the organisational settings (Kuhlmann *et al.,* 2013). Formally stated:
H_4: Clear division of tasks positively influences professional autonomy.

Linkage between channelized flow of information and modularity
Modularity reflects the decomposition of complex processes into simple modules. Flow of information among these modules is critical (Soffers *et al.,* 2014) and a channelized flow of information strengthen the underlying modular architecture. Formally stated:
H_5: Channelized flow of information positively influences modularity.

Linkage between professional autonomy and modularity
Professional autonomy together with re-organization of services into independent units help in improving modular architecture (Silander *et al.,* 2017). At care-unit level providers configure service delivery processes and design treatment protocols (de Blok *et al.,* 2009; Rahikka *et al.,* 2011). Professional autonomy enables conceptualization of modular design and results in enhanced level of quality care (Vahatalo and Kallio, 2014). Formally stated:
H_6: Professional autonomy positively influences modularity.

Methodology
The paper follows a survey-based approach and the unit of analysis is specialized hospitals. Based on the review of literature a model linking constructs of professional competence, technological versatility, clear division of tasks, channelized flow of information, professional autonomy and modular healthcare service delivery is proposed. Data were collected from 227 doctors and nurses dealing with out-patients services through a survey of tertiary care specialized hospitals listed under the list of Joint Commission International-USA operating in India during January 2017 to June 2018. Partial least squares structural equation modeling (PLS-SEM) was used for data analysis. Empirical findings were analyzed in conjunction with the literature.

Findings and discussion
Assessment of measurement model
As suggested by Hair *et al.,* (2017), first, the measurement model was assessed for validity and reliability of the indicators. Second, the structural model was evaluated to assess the strength of the hypothesized paths among the variables. The psychometric properties of scales were analysed through an assessment of discriminant validity and reliability. Table I depicts factor loadings. All factor loadings for indicators measuring the same construct are statistically significant ($p<0.05$), supporting convergent validity. As depicted in Table II composite reliabilities (CRs) and average variances extracted (AVEs) are above recommended minimums of 0.70 and 0.50, respectively. Thus, all factors demonstrate good internal consistency and high levels of convergence, supporting the reliability and validity of multiple-item scale. Similarly, square root of AVE of a construct comes out to be greater than its correlations with other constructs thereby, demonstrating discriminant validity. The Heterotrait Monotrait (HTMT) values for the indicators were calculated using the complete bootstrapping procedure of the SMARTPLS v3 software. All the values were below the acceptable range of 0.90 (ranging from 0.562 to 0.844) indicating the discriminant validity.

Table I. Factor loadings

Factors (Representing actions of hospital staff in terms of …)	Loadings	t- stat.*
1. Professional expertise (PE)		
1.1 Inquisitive to learn new advancements in the professional domain	0.763	18.538
1.2 Ability to solve unexpected problems	0.831	27.605
1.3 Proficiency in handling lab tools and equipment	0.727	12.026
1.4 Accountability and achievements of professional benchmarks	0.820	27.671
2. Technological versatility (TV)		
2.1 Provide accurate medical data about patient	0.794	21.971
2.2 Uses online systems for payment management	0.739	17.594
2.3 Adopts upcoming advanced technological enablement	0.767	18.772
2.4 Automated system for managing patient complaints	0.702	10.555
3. Clear division of tasks (CD)		
3.1 Establishment of clear goals and tasks	0.751	15.568
3.2 Commitment towards completion of defined task	0.740	14.421
3.3 Attains work life balance with specified goals	0.779	18.124
3.4 Adherence to treatment protocols while coordinating care	0.755	15.418
4. Channelized flow of information (CF)		
4.1 Integrated and seamless linkages for uninterrupted service	0.743	16.995
4.2 Evidence based decisions	0.704	13.075
4.3 Prompt service in contingent situations	0.713	16.08
4.4 Learning environment to promote new methods	0.728	13.758
5. Functional autonomy (FA)		
5.1 Interest in improvements that benefit patient	0.744	12.852
5.2 Partners in planning and goal setting activities	0.731	12.302
5.3 Builds capabilities to cope with emerging demands	0.758	13.021
6 Modularity (MOD)		
6.1 Adopts demand-based policies	0.730	15.829
6.2 Adapts to the requirements of high expertise	0.760	16.225
6.3 Demarcates clear roles and division of tasks	0.797	21.317
6.4 Follows standardized channel/treatment protocols	0.718	13.607

**t-statistics significant at 0.05*

Table II. Inter-construct correlations: consistency and reliability tests

Cons.	R^2	Q^2	AVE	CR	α	Inter-construct correlations**					
						PE	TV	CD	CF	FA	MOD
PE	*	*	0.619	0.866	0.794	*0.787*					
TV	*	*	0.564	0.838	0.743	0.693	*0.751*				
CD	0.421	0.226	0.572	0.843	0.751	0.649	0.699	*0.757*			
CF	0.561	0.26	0.522	0.813	0.685	0.748	0.695	0.686	*0.722*		
FA	0.480	0.251	0.554	0.788	0.715	0.662	0.701	0.529	0.569	*0.744*	
MOD	0.586	0.305	0.565	0.839	0.746	0.659	0.632	0.682	0.716	0.698	*0.752*

Cons.: Constructs, α: Cronbach's α, * exogenous construct, **Square root of the AVE on the *diagonal*

Before analysing the structural model, the variance inflation factor (VIF) was assessed to compute multicollinearity. The VIF results for each construct, which were below threshold value of 5.0 indicate that collinearity issues between the constructs were absent.

Assessment of structural relationships

A Q^2 value of larger than zero implies that the exogenous constructs have predictive relevance for the endogenous constructs included in the model (Hair *et al.,* 2017). The hypothesized relationships were tested using the PLS algorithm to generate the standardized path coefficients. As a follow-up analysis, a bootstrapping method was used to generate the significance of path coefficients. These results are summarized in Table III. As depicted in Table IV the standardized root mean square residual, normed-fit-index, and rms_theta were within the acceptable range. The chi-square values for the model were 436.374 and 474.719 for the saturated and estimated models, respectively.

Table III. Assessment of paths

Paths (Hypotheses)	**Path coeffi.**	**t-stat.***	**Sig.****	**Inference**
Professional expertise positively influences clear division of tasks	0.693	14.771	0.000	Supported
Technological versatility positively influences clear division of tasks	0.649	11.403	0.000	Supported
Clear division of tasks positively influences channelized flow of information	0.422	5.834	0.000	Supported
Clear division of tasks positively influences functional autonomy	0.391	5.212	0.000	Supported
Channelized flow of information positively influences modularity	0.765	18.332	0.000	Supported
Functional autonomy positively influences modularity	0.510	6.358	0.000	Supported

**significant at 0.05, **significant at 0.001*

Table IV. Model fit indices

Model fit assessment		**Fit values of the structural model**	**Inference**
Fit indices	**Norms**		
Normed-fit-index	Should lie between 0 and 1 and value should be close to 1	0.698	Data shows a reasonable fit with the underlying model
Standardized root mean square residual	Should be less than 0.10	0.073	
rms_theta	Should be less than 0.12	0.10	

The coefficient-of-determination (R^2) measures the predictive accuracy of the constructs. These values represent the amount of variability in the endogenous constructs of clear division of tasks, channelized flow of information, functional autonomy and modularity, which were 42.1%, 56.1%, 48% and 58.6%, respectively; and were explained by the respective constructs. These values are moderate and reflect predictive relevance and are shown in Figure 1.

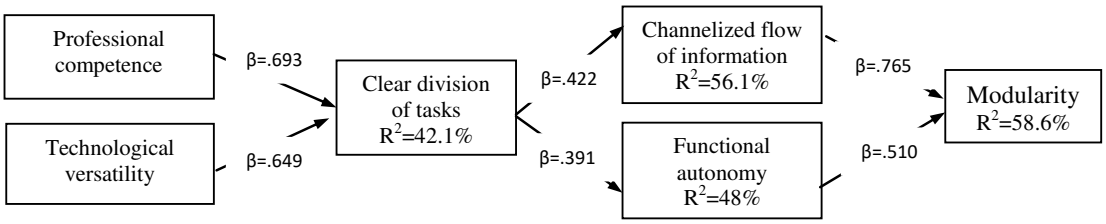

Figure 1 – Path coefficients in the structural model

In the context of modular healthcare services, the posited relationship between professional expertise and clear division of labour comes out to be positive (path co-efficient is 0.693). The respondents felt that their level of expertise in delivering quality care facilitates them to specify responsibilities. Clear division of tasks increases the effectiveness of internal interactions, thereby, facilitating the external service delivery processes.

Results show that technological versatility positively influences clear division of tasks (path co-efficient is 0.649). Technological versatility can act as a catalyst for conceptualization of modular services because technological approaches increase the efficiency of healthcare service delivery. The complexities of the care process can be simplified, leading to better resource utilization. Technology incorporated with clear division of tasks has the potential to transform healthcare service delivery through enhanced level of coordination and timely delivery of care processes.

Clear division of tasks positively influence channelized flow of information (path co-efficient is 0.422). Clear division of tasks serve the purpose of communicating expectations and managing treatment protocols. Assignment of service providers through clear division of tasks steer service providers towards a common goal. This in turn enable hospitals to achieve their strategic goals such as flexibility and adaptability. Goal alignment strengthens leadership and creates a channelized pathway for information sharing. Channelized flow of information helps in fostering relationships that help in managing uncertainties (Okhyusen and Bechy, 2009; Lillrank, 2012).

The relationship between clear division of tasks and functional autonomy comes out to be positive (path co-efficient is 0.391). When a hospital fosters a culture of proactiveness, autonomy, competitive aggressiveness, motivation, effective leadership, and build support infrastructure, then it could deliver enhanced level of care and achieve competitive advantage.

The posited relationship between channelized flow of information and modularity comes out to be positive (path co-efficient is 0.765). Respondents feel that channelized flow of information enable modular architecture. In modular architecture the service components are broken into modules which enhance overall efficiency of the system. These modules need to be connected for facilitating service delivery processes and connection between these modules need to be strengthened by channelized flow of information.

Finally, functional autonomy positively influences modularity (path co-efficient is 0.510). Each module has its own actors who will be performing service delivery processes. The functioning of a module can be enhanced when each actor acts autonomously under certain clinical guidelines. Functional autonomy helps the stakeholders to make better decisions about the care delivery processes.

Conclusion

This paper contributes to nascent literature on modularization of healthcare services. Conceptualization of model for modularization of healthcare services is the central contribution. Findings would be of interest to healthcare practitioners interested in modularization strategy. Findings of this paper will help practitioners in carving out

customer involvement during the process, managing heterogeneity of customer request, decomposition of service offerings, standardization of interfaces with design and planning rules, mixing and matching of components

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Queuing model applicable in surgery OPD of a hospital to reduce the queue length of patients

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Abstract:

This case study has been done in Surgery Out-Patients Department (OPD) of one of the largest hospital of northern India in order to eradicate problem of overcrowding using data of eight Mondays. Using Queuing model, the utilization factor is also calculated for the surgery OPD on Mondays' for various time intervals. The maximum arrival rate (λ=3.2235) of patients is observed during the time period of 8:00 AM – 8:30 AM, while it is minimum during the time period of 10:30 AM – 11:00 AM. This paper also presents cost analysis and adequate numbers of service counters to run the system efficiently.

Keywords: ***Queuing Model, Service Quality in healthcare, Medicine OPD, Waiting time, Customers satisfaction.***

Table 1: Nomenclature

Symbols	Description	Symbols	Description
M	Markovian arrival or departure distributions	t	Time interval
E_k	Erlangian or gamma inter-arrival distribution with parameter k	P_0	Probability of zero customer in the system
GI	General independent arrival distribution	μ	Service Rate
G	General departure distribution	c	Number of counters
D	Deterministic inter-arrival times	n	Number of customer in the system
FCFS	First Come First Serve	L_s	Expected number of customer in the system
LCFS	Last Come First Serve	L_q	Expected number of customers in the queue
SIRO	Service in random order	W_s	Average time a customer spends in the system
GD	General service discipline	W_q	Average waiting time of a customer in the queue
n	Number of arrivals	ρ	Utilization factor (Rate)
λ	Arrival rate	OPD	Out-Patients Department

Introduction

Queuing theory is the main aspect of waiting time models where discussion involves stochastic process. The main purpose of application of the queuing theory is to briefly investigate those queuing problems in the field of industries, transportation and business which are concerned times due to man and machine involve and the production of an item is done two or more distinct successive phases. Healthcare sectors are major sector of any nation those represent the depth of seriousness of country towards providing quality service to keep its people safe from any possible outbreak of diseases.

First of the queueing theory was developed by Erlang (1903) to eradicate the congestion problem of telephone traffic. Due to enormous number of calls, telephone operators were not able to handle this congestion and this need of proper management of queue problems kindled the need of queueing theory. Kim et al. (1999) analysed the processes of admission and discharge of patients from intensive care unit (ICU) in a public hospital of Hong Kong. It was found earlier that the decision-making scenarios of ICU were completely subjective and this behaviour initiated the need of this study to give specific criteria on which decisions could be made. De-Bruin et al. (2007) investigated the bottlenecks of emergency department in the specific area of cardiac in-patient flow. The main motto of the study is to find out the optimum number of beds required to minimize the adverse effect of refused admissions. Li et al. (2009) suggested a model which is based on combination queuing theory and goal programming, to make a multi-objective decision making system for Zichuan hospital, China. Queuing theory was used to estimate the arrival of patients and model M/PH/m was used with arrival pattern to be Poisson in nature. Kumar and Sharma (2012) studied the problems related to reneging decision of customers. They designed a new model to counter this issue and customers were convinced to stay in a line by different mechanisms. A simple queuing model was implemented on the queue problem with arrival and service times to follow negative- exponential distribution. Ameh et al. (2013) conducted a survey to reduce the waiting time and enhance the satisfaction level of patients. Among these 210 patients, 164 patients were found to spend two or less hours in queue and less than one hour with a doctor. They found that 144 patients were satisfied with their overall experience in a hospital. Gupta and Hira (2014) stated that the analyses of queueing systems depend on the use of random variables that are functions of time. Typically, these variables are used to describe discrete properties, such the number of jobs in system. Mustafa and Nisa (2015) studied the different departments of hospital to find a best suit to follow single or multi server queuing theory. Both M/M/1 and M/M/2 were implemented on queues to find remaining queue parameters. The general queue simulation was run on these parameters to analyse the network of queuing theory.

Xie et al. (2016) studied the concept of reverse triage policy where less wounded is given priority in giving a medical treatment. In this study, a queuing model was developed with transfers and abandonments by considering deterioration of condition of patients with the passage of time. They suggested to adopt dynamic control policy best suited according to a specific condition of a country and a hospital. Bahadori et al. (2017) studied the magnetic resonance imaging (MRI) department of hospital in Iran. The study emphasized on optimizing the performance of MRI department by using simulation and queuing theory techniques to increase the productivity of the department and satisfaction level of patients.

Botani and Hassan (2017) studied the pattern of queuing network of CT scan unit in Erbil teaching hospital in a quest to solve problems related to restriction of line and mitigate the issue of long waiting time. This study was conducted to find the suitable queuing model for the unit and run it on optimal level of performance. Bittencourt et al. (2018) applied queuing theory to manage the capacity of hospital and deal with the congestion problem due to increased demand of healthcare facilities. Queuing model was constructed on six months data of in-patients unit of university hospital. Main parameters that were under study were waiting time, bed capacity, probability of waiting, length of stay and others. Implementation of queuing theory helped to find a bottleneck in management of bed capacity of hospital. Maintaining admission and type of patients could easily help hospital management to increase their capacity.

Multi-channel Queuing theory (M/M/c): (FCFS/∞/∞)

The above model is a system with Poisson input and Poisson output with number of channels = c, where c is > 1, the capacity of line is infinite and first come first served discipline. Here the length of waiting line depends on the number of channels engaged. In case the number of customers in the system is less than the number of channels i.e. n < c, then there will be no problem of waiting and the rate of servicing will be μ n as only n channels are busy, each servicing at the rate m. In case n = c, all the channels will be working and when n ≥ c, then 'nc' elements will be in the waiting line and the rate of service will be μp_n. Hira and Gupta (2014) suggested following equations to illustrate situations as follows:

$$\sum_{n=0}^{\infty} p_n = 1 \qquad \text{Eqn. (1)}$$

$$\sum_{n=0}^{c-1} p_n + \sum_{n=c}^{\infty} p_n = 1 \qquad \text{Eqn. (2)}$$

$$\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n . p_0 + \sum_{n=c}^{\infty} \frac{1}{c^{n-c}.c!}.\left(\frac{\lambda}{\mu}\right)^n . p_0 = 1 \qquad \text{Eqn. (3)}$$

Solving Eqn. (1.6), we will get the value of probability of zero customer in the system, p_0 expressed as

$$p_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^c}{c!}.\frac{c\mu}{c\mu-\lambda}} \qquad \text{Eqn. (4)}$$

Where:

P_0 = Probability of zero customer in the system, μ = Service Rate, λ = Arrival rate, n = number of customers in the system, c = number of counters.

Various parameters of the multi-channel system can be calculated with the help of Eqn. (4)

Expected number of customer in the system, L_s

$$L_s = \frac{\lambda.\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2}.p_0 + \frac{\lambda}{\mu} \qquad \text{Eqn. (5)}$$

Expected number of customers in the queue, L_q

$$L_q = \frac{\lambda.\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2}.p_0 \qquad \text{Eqn. (6)}$$

Average time a customer spends in the system, W_s

$$W_s = \frac{L_s}{\lambda} = \frac{\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2}.p_0 + \frac{1}{\mu} \qquad \text{Eqn. (7)}$$

Average waiting time of a customer in the queue, W_q

$$W_q = \frac{L_q}{\lambda} = \frac{\mu\left(\frac{\lambda}{\mu}\right)^c}{(c-1)!(c\mu-\lambda)^2}.p_0 \qquad \text{Eqn. (8)}$$

Probability that a customer has to wait, p

$$p(n \geq c) = \frac{\mu(\frac{\lambda}{\mu})^c}{(c-1)!(c\mu-\lambda)^2}.p_0 \qquad \text{Eqn. (9)}$$

Probability that a customer enters the service without waiting, 1-p

$$1 - p(n \geq c) = 1 - \frac{\mu\left(\frac{\lambda}{\mu}\right)^{c}}{(c-1)!(c\mu-\lambda)^{2}} \cdot p_0 \quad \text{…….....} \quad \text{Eqn. (10)}$$

Average number of idle servers,

= c – (average number of customers served) …….. Eqn. (11)

Utilization factor (rate): $\rho = \lambda/c\mu$ ..... Eqn. (12)

Introduction of the Hospital

It is a premier medical and research institution in the northern India. It has educational, medical research, and training facilities for its students. This medical institute has bedding capacity of more than two thousands. This hospital was declared centre of excellence in 1960 to endeavour to develop patterns of teaching in postgraduate medical education in various specializations as and producing specialists in several disciplines of medicine.

Surgery OPD is a second major OPD of PGIMER hospital and it takes 6% of load of all the OPD departments by itself only. The OPDs remains open from 8.00 AM to 11.00 AM for registration of patients. In order to access the total number of patients visited the Medicine OPD, data of two week are collected and summarized in the Table 2 which shows the average number of patients in week' days. It is observed that on average 518 numbers of patients visit in the Surgery OPD. This study focuses on Mondays' data of the Surgery OPD and analysis is presented in this presented.

Analysis of study

First the study of the arrival pattern of patients arriving in OPD is done for specific time interval. The study of the number of patients arriving in a specific time interval of half an hour is done for the time period of five hours i.e. 6.00 AM to 11.00 AM. After analysing the data, the suggestions to increase/decrease the number of service counters have been given in this paper.

Number of arrivals and Arrival rate (λ)

Total of four Mondays' data of patients of Surgery OPD have been collected and average nos. of arrivals and average Arrival rate (λ)for each half an hour duration is shown in Table 2.

Table 2 Arrival of patients in Surgery OPD

Sr. No.	Time Duration	Average Nos. of arrivals	Arrival rate (λ)
1.	Before 6 AM	28	*
2.	6:00 AM - 6:30 AM	24	0.800
3.	6:30 AM - 7:00 AM	35	1.167
4.	7:00 AM- 7:30 AM	44	1.467
5.	7:30 AM - 8:00 AM	23	0.767
6.	8:00 AM- 8:30 AM	97	3.233
7.	8:30 AM - 9:00 AM	68	2.267
8.	9:00 AM - 9:30 AM	77	2.567
9.	9:30 AM - 10:00 AM	78	2.600
10.	10:00 AM- 10:30 AM	60	2.000
11.	10:30 AM - 11:00 AM	15	0.500

***** Arrival rate (λ) cannot be computed as the patients already arrived before 6.00 A.M.

Computation of various parameters of queuing model

Various parameters of applied queuing model in this case study are computed and shown in Table 3.

Table 3 Computed Parameters at various utilization factors on Mondays' Surgery OPD

Interval	Parameters	Calculated values of parameters		
8:00 AM - 8:30 AM	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	3.2235	3.2235	3.2235
	No. of Counters (c)	3	4	5
	Utilization Factor (ρ)	1.0388	0.7791	0.6233
	Probability of Zero Patients in the	N/A (as ρ is greater than one)	0.2209	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)		3.5264	
	Average No. of Patients in the Queue (L_q)		2.7473	
	Average waiting Time in System (W_s)		1.0940	
	Average Waiting Time in Queue (W_q)		0.8523	
8:30 AM - 9:00 AM	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	2.2664	2.2664	2.2664
	No. of Counters (c)	2	3	4
	Utilization Factor (ρ)	1.0955	0.7303	0.5478
	Probability of Zero Patients in the	N/A (as ρ is greater than one)	0.2697	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)		2.784	
	Average No. of Patients in the Queue (L_q)		1.9781	
	Average waiting Time in System (W_s)		1.1950	
	Average Waiting Time in Queue (W_q)		0.8728	
9:00 AM- 9:30 AM	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	2.5828	2.5828	2.5828
	No. of Counters (c)	2	3	4
	Utilization Factor (ρ)	1.2485	0.8323	0.6242
	Probability of Zero Patients in the	N/A (as ρ is greater than one)	0.1677	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)		4.9631	
	Average No. of Patients in the Queue (L_q)		4.1308	
	Average waiting Time in System (W_s)		1.9216	
	Average Waiting Time in Queue (W_q)		1.5994	
9:30AM- 10:00 AM	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	2.5824	2.5824	2.5824
	No. of Counters (c)	2	3	4
	Utilization Factor (ρ)	1.2483	0.8322	0.6241
	Probability of Zero Patients in the	N/A (as ρ is greater than one)	0.1678	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)		4.9585	
	Average No. of Patients in the Queue (L_q)		4.1264	
	Average waiting Time in System (W_s)		1.9201	
	Average Waiting Time in Queue (W_q)		1.5979	
10:00 AM- 10:30 AM	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	2.001	2.001	2.001
	No. of Counters (c)	1	2	3
	Utilization Factor (ρ)	1.9345	0.9672	0.6448
	Probability of Zero Patients in the	N/A (as ρ is greater than one)	0.0328	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)		29.5133	
	Average No. of Patients in the Queue (L_q)		28.5460	
	Average waiting Time in System (W_s)		14.7493	
	Average Waiting Time in Queue (W_q)		14.2659	
10:30AM -	Service Rate (μ)	1.0344	1.0344	1.0344
	Arrival rate (λ)	0.4866	0.4866	0.4866

11:00 AM	No. of Counters (c)	1	2	3
	Utilization Factor (ρ)	1.0344	1.0344	1.0344
	Probability of Zero Patients in the	0.5296	NOT COST EFFECTIVE	NOT COST EFFECTIVE SYSTEM
	Average No. of Patients in the System (L_s)	0.8883		
	Average No. of Patients in the Queue (L_q)	0.4179		
	Average waiting Time in System (W_s)	1.8255		
	Average Waiting Time in Queue (W_q)	0.8587		

Table 3 show the possible number of counters those should be remained open to serve patients in all possible manners for all the working days. Utilization factor shows the effectiveness of the system. Its highest value of the effective system is unity and any value less than 0.7 is named as 'Not Cost-effective system' and if it is above unity; the system is considered to be inefficient. There are total of 3 nos. of counters to serve the patients in Surgery OPD and remain open throughout the three hours (8.00AM –11.00 AM) span period. The tentative numbers of counters; having utilization factor between 1.00 and 0.70 are taken to reduce the waiting time of the patients in Surgery OPD.

Following facts are observed from the Table 4:

- When the utilization factor is above unity, other parameters of queuing have not been calculated.
- The utilization factor reduces on increasing the numbers of service counters for all the time periods.
- The numbers of service counters are computed at various levels of utilization factors for all the time periods.
- Maximum arrival rate (λ =3.224) of patients is observed during the time period of 8:00 AM – 8:30 AM, while it is observed minimum during the time period of 10:30 AM – 11:00 AM.
- It is also observed that probability of zero patients in the system (P_o) is maximum (52.9%) during the time period of 10:30 AM to 11:00 AM and minimum (3.28%) during the time period of 10:00 AM to 10:30 AM.
- Average No. of patients in the system (L_s) is maximum (29.51) for the time period of 10:00 AM to 10:30 AM and minimum (0.89) for the time period of 10:30 AM to 11:00 AM.
- Average waiting time in the system (W_s) is maximum (14.75 min.) during the time period of 10:00 AM to 10:30 AM and minimum (1.09 min.) during the time period of 8:00 AM to 8:30 AM.

Proposed System

The working hours are divided into two halves intervals and recommendations are made accordingly. Table 4 shows the number of counters required for efficient working of the system at specific utilization factors.

Table 4 Number of counters required for two halves at different Utilization factors

Interval	Service Rate	Arrival Rate	Current No. of Counters	Required No. of Counters for Single Interval	Utilization Factor of Single Interval	Average No. of Counters for Utilization Factor = 0.99	Average No. of Counters for Utilization Factor = 0.7
8:00 AM to 8:30AM	1.0344	3.2235	3	4	0.7791	3	4
8:30 AM - 9:00 AM	1.0344	2.2664	3	3	0.7303		
9:00 AM - 9:30 AM	1.0344	2.5828	3	3	0.8323		

9:30 AM - 10:00 AM	1.0344	2.5824	3	3	0.8322	2	3
10:00 AM- 10:30AM	1.0344	2.001	3	2	0.9672		
10:30 AM -11:00 AM	1.0344	0.4866	3	1	0.4704		

Extra Manpower and cost analysis

Extra manpower is calculated for all the Mondays' of the month by considering four hours as a working span of a single employee at the two values of utilization factors of 0.99 and 0.70. Cost analysis is done on Surgery OPD for Mondays' by considering fixed and variable costs as shown in Table 5.

Table 5 Cost analysis for utilization factor of 0.99

Expenditure	Name of the Item	Cost per Item	No. of Items	Total Cost for One Year (in INR)	Total Cost for Two Years (in INR)	Total Cost for Three Years (in INR)
One Time Investment Items	Computer System	25000	0	0	0	0
	Chair	1500	0	0	0	0
	Table	3000	0	0	0	0
	Bill Printing Machine	2500	0	0	0	0
Recurring Items	Salary of Employees	15000	1	180000	360000	540000
	Additional Cost	300	1	3600	7200	10800
Total Cost				1,83,600	3,67,200	5,50,800

Table 5 shows the extra employees needed to be hired for efficient working and to reduce the waiting time in the system at the utilization factors of 0.99 and similarly yearly expenses for utilization factor of 0.70 is computed as 4,31,200 INR but not shown in the paper due to limitation of pages.

Conclusions

Surgery OPD is a major OPD of this hospital as it serves 518 patients every day. Total three numbers of counters are available in this OPD to serve various patients. It is found that most of the half-an-hour intervals of Surgery OPD is having utilization factor more than one. To reduce waiting time and to serve the patients in a better way, more numbers of counters are needed to be opened at the various levels of utilization factor. The purpose of the management should be to provide to quality service to the patients. It is computed that one and two more numbers of serving counters are required at the values of utilization factors of 0.99 and 0.70 respectively. Thus, the total expenditure for one year will approximately be 1,83,600 INR at the utilization factor of 0.99 while it is 4,31,200 INR at the utilization factor of 0.70.

Most of the studies have a common limitation of assuming an ideal model of process and sometimes the given assumptions of the model may be violated. This case study shows that how a simple implementation of basic models of queuing theory can be useful to handle majority of problems related to overcrowding of available resources in a proper manner in health care sector.

The present queening model in healthcare industry provides the necessary information to the management regarding system capability. There is strong need of top management commitment before implementing any queuing project. The top management should incorporate the quality initiatives in their business strategy in order to improve the healthcare quality.

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Appendix A - Calculations for Table 3

Various calculations for Table 3 at the time interval of 8:00 AM to 8:30 AM for 17 service counters

(i) Probability of Zero Patients in the System (P_o) as per the Equation 4.

$$p_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{\left(\frac{\lambda}{\mu}\right)^n}{n!} + \frac{\left(\frac{\lambda}{\mu}\right)^c}{c!} \cdot \frac{c\mu}{c\mu - \lambda}}$$

Where:

P0 = Probability of zero customer in the system
μ = service rate = 1.0344

λ = arrival rate = 17.5702
n = number of customers in the system = 527
c = number of counters = 17

$$p_0 = \frac{1}{\sum_0^{484} \frac{\left(\frac{17.5702}{1.0344}\right)^{527}}{527!} + \frac{\left(\frac{17.5702}{1.0344}\right)^{17}}{17!} \cdot \frac{17*1.0344}{17*1.0344-17.5702}}$$

$$= \quad 0.0008$$

(ii) Average number of patients in the system, L_s, using Equation (5)

$$L_s = \frac{\lambda . \mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} . p_0 + \frac{\lambda}{\mu}$$

$$L_s = \frac{17.5702 * 1.0344 \left(\frac{17.5702}{1.0344}\right)^{17}}{(17-1)!\,(17*1.0344-17.5702)^2} * 0.0226 + \frac{17.5702}{1.0344}$$

= 1203.4384

Where: μ = service rate = 1.0344, λ = arrival rate = 17.5702, n = number of customers in the system = 527
c = number of counters = 17

(iii) Expected number of customers in the queue (L_q), using Equation (6)

$$L_q = \frac{\lambda . \mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} . p_0$$

$$= \frac{17.5702 * 1.0344 \left(\frac{17.5702}{1.0344}\right)^{17}}{(17-1)!\,(17*1.0344-17.5702)^2} * 0.0226$$

= 1202.4392

(iv) Average time a patient spends in the system (W_s), using Equation (7)

$$W_s = \frac{L_s}{\lambda} = \frac{\mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} . p_0 + \frac{1}{\mu}$$

$$= \frac{1.0344 \left(\frac{17.5702}{1.0344}\right)^{17}}{(17-1)!\,(17*1.0344-17.5702)^2} * 0.0226 + \frac{1}{1.0344}$$

= 68.4932

= 01:08:29 Minutes

(v) Average waiting time of a customer in the queue (Wq), using Equation (8)

$$W_q = \frac{L_q}{\lambda} = \frac{\mu \left(\frac{\lambda}{\mu}\right)^c}{(c-1)!\,(c\mu-\lambda)^2} . p_0$$

$$= \frac{1.0344 \left(\frac{17.5702}{1.0344}\right)^{17}}{(17-1)!\,(17 * 1.0344 - 17.5702)^2} * 0.0226$$

= 68.4363

= 01:08:26 Minutes

Authors Biography

Dr. Deoraj Prajapati is a **Professor** with teaching and research experience of more than 22 years and published more than 128 research papers in international and national journals of repute and in the proceedings of the conferences. He is also reviewer of more than 8 international journals. He also guided four Ph.D. and more than 24 post graduate theses and guiding 5 research scholars at present. He has also chaired international and national conference in India and abroad. He also organized two short term courses and two national conferences for the faculty of technical institutions and industries. He is also recipient of first D. N. Trikha research award for excellent research publications in international journal for the year 2009 in PEC University of Technology.

Mobile health care facilities vs. health centres – Comparing the service structure strategies in reducing CO_2 emissions

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Abstract

Societies are considering the accessibility of health services and its impact on environmental sustainability. The services are provided by both mobile and centralised solutions. This study compares the CO_2 emissions of these strategies by applying a geographical information system (GIS)-based route allocation that is referred to qualitative data from focus groups with health care management professionals. The results show that in the sparsely populated case area, the CO_2 emissions can be reduced 49% by applying a mobile health care facility model in primary health care. However, the presented model must be carefully considered to fit to the health service entity.

Keywords: Healthcare logistics, Mobile services, Sustainability, Carbon emissions

Introduction

Healthcare systems and organizations are facing challenges through the needed cost reductions, expected service improvements and also modern requirements for energy efficiency. These challenges are especially emphasised in sparsely populated areas due to the long distances and decreasing population. Proposed approaches to these challenges are managing the locations of health care service facilities HCF (see, e.g., Ahmani-Javid et al. 2017, Kotavaara and Pohjosenperä, 2018) and moving health care service facilities (see, e.g., Caires, 2017, Guruge et al., 2009; Gibson et al., 2014; Kojima, 2017). Both approaches heavily affect the accessibility of the health services and costs of the provided service entity. However, there still remains a gap in knowledge of how these different scenarios affect the total CO_2 emissions of the healthcare system.

This paper compares two service structure strategies for primary healthcare in a sparsely populated area in order to find the minimum level of CO_2 emissions of the system. The case area is Koillismaa, which is formed by the three most sparsely populated municipalities in the region of Northern Ostrobothnia in Finland. In the Finnish healthcare system, the municipalities organise the public primary healthcare services whereas hospital districts handle the special health care in larger geographical areas. The national

government has attempted to combine these in such a way that they can be managed together regionally, but currently the reform is not going further. However, the visible challenges and uncertain situation offer a fruitful case for analysing the accessibility of mobile health care facilities with regard to minimising travel time as well as CO_2 emissions.

The case analysis is performed by calculating the outcome of two scenarios. The first is the ongoing strategy, where the primary health care patients travel to the health centre to be treated and then back home. The second scenario applies a mobile health care model to offer new health care service locations for the population living far from the health centres. The accessibility and the back-and-forth travelling kilometres of both strategies are calculated by using Geographic Information Systems (GIS)-based transport accessibility methods (Miller and Shaw 2001) with actual road and healthcare facility data. Thus, the research utilises accurate location data of both inhabitants and the service network as well as the road infrastructure in the case area. CO_2 emissions are included in road network data as travel cost attributes in addition to minutes and kilometres (see Määttä-Juntunen 2011) by using average CO_2 emissions for different types of vehicles defined by the VTT Technical Research Centre of Finland (cited 19.2.2019).

The purpose of the study is to find an ecologically sustainable model for delivering primary healthcare service through health centres and mobile health care facilities. The empirical results from the case area reflected current literature about mobile health care facilities and were compared to the metrics that are used to estimate the influences of CO_2 reductions. Hence, this research aims to contribute to answering the following questions. How does implementing mobile healthcare facilities affect the CO_2 emissions of the healthcare system? Again, how does optimising CO_2 emissions influence societal sustainability goals? Overall, this study estimates and compares the CO_2 emissions of the two selected service strategies and, thus, opens up discussion about mobile health care facilities' impact on societies' reaching their goals concerning environmental sustainability.

Next, the paper presents overview of the literature of mobile healthcare facilities. Then the multidisciplinary research design of using both the GIS-method and qualitative case analysis is explained in Section 3, which also includes an overview of the case area. The case is further analysed in Section 4 and concluded in Section 5.

Mobile health care facilities

The *Mobile health care* (Caires, 2017) or *Mobile health clinics* (Guruge et al., 2009) represent transportable healthcare and can also be called *Mobile medical clinics* (Gibson et al., 2014; Kojima, 2017) or *Mobile clinics* (Lafuente et al., 2007; Pitt et al., 2012). 'Mobile health care' can also be understood in some cases to refer to wireless communications solutions such as health care applications in mobile phones and other wireless interfaces (Khazbak et al., 2017; Mangu, 2017). *The mobility of health care professionals* on the other hand means the movement of doctors and other health care occupants to provide the demand of health care services (Ribeiro, 2014).

Mobile healthcare clinics are an alternative solution to delivering care to people with transportable healthcare units that enable healthcare offsite from institutions and healthcare agencies to underserved populations that might be difficult to reach (Guruge et al. 2009). They are healthcare strategies that increase access to care by people with geographic, structural and social barriers, therefore decreasing inequality for marginalised groups by implementing the traditional, fixed healthcare media of healthcare (see, e.g., Gibson et al., 2014). Mobile healthcare clinics make it possible to deliver healthcare at a reasonable distance from groups that are restricted by location (Leese et al., 1993; Gibson et al., 2014) or other obstacles such as limited access to transportation (Hastings et al., 2007). They are sometimes described as non-traditional

health care strategies (Gibson et al., 2014). One study found that mobile medical clinics have been especially successful in delivering services to rural (Peritogiannis et al., 2011) and urban minorities (Daiski, 2005). Mobile healthcare can also be favourable for the populations that are vulnerable due to poor traditional healthcare. (Gibson et al., 2014.)

Mobile health care has been implemented for a large variety range of health-related services, including the increase of access to services for the elderly living in rural areas, screening at-risk-populations such as drug users and the homeless, providing maternal health care services, screening for sexually transmitted infections, preventive health care such as dental care, screening for breast and/or cervical cancers and providing crisis care for mental illness. (Guruge et al., 2009.) Mobile medical clinics can be a sufficient means of delivering health care, health promotion and health-related education. They have a tendency to use fewer operators for larger areas in comparison to traditional health care centres, which is extremely practical in areas where the geographical distribution of patients is widespread (Kojima et al., 2017).

One application for Mobile healthcare facilities is blood donation logistics. In these systems, cars and personnel drive to locations closer to donors to collect blood that is needed in health care operations. The bloodmobiles can attract more donors than fixed donation points by offering better accessibility by bringing the location closer to the donors, hence saving their time. These bloodmobiles can additionally be served by 'shuttle car', collecting the timely critical blood for the depot, allowing the mobile healthcare facilities more time to collect blood (Şahinyazan et al., 2015)

Of these mobile solutions presented above, this paper focusses principally on mobile health care facilities (mobile HCF) that provide primary healthcare for sparsely populated areas. The users of the service are selected by their home location in the case area.

Case area

The empirical case area Koillismaa is located in the Northern Ostrobothnia hospital district in Northern Finland. The region itself has 408,752 inhabitants in the area of 40,000 km², which works out to an average population density of 11.2 inhabitants per km². Most of the population is located in city centres, leaving the majority of the region sparsely populated. A total of 392,190 amongst the population (96%) have their home locations within 20 minutes car travel from nearest health centre. Thus, 16,562 inhabitants have over 20 minutes' travel time to a health centre and the longest times reach 77 minutes or 82 kilometers.

Nearly half of these far distance inhabitants (7,805 people) live in three municipalities: Kuusamo, Taivalkoski and Pudasjärvi, which form the area of Koillismaa, located in the northeastern part of the region. The 27,261 inhabitants live in the area of 14,327 km², resulting in a very sparsely populated area (1.9 inhabitants per km²) which is also characterised by old age structure (28.2% are age of 65 or over) with high demand on health services.

Methodology

To find relevant empirical background for the study, a qualitative case approach is implemented as the issue is in the developmental stage, rather complex and alternates between the empirical field and different theoretical frameworks (Voss et al., 2002; Yin, 2009). The empirical data of the study is collected through various methods and multiple sources to add breadth and depth in understanding the phenomenon (Yin, 2009). By applying both the GIS and qualitative case methods, this study aims to increase both the research and managerial relevance of the research (see, e.g., Ketokivi and Choi, 2014).

Data collection methods contain interviews and forms of group discussions. Focus groups are especially useful in identifying important qualifiers or contingencies that may be associated with an answer to a structured question. Furthermore, focus groups offer an

opportunity for feedback from and response to the comments of others (Stewart and Shamdasani, 2014, p. 178).

The mobile health care facility strategies and their affect on CO_2 emissions are empirically discussed in focus group discussions with the research project ideating group (3) and steering group (3), which include professionals from both public and private healthcare organisations from the case region. Furthermore, the accessibility of primary healthcare services and mobile strategies are discussed in five focus group discussions/semi-structural interviews with health care professionals in the case region.

In this study, opportunities to reduce CO_2 emissions and increase service accessibility by extending health services close to rural areas with service vehicles were tested with Geographic information Systems (GIS)-based transport accessibility analyses (see Miller & Shaw 2001). Transport GIS-based analyses enable the measurement of travel distance, time and emissions for different types of vehicles routed from origins to destinations in a graph model of a road network. Analyses are executed with the ESRI ArcGIS Network Analyst extension, and are home to service site routes and customer potential which are generated with Location-Allocation analysis and a Vehicle Routing Problem method is applied to generate tour-based service routes. A passenger car travels from a home location to the closest health service locations, which are estimated to compare the service efficiency of different service scenarios in terms of accessibility. To produce a scenario for rural health services based on service vehicles, service routes were generated and optimised to satisfy service demand with minimised travel time.

In producing a service vehicle scenario, first a small rural population concentration which needs more than 20 minutes travel time to health centres cluster in the centres of built-up areas, villages, hamlets and commercial activity sites. Populations closer than 15 minutes are first allocated to these 66 local service points, resulting in customer potential levels between 333 and 11. Secondly, service vehicle routes were optimised to cover these service points. The maximum time of each route is limited to 9 hours due to EU driving time legislation. A weekly demand evaluated on the basis of estimated average service time consisting of population outside labour, an annual service which is used at a rate of 3.4 times per person (see Lankila et al., 2016) and 20 minutes' average service time. Thirdly, service efficiency of health centres and service vehicles assessed by measuring driving and service time, travelled kilometres and CO_2 emissions.

Spatial data consists of Digiroad network data (Finnish Transport Agency, 2018) including all regularly used roads and speed limit data, locations of health centres, YKR population grid cell data (2017) and YKR data of built-up areas, villages, hamlets and commercial sites (2015). Road network data enables estimation of travel times (see Kotavaara et al., 2017), which were estimated for passenger cars and service vehicles, for which travel speeds were estimated at the level of a delivery van or smaller truck, and the maximum speed was limited to 80 km/h. Turn penalties are defined according to Jenelius and Koutsopoulos (2013), 10 seconds to left turn, 7 seconds to right turn and 30 seconds for a right turn when crossroads without a turn take 3 seconds. CO_2 emissions included road network attributes in addition to minutes and kilometres (see Määttä-Juntunen, 2011). The VTT Technical Research Centre of Finland (cited 10.4.2019) has evaluated CO2-emissions for different types of vehicles and travel cost attributes for passenger cars and van with a full mass of 2.7 tonnes.

Case analysis

This study examines two scenarios for providing primary health care services in the case area. In the first scenario, the patients travel to health centres that are located in the centre of the municipals. Each trip is made using passenger cars. As a simplification, this case does not take into account the use of other transport modes as taxis, buses, motorcycles,

bicycles, walking, et al. as the distances are long and public transportation is very limited. The home locations and straight lines to health centres are illustrated in Figure 1.

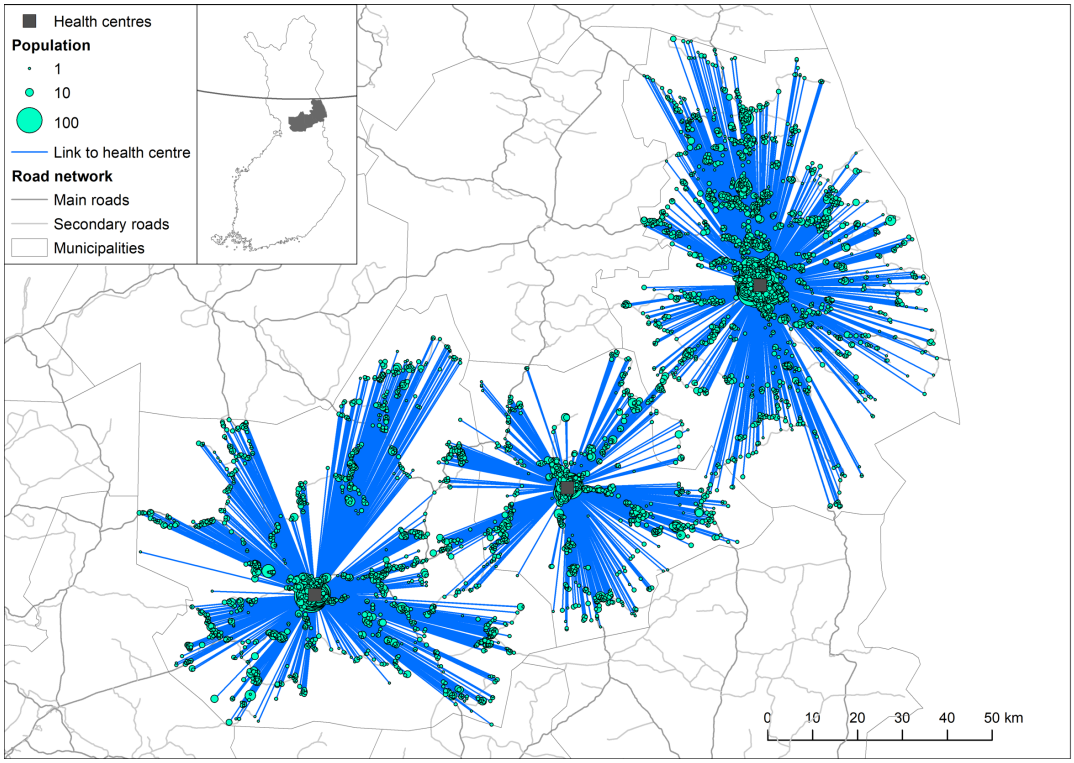

Figure 1 – Scenario 1: Accessibility of the health centres

In scenario 2, the same health centres serve the patients within a 20-minute time range. However, patients living more than 20 minutes away from the health centre are served through mobile service facilities, i.e., vans that drive the calculated routes once a week. The calculated locations for mobile facilities and their accessibility are illustrated in Figure 2. Some of the most distant locations are far from these mobile locations and are therefore calculated to use the health centres.

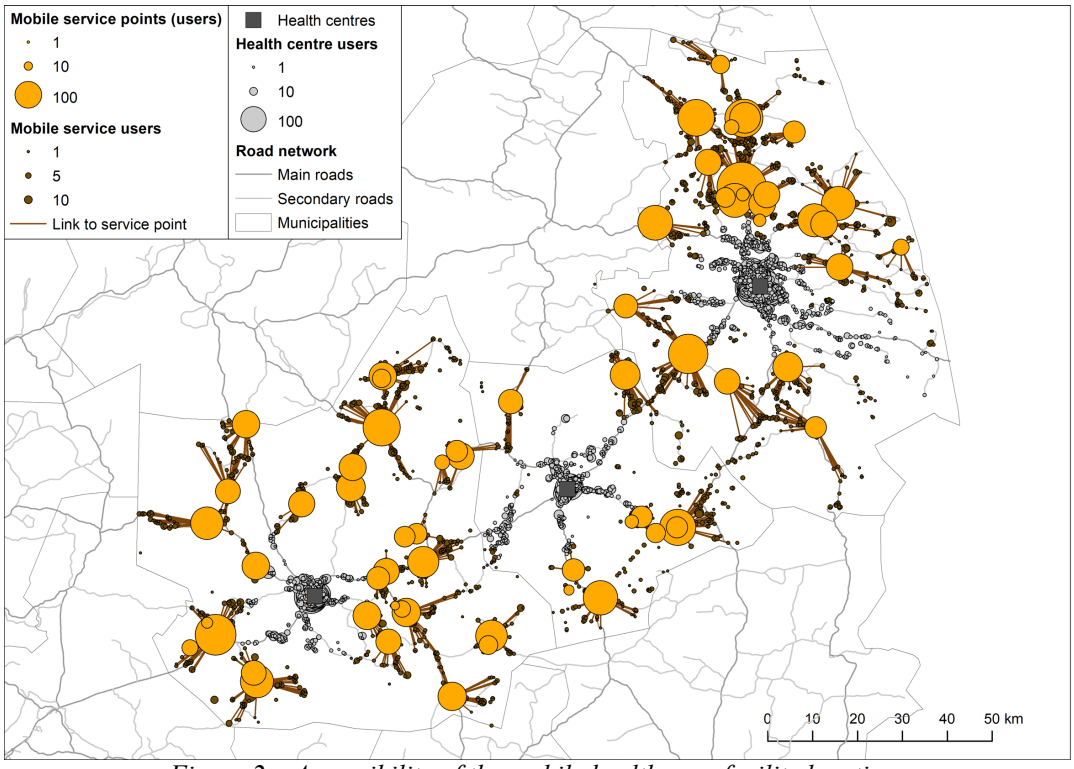

Figure 2 – Accessibility of the mobile health care facility locations

The van routes are calculated to cover the mobile facility locations once a week with maximum 9 hours working time per day. The van starts from a local health centre and returns to the same location at the end of each day. The 15 routes are illustrated in Figure 3 and are detailed in Table 1. All the routes can be covered within five working days with three vans, one per municipality. Each route requires between 1.5 and 4.2 hours of driving time, leaving 4.6-7.2 hours to operate as a mobile health facility.

Table 1 – Calculated routes

Route	total h	driving h	km	CO_2 kg
1. Taivalkoski	8.9	2.0	112	20.1
2. Taivalkoski	8.7	2.6	165	27.3
3. Taivalkoski	8.4	3.1	193	31.8
4. Kuusamo	8.7	1.5	94	23.7
5. Kuusamo	8.8	1.7	105	17.5
6. Kuusamo	8.4	2.3	136	22.8
7. Kuusamo	8.5	1.6	88	14.9
8. Kuusamo	8.9	3.5	192	32.6
9. Kuusamo	8.8	4.2	263	43.4
10. Pudasjärvi	8.6	1.9	121	20.1
11. Pudasjärvi	5.6	1.5	83	14.5
12. Pudasjärvi	8.7	2.4	139	23.6
13. Pudasjärvi	8.7	2.2	129	21.8
14. Pudasjärvi	8.3	1.8	112	18.6
15. Pudasjärvi	7.7	1.8	109	18.0
Total	125.5	34.0	2053	351

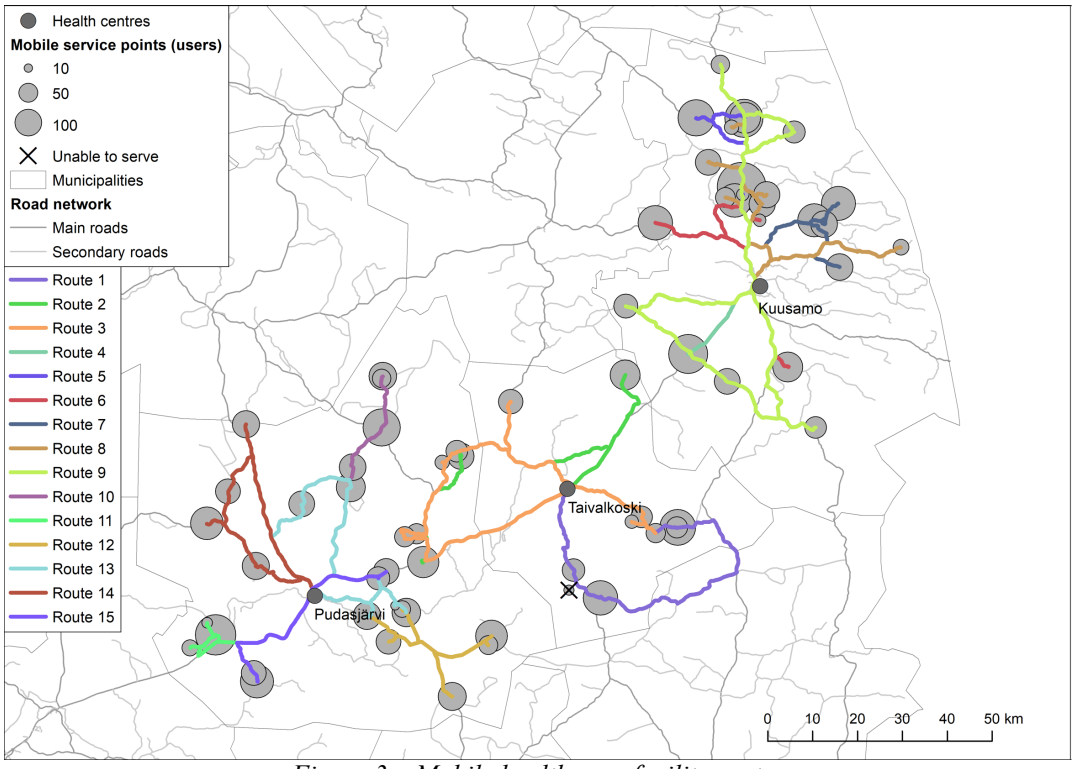

Figure 3 – Mobile health care facility routes

In scenario 2 most of the population (76%) live within 20 minutes accessibility from the health centres and, thus, uses the health centres as in scenario 1. The patients who live more than 20 minutes away from a health centre are now served through mobile HCF, which decreases the CO_2 emissions that they produce while using the service. However, scenario 2 also produces CO_2 emissions through the vans that drive the routes. The detailed driving time, kilometres and CO_2 emissions of scenario 2 with HC users, mobile HCF users and the routes is presented in Table 2. The digits are transformed to an annual scale by multiplying the weekly routes by 52 and by multiplying the hours, driving distances and CO_2 emissions by 3.4, which is the amount each citizen in Finland uses to reach primary health care services annually (Lankila et al., 2016).

Table 1 – Scenario 2 in detail (annual)

	Health centre users	Mobile HCF users	Mobile HCF routes	Mobile HCF total
Population	20,639 (76%)	6,622 (24%)		
Hours	18,928	3,975	1,770	24,674
Km	811,509	201,787	106,741	1,120,037
CO_2 kg	127,976	28,974	18,238	175,188

Table 2 presents an extreme scenario comparing the mobile HCF users` trips to their mobile location and to the health centre. These users influence the largest savings, more than 80% in time, driving kilometres and CO_2 emissions.

Table 2 – Comparison of mobile HCF users` trips to mobile HCF and to HC (annual)

	To health centre	To mobile HCF	Saving	Saving %
Hours	25,141	3,975	21,166	84
Km	1,582,520	201,787	1,380 733	87
CO_2 kg	217,897	28,974	188,923	87

Finally, comparing both of the scenarios (Table 3), running scenario 2 with mobile healthcare facilities saves 44% in time, 53% in driving distance and 49% in CO_2 emissions. Annually, the 346 tonnes of CO_2 emissions can be reduced to 175 tonnes.

Table 3 – Comparison of annual CO_2 emissions of the scenario 1 and 2

	Scenario 1 Health centres	Scenario 2 Mobile HCF	Saving	Saving %
Hours	44,044	24,674	19,370	44
Km	2,392,475	1,120,037	1,272,438	53
CO_2 kg	345,658	175,188	170,470	49

Concluding discussion

This paper explores ecologically sustainable model for delivering primary healthcare service in sparsely populated area. The case analysis is presented to compare the centralised and mobile health care facility models. Our study thus illustrates how mobile health care facilities can be considered one method for achieving a decrease in CO_2 emissions by the primary health care system. The empirical results show 49% decrease in CO_2 emissions if the patients over 20 minutes driving time from the health centres are served through mobile health care facilities.

For the discussion of mobile health care facilities, this paper brings new methods of taking account of CO_2 emissions. The results show that strategic change from a centralised to a mobile model can have an impact on driving distances, driving time and CO_2 emissions. Managerially, this study offers a vision for developing health care systems that are part of societies that aim to achieve ecological sustainability. The reduction of 170 CO_2 is somewhat notable when considering the quite small population in the case area.

The presented model aims to minimise CO_2 emissions. Certainly, the results need to be further considered to fit the nuanced entity that the health care system is. Relevant questions include, for example, what kind of call-based system is required to manage the system and also whether the population in the area justifies the need for three mobile health care facilities with the needed personnel.

This research studies the service strategies in one particular geographical area (three municipalities), which puts limits on applying the results universally. However, on both a national and global scale, the case area is very sparsely populated, which intensifies the effects of the initiatives on reducing CO_2 emissions. Hospitals, hospital districts, city organisations and privately-owned healthcare services can use the results in developing their services to reach the set and aspired goals in environmental efficiency. Especially in Finland, the current healthcare reform offers momentum for renewing the health service structure to match the service needs as well as the goals of lower CO_2 emissions. Overall, this provides an example for societies aiming for environmental sustainability. Future studies can highlight the energy efficiency of other mobile health care solutions as the

mobility of health care professionals and using data connections in some parts of health services.

Acknowledgements
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Disclosing the relationship between Digital Technologies and Healthcare Resilience

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Abstract

The use of Digital Technologies (DT) in healthcare industry is contributing to change the way care process activities are accomplished. Although stating that their implementation improves operational outcomes is quite instantaneous, evaluating improvements in terms of patient safety represents a hurdle. By including into the discourse the healthcare resilience dimension, our goal is to shed light into the relationship between DT and patient safety, providing a different point of view from which to consider how technology can help healthcare organizations to deal with care process failures. A multi-respondent survey provided us with data that we used to test a theoretical framework, using the structural equation modeling procedure.

Keywords: Digital Technologies, Healthcare Resilience, Absorptive Capacity

Introduction

A number of care processes involves the usage of Digital Technologies (DT); consequently, understanding the impact of DT into the healthcare operations becomes a necessity for scholars and managers (Chaudhry et al., 2006). In particular, as regards to patient safety, previous studies have shown contrasting results, e.g. Froehle and White (2014) and Sharma et al. (2016).

In this paper we change the point of view from which to look at the relationship between DT and patient safety; by exploring how this group of technology enables physicians and nurses to be more *resilient* we were able to better unravel this link. In fact, during the delivery of healthcare services, because of their innate complexity, lots of failures may occur. Among them, the operational failures, such as patient identification errors or missing equipment (Tucker et al., 2008) can have a very strong impact in terms

of patient safety, causing the so-called adverse events (Halbesleben et al., 2008; Stevens and Ferrer, 2016). It is practically impossible to avoid all these failures occur (Hollnagel, 2008), so healthcare organizations have strengthened their capability to manage them (Tucker, 2009) or to assimilate stress and carrying on activities and tasks even when something negative occurs (Weick and Sutcliffe 2011). We suppose that this focusing on this capability, named *resilience*, can help to better understand the relationship between DT and patient safety. In particular, we see resilience as a *dynamic capability*, namely a capability that allows organizations to integrate, build, and reconfigure internal and external competences to address rapidly changing environments (Teece et al., 1997).

To the best of our knowledge, no previous studies have analysed the relationship between DT and resilience seen as a dynamic capability. To comprehend this linkage, we use the notion of *absorptive capacity* (ACAP); in fact, having the capacity to acquire and use knowledge, in particular the patient-specific knowledge, readily and rapidly, can help physicians and nurses in managing operational failures, avoiding they cause an adverse event (Hopp et al., 2018).

To study this phenomenon, based on dynamic capability view, we defined a conceptual framework where ACAP mediates the relationship between DT and resilience. We collected data from 159 respondents of 53 Italian healthcare organizations, which were studied using the structural equation modelling technique.

Theoretical Background and Hypotheses Development

The Dynamic Capabilities perspective

Teece et al. (1997) introduced the concept of dynamic capabilities, defining them as those capabilities that allow an organization to address rapidly changing environment. To do so, companies change their ordinary procedures (Lavie, 2006) by modifying their available assets (Helfat et al., 2007).

A number of papers within the management area of knowledge refers to dynamic capabilities (e.g. Dabhilkar et al., 2016; Dobrzykowski et al., 2016), because in sub-fields such as supply chain management or healthcare operations management, the environment where workers operate is turbulent, and the need to have this kind of capabilities may represent a significant source of competitive advantage.

Generally, the studies that focus on dynamic capabilities use this concept as a "view", in order to frame and justify the linkages among different dimensions (e.g. Chowdhury and Quaddus, 2017). In this paper, we use the definition provided by Barreto et al. (2010) of the dynamic capabilities (the firm's capabilities to resolve problems in a systematic way) and of the firm tendencies that enable these capabilities (sense opportunities and threats, make timely choices, make market-oriented choices, modify firm's assets). In this way we were able to frame the constructs and their relationships being studied in a comprehensive way.

Resilience and Patient-Specific Knowledge ACAP

Dynamic capabilities are a significant means that healthcare organizations should have in order to cope with the uncertainty. In fact, the professional nature of healthcare services, characterized by high level of process variation, makes their progress really difficult to foretell (Dobrzykowski et al. 2016); subsequently, considering that dynamic capabilities enable the workers to sense and solve very different problems (from a missing syringe to

patient condition never treated), they represent nearly a mandatory ability that healthcare workers should have.

In the recent years, because of its similarities with the concept of dynamic capability, the resilience, defined as "the ability to anticipate, prepare for, respond and adapt to events—both sudden shocks and gradual change; that means being adaptable, competitive, agile and robust" (British Standard Institution, 2014), has been considered as a dynamic capability (Dabhilkar et al., 2016; Sutcliffe and Vogus, 2003), and in this paper we do the same.

In accordance with the definition by Barreto et al. (2010), in order to be resilient it is important that workers are able to make decisions when dealing with uncertainty; in particular, care processes calls for a number of decision-making tasks which are based both on workers' expertise and knowledge base (von Nordenflycht, 2010). Among the different kinds of knowledge, the one concerning the patient, based on specific data collectable through sources such diagnostic exams, lab test, etc., enable healthcare organizations to make care process more effective (Chakravarty, 2014). Specifically, in case of operational failure occurrence, to have a satisfactory amount of patient-specific knowledge and being able to exploit it can meaningfully help healthcare providers to cope with the problem, avoiding it transforms in an adverse event. Because of this, in this paper we use ACAP concept in order to link DT and resilience. In fact, ACAP may be defined as the capability of an organization to acquire and exploit knowledge (Zahra and George, 2002); furthermore, as a dynamic capability (as it has already been considered in different papers), it can enable to make well-timed decisions (Barreto, 2010).

Because of what above mentioned, the first hypothesis is:

> *H1: The patient-specific knowledge absorptive capacity of a healthcare organization is positively associated with its resilience capability.*

Digital Technologies and Knowledge and ACAP

A number of studies focused on the relationship between technologies and patient safety, with opposite results (Chaudhry et al., 2006; Sharma et al., 2016b). These studies often focus on technologies used to cope with patient safety, but not used by line professionals during their operational activities, such electronic health record. Conversely, there are a number of DT that can have a positive impact in terms of patient safety even if they are not specifically for this goal. This because this group of technology has an impact on the daily activities executed by professional, enabling them to be more resilient by increasing the amount of available patient-specific knowledge. The impact of DT on knowledge has already been studied, e.g., by Sher and Lee (2004), who underlined the possibility these technologies have to enhance dynamic capabilities, or by Hopp et al. (2018), who highlighted how the DT can improve the acquisition of patient-specific data and, consequently, information and knowledge.

In healthcare, other than the simple and obvious *adoption* of technologies, there are two different mechanisms that allow a healthcare professional to implement DT in a meaningful way in order to increase the ACAP. The first concerns with the extensive *usage* of the technology within the organization, which can have an impact in terms of learning and accumulating knowledge (Queenan et al., 2011). Several DTs, for instance those used for diagnostic exams or lab test, surely improve patient-specific information

stream (Bardhan and Thouin, 2013) and facilitate the decision-making process that is executed by the line professionals in case of an operational failure occurrence.

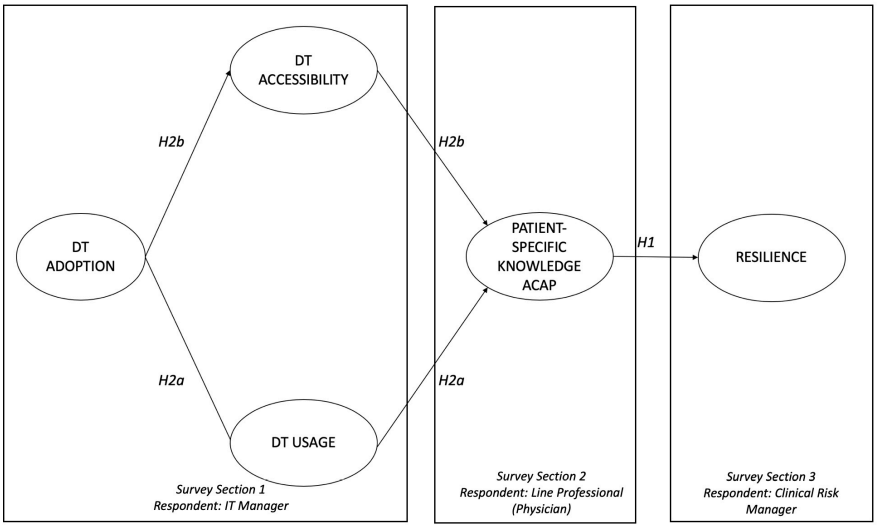
Second, the level of accessibility of DT, namely how easy and quick is for physicians and nurses to approach the DT, is a crucial enabler of patient information availability and is fundamental in order to exploit the acquired knowledge in a significant way (Roberts et al., 2012). In fact, one of the characteristics of healthcare context is the high level of collaboration and communication among workers (Mihailidis and Bardram, 2006), and there are a number of DT which potentially may improve these strong and mandatory relationships.

Thus, the other two hypotheses are grounded on the possibility that DT usage and DT accessibility may improve the patient-specific knowledge ACAP by means of the mechanisms of the usage of and the accessibility to the DT:

H2a: Digital technology adoption is associated with patient-specific knowledge absorptive capacity through the mechanism of digital technology usage.

H2b: Digital technology adoption is associated with patient-specific knowledge absorptive capacity through the mechanism of digital technology accessibility.

Figure 1 – Theoretical Model



Research Method

Questionnaire design and data collection

We defined a multi-respondent survey composed of three different sections in order to collect data. The unit of analysis is represented by the single healthcare organizations, while the respondents are different for every section. The first focuses on DT adoption, accessibility and usage, the second focuses on the PSKACAP assessment, while the third focus on the degree of resilience.

The population is composed of 575 Italian public-private hospitals. The choice to focus on this kind of healthcare organizations concerns the dimensions we wanted to study. In fact, our research focus is on patient safety with particular regards to related operational facets. Subsequently, we needed to ask questions to workers and management figures in direct contact with day-to-day operations. Considering that part of the survey questions is directed to managers, we needed they were in daily contact with the organization's operations; this condition was not satisfied in pure public healthcare organizations mainly because of their size.

In order to provide the survey, we started from a dataset we downloaded from the Italian Ministry of Healthcare website containing the data of the whole Italian population, then we contacted the Clinical Risk Manager (CRM) of every organizations through email or phone, explaining the study and providing him the survey through email. We collected 159 responses, which constitute full responses from 53 healthcare organizations.

Table 1 – General statistics of the sample vs. population

		Sample	Population
No. of organizations		53	575
Geographical distribution	South	43%	37%
	Centre	21%	21%
	North	36%	42%
Age (years)	<20	21%	21%
	21–50	44%	54%
	>50	35%	25%
No. of beds (average)		118.6	110.13

3.3. Variables and Measures

3.3.1. Resilience

The dependent variable of the model is the resilience. In order to assess it, we focused on the happening of the so-called cascade event (Levinson, 2010), which are a particular kind of adverse event which originate from an operational failure, which generate another operational failure, and so, as a "cascade", causes harm for patients. A resilient organization has the ability to stop the cascade, consequently the less their number, the more the organization is resilient. Relying on Levinson's study of this typology of events, through the coding methodology, we defined six groups of cascade events, which different each other on the basis of the beginning operational failure. Finally, we assessed resilience by questioning CRM the occurrence of each category (table 2).

3.3.2. DT adoption, DT usage and DT accessibility

In order to assess the DT adoption, the survey contains a number of healthcare information technology/system, listed the Health Information Management System Society (HIMSS) dataset (https://www.himss.org), and the IT manager was asked to flag those present in his healthcare organization. We selected 32 typologies of system/technology that better fit with the scope of the study. Example of these technologies/systems are: Room allocation systems, Discharge reporting, Surgical report management, Health records, Specialist examination management, Ward "take in charge", Surgical operations and diagnosis, Hospital discharge form closing, DRG computation, Interface with lab, Interface with radiodiagnostic. This course of action was already followed in other studies aiming to assess the adoption of information technology in healthcare context (Sharma et al. 2016; Bardhan and Thouin, 2013).

To assess the DT usage we used two items, with the goal to evaluate how many wards within the healthcare organization use how many IT functionalities. To define the questions, we based on the work of Queenan et al. (2011) (table 2).

Finally, to assess accessibility we focused on the existence of devices which allow line professionals to have an easy access to information. In this case, we started from the statement of e-health functionality (Ruiz Morilla et al., 2017) and, relying on the contribution of two experts, we were able to create three items (table 2).

3.3.3. PSKACAP

The PSKACAP was operationalized using six different items (table 2). The first three in order to evaluate the capability of the organization to acquire patient-specific knowledge in particular the facility in getting it (Lichtenthaler, 2009; Zahra and George, 2002). The other three to assess if the line professionals are able to use the available knowledge in a meaningful way (Jansen et al., 2005; Pavlou and El Sawy, 2006).

3.3.4. Controls

The four control variables that we used are in some way related to the level of patient safety or organization resilience. We used an item to assess the usage of information technology closely related to patient safety but not to operational activities. The second one is the number of bad, which is closely related to the healthcare organization size which can potentially be linked to the complexity of the activities executed in the hospital and, consequently, to patient safety. The third is the case-mix index, which is a proxy of the gravity of patients' disease. Fourth, we asked the number of adverse and sentinel events occurred, because of its possible correlation to the cascade events occurrence.

Results

We used the Structural Equation Modeling (SEM) to verify the hypotheses before stated. Every item was assessed by using a five-point Likert scale; the only exception is represented by the DT adoption whose items are binary (yes/no). Considering its number of items, we decided to create 4 parcels and assign each one of the 32 items to one parcel whose value is defined by the sum the value of the related items (Garver and Mentzer, 1999).

The Confirmatory Factor Analysis (CFA) brought us to cross four items, while undimensionality, reliability and convergent validity were all confirmed (table 3a). The discriminant validity of the dimensions presents some problems for the couple PSKACAP-DT, because the value of the AVE is a bit bigger than their correlation (table 3b; table 3c), but considering the very small difference and the relatively small number of sample units, we decided to not modify the model. Finally, all the CFA indices (table 3a) are acceptable.

Table 2 – Survey items

CONSTRUCT	MEASUREMENT ITEMS	SCALE	SOURCES	RESPONDENT
DT USAGE	**dtusa_1**: Few departments use a DT **dtusa_2**: Many of the functionalities and modules available in the DT in the departments are used	5-point Likert scale	Queenan et al., 2011	IT Manager
DT ACCESSIBILITY	**dtacc_1**: You can access the DT via smartphone / tablet **dtacc_2**: It is possible to access the DT from a few locations **dtacc_3**: There are terminals inside the inpatient rooms that allow access to the Computerized Medical Record or to the DT	5-point Likert scale	Ruiz-Morilla et al., 2017, Experienced IT Managers	Physician/ Nurse
PATIENT-SPECIFIC KNOWLEDGE ACAP	**pska_1**: Patient information can be accessed very quickly **pska_2**: Patient information is very clear **pska_3**: Information about the patient to whom I have access rarely is useful **pska_4**: Through the available information on the patient, it is often possible to find the most appropriate way to act **pska_5**: Through the available information on the patient, if the most appropriate way to act is found (see previous question), it is often possible to act in this way **pska_6**: New patient information is rarely compared to previous ones	5-point Likert scale	Lichtenthaler 2009; Zahra and George, 2002; Pavlou and El Sawy, 2006; Jansen et al. 2005	Physician/ Nurse
RESILIENCE	**res_1**: A delayed intervention / treatment has often led to an adverse event **res_1**: A retarded intervention / treatment often led to a sentinel event **res_2**: A diagnosis / treatment not made has often led to an adverse event **res_2**: A diagnosis / treatment not made has often led to a sentinel event **res_3**: Administration or interruption of pharmacies (administration of analgesic or anticoagulant, interruption of a diuretic, etc.) associated with problematic conditions of the patient (presence of a hematoma, low platelet count, congestive heart failure, etc. ...) often led to an adverse event **res_3**: Administration or interruption of drugs (administration of analgesic or anticoagulant, interruption of a diuretic, etc ...) associated with problematic conditions of the patient (presence of a hematoma, low platelet count, congestive heart failure, etc. ...) often led to a sentinel event **res_4**: A surgical intervention / surgical procedure / invasive exam (colorectal surgery, thoracic tube removal, cystoscopy, colectomy, etc ...) with consequent complications often led to an adverse event **res_4**: A surgical intervention / surgical procedure / invasive exam (colorectal surgery, thoracic tube removal, cystoscopy, colectomy, etc ...) with consequent complications often led to a sentinel event **res_5**: The use of an invasive medical / surgical presidium (venous catheter, etc ...) often led to an adverse event **res_5**: The use of an invasive medical / surgical presidium (venous catheter, etc ...) often led to a sentinel event **res_6**: An error (haemorrhage of the femoral artery at the injection site, intravenous volume overload, excessive saline administration, inhalation of external material, etc ...) often led to an event **res_6**: An error (haemorrhage of the femoral artery at the injection site, intravenous volume overload, excessive saline administration, inhalation of external material, etc ...) often led to a sentinel event	5-point Likert scale	Coding of cascade events in Levinson (2010)	CR Manager

Table 3a – Measurement model statistics

Indicator	Standard Loadings	Construct	Cronbach's alpha	CR	AVE
dtado_1	0.932	DT Adoption	0.918	0.920	0.745
dtado_2	0.913				
dtado_3	0.692				
dtado_4	0.893				
dtusa_1	0.793	DT Usage	0.757	0.760	0.612
dtusa_2	0.772				
dtacc_1	0.909	DT Accessibility	0.834	0.845	0.651
dtacc_2	0.860				
dtacc_3	0.621				
pska_2	0.641	PSKACAP	0.808	0.814	0.526
pska_4	0.791				
pska_5	0.827				
pska_6	0.620				
res_1	0.784	Resilience	0.809	0.812	0.520
res_2	0.748				
res_3	0.684				
res_6	0.661				

Model fit: $\chi2(109) = 127.15$, $\chi2/df = 1.17$; GFI = 0.96; TLI = 0.949; CFI = 0.959; RMSEA = 0.056, SRMR = 0.07

Table 3b – Measurement model descriptive statistics

	Mean	Standard Deviation
DT Adoption	5.142	2.052
DT Usage	4.368	0.728
DT Accessibility	2.824	1.248
PSKACAP	4.359	0.542
Resilience	2.802	0.910

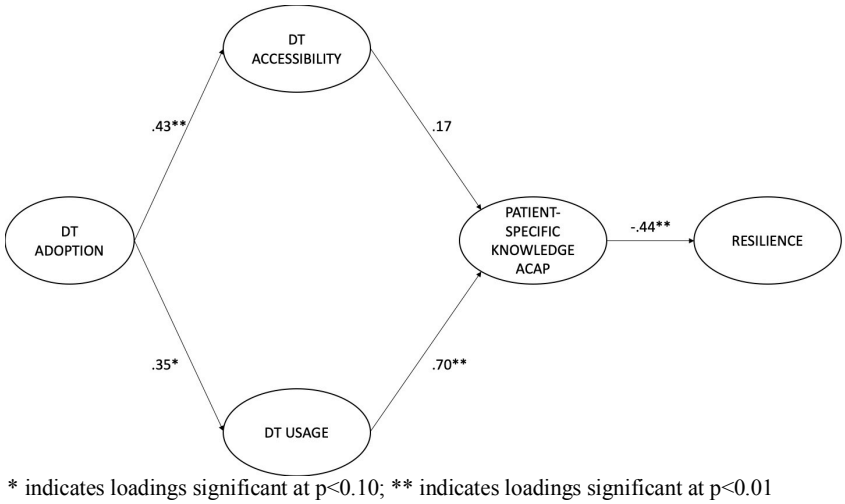
Table 3c – Measurement model correlation matrix

	DT Adoption	DT Usage	DT Accessibility	PSKACAP	Resilience
DT Adoption	**0.745**				
DT Usage	0.310*	**0.612**			
DT Accessibility	0.358**	0.140	**0.651**		
PSKACAP	0.208	0.588**	0.187	**0.526**	
Resilience	-0.216	-0.349*	-0.376**	-0.342*	**0.520**

*p<0.05; ** p<0.01

Figure 2 depicts the structural model. In the first version we included the four control variables, but considering their relationships with the other dimensions are not significant, we dropped them from the model (Cao and Zhang, 2011).

Model fitting statistics suggests us the model fits the collected data (figure 2). Analysing the path coefficients, we can state that, as hypothesized, the linkage between PSKACAP and resilience is significative and negative (the minus sign because the more the organization is resilient, the less is the value of the items), finally the two linkages between DT adoption and DT usage and DT accessibility are positive and significant. The only linkage which is not statistically significant is the one from DT accessibility to PSKACAP. The direct consequence is that, starting from DT adoption, the only pathway that leads to resilience goes through DT usage and PSKACAP.



* indicates loadings significant at p<0.10; ** indicates loadings significant at p<0.01
($\chi2(114) = 133.73$, $\chi2/df = 1.173$, GFI = 0.96, TLI = 0.947, CFI = 0.956, RMSEA = 0.057, SRMR = 0.092)

Figure 2 – Structural model

Finally, analysing the values of the indirect effects (table 4), what is most interesting is the linkage between DT usage and resilience, which is significant. This suggests there may be other mechanisms/dynamic capabilities, apart from resilience, which being

enabled by DT adoption and DT usage, can improve the capability of the healthcare organizations to be more resilient.

Table 4 – First structural model indirect effects

Paths	Std. Estimate	p
DT Adoption → PSKACAP	0.311	0.013
DT Usage → Resilience	-0.309	<0.001
DT Accessibility → Resilience	-0.073	0.220
DT Adoption → Resilience	-0.137	0.063

Discussion and Conclusion

This research enlightens how the implementation of DT in healthcare increases the resilience of an organization, partially by means of its PSKACAP. This result is valuable for research dealing with patient safety, because of its contribution to clarify the positive impact the adoption of DT may have on it. In particular, the ways the technologies impact on resilience/patient safety follow previous results, which highlighted the importance to decompose the interaction of line professionals with technologies (Queenan et al. 2011). Furthermore, the proposed operationalization of resilience in healthcare (looking at the list of cascade events) represents an important contribution for scholars who aim at quantifying patient safety in a complementary way to the previous measures (such the occurrence of adverse events), that do not enclose the resilience capability of healthcare organizations. Furthermore, the introduction of PSKACAP within the frame of the ACAP theory can provide a meaningful instrument to study the role of patient information in healthcare, which could have a key role in the next future because of the increasing implementation of IoT technologies, which enable the collection of a huge patient-specific amount of data.

Finally, the outcomes of this research should lead managers to consider the capability of DTs to increase resilience when they have to choose whether to adopt them or not. In fact, the adoption of "classical" technologies in support of clinical risk management is essential, but the need to be resilient for line professionals force managers to consider how other technologies can enable the implementation of resilient behaviour, in order to cope with operational failures in a meaningful way.

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Direct and Indirect Effect of Procurement Performance in the UAE Healthcare Sector

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Abstract

This research aims to study the role of the staff competency as a mediator to determine the relationship between procurement performance and the influencing factors to obtain procurement performance. The research applied a Partial Least Square based structural equation modelling (PLS-SEM) method to analyse the data collected from the questionnaire survey. The results show that staff competency acts as a full mediator between the procurement performance and e-procurement, procurement policies and producers and organization structure. While it is only partially mediating between the procurement performance and quality management and planning.

Keywords: Procurement Performance, Healthcare sectors, Performance Measurements, Staff Competency.

Topic(s)

- 1.7. Healthcare Operations Management
- 2.29. Purchasing and Procurement
- 2.5. Empirical Research in Operations Management

Introduction

Measuring procurement department performance nowadays become essential to any organization to have a competitive advantage. Procurement is essential to organizations, and its strategies became part of the business achievement. It improvements efficiency and competitiveness and to understand these, it is important to give weight about the strategic factors that influence the performance of the procurement function (Walter et al. 2015). Internal and external forces are influencing the ability to identify the procurement objectives. Relatives between different factors such as procurement planning, staff competency, procurement procedures, E-Procurement, procurement planning, and

procurement quality management, all have an impact on the performance of the public procurement function and therefore they need further research attention (Kim et al. 2013).

Healthcare sectors in the United Arab Emirates

Over the past five years, the healthcare sectors in the United Arab Emirates (UAE) have evolved very fast. In 1971, the country used to have seven hospitals and 12 health centers (U.S.-U.A.E. Business Council, 2018). Currently, the country has 126 public and private hospitals with a joint volume of over 12,000 beds according to the statistics authority Business Council, 2018). The healthcare sectors in the UAE are overgrowing to meet the needs of population growth and the nation's goals to become the national medical tourism center. This rapid expansion led to many challenges to respond to the increased demands by providing the right products and services with sufficient costs and high quality (Bienhaus and Haddud, (2018) and thus warrant for further research.

Literature Review

According to Smith and Conway (1993), to have a successful procurement department, the organization needs to measure its performance using seven success factors: procurement strategy, information management, control system, skilled staffs, corporate management role, risk-taking and positive approach, coordination and focused effort. Procurement performance effected by these procurement processes, effectiveness and efficiency (Van, 2006). The performance of the procurement is the primary driver to gain competitive advantage and improve the quality of the product or services. Continuance assessment of procurement performance will help the organization to minimize the spending, reduce cost, increase profitability and approved suppliers. Comprehensive public procurement policies and practices are essential elements of good governance. Therefore, any unnatural procurement activities in government sectors might lead to a waste of public resources and money.

E-Procurement

E-Procurement is one of the most crucial factors influencing procurement performance. E-procurement the use of technology systems in procurement functions such as placing orders, tendering, negotiations and sourcing materials (Croom and Brandon-Jones; 2007). Public and private sectors use e-procurement for important reasons such as (1) cut in cost, (2) real-time bidding, (3) process transparency, (4) decrease purchasing cycle-time, (5) increase suppliers database and (6) suppliers quality control (Wu et al. (2015). It helps to have full access to suppliers and buyers all over the world and the selection of modern products with sufficient product information. Therefore, e-procurement has a significate influence on procurement performance in government sectors.

Procurement policies and procedures:

Procurement policies and procedures are the guidelines for the staffs to follow to perform activities and constraints on how the procurement should function to achieve the organization strategy (Moncska et al., 2010). Organizations use standard procurement procedures to cover all features of the procurement cycle, including a selection of vendors and suppliers, contracts negotiations, placing orders and payments control (Oumaand Jennifer, 2014) to ensure the efficiency of the procurement department. Without clear

policies and procedures, the procurement department will not function correctly, and that might cause business failure.

Statement of the Problem

Procurement function is one of the essential functions in any organization no matter its core business. Procurement department has enormous contributions to organizational effectiveness and efficiency (Croom and Jones (2007). If the procurement department performs inefficiently in its procurement activities, all other departments will be affected, and consequently, the impact will be excessive on the organization's Supply Chain (Snider and Rendon, 2008). In order to keep the procurement department functioning effectively and efficiently, the performance of this department needs to be monitored and measured to cope with the rapid changes in the supply chain. This study aims to study the research question of: what factors are influencing procurement performance in the UAE healthcare sectors?

Research Objectives

The main objectives of this research are:

- To identify which factors have the most significant influence on the procurement performance in UAE healthcare Sectors.
- To provide a framework to help overcome the adverse side effect of the factors influencing the procurement performance in UAE healthcare Sectors.

Research Design

The following hypotheses are developed;

H_1:

a. There is a significant effect of E-Procurement on procurement performance in the UAE healthcare sectors.
b. There is a significant effect of procurement policies and procedures on procurement performance in the UAE healthcare sectors.
c. There is a significant effect of procurement organization structure on procurement performance in UAE healthcare sectors.
d. There is a significant effect of quality management on procurement performance in the UAE healthcare sectors.
e. There is a significant effect of procurement planning on procurement performance in the UAE healthcare sectors.

H_2: There is a significant effect of staff competency on procurement performance in the UAE Emirates healthcare sectors.

H_3:

a. Staff competency acts as a mediator between E-Procurement and procurement performance in the UAE healthcare sectors.
b. Staff competency acts as a mediator between procurement policies and procedures and procurement performance in the UAE healthcare sectors.
c. Staff competency acts as a mediator between procurement organization structure and procurement performance in the UAE healthcare sectors.
d. Staff competency acts as a mediator between quality management and procurement performance in the UAE healthcare sectors.

e. Staff competency acts as a mediator between procurement planning and procurement performance in the UAE healthcare sectors.

The conceptual model is presented in Figure 1 as follows.

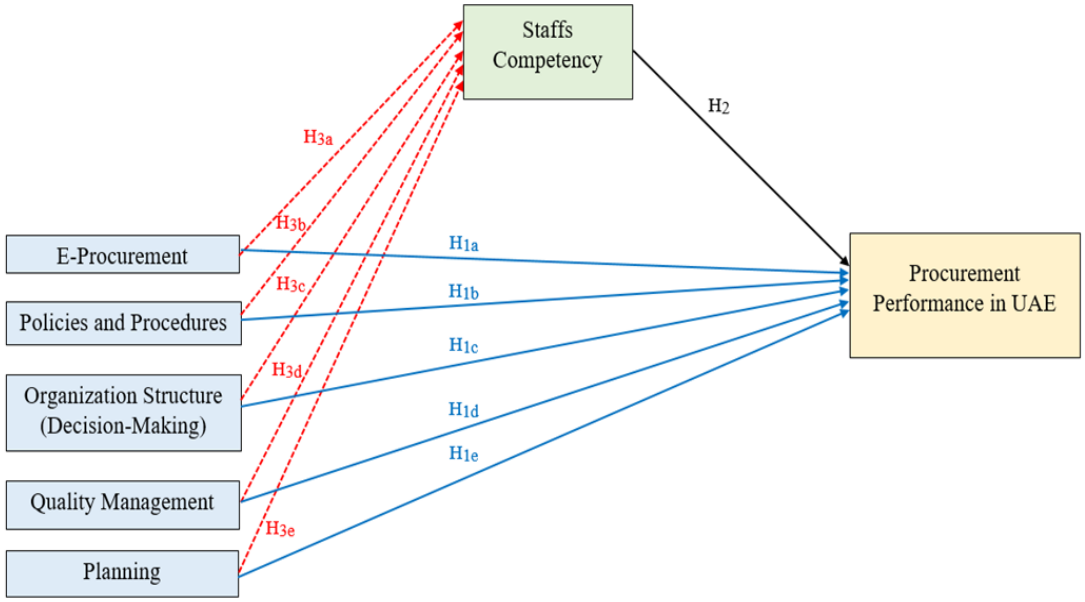

Figure 1 The Conceptual Model

Research Methodology

A survey questionnaire is designed to get the required data about the dependent and independent factors affecting the procurement performance in UAE healthcare sectors. The questions based on the Likert scale with the aim of determining the factors affecting the procurement performance in healthcare sectors.

Data Collection

This research study used primary and secondary data to fulfill the research objectives. The primary data collection tools are a questionnaire survey containing closed-ended questions. The questionnaire survey questions were constructed to obtain information on factors influencing procurement performance in healthcare sectors in the United Arab Emirates. The questionnaire survey consisted of seven sections, and each section consisted of questions related to the factors influencing the procurement performance. The questionnaire allowed better consistency in the way questions were placed, ensuring greater compatibility in the answers. The use of close-ended questions on the questionnaire allowed for consistency of answers to questions. Secondary data was collected through desk search methods from published reports that include journals, periodicals, and supply chain and procurement publications. The questionnaire was distributed by emails to the disciplines using web link using Qualtrics.com website.

From the targeted healthcare sector in the UAE, total number of 127 complete responses were received which represents 47% response rate. The collected data was analysed by using the Smart PLS v3 and the results are represented in Figure 2, indicating the direct and indirect relationships.

Validity and Reliability

This research project carried out a pilot study to validate the questionnaire. To start the validation process of the research tool, the research required opinions of experts in the field of the research study, especially the researcher's supervisors. This helped the necessary revision and modification of the research tool thus enhancing validity. This simplified the necessary review and alteration of the research tool so increasing validity. A group of 10 individuals will be used as a pilot group from the study population to test the validity and reliability of the research tool. The clearness of the tool items to the respondents was started to enhance the tool's validity and reliability. Reliability was attained by correlating the scores of each questionnaire for each variable. Cronbach's alpha value above 0.70 as a threshold value was considered to test for internal consistency (George and Mallery, 2003).

Data Analysis and Presentation

The collected data was summarized, coded and tabularized to be used with SmartPLS v3. This software will be used to process the data to be analyzed using descriptive statistics. The descriptive statistics will include means, standard deviation, and hypothesis test was used to analyze the data to establish the extent to which factor affects the procurement performance.

Hypothesis Testing of Structural Model

Results relating to the Hypotheses shown in Table.1, demonstrating the significance level of the final model (Figure. 4-2) with statistical p-value and t-value having the staff competency as a mediator and with a direct impact by the independent factors to the dependent variable. The model results proved that hypotheses H3a, H1c, H3c, H1e, H3b, H1d, and H2 are non-significant when they are tested in a relationship with the staff competency as a mediator and against the procurement performance. Only H1a (E-Procurement > Procurement Performance), H3e (Procurement Planning > Staff competency) and H1b (Procurement Policies and Procedures > Procurement Performance) are found to be significant with a satisfying p-value ($p < 0.05$) and t-value ($t > 1.976$). These results are bootstrapped by increasing the sample size up to 1000 (Figure. 4-2). A high t-values indicates that the groups of people participated in the survey are different and small t-values indicates that the groups of people are similar.

From the analyzed data for the full model with the independent's factors linked to the staff competency and linked to the dependent factor, the results show that only four factors do have a significant effect toward the procurement performance, which is E-Procurement, Procurement Planning, Procurement Policies, and Procedures and Quality Management. The staff competency has a non-significant and negative impact toward the procurement performance. As a result, the hypotheses with a significant impact can be accepted and the hypotheses non-significant impact will be rejected.

Table 1. Hypothesis Test Results for the Structural Model

Model path functions	Hypothesis	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Significance
E-Procurement > Procurement Performance	H1a	0.464	0.441	0.202	2.296	0.022	Significant
E-Procurement > Staff competency	H3a	-0.057	-0.014	0.208	0.275	0.783	Non-significant
Organization Structure > Procurement Performance	H1c	-0.087	-0.064	0.13	0.667	0.505	Non-significant
Organization Structure > Staff competency	H3c	0.124	0.138	0.118	1.05	0.294	Non-significant
Planning > Procurement Performance	H1e	0.069	0.071	0.199	0.348	0.728	Non-significant
Planning > Staff competency	H3e	0.379	0.365	0.12	3.154	0.002	Significant
Policies and Procedures > Procurement Performance	H1b	0.358	0.323	0.173	2.076	0.038	Significant
Policies and Procedures > Staff competency	H3b	0.082	0.09	0.192	0.43	0.667	Non-significant
Quality Management > Procurement Performance	H1d	0.227	0.28	0.203	1.123	0.262	Non-significant
Quality Management > Staff competency	H3d	0.469	0.419	0.152	3.077	0.002	Significant
Staff competency > Procurement Performance	H2	-0.105	-0.12	0.208	0.503	0.615	Non-significant

According to Baron & Kenny, (1986), a mediator impact is experimented by running the model with the mediator in the structure to determine how much the mediator influence the independent variable and the dependent variable. In this research, It was established that staff competency has a limited influence against the procurement performance with a negative impact. The results from Figure 2, shows that among all the factors influencing the procurement performance with the staff competency as mediator are E-Procurement, policies and procedures and organizational structure where the direct path t-values are 1.333, 1.253 and 1.765, which are less than the accepted threshold values for a t-value of 1.976 according to Hair, Sarstedt, Hopkins, and Kuppelwieser (2014).

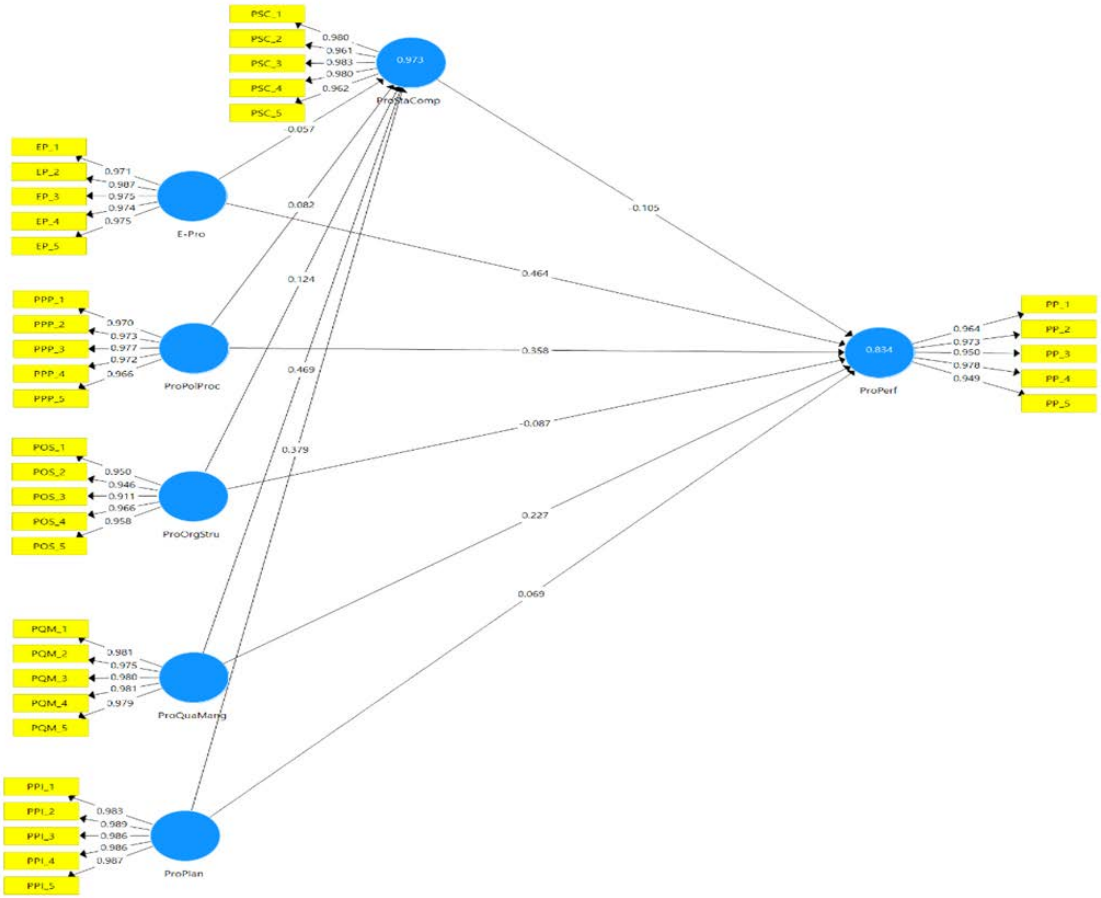

Figure 2. Direct, indirect and total effect of procurement functions with staff competency as mediation factor

Although the literature did support the positive and high influence against the procurement performance, the research study results did not support that. Staff competency according to the literature is the factor that controls and influence other factors. The reasons could be that the staffs are not empowered to perform by themselves as the results showed that the policies and procedures have a high influence against their performance. It could be these policies and procedures are not robust to guide the staffs to enhance the performance as much as to control them to do the job.

This research showed the importance of measuring the procurement department performance. The targeted sectors have problems with the current performance. The research study determined that performance measurement was neglected in these sectors which led to this results. The reasons were discussed earlier need to be more investigated which will reveal the root cause of these problems and might discover new once, also new factors affecting the procurement performance. The performance of any organization relies on the functional department's performance, and continuous measurement to the performance will help to eliminate the negative effects and will help to use the positive effects to improve the performance.

Conclusion

The research study developed a framework for the factors influencing the procurement performance with a mediator. The analysis confirmed that factors such as E-Procurement

policies have a significant positive influence against the procurement performances. Also staff competency acts as a full mediator against the procurement performance. The research study was limited to the United Arab Emirates region concerning its geographical coverage. The results of this research could be used by organizations that are seeking to improve their procurement department performance and its functionality. This research study is the first to examine and determine the factors influencing the procurement performance in United Arab Emirates healthcare sectors.

The outcomes of this research study have some managerial implication for the healthcare sectors in the United Arab Emirates at large and to procurement department management in particular. The research study found out that E-Procurement, policies, and procedures as the most critical factors affecting procurement performance. Procurement department managers from different level mainly need to work on these factors to mitigate their effect ultimately to improve the work performance of the procurement unit.

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Leaders' behavioural change throughout a hospital's lean implementation

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Abstract

This article empirically examines the relationship between leadership behaviours and the implementation level of Lean Healthcare (LH). At three points in time, with a six-month interval between each point, we surveyed and interviewed 12 leaders from a Brazilian public hospital adopting LH. Our findings indicate that leaders who actively adopt LH practices also demonstrate more task- and relations-oriented behaviours, whereas low LH adopters may drop their display of those behaviours over time. This finding parallels with Kübler-Ross's change curve that describes how an individual's confidence, morale and effectiveness levels may vary as a change process, such as LH implementation, unfolds.

Keywords: Lean healthcare, Leadership, Behavioural change.

Introduction

Studies trying to understand the determinants of the successful adoption of Lean Manufacturing (LM) practices have increased significantly over the last few years (e.g., Shah & Ward, 2003; Marodin & Saurin, 2013; Netland et al., 2015; Tortorella et al., 2015). LM has been adopted in several sectors and its implementation involves various challenges (Danese et al., 2018; Nordin et al., 2012). To succeed, the literature emphasizes the importance of an underlying LM culture, which is considered a fundamental element for its long-term sustainability (Hines et al., 2004; Bhasin & Burcher, 2006). Leaders are fundamental for establishing such a culture (Shook, 2010; Marodin & Saurin, 2015a; Alagaraja, 2014); they have the responsibility of influencing individuals and guiding them to achieve strategic and operational objectives.

According to House et al. (2004), LM implementation creates expectations regarding leaderships' behaviours. Mann (2009) reinforces that twenty percent of the effort in the lean transformation process relates to the implementation of practices and tools, while eighty percent focuses on changing leaders' behaviours, including cooperation, delegation and high motivation of personnel (Emiliani, 2003; Angelis et al., 2011; Pamfilie et al., 2012). Further evidence suggests that in order to implement a change

process successfully, such as LM, organisations need to have transformational leaders at the top (Suresh et al., 2012) who emphasise the desired behaviours toward the expected culture and outcomes, which must be carried out by leaders in middle management ranks (Emiliani, 2008; Van Dun et al., 2017). Among others, also Gelei et al. (2015) investigated which leadership behaviours contribute to successful lean implementation.

LM has been particularly widely integrated into the management of healthcare organisations over the last ten years. Lean Healthcare (LH) (Young et al., 2004; Kim et al., 2006; Graban, 2011) is a means for delivering higher quality and more efficient care (Trisolini, 2002). Therefore, to enable patients and healthcare organisations to reap the benefits from LH implementation, proper leadership behaviours must be demonstrated accordingly within the usual highly-complex healthcare context. Thus, the research question of this study is: *How do leaders' behaviours change throughout the lean implementation in a healthcare organisation?*

A longitudinal study was conducted to identify not only how leaders' behaviours change as lean practices are implemented in a healthcare organisation, but also with variations in practice adoption throughout the LH implementation journey. Our results integrate change management theory into the field of operations management.

Literature review

Lean healthcare

A challenge when describing lean implementation is that there is no consensus on how to define lean, since its principles can be expressed and understood in several different ways (Souza, 2009; Pettersen, 2009). Although Liker's (2004) and Womack et al.'s (1990) descriptions of lean have been cited frequently, they have been criticised for not paying attention to human resources in a lean organisation (Hines et al., 2004). Shah and Ward's (2007) definition does include employee involvement in problem solving, but they do not address decentralized participation in decision-making, which is also an important aspect in the healthcare context.

The difficulty in implementing LH successfully and thereby achieving long-term benefits can be further explained by the discrepancy between an organisation's strategy and the actual change (Sull, 2007). Such a strategy-to-performance gap usually occurs during LH implementation due to the primary focus on technical aspects and short-term results, rather than on developing sociocultural factors that support the change process (Kaplan et al., 2014). A more holistic change approach is thus required in order to obtain long-term improvements in the core processes (Mazzocato et al., 2010).

Establishing a LH organisation means lean practices must be part of a comprehensive management system that is supported by committed leaders (Kaplan et al., 2014; Mann, 2009; Steed, 2012). However, only a few empirical studies looked at the specific leadership behaviours that positively affect successful LH implementation (Almeida et al., 2018; Crema & Verbano, 2013; Holden, 2011). Table 1 consolidates the most frequent lean practices evidenced in the literature. As these practices have been found across different industry sectors, they may be representative of LH implementation.

Lean leaders' behaviours

As noted before, leadership is a critical variable for successful LH implementation (e.g., Young et al., 2004; Jimmerson et al., 2005; Womack et al., 2005; Souza & Pidd, 2011; Steed, 2012; Kaplan et al., 2014; Samuel & Novak-Weekly, 2014). Mann (2009) suggested that leaders are not only responsible for making strategic plans but also for guiding the actual organisational transformation towards a lean enterprise. Managers' support and commitment are also seen as key factors for enabling staff to improve their

Table 1 – Most cited lean practices

Lean practices	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	Agreement
1-Flexible manpower	X		X			X		X	X	X	X		X	X	X	67%
2-Pull system	X	X		X		X	X	X	X	X	X	X		X	X	80%
3-Takt time	X	X		X		X		X				X		X	X	53%
4-Continuous flow	X	X		X		X	X	X	X	X	X	X		X	X	80%
5-Material supply	X	X	X	X			X	X	X	X	X	X		X	X	80%
6-Zero defects	X	X			X	X	X	X	X	X				X	X	67%
7-Quality assurance	X	X	X	X				X	X	X				X	X	60%
8-Product/process quality planning	X		X	X	X			X	X	X		X		X	X	67%
9-Standardized work	X	X		X	X		X	X	X	X	X	X	X	X	X	87%
10-Production levelling	X			X	X	X	X	X	X	X	X	X		X	X	80%
11-Maintenance system	X	X		X		X	X	X	X	X	X	X		X	X	80%
12-Workplace organisation	X	X					X	X	X	X	X	X	X	X	X	73%
13-Goal oriented teams	X					X	X			X	X		X	X	X	53%
14-Cross functional work		X		X	X					X	X			X		40%
15-Problem solving methods	X		X		X	X	X	X	X	X	X	X	X	X	X	87%
16-Policy deployment			X	X		X				X	X		X	X		47%
17-Small group activities				X	X					X				X		27%

(1) Shah and Ward, 2003; (2) Doolen and Hacker, 2005; (3) Treville and Antonakis, 2006; (4) Shah and Ward, 2007; (5) Furlan et al., 2011; (6) Stone, 2012; (7) Moyano-Fuentes and Sacristán-Díaz, 2012; (8) Marodin and Saurin, 2013; (9) Stentoft and Vagn, 2013; (10) Netland and Ferdows, 2014; (11) Bhamu and Singh Sangwan, 2014; (12) Jasti and Kodali, 2015; (13) Bortolotti *et al*., 2015; (14) Netland et al., 2015; (15) Marodin *et al*., 2015.

Table 2 – Most cited lean leadership behaviours (adapted from De Almeida et al., 2018)

Behaviours	Main orientation
1-Demonstrating commitment and support	Relations
2-Showing modesty and openness	Relations
3-Acting as a role model	Relations
4-Developing and training employees	Relations
5-Empowering employees	Relations
6-Creating a learning environment	Relations
7-Celebrating and recognizing success	Relations
8-Intellectual stimulation	Relations
9-Committing to self-development	Task + Relations
10-Visiting the work floor (*gemba walk*)	Task + Relations
11-Getting and giving information	Task
12-Formulating and communicating goals and objectives	Task
13-Monitoring and evaluating	Task
14-Visibly applying lean	Task
15-Experimenting	Task

processes and obtain sustainable results (Grove et al., 2010; Crema & Verbano, 2013). But it remains unclear what such leader support may entail in a healthcare setting.

Some regard strong, charismatic relations-oriented leadership as necessary for successful LH implementation (Grove et al., 2010). At ThedaCare, for instance, the change from autocratic, task-oriented leadership to relations-oriented behaviours such as mentoring, facilitating, teaching and supporting was seen as a determining factor for their success (Toussaint & Berry, 2013). Healthcare leaders must create a shared vision that inspires followers, encourages desirable behaviours and fosters an organisation's capacity for change (Oxtoby et al., 2002). However, LH inherently also requires leaders to focus on task improvement (Birken et al., 2012).

In order to retrieve healthcare-specific behaviours associated with an effective lean leader, we performed a systematic literature review (see for a full documentation: Tortorella et al., in press). Twenty-seven studies were selected and content-analysed. Table 2 highlights the fifteen most cited lean leadership behaviours constituting both task- and relations-oriented behaviours. Despite the growing body of knowledge on the topic, none of these studies analysed how leadership behaviours might shift throughout different stages of LH implementation. Following Liker (2004) and Liker and Meier (2006), our aim was to investigate whether people gradually start to change their behaviours and mindsets as new workplace practices are introduced.

Method

A longitudinal, mixed-methods study was conducted among ten hospital-based leaders who led the lean initiatives within their departments. The research expands upon the study of Tortorella et al. (in press) by presenting additional analyses.

Sampling

We selected individual leaders from a public hospital that had started implementing LH two years prior to this study and had collaborated with our previous research. Hence, the respondents' work context was similar, including organisational culture and hospital-wide support for LH implementation. The leaders had a middle managerial position as this is a key role for innovation in healthcare organisations (Birken et al., 2012). The final sample consisted of twelve leaders. Most respondents were nurses (33%) and 42% of them had up to five years of leadership experience. The majority (92%) were older than 30 years and led teams with more than five members (58%).

Data collection procedure

The data was personally collected from each leader at three points in time, with a six-month interval between each time. The first questionnaire was conducted in June 2017 (t_1), the second one in December 2017 (t_2) and the last in July 2018 (t_3). The printed questionnaires were completed by the leaders during individually scheduled meetings. This procedure avoided non-response bias.

We also collected qualitative data by conducting semi-structured interviews with each respondent. When building theory, augmenting quantitative data with qualitative data is usually encouraged, since it helps to check and explain results (Voss et al., 2002). The approximately thirty-minute interviews occurred at each questionnaire appointment in order to complement the information gathering.

Measures

The first part of the questionnaire collected the respondent's demographic information. The second part measured the degree of adoption of the 17 lean practices listed in Table 1 since it represents the level of LH implementation within each respondent's department. Previous studies suggest that the evaluation of pre-defined practices can be considered as an effective approach to identify the organisation's maturity level regarding lean implementation (e.g., Shah & Ward, 2007; Netland & Ferdows, 2014; Marodin et al., 2015). A five-point Likert scale was applied to each item, whereby '1' denoted no evidence of implementation and '5' referred to full implementation. The final part was a self-assessment of the respondent's task- and relations-oriented behaviours based upon the adoption frequency of the fifteen behaviours of lean leadership displayed in Table 2. The respondents indicated on a Likert scale ranging from 1 (never adopted) to 5 (always adopted), how frequently they demonstrated each behaviour. All the Cronbach's alphas were satisfactory (lean practices: 0.969; task- and relations-oriented behaviours: 0.999 and 0.809, respectively).

Data-analysis

We first clustered the data according to the adoption level of lean practices. Thus, we considered LH implementation to be a single dimension based upon the total scores of each respondent at a specific moment of data collection (t_1, t_2 and t_3). The consolidation of a holistic set of practices into one single lean dimension is a common approach (e.g., Marodin et al., 2016). The respondent's total scores were regressed on each of the time intervals using ordinary least square (OLS) regressions, resulting in unstandardized

coefficients associated with each of the twelve respondents (see Table 3). Based upon the unstandardized coefficients' median (15.5), we determined the high lean adopter (HLA) respondents whose coefficients were greater than the median, i.e., a more pronounced growth in terms of LH practices adoption during the study. In turn, low lean adopters (LLA) were the ones whose coefficients were lower than the median and presented a slower increase in their LH practices adoption levels. We also standardized the coefficients in order to find the leaders with the strongest LH adoption, i.e., above 1.0. They showed a big leap in terms of LH practices and, hence, were denoted as extremely high lean adopters (EHLA). Five respondents were categorized as LLA, four were all grouped into as HLA and only two respondents were considered to be EHLA. One respondent was excluded from the database since the standardized coefficient value was not significant.

Table 3 – Coefficients from the OLS regression for each respondent and group identification

Respondents	Unstandardized coefficients	R^2	Standardized coefficients	Group
r_3	1.00	0.250	-2.28	Excluded[b]
r_2	9.50	0.986	-0.90	LLA[a]
r_5	14.00	0.879	-0.17	
r_6	11.00	0.989	-0.66	
r_7	14.00	0.879	-0.17	
r_{12}	15.00	0.871	-0.01	
r_1	16.00	0.988	0.16	HLA[a]
r_4	19.00	0.944	0.64	
r_8	17.50	0.956	0.40	
r_{10}	16.50	0.999	0.24	
r_9	22.50	0.980	1.21	EHLA[a]
r_{11}	24.50	0.961	1.54	

Notes: [a] Coefficients were significant at 5%. [b] Coefficient was not significant.

Subsequently, we calculated the means for the level of LH adoption as well as the task- and relations-oriented behaviours of each group of respondents (EHLA, HLA, LLA). Table 4 shows the group means at each point in time. The behaviours (dependent variables) of each group were plotted separately in a scattered graph against their respective means for LH implementation (independent variables). Based upon a curve fitting with interpolation, we verified the mathematical function that best fitted the data points in order to visualise the data (Arlinghaus, 1994; Hauser, 2009). Using Microsoft Excel, the fitted curves were extrapolated beyond the range of the inputted data in order to understand the possible trend of these behaviours better with respect to extensive LH implementation. The interview data were transcribed and content-analysed.

Table 4 – Behaviours and lean practices means according to each moment of data collection

Moment	LLA			HLA			EHLA		
	LH adoption	Task-oriented	Relations-oriented	LH adoption	Task-oriented	Relations-oriented	LH adoption	Task-oriented	Relations-oriented
t_1	1.64	3.07	3.27	1.72	3.54	3.50	1.18	2.67	2.67
t_2	1.84	3.50	3.64	2.68	3.92	3.75	2.97	3.75	3.44
t_3	3.13	4.40	4.40	3.75	4.46	4.42	3.94	4.42	4.28

Results

Figures 1 and 2 show the results of both the relations- and task-oriented behaviours within the LLA, HLA and EHLA groups. Polynomial curves were found for all three respondent groups where R^2 equals to 1. Using the obtained mathematical functions, we extrapolated the data in order to identify and sketch a behavioural pattern. Both relations- and task-oriented behaviours appear to have similar trends as LH implementation evolves, regardless of their group. Although HLA and EHLA show similar curves, EHLA leaders have more accentuated relations-oriented behaviours in

the long term than HLA ones. The same pattern is not observed for task-oriented behaviours. These outcomes suggest that leadership behavioural changes are actually more prominent in the long run. This result is somewhat aligned with D'Andreamatteo et al. (2015) who suggested that changing leaders' behaviours is time-consuming and cannot be significantly shifted in the short-term. The EHLA findings also support Van Dun et al.'s (2017) and Tortorella et al.'s (2017) conclusions that effective lean middle managers demonstrate relations-oriented behaviours more frequently.

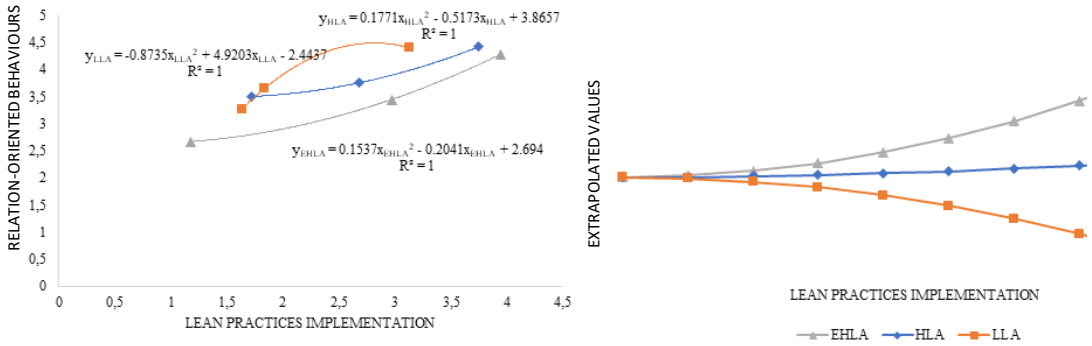

Figure 1 – Leaders' relations-oriented behaviours according to lean practices implementation

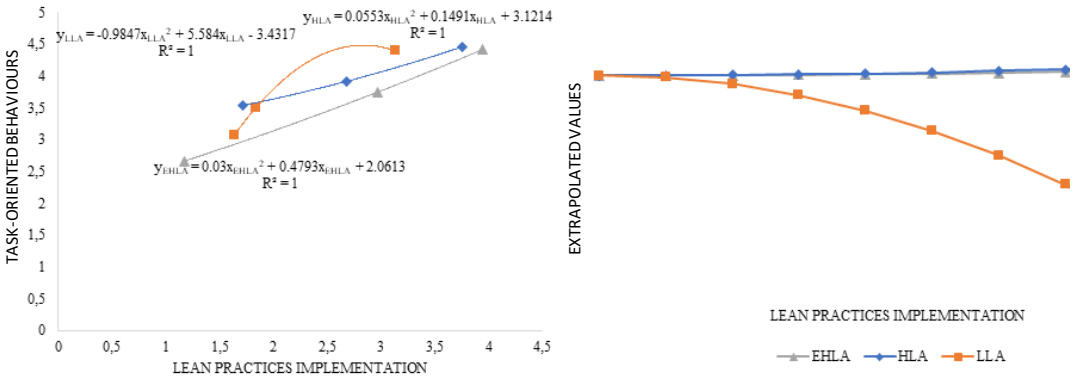

Figure 2 – Leaders' task-oriented behaviours according to lean practices implementation

Additionally, the results indicate that leaders who fully embrace LH implementation (i.e., EHLA and HLA) tend to adapt their behaviours towards both a task- and relations-orientation with more-or-less the same intensity. These leaders may be able to situationally adopt different kinds of behaviours. An explanation for such variations among the respondent groups was found in the interview data (see Table 5). The EHLA and HLA leaders indicated that their followers were really committed to LH implementation and embraced the lean culture of continuous improvement. They also argued that, as implementation advanced, they as leaders acquired new, valuable change and managerial skills. In turn, the leaders who implemented lean practices (LLA) poorly complained about the lack of senior management support during the implementation process and their difficulties in engaging their followers in continuous improvement activities. This shows the rather poor relationship between LLA leaders and their followers as well as their higher-level leaders.

Overall, our findings of the perceived leadership behaviours throughout the LH implementation show parallels between the change curve theory developed by Kübler-Ross (1969) and later enhanced by Zell (2003), Hazen (2008) and Rosenbaum et al. (2018). It is widely accepted in the change management literature that the levels of an

individual's confidence, morale and effectiveness vary as a change process unfolds (Elrod II & Tippett, 2002). Five change stages are suggested, beginning with denial and anger, moving towards bargaining for support, depression and, finally, acceptance. On the one hand, the LLA leaders' behavioural variation in our study can be associated with the denial and stages, respectively: After the initial high expectations of LH, these leaders are still struggling to accept and comprehend the behavioural requirements for a successful LH implementation. On the other hand, EHLA and HLA leaders, who are rapidly implementing LH practices, seem to overcome those initial change stages towards the acceptance stage, which gives them the confidence to explore new behaviours thereby becoming active change agents.

Table 5 – Examples of LLA, HLA and EHLA comments throughout the study

Respondent's group	t_1	t_3
LLA	*"I think the most important thing for lean implementation to succeed is the support, engagement and commitment of the management. In general, senior managers tend to base strategies, budgets and daily decisions solely on numbers, without developing a personal and first-hand knowledge of what goes on in the frontline."*	*"When I started implementing lean at the hospital, my first intention was to schedule some trainings so that my employees could start to implement lean practices. I soon realized that the change process in practice is very different from theory. In fact, only two of my followers actually implemented lean."*
HLA	*"Managers implementing LH will experience resistance. People feel criticized and some get angry. That is why I always try to keep the dialogue open, asking what they think the solution should be and why change causes so much trouble. I give room for criticism and objections in order to understand people's views."*	*"During LH implementation I concluded that it was impossible to improve things by myself. I needed to get everyone on the bus."*
EHLA	*"As a manager, I like to set goals and motivate my employees by emphasizing that all of them can influence the change process but have to take responsibility."*	*"To convince my employees of the benefits of LH implementation, I had to change my own mindset. In order to reduce people`s resistance, I started to spend more time on the work floor and stimulated them to participate more during the improvement meetings. I realised that I needed to set the example if I wanted to engage my employees in the change process."*

Conclusion

This research describes the perceived behaviours of leaders over the course of one year, within a public hospital adopting LH, but our findings may apply to a wider population. Our results offer insights into the entailed changes within LH implementation, indicating that leader behaviours may (or must) shift as LH advances in maturity. In fact, our findings indicate that the effect of LH implementation on the leadership behavioural shift can be underpinned by the change curve theory (Kübler-Ross, 1969); i.e., leaders who embrace the necessary change and are positioned at the exploring or acceptance stages of the change curve are more likely to demonstrate both task- and relations-oriented behaviours. In turn, hospital's leaders who struggle with implementing lean practices could be positioned at the denial and anger stages. Over time, leaders are likely to adopt both task- and relations-oriented behaviours intensively. However, as LH implementation evolves it requires significant changes in leadership behaviours whereby effective LH leaders are likely to demonstrate more prominent relations-oriented behaviours than those who are less active in adopting LH practices.

Senior healthcare managers in organisations interested in LH transformation can use our findings to understand their middle managers' behaviours better as the implementation evolves. Furthermore, by identifying the leaders who are making smaller leaps in LH implementation, senior management can anticipate necessary countermeasures to develop and enhance their soft skills, thus enabling a smoother and less conflicting change. Additionally, our study indicates that it is necessary to have a

reasonable combination of different leadership behaviours (task and relations) to enhance the chances of a successful LH implementation; although relations-oriented behaviours seem to be more prominent in the long-term. This fact is especially important for healthcare middle managers, whose intense technical background usually lack leadership aspects that might enhance their daily-routine management.

This study's small sample size limited any sophisticated data analysis techniques to give more robust empirical evidence. Moreover, extending the data collection period would have enabled better inference about the leader behavioural changes derived from LH implementation that typically take (more) time. Therefore, future research should not only increase the number of respondents, but also improve the data collection to gather more information on both leadership behaviours and LH implementation throughout the change process. Such studies could verify the validity of our outcomes, enriching the insights into theory and practice.

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Application of lean and breakthrough technologies in healthcare services: A bibliometric study (2007 to 2018)

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Abstract

The use of the Internet of Things and the demand for quality services in the healthcare is increasing. This study proposed to carry out a bibliographic review on the subject. The methodological approach adopted was the bibliometric. Databases used were ISI Web of Science, Scopus, Lilacs, PubMed and Cinahl. The analyses suggest that the continuous improvement of processes and the quality of services offered are factors that influence the development of teams that direct their efforts towards patient safety. However, when processes are associated with cyber physical systems, they have difficulties in establishing reliable levels of patient data security.

Keywords: Healthcare Operations Management; Operations Innovation; Technology Management in Operations.

Introduction

Process reengineering methodologies have become an international management phenomenon (Waring and Bishop, 2010), as there is increasing pressure on health services to increase their efficiency. In an effort to achieve this goal, health services have sought alternatives to traditional models, where lean manufacturing stands out as a process improvement methodology (Radnor *et al*., 2012) associated with Internet of Things (IoT) which seeks to improve the user experience of health services in relation to the occurrence of failures, making it more efficient (Lin *et al.*, 2017).

The connection between lean healthcare (LH) - a derivation of lean manufacturing applied in healthcare - and the IoT allows services to be interpreted from the perspective of value creation, where the value created is valued by customers as a way to qualify the service offered, in a way that this service has as available resources (Wetter-Edman *et al.*, 2014).

The lean methodology is considered a radical alternative to the traditional mass-production model, whose goal is to maximize operational efficiency, quality, speed and cost of operations (Holweg, 2007). The lean approach finds popular appeal in healthcare since it aims to redesign clinical practices and resources around simplified, efficient and value-added care (Waring and Bishop, 2010).

The approach adopted in health systems is different from that adopted in manufacturing systems, since the processes are different, with the particularity of working with human lives. The definition of lean for health systems varies in interpretation and practice, and is commonly called lean healthcare. LH is neither an adapted manufacturing tactic nor a cost reduction program; is a management strategy that is based on process improvement in a system (Nelson-Peterson and Leppa, 2007). The management practice is based on the philosophy of continuously improving processes, reducing activities with little or no added value to the patient, changing processes and precarious working conditions (Radnor *et al.*, 2012).

It promotes a structured approach to problem solving and improvement efforts linked to hospital strategy (Mazzocato *et al.*, 2012) and illustrates the desire of policymakers to reorder clinical work by introducing managerial philosophies and techniques, involving the systematic evaluation of the existing work process to determine the evidence of its waste and inefficiencies, increasing productivity and efficiency according to the new evidence (Waring and Bishop, 2010).

Given this diversity, and in addition to standardization efforts, interoperability plays a key role in the success of health systems. This leads to a heterogeneous mix of traditional technologies and processes, generating a new way to implement internet-based quality systems, as well as their integration into other media, a clear challenge (Rahmani *et al.*, 2018). Under this new perspective, a design for service emerges, which provides approaches, skills and tools capable of allowing the actors involved in the process to be part of a new service system design (Wetter-Edman *et al.*, 2014).

Health professionals need to be aware that lean helps in process improvement and value stream mapping, offering many opportunities for health organizations and their continuous improvement initiatives (Vats *et al.*, 2012). When applied correctly, they help evaluate the value of each step in the process, as well as measure and identify the variation of a process for conducting positive and repeatable results (Vats *et al.*, 2011). The physical environment in which a service is delivered or an experience is created is often considered a key variable that influences customer perceptions and behavior (Zomerdijk and Voss, 2010).

Three key aspects were identify for lean methodology to be introduced in a hospital: the evaluation of existing processes, the adoption of process improvements and the monitoring of performance on the improvements implemented (Radnor *et al.*, 2012). This add the need and willingness to improve organizational performance, creating alternative solutions, and increased team communication (Mazzocato *et al.*, 2010).

The use of differentiated, disruptive methodologies assists in the creation of new values associated to the services offered, so that connectivity and information sharing between top management and clients are positively related (Gunasekaran *et al.*, 2017). This makes companies increasingly innovate with differentiated offerings for consumers, creating more complete solutions that combine product and service components, shifting the product-centric perspective to a solution-oriented perspective (Costa and Patricio, 2018).

From this perspective, a growing trend is seen with the use of technologies in health services, which allows a transparent and intelligent interaction between the computational elements and the medical devices. Based on the discipline of computing, sensing, communication and embedded systems technologies, cyber-physical systems (CPS) are part of a natural evolution resulting from the rapid development of information and communication technologies (Gu *et al.*, 2017).

The concept of IoT arises in this context, which should be seen as a multilayer architecture (Lin *et al.*, 2017). The basic difference between CPS and IoT is that the CPS

is considered a system (Lin *et al.*, 2017) which includes several devices connected to the internet, where the devices are also included (Mahmood *et al.*, 2017) while IoT is considered pure internet (Lin *et al.*, 2017) and includes a large number of devices that can communicate through different networks (Mahmood *et al.*, 2017).

Web-based health systems of IoT are proliferating. Many of these systems have a high degree of complexity due mainly to the characteristics of human health and physiology, all complex and dependent on the person (Stankovic, 2016). These complexities give rise to many new research problems, emphasizing the gap between methodologies of service management, quality management and information technology.

To fully realize the potential benefits of lean, organizations need to minimize the impact of barriers and provide specific conditions to the local context (Mazzocato *et al.*, 2012). In a hospital, the work of multidisciplinary teams is also important for the good acceptance of the different methodologies and technologies.

The transformation of the quality system must be part of a comprehensive management system, within an institutional culture of support and with committed leadership. Quality improvement specialists do not work in isolation, but rather in collaboration with operational leaders (Kaplan *et al.*, 2014).

Many clinical leaders motivate teams to develop improvements rather than a unified improvement program with other departments or organizational units (Radnor *et al.*, 2012) by simply adopting specific lean techniques to solve a specific problem within a unit or specific department (Mazzocato *et al.*, 2010). This makes the professionals offer resistance to change, being reluctant to adopt new working procedures (Nelson-Peterson and Leppa, 2007) and new technologies.

Methodology

The methodological approach adopted was the bibliometric. The keywords of the search were: ‘breakthrough technologies’, ‘internet of things’, ‘lean healthcare management’ and ‘healthcare services’, all related to each other and searched with the 'AND' connector. The search was performed in five different databases: ISI Web of Science, Scopus, Cinahl, Lilacs and PubMed, because of their relevance to the health area.

The initial survey of the sample, considering all articles, resulted in 2870 articles. After analyzing the filters considered in each database, this number dropped to 937 articles. The duplicate articles were disregarded, leaving 755 articles, which composed the final base. The articles of the final base had their abstracts evaluated, allowing to fit the articles really relevant to the proposed theme, which resulted in 125 articles. Figure 1 shows the main topics covered in the articles throughout in this period.

5S									1	1			1,60%
Add value to services	1	1	1	3		2	1		3		**4**		12,80%
Efficiency			1	1		2	1	2	3	**5**	1		12,80%
Critical success factor											1		0,80%
Lean and Six Sigma									2	1	1		3,20%
Processes improvement		1	1	2	2	3	1	3	**4**	**8**	**8**		26,40%
Organizational improvement				2		1		3	1	1			6,40%
Quality in services				3	1	2		3	3	2	3	1	14,40%
Breakthrough technologies in healthcare											**16**	**6**	17,60%
Patient safety						1	1	1	2	**4**			7,20%
Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	% Sample

Figure 1 - Subjects covered in the articles, from 2007 to 2018.

Considering the period from 2007 - first article about the theme, until 2018, studies that involved processes improvement (33 articles), breakthrough technologies in healthcare (22 articles), quality in services (18 articles), add value to services and efficiency (16 articles each) had the largest amount of publications. In contrast, articles discussing lean and six sigma have little relevance in the period.

To complement the analysis, the Bradforf Dispersion Law was used, since it allows analyzing the relationships between the articles with the highest number of citations and the respective journals where the article was published (Araújo, 2006). In this study, articles with 30 citations or more were considered, which correspond in 19 articles, 66,92% of all citations of the sample. Table 1 shows the most cited articles and their respective journals.

Table 1 - Most cited articles, journals and number of citations.

Article	Journal	Citations
Service Design for Experience Centric Services.	Journal of Service Research	192
Lean in healthcare: The unfilled promise?	Social Science & Medicine	178
Lean thinking in healthcare: a realist review of the literature.	Quality & Safety in Health Care	176
Lean healthcare: Rhetoric, ritual and resistance.	Social Science & Medicine	118
A critical look at Lean Thinking in healthcare.	Quality & Safety in Health Care	102
Lean service operations: Reflections and new directions for capacity expansion in outpatient clinics.	Journal of Operations Management	73
Creating an environment for caring using lean principles of the Virginia Mason production system.	Journal of Nursing Administration	70
Lessons for Lean in healthcare from using six sigma in the NHS.	Public Money & Management	65
Customer Experience Modeling: From customer experience to service design.	Journal of Service Management	61
Health-CPS: Healthcare Cyber-Physical System Assisted by Cloud and Big Data.	IEEE Systems Journal	48
Wearable 2.0: Enabling Human-Cloud Integration in Next Generation Healthcare Systems.	IEEE Communications Magazine	42
The role of actor associations in understanding the implementation of Lean thinking in healthcare.	International Journal of Pperations & Production Management	42
Big data and predictive analytics for supply chain and organizational performance.	Journal of Business Research	41
Lean thinking in hospitals: Is there a cure for the absence of evidence? A systematic review of reviews.	BMJ Open	39
A Survey on Internet of Things: Architecture, Enabling Technologies, Security and Privacy, and Applications.	IEEE Internet of Things Journal	39
Writing The New Playbook For US Health Care: Lessons From Wisconsin.	Health Affairs	35
Implementation of releasing time to care - the productive Ward.	Journal of Nursing Management	34

How does lean work in emergency care? A case study of a lean-inspired intervention at the Astrid Lindgren Children's hospital, Stockholm, Sweden.	BMC Health Services Research	34
Servitization: revisiting the state-of-the-art and research priorities.	International Journal of Operations & Production Management	31

The number of citations is an important factor, since it reflects the impact of the article in the considered study environment (Haunschild *et al.*, 2016). The metadata was imported with VOSviewer software, version 1.6.9, and network analysis was performed with Netdraw software, version 2.158.

Results

The sample of the publications shows a map oriented for the period from 2007 to 2018. The first article published with greater relevance was in 2007. From this year, there was an increase of the publications in the health area and, from 2017, in IoT, with a considerable number of publications.

The database search occurred in April 2018. Have a peak of publications in 2017, with 33 publications, which corresponds to 26.40% of the final sample. Of the 2017 sample, 33% of the publications correspond to articles directed to the theme of IoT. In 2015 and 2016, articles of this theme were not published, according to the keywords used in the search. This reflects the importance of the proposed study and a greater direction to the conjuncture of the use of these technologies in healthcare.

Figure 1 show the areas of processes improvement correspond to 26.40% of the sample, breakthrough technologies in healthcare, 17.60%, quality in services, 14.40%, add value to services and efficiency, 12.80% each. These articles represent 83.34% of sample and all topics are related to the improvement of processes focused on the quality and level of satisfaction of services.

In addition to the selected articles, the sample highlights that 11 different journals published 52,35% of the articles, with emphasis on the journal BMC Health Services Research, with 17 publications. That shows the importance of quality in the processes in healthcare services. Table 2 shows a summary of journals with the highest number of publications.

Table 2 - Sample of journals and publications

Journal	Publications	% Unitary	% Accumulated
BMC Health Services Research	17	13,49	13,49
Herd Health Environments Research Design Journal	7	5,56	19,05
International journal of Health Care Quality Assurance	6	4,76	23,81
International journal of Operations Product Management	6	4,76	28,57
Journal of Health Organization and Management	6	4,76	33,33
BMJ Quality Safety	4	3,17	36,5
Journal for Healthcare Quality	4	3,17	39,67
Journal of Medical Systems	4	3,17	42,84
Journal of Nursing Administration	4	3,17	46,01
Leadership in Health Services	4	3,17	49,18
Quality Safety in Health Care	4	3,17	52,35

The analysis of the keywords was performed considering a minimum relation of five connections between them and shows a network where the technologies of rupture have a strong influence, relating to all the other and emphasizing the connections with the words decision-making, impact, quality improvement and clinical practices. This highlights the importance of these factors in the study, since it has strong affinity with lean principles. Figure 2 show a keywords network.

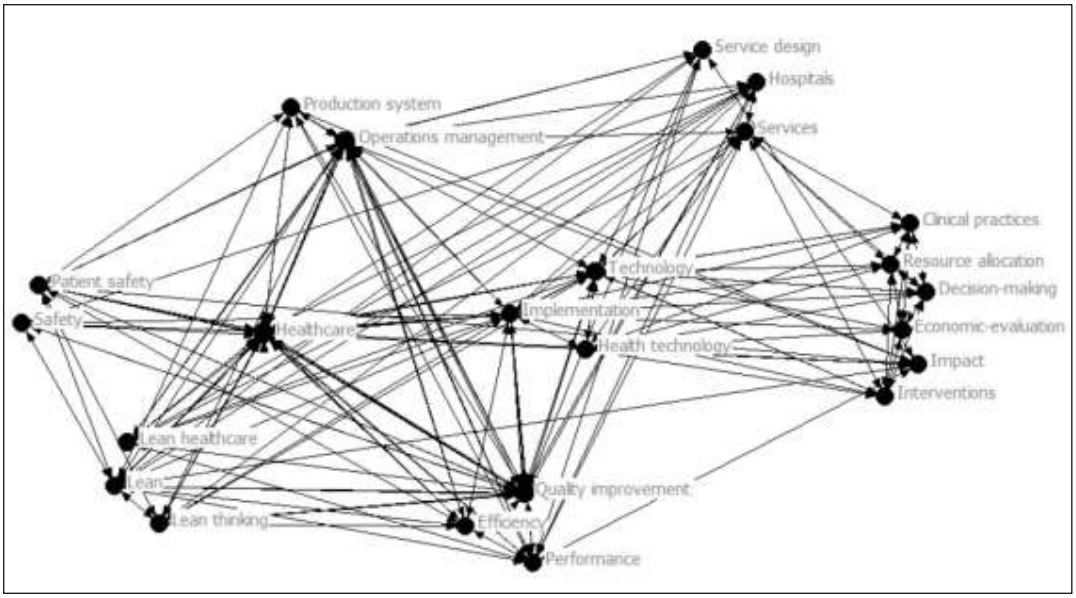

Figure 2 - Keywords network

It is also worth noting that the implementation of the technologies of rupture occurs from the factors related to quality, lean healthcare, services offered and a culture of impact in clinical practices, directing to the correct allocation of resources, i.e. the provision of patient-oriented health services.

Discussion

Lean is applied successfully in a wide variety of health settings and, while emphasizing a holistic view, most reported cases show restricted technical applications with limited organizational reach (Mazzocato *et al.*, 2010; Radnor *et al.*, 2012).

The address lean healthcare as a difficult subject to be deployed in hospitals (Waring and Bishop, 2010), where a critical look at lean healthcare and its association with other quality methodologies (Young and McClean, 2008).

The application of lean as a methodology for improving the quality of health services has been shown to be of significant importance, since the methodology is approached from different perspectives, according to the needs of each institution. Lean healthcare fits into this niche, notoriously when applied in process management.

These challenges are also related to lean, which works in the fine line between efficiency and poor process management, standing out for having strong relationships with patient safety and health worker involvement. The first is to emphasize the importance of patient safety and the second to validate the importance of patient safety, highlighting the involvement of health professionals in achieving satisfactory levels of safety.

So, there area a lot of difficulties encountered to implement the lean methodology in the health sector, in such a way tha is an element of resistance on the part of the

professionals involved (Waring and Bishop, 2010; Mazzocato *et al.*, 2012; Radnor *et al.*, 2012; Kaplan *et al.*, 2014; Moraros *et al.*, 2016).

When lean methodology if not applied properly, does not generate significant results, since this methodology consists of multiple elements that interact with each other (Andersen *et al.*, 2014). The problems presented by lean are due when not deployed with the necessary resources, emphasizing the difficulty in different working groups interact for the methodology (Mazzocato *et al.*, 2012; Radnor *et al.*, 2012; Andersen *et al.*, 2014). Lean, when applied in isolation, produces little or no significant results (Young and McClean, 2008).

The relationship between healthcare, reengineering and service performance shows that processes that influence institution structures, when applied correctly, impact good performance in quality management.

To alleviate health problems, technology development plays a key role in improving the infrastructure used, such as automated health monitoring technologies, so that medical device systems can increase the efficiency and safety of health care, and help specialists overcome critical problems related to medical devices (Dey *et al.*, 2018). This shows that the use of lean tools has great insertion capacity, mainly for the continuous improvement of processes.

Health sector is composed of a series of processes or actions aimed creating value for patients with thousands of processes interacting with each other (Nelson-Peterson and Leppa, 2007), in a such way stating that lean has been expanded to the health sector (Moraros *et al.*, 2016).

The lean methodology adopts as a precept the importance of value, ie the search for the elimination of waste and the aggregation of value to all processes (Brackett *et al.*, 2013). Lean simplifies the standardization of tasks, processes, and reduction of bureaucracy, with a successful implementation of these improvements releases organization resources, which are redirected to the provision of direct patient care (Grove *et al.*, 2010), generates value in services for patients (Nelson-Peterson and Leppa, 2007; Mazzocato *et al.*, 2010; Waring and Bishop, 2010; Radnor *et al.*, 2012; Seidl and Newhouse, 2012).

The same process is occurring with internet technologies, where CPS and the IoT can provide secure, efficient and intelligent services, sharing and managing resources and data between different networks, providing high quality (Lin *et al.*, 2017) and a re-design in services. The development of these new service systems solutions has the potential to allow greater value and increase the competitiveness of companies (Costa and Patricio, 2018) whatever the field of activity.

In today's medical technologies, rapid progress has led to a new generation of health care as well as new treatment strategies (Dey *et al.*, 2018). The design and delivery process helps patients and institutions to create the desired experiences (Teixeira *et al.*, 2012). The benefits are mainly increasing by the agility, flexibility and delivery options made possible by the interconnected services (Yang *et al.*, 2017).

However, the increasing and continuous use of these technologies imposes a challenge on the amount of data generated (Gu *et al.*, 2017) and on the safety of these data, since it is patient information (Rahmani *et al.*, 2018). Traditional analytical techniques are unable to cope with the complexity of the CPS, as well as not being able to predict system behavior with respect to security, reliability, and privacy (Dey *et al.*, 2018).

Among the security issues facing these systems is the fact that operators of such systems are likely to have limited knowledge of the security and privacy of CPS (Almohri *et al.*, 2017). As a result, a sequence of unanswered executions required of the system may simply jeopardize the patient's privacy and/or safety.

The amount of information collected by CPS in hospital settings is vast. An increasingly common source of data for predicting clinical risks, presenting unique analytical opportunities and challenges (Goldstein *et al.*, 2017).

However, health care monitoring data transmission using low-cost sensors and various media was directed to a major concern with the prevailing platforms, leading to inefficient processing of the massive amount of real-time data (Dey *et al.*, 2018).

When health services become more complex, the amount of data received from the patient overloads an already flooded environment of information, where life-critical requirements are critical, since the system can not directly or indirectly cause life-threatening (Stankovic, 2016).

The internet potential of IoT in healthcare is very great and can provide a revolution in the way processes between management, healthcare professionals and patients happen.

Internet and computing revolutions have opened up a vast array of new control potentials that can impact human life, including the health sector (Dey *et al.*, 2018). Lean healthcare, on the other hand, is a theme based on subjectivity between different terms, elements and a certain difficulty in quantitatively measuring the real benefits that the methodology can bring to health systems.

Therefore, the application of lean healthcare, associated with IoT technologies and within a context of interaction with health professionals, shows relevant difficulties in the process of applying continuous improvement methodologies focused on quality.

Conclusion

The work had as objective to analyze the literature on lean healthcare and the integration with the IoT in hospital services. It sought to identify the main elements and aspects related to the proposed theme, as well as the research gaps. Descriptive analyzes showed an overview of lean healthcare and interactions with CPS, the relationships between authors and the main internet-related topics of things.

The lean healthcare research stands out on three main fronts: processes, quality and services. Health institutions that adopt lean healthcare for continuous improvement in products and services need the support of management to implement the methodologies, since they often break down internal obstacles, both in infrastructure and human resources. Improving lean efficacy in health care needs to involve management in continuing problem solving (Mazzocato *et al.*, 2010).

For hospital institutions, safety and patient care, coupled with the perspectives that CPS and lean systems generate, are fundamental, since they allow to evaluate their application in two different perspectives: the improvement of processes and the addition of value to the patient. However, this understanding can be variable, since hospitals have different human resources, which are influenced by different organizational forms. Thus, the team plays a fundamental role in the implementation of lean methodologies and CPS.

The empowerment of the team is able to enable leaders to disseminate learning and the sustainability of the improvements on an ongoing basis (Morrow *et al.*, 2014). However, lean can change the roles, responsibilities, and characteristics of health worker (Drotz and Poksinska, 2014). In face of this contradiction of ideas, future work can deepen the relations between the implementation of lean and CPS and the work done by the teams, especially when related to the improvements proposed by both.

Lean applications emphasize, in most cases, waste reduction, since lean is a managerial concept (Nelson-Peterson and Leppa, 2007; Radnor *et al.*, 2012). However, patient safety, coupled with ease of access to services over the internet, has been increasing its influence on the subjects studied, since it directs the focus to the patient. Future studies can deepen

the analysis between patient relationships and the level of security of their data. This issue is worrying, needs more attention, being little explored in the literature.

A better approach is needed in the relationship between worker qualification, the use of lean and internet methodologies as a way to evaluate productivity in the health environment, the relationship with patients and suppliers, and the development of systems capable of stimulating the innovation of processes in search of continuous improvement.

The study has some limitations. It should not be generalized, since the database studied comprises a restricted set of articles, selected from the keywords used in the search. The articles in which the abstract was directed to the proposed theme were selected, without the complete reading of the study. It may have occurred that some important works in this field have not been evaluated.

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Development of linear regression model for length of stay of Neonatal jaundice patients

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Abstract

This paper is an attempt to provide regression analysis for the Length of Stay (LOS) of Neo-natal Jaundice (NNJ) patients in a northern Indian rural hospital considering data of three months. The Cause and Effect analysis is done in order to find the root cause/s of the longer LOS. The waiting time for registration (WTR), waiting time for tests (WTT), waiting time for phototherapy (WTP) and time for discharge implementation (TDI) are found responsible parameters for longer LOS. The first and second order regression equations are developed and percentage errors between predicted and observed values have also been calculated.

Keywords: Regression Analysis, Neonatal Jaundice, Length of Stay

Introduction

Healthcare quality is a matter of serious concern as there is continuous increase in the investment with little interest towards quality. In year 2000, US Institute of Medicine (IOM) released some reports; which highlight the necessity of safe and quick healthcare system. If specifically talk about one of his report released in 1999, the authors estimated that medical errors leads to 98,000 patient's death per year. All these reports clearly states that there is importance of building quality healthcare system where the patients can get faster and safer recovery.

The importance of quality initiatives in healthcare can be realised from severity factor. As compared to other service sectors, the need of implementation of quality initiatives in healthcare is much more important. For example, if we specially talk about pizza delivery service, there is a requirement to deliver the pizza in 30 minutes. In case, the delivery is not attempted within specified time, it can lead to loss of customer but does not cause any loss in terms of life whereas in case of healthcare, the delay of one or two minutes can make a difference in terms of life or death.

This paper is an attempt to do the regression analysis for the Length of Stay (LOS) of Neonatal Jaundice patients in a northern Indian rural hospital. Regression analysis basically helps to predict the certain variable based on the input of some independent variables. Detailed procedure of NNJ patient starting from their entrance to departure is observed and cause and effect analysis is done in order to find out the root cause of the longer LOS.

Neonatal Jaundice (NNJ)

Hyperbilirubinemia or NNJ is an excessive level of accumulated bilirubin in the blood and is characterized by jaundice, a yellowish discoloration of the skin, sclerae, mucous membranes and nails. Other symptoms may include excess sleepiness or poor feeding. Complications may include seizures, cerebral palsy, or kernicterus. This disease occurs in 60% of the term and 80% of preterm neonates. However significant jaundice occurs in 6% of the term babies.

In many cases, there is no specific underlying disorder. In other cases it results from red blood cell breakdown, liver disease, infection, hypothyroidism, or metabolic disorders. A bilirubin level more than 2 mg/dL may be visible. Concerns, in otherwise healthy babies, occur when levels are greater than 18 mg/dL, jaundice is noticed in the first day of life, there is a rapid rise in levels, jaundice lasts more than two weeks, or the baby appears unwell. In those with concerning findings further investigations to determine the underlying cause are recommended.

For the treatment of NNJ, most commonly used treatment is phototherapy where baby is kept in a machine for specific period of time. Phototherapy is treatment with a special type of light. It's used to treat new-born jaundice by lowering the bilirubin levels in your baby's blood through a process called photo-oxidation. Photo-oxidation adds oxygen to the bilirubin so it dissolves easily in water. This makes it easier for your baby's liver to break down and remove the bilirubin from their blood.

Literature Survey

Thrope (1988) made use of regression analysis to determine hospital payment. In this paper, the author used regression correctly to establish reimbursement rates for hospitals under prospective payment system. Skrifvars et al. (2003) developed multiple logistic regression models for the survival at six months in patients resuscitated from out of hospital ventricular fibrillation. This study suggested that in-hospital factors are associated with survival from out-of-hospital cardiac arrest.

Heuvel et al. (2005) reduced the length of stay (LOS) in children department. The authors identified that there was significant decrease in LOS when patients were allowed to stay with their admitted children during night. It also caused annual saving of $30,000. Drenckpohl et al. (2007) utilised Six Sigma methodology in order to reduce errors in breast milk administration for neo-natals. The authors discussed the possible hazard due to inappropriate administration of breast milk. At the end, errors were reduced to less than 3.4 defects per million opportunities. Gregori et al. (2011) provided a review on regression model for analysing costs in healthcare sector. The authors showed that how methods can produce different results depending on the degree of matching between the underlying assumptions of each method and the specific characteristics of the healthcare problem.

Ligher et al. (2014) utilised Six Sigma in Akron children's hospital and there was 90% decrease in waiting time for MRI in the radiology department. This increases the opportunities of more number of MRIs of patients with increased revenue. Combes et al. (2014) predicted the length of stay in emergency department using regression model.

These models were validated and successfully applied to the classification and prediction of the LOS in the Pediatric emergency department at Lille regional hospital centre, France. Bebbington and Furniss (2015) provided a linear regression analysis in order to predict a large increase in demand for elective hand surgery in England. They analysed the data for carpal tunnel syndrome, cubital tunnel syndrome etc. from 1998 to 2011 and with the the help of linear regression, they estimated trends in both diagnosis and surgery until 2030.

Barrios and Jiménez (2016) applied Six Sigma methodology to shorten the appointment lead time in Obstetrics outpatient department of maternal child hospital in Colombia. Al-Khatib et al. (2016) implemented multivariable regression analysis for the assessment of the generation rate and composition of hospital solid waste for the design of sustainable management system in the developing countries. Redondo-González (2017) performed validity and reliability of administrative coded data for the identification of hospital acquired infections using regression analysis. It is found that administrative coded data may not be sufficiently accurate or reliable for the majority of healthcare associated infections.

Meadows et al. (2018) predicted the length of stay of intensive care unit following cardiac surgery using regression analysis. They showed that both the additive and logistic EuroSCORE can be used to stratify cardiac surgical patients in various predicted length of stay in ICU. Valsamis et al. (2019) developed segmented linear regression models for assessing change in retrospective studies in healthcare. The authors aimed to develop a rigorous mathematical method to analyse temporal variation and overcome limitations in the retrospective studies.

About the hospital

The hospital under study is rural government Indian hospital situated in northern hill region. The hospital has bad capacity of 120. Along with well-equipped machines and equipment's, the hospital has positive attitude workers and staff.

Procedure to Treat the NNJ Patient

Figure 1 shows the procedure to treat the patients staring from their entrance into the department to their discharge. It is clear from the flow chart that as the patient (i.e. parents with their child) enters into the department; they have to go through the registration process. After that, child is examined by the doctor. On the basis of examination, doctors calls for TSB (Total Serum Bilirubin) test, in order to check the bilirubin level in the body. The result of the TSB test decides that whether the patient should go through phototherapy or should discharge after medication. If the bilirubin level is abnormal, then the child goes through phototherapy where the child is kept for 8 to 12 hours depends upon the bilirubin level in the body. The procedure of phototherapy and TSB test is repeated until the bilirubin level is not normal in the child. Finally the baby is discharged after proper medication.

Cause and Effect Analysis

The data related to LOS of 105 children is conducted over a period of 3 months. The average LOS and standard deviation is found out to be 34.53 hours and 20.01 hours respectively. It is clear from the observed states that there is lot of variation in the data which needs to be control or minimised. The calculated range of the LOS is 101 hours with 116 hours and 15 hours as maximum and minimum readings.

Figure 2 shows the cause and effect diagram for the LOS of NNJ patients. The detailed discussion is done with doctors and staff members in order to identify the

possible causes; enlisted in cause and effect diagram. The causes such as 'Waiting Time for Registration' (WTR), 'Waiting Time for Phototherapy' (WTP), 'Waiting Time for Tests' (WTT) and 'Time for Discharge Implementation' (TDI) are validated by statistical analysis. The other potential causes such as 'Familiarity with Equipment', 'Staff Availability', Lack of Positive attitudes towards Work', 'Bad Ergonomics', 'Availability of Technician', 'Doctors Preferred Setting' etc. could be validated by only through monitoring the process i.e. GEMBA.

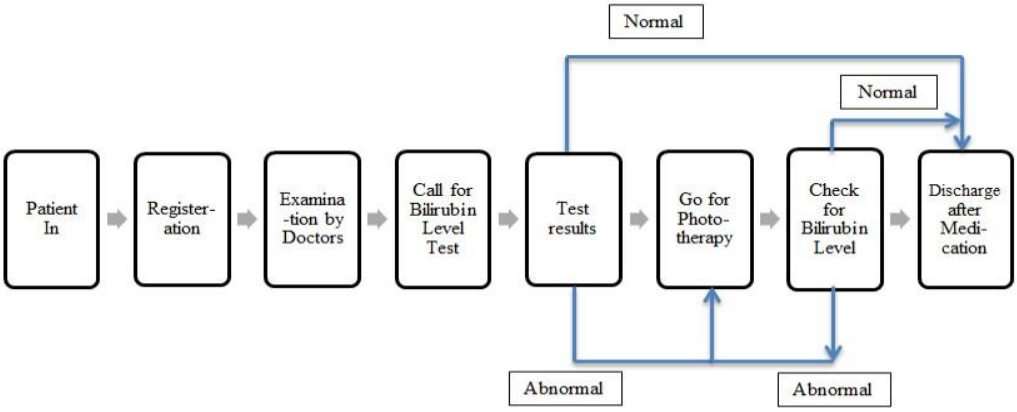

Figure 1: Procedure to treat Neonatal Jaundice Patient

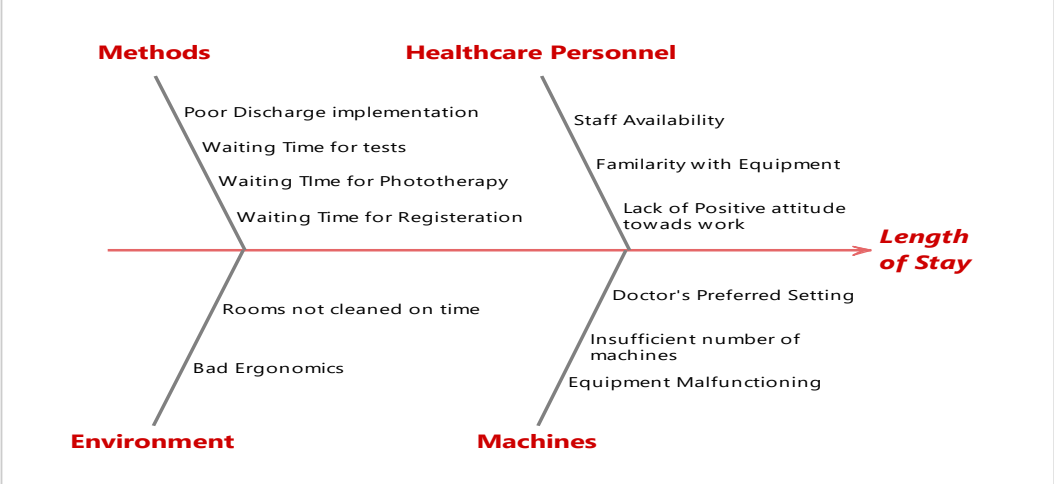

Figure 2: Cause and Effect Analysis for Length of Stay of NNJ Patients

In the GEMBA method, the process is observed for specific period of time in order to find out the availability of specific cause. So some of the causes are validated through GEMBA and rest are validated by statistical analyses. The process is monitored for specific period of time and results of GEMBA are summarized in Table 1.

The data for WTR, WTP, WTT and TDI are individually collected for each of the patients and summarized in Appendix A. It is found that 28.77% of average length of stay is due to these four potential causes. Individually, the average LOS is affected by 5.79%, 6.64%, 6.65% and 9.77% from WTR, WTT, WTP and TDI respectively. So, these four factors are taken for regression analysis of the Length of Stay (LOS)

Table 1: GEMBA observations and Results

Sr. No.	Causes	Observations	Conclusion
1	Staff availability	Staff members are easily available in the department	No Root Cause
2	Familiarity with equipment	Staff and doctors have good understanding of equipment	No Root Cause
3	Lack of positive attitude towards work	Staff have positive response to their work	No Root Cause
4	Doctor's Preferred Setting	Technician provides machine to doctors with their preferred setting	No Root Cause
5	Equipment Malfunctioning	Some time, there is malfunction of equipment but that is rectified in shortly by Technician	No Root Cause
6	Insufficient Number of Machines	There are only three machines due to which waiting time is more	Root Cause
7	Bad ergonomics	Improper ergonomics design of work place causing excessive stretching and bending during the work	Root Cause
8	Rooms not cleaned on time	Rooms are always cleaned on time	No Root Cause

Development of Regression Model

Regression analysis is a process of predicting the relationship between two or more variables. In this, one variable is dependent variable and other variables are independents variables. In our case the LOS is dependent variable & WTR, WTP, WTT and TDI are independent variables. In Simple linear regression, there are only two variables and in multiple regressions there are two or more variables. Basically multiple regressions are an extension of simple regression. So the regression model helps us to predict the value of specific variable based on the values of others variables.

The functional relationship between dependent output parameter (Klocke, 2001) Rawlings et al. (1989) with the independent variable under investigations could be postulated by

Equation (1):

$$y = A.(X_1)^a (X_2)^b \ldots\ldots\ldots\ldots (X_n)^n$$

Where, y is dependent output variable such as LOS and a, b,…., n are the exponents of independent variables. X_1, X_2, X_3……. Xn are independent variables. A logarithmic transformation can be applied to convert the non-linear equation into linear form as shown below:

Equation (2):

$$\text{Log } y = \log A + a.\log(X_1) + b.\log (X_2) + \ldots\ldots\ldots\ldots\ldots\ldots + n.\log (X_n)$$

The Equation (2) can be rewritten into the following linear mathematical model

Equation (3):

$$\eta = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \beta_n X_n$$

Where, η is a logarithmic scale of Length of Stay. X_1, X_2, X_3,……..X_n are logarithmic transformations of different independent variables. The corresponding parameters β_0, β_1, β_3……. β_n need to be estimated.

Due to experimental error, the true response is: $\eta = y - \mathcal{E}$, Where,y and $\mathcal{E}$ are the logarithmic transformations of the measured output and the experimental error respectively. For simplicity the Equation (3) is rewritten as

Equation (4):
$Y = b_0 + b_1X_1 + b_2X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + b_nX_n$

Where, Y is the values of predicted LOS, after logarithmic transformation and b_0, b_1, b_2….b_n are estimates of the parameters, β_0, β_1, β_3,……., β_n respectively.

The detailed data for WTR, WTP, WTT and TDI are collected and summarized in Appendix: A. The functional relationship between dependent output parameters and the multiple independent variables is estimated by using equations (1) to (4). The values of b_0, b_1, b_2, b_3 and b_4 can be found out by linear regression analysis, which is conducted with Minitab software (Minitab 17.0 for windows). The Table 1 presents the empirical expression developed by 1st order model for four variables.

Table 1 Empirical expression developed by 1st order model for first project

Predictor	b_0	X_1	X_2	X_3	X_4
Coefficient of LOS	-19.93	4.50	12.16	7.58	0.12

The developed empirical model by 1st order model for length of stay can be expressed as.

Equation (5):
Length of Stay = -19.93 + 4.50 WTR + 12.WTT + 7.58 WTP + 0.12 TDI

Or $Y = -19.93 + 4.50\ X_1 + 12.16\ X_2 + 7.58\ X_3 + 0.12\ X_4$

The developed empirical model by regression analysis for LOS is given below.

Equation (6):
Length of Stay = $A\ (X_1)^a\ (X_2)^b\ (X_3)^c\ (X_4)^d$

Where A = - 19.93, a = 4.50, b = 12.16, c = 7.58, d = 0.12
With the help of the observed data of Appendix A and the above mentioned equation, the relative error between measured output values and predicted output values of LOS can be calculated. The average percentage error between predicted and observed values is calculated to be 26.83%. The detailed data of predicted & observed values and percentage error between for first order model are not shown in this paper due to limitation of pages. However, the same is shown for second order model in Appendix B.

The developed first order empirical model for LOS reveals lack of fitness due to high prediction errors i.e. 26.83%. As a result, second order model has been developed as given below in Equation 7:

Equation (7):
$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{14}X_1X_4 + b_{23}X_2X_3 + b_{24}X_2X_4 + b_{34}X_3X_4 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{44}X_4^2$

The values of coefficients for LOS can be found out by linear regression analysis of second order model using the experimental data. The logarithmic values of experimental data given in Table 2 are used to formulate empirical equations.

Table 2 Value of coefficient of LOS by 2nd order model

Predictors	b_0	X_1	X_2	X_3	X_4	X_1^2	X_2^2	X_3^2
Coefficients	41.09	-9.06	-14.27	-10.72	0.218	0.108	3.99	1.06
Predictors	X_4^2	X_1X_2	X_1X_3	X_1X_4	X_2X_3	X_2X_4	X_3X_4	
Coefficients	0.95	1.74	3.93	0.096	3.64	-1.40	-1.39	

The developed 2nd order empirical model by regression analysis can be expressed as.

Equation (8):

$$Y = 41.09 + (-9.06)\,X_1 + (-14.27)\,X_2 + (-10.72)\,X_3 + 0.218\,X_4 + 0.108\,X_1^2 + 3.99\,X_2^2 + 1.06\,X_3^2 + 0.95\,X_4^2 + 1.74\,X_1X_2 + 3.93\,X_1X_3 + 0.096\,X_1X_4 + 3.64\,X_2X_3 + (-1.40)\,X_2X_4 + (-1.39)\,X_3X_4$$

Predicted output values for LOS are calculated with the help of Equation 8. Relative error between predicted and measured output values for LOS is calculated and presented in Appendix B. The average percentage error between predicted and observed values is reduced to 17.58% which was 26.83% with first order model.

Validation of Regression Model

The model equation is validated, using the coefficient of determination (R^2) and the F-test from the analysis of variance (ANOVA) methods. The coefficient of determination (R^2) is simply square of the correlation coefficient (r). It is used to judge the model equations whether they are significant or not, in explaining the relationship between the design input variables and objective functions. The larger R^2 is, the better the model. The value of R^2 lies between 0.0 to 1.0. It is very much clear that second order model is more accurate than first order model. So validation is done for second order model. The value of R^2 is computed as 0.766 (From Minitab) for this condition. So, the derived model equations are valid, according to this method.

Using the ANOVA method, it is observed that the formulated multivariable linear regression equations are significant at 0.05 level of significance in explaining the relationship between dependent variable and input design variables.

From the regression model, the calculated F value (F_{cal}) (From Minitab ANOVA table) comes out to be 20.99 whereas the tabulated F value (F_{tab}) is 1.81. Since $F_{cal} > F_{tab}$, the model is significant at 95% confidence level.

Sample Calculations

The calculation for predicted length of stay for second order model (Appendix B) for observation number 1 is as

Equation (9):

$$\text{Length of Stay (LOS)} = 41.09 + (-9.06)\,X_1 + (-14.27)\,X_2 + (-10.72)\,X_3 + 0.218\,X_4 + 0.108\,X_1^2 + 3.99\,X_2 2 + 1.06\,X_3^2 + 0.95\,X_4^2 + 1.74\,X_1X_2 + 3.93\,X_1X_3 + 0.096\,X_1X_4 + 3.64\,X_2X_3 + (-1.40)\,X_2X_4 + (-1.39)\,X_3X_4$$

The values of X_1, X_2, X_3 and X_4 are taken from Appendix A for observation number 1. After putting the values:

LOS = 19.89 hours.

Now, the percentage error in prediction of observation number 1 is calculated as follow:

Equation (10):

Percentage error= $\frac{Predicted\ Value - Observed\ Value}{Predicted\ Value}$

Predicted and observed values are given in Appendix B.

Percentage error = $\frac{19.89-17.57}{19.89}$

Percentage error = 0.1166 = 11.67%

Conclusions

This paper is basically an attempt to implement regression analysis in rural Northern Indian Hospital. The detailed study of the procedure to treat the neonatal jaundice patients along with cause and effect analysis helps to find out the factors affecting the length of stay. Finally, the first and second order regression model is developed for LOS of NNJ patients with waiting time for registration, waiting time for tests, waiting time for phototherapy and time for discharge implementation as independent variables. The percentage errors between observed and predicted variables are also calculated. It is observed that second order model is more accurate than first order model. Finally the validation of the model is also done with coefficient of determination (R^2) and the F-test from the analysis of variance (ANOVA) method. The regression model will helps the doctors and staff to assess and control the length of stay by controlling and minimizing the above mentioned four independent variables.

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Appendix A: Observations of WTR, WTT, WTP, TDI and LOS

S. No	WTR	WTT	WTP	TDI	LOS	S. No	WTR	WTT	WTP	TDI	LOS
1	**0.83**	**1.85**	**1.5**	**2.5**	**17.57**	54	**1.5**	**1.25**	**1**	**2.75**	**20.75**
2	**1.95**	**2.25**	**3.5**	**4.5**	**43**	55	**2.45**	**2.5**	**1.75**	**3.5**	**41.75**
3	**2.25**	**2.85**	**4**	**4**	**46.75**	56	**1.45**	**1.5**	**1.5**	**2.65**	**20.5**
4	**2.5**	**2.9**	**3.35**	**2.55**	**46.5**	57	**1.25**	**2**	**0.8**	**2.35**	**23**
5	**1.45**	**1.95**	**2.85**	**3.2**	**38**	58	**1.7**	**3.75**	**2.55**	**3.6**	**42**
6	**2.5**	**3.45**	**0.5**	**5**	**43.08**	59	**2.2**	**2**	**1.45**	**1.9**	**19.83**
7	**0.65**	**1.5**	**1.5**	**4**	**19**	60	**1**	**1.5**	**1.8**	**2.5**	**19.83**
8	**2.25**	**3.5**	**2.45**	**2.5**	**43.08**	61	**0.9**	**1.75**	**2.55**	**3**	**22.83**
9	**2.5**	**3.45**	**2.5**	**3.5**	**42**	62	**0.5**	**1.65**	**1.95**	**1.7**	**19**
10	**1.5**	**2.75**	**0.75**	**3.25**	**25.25**	63	**0.5**	**3.25**	**3.75**	**3.45**	**40**
11	**0.75**	**1.85**	**1.5**	**4.5**	**19.58**	64	**2.55**	**2.85**	**3.75**	**4.75**	**40.33**
12	**1.2**	**1.75**	**1.85**	**3.95**	**19.17**	65	**2**	**2**	**1.85**	**3.55**	**22**
13	**1.65**	**1.25**	**1.2**	**2.5**	**17.17**	66	**2.75**	**2.5**	**1.45**	**3.5**	**25.75**
14	**1.5**	**2.2**	**1.75**	**2.75**	**21**	67	**1.5**	**2.85**	**3.2**	**4.5**	**38.75**
15	**2.25**	**2.95**	**3.5**	**2.45**	**40.33**	68	**0.5**	**3.45**	**2.8**	**5.45**	**42**
16	**1.5**	**3**	**1.65**	**3.25**	**23**	69	**2.5**	**2.25**	**1.65**	**3.6**	**22**
17	**3.65**	**4**	**2.25**	**3.65**	**68**	70	**0.95**	**1.5**	**3**	**2**	**19**
18	**3.25**	**3.5**	**4.5**	**2.95**	**116**	71	**1.6**	**2.25**	**2.5**	**2.5**	**24.58**
19	**2**	**2.75**	**3.45**	**2**	**45**	72	**0.5**	**3.45**	**2.85**	**6.5**	**38.5**
20	**1.45**	**1.25**	**2.5**	**2.25**	**19.17**	73	**3.75**	**1.45**	**1.4**	**3.65**	**21.8**
21	**2.25**	**1.8**	**2.6**	**1.5**	**20.33**	74	**2.45**	**3.8**	**1.8**	**4.85**	**41.58**
22	**2.75**	**2.75**	**3.75**	**2.75**	**55.67**	75	**1.65**	**4.5**	**2.75**	**3.95**	**88.33**
23	**4.5**	**3.2**	**4.5**	**3.9**	**111.58**	76	**2.35**	**2.8**	**3.45**	**4.45**	**40.33**
24	**1.65**	**2**	**1.8**	**3.75**	**24.5**	77	**2.5**	**3.5**	**4.5**	**5.65**	**63.5**
25	**1.25**	**1.5**	**1.5**	**4.8**	**24.5**	78	**4.5**	**1.95**	**2.25**	**3.55**	**32.13**
26	**2.25**	**2.2**	**2**	**1.9**	**68.75**	79	**2.5**	**2.9**	**3.9**	**4.5**	**43.75**
27	**2.75**	**3.45**	**1.85**	**4.5**	**43.67**	80	**3**	**1.95**	**1.5**	**3.2**	**19**
28	**2.75**	**2.65**	**2.2**	**5**	**41.17**	81	**2.6**	**2.5**	**2.5**	**3.95**	**42.5**
29	**3.45**	**2.5**	**3.2**	**2.8**	**42.67**	82	**3.5**	**0.95**	**2.5**	**2.45**	**19.33**
30	**1.2**	**2**	**1**	**2**	**18**	83	**1.5**	**1.8**	**1.5**	**1.85**	**18.16**
31	**2.85**	**2.65**	**1.95**	**3.5**	**42.41**	84	**2.5**	**1.65**	**2.5**	**2.2**	**25**
32	**1.75**	**2.45**	**2**	**2.9**	**23.08**	85	**2.4**	**1.2**	**2.95**	**3.25**	**21**
33	**0.65**	**1.65**	**0.85**	**3.65**	**15**	86	**1.5**	**2.95**	**1.65**	**5.45**	**43.41**
34	**0.75**	**1.6**	**1.5**	**2.25**	**22.5**	87	**3.2**	**1.75**	**2.5**	**3.65**	**25.5**
35	**1.5**	**2.5**	**1.4**	**3**	**22.08**	88	**1.5**	**2.45**	**3.25**	**4.56**	**48.5**
36	**1.35**	**1.75**	**1.95**	**1.5**	**19.41**	89	**0.75**	**2.85**	**1.95**	**2.9**	**26.5**
37	**2.95**	**3.45**	**2.45**	**3.55**	**99**	90	**1.95**	**0.75**	**2.2**	**3.5**	**21**
38	**0.7**	**1.4**	**2.5**	**1.85**	**20**	91	**2.2**	**2.95**	**3.45**	**4.5**	**45**
39	**1.5**	**1.95**	**0.6**	**1.65**	**19.25**	92	**3.7**	**1.5**	**2.75**	**3.75**	**43.5**
40	**1.35**	**1.25**	**0.85**	**3.55**	**16.83**	93	**3.5**	**1.45**	**1.5**	**2.95**	**23**
41	**2.5**	**0.95**	**1.85**	**3.25**	**23.5**	94	**1.5**	**1.65**	**1**	**3.25**	**22**
42	**0.85**	**1.4**	**2**	**3**	**22**	95	**2.5**	**2.55**	**3.25**	**4.95**	**42.5**
43	**1.75**	**1.25**	**1.65**	**2.65**	**21.08**	96	**2.85**	**1.2**	**2.5**	**2.2**	**17.5**

44	**2.45**	**2.2**	**3.45**	**1.5**	**42.2**	97	**3.5**	**2.25**	**1.5**	**3.65**	**22.5**
45	**1.5**	**1.6**	**1.85**	**2.15**	**16.5**	98	**0.5**	**0.75**	**2**	**2.8**	**17.25**
46	**1.95**	**1.75**	**2.2**	**3.6**	**23.91**	99	**0.95**	**2.6**	**2.8**	**3.85**	**40.5**
47	**2.85**	**2.95**	**3.5**	**4.25**	**70.83**	100	**2.25**	**3.15**	**3.75**	**6.5**	**42.25**
48	**2.5**	**3.25**	**4**	**6.5**	**96**	101	**2.5**	**1.25**	**2.5**	**3.25**	**19.66**
49	**0.6**	**1.9**	**0.8**	**2**	**18**	102	**1.5**	**2.1**	**0.75**	**2.6**	**22.25**
50	**2.25**	**3.5**	**2.85**	**5.5**	**46.75**	103	**1.65**	**2.85**	**1.5**	**4.75**	**42.75**
51	**2.8**	**2.8**	**1.5**	**2.25**	**25**	104	**1.65**	**3.25**	**2.45**	**3.52**	**42.75**
52	**3.75**	**3.5**	**2.55**	**3.75**	**41.75**	105	**0.9**	**1.25**	**2**	**3**	**22**
53	**2.6**	**1.4**	**1.25**	**1.75**	**26.25**						

***WTR= Waiting time for registration, WTT= waiting time for tests, WTP =Waiting time for Phototherapy**
TDI = Time for discharge implementation and LOS= Length of Stay

Appendix B: Comparison between Predicted and Observed values of LOS for second order model

S. No.	PV	OV	PE	S. No	PV	OV	PE	S. No	PV	OV	PE
1	**19.89**	**17.57**	**11.67**	36	**21.26**	**19.41**	**8.70**	71	**27.60**	**24.58**	**10.95**
2	**35.55**	**43**	**-20.97**	37	**55.19**	**99**	**-79.38**	72	**42.07**	**38.5**	**8.50**
3	**53.92**	**46.75**	**13.29**	38	**17.53**	**20**	**-14.09**	73	**21.17**	**21.8**	**-2.96**
4	**53.39**	**46.5**	**12.90**	39	**19.27**	**19.25**	**0.09**	74	**52.24**	**41.58**	**20.41**
5	**24.46**	**38**	**-55.33**	40	**23.23**	**16.83**	**27.56**	75	**73.85**	**88.33**	**-19.60**
6	**37.02**	**43.08**	**-16.38**	41	**20.52**	**23.5**	**-14.55**	76	**47.91**	**40.33**	**15.82**
7	**22.43**	**19**	**15.30**	42	**18.29**	**22**	**-20.28**	77	**78.04**	**63.5**	**18.63**
8	**53.25**	**43.08**	**19.10**	43	**18.82**	**21.08**	**-12.02**	78	**35.68**	**32.13**	**9.96**
9	**52.46**	**42**	**19.94**	44	**44.40**	**42.2**	**4.95**	79	**56.42**	**43.75**	**22.46**
10	**25.72**	**25.25**	**1.82**	45	**19.63**	**16.5**	**15.94**	80	**23.03**	**19**	**17.51**
11	**24.37**	**19.58**	**19.67**	46	**23.41**	**23.91**	**-2.14**	81	**36.14**	**42.5**	**-17.59**
12	**21.90**	**19.17**	**12.47**	47	**56.77**	**70.83**	**-24.77**	82	**24.70**	**19.33**	**21.75**
13	**18.68**	**17.17**	**8.06**	48	**67.20**	**96**	**-42.85**	83	**20.09**	**18.16**	**9.63**
14	**23.28**	**21**	**9.81**	49	**21.33**	**18**	**15.59**	84	**25.93**	**25**	**3.60**
15	**54.26**	**40.33**	**25.67**	50	**55.95**	**46.75**	**16.44**	85	**24.63**	**21**	**14.76**
16	**31.80**	**23**	**27.68**	51	**32.12**	**25**	**22.18**	86	**35.96**	**43.41**	**-20.72**
17	**70.97**	**68**	**4.18**	52	**64.04**	**41.75**	**34.81**	87	**30.38**	**25.5**	**16.05**
18	**96.63**	**116**	**-20.04**	53	**17.13**	**26.25**	**-53.26**	88	**32.83**	**48.5**	**-47.73**
19	**48.61**	**45**	**7.42**	54	**19.75**	**20.75**	**-5.07**	89	**28.38**	**26.5**	**6.62**
20	**19.05**	**19.17**	**-0.63**	55	**29.25**	**41.75**	**-42.73**	90	**21.01**	**21**	**0.05**
21	**28.50**	**20.33**	**28.66**	56	**19.13**	**20.5**	**-7.17**	91	**49.19**	**45**	**8.52**
22	**57.54**	**55.67**	**3.26**	57	**20.45**	**23**	**-12.49**	92	**33.15**	**43.5**	**-31.21**
23	**103.2**	**111.58**	**-8.05**	58	**53.24**	**42**	**21.11**	93	**19.89**	**23**	**-15.66**
24	**23.43**	**24.5**	**-4.55**	59	**21.68**	**19.83**	**8.53**	94	**20.82**	**22**	**-5.67**
25	**26.06**	**24.5**	**6.00**	60	**18.60**	**19.83**	**-6.64**	95	**43.79**	**42.5**	**2.95**
26	**27.46**	**68.75**	**-150.33**	61	**19.33**	**22.83**	**-18.11**	96	**23.83**	**17.5**	**26.57**
27	**47.00**	**43.67**	**7.09**	62	**18.69**	**19**	**-1.64**	97	**27.36**	**22.5**	**17.76**
28	**38.81**	**41.17**	**-6.08**	63	**40.24**	**40**	**0.59**	98	**18.44**	**17.25**	**6.43**
29	**51.27**	**42.67**	**16.78**	64	**54.27**	**40.33**	**25.68**	99	**28.31**	**40.5**	**-43.04**
30	**20.43**	**18**	**11.89**	65	**23.98**	**22**	**8.28**	100	**59.57**	**42.25**	**29.08**
31	**34.24**	**42.41**	**-23.87**	66	**27.86**	**25.75**	**7.58**	101	**23.27**	**19.66**	**15.53**
32	**27.56**	**23.08**	**16.27**	67	**38.49**	**38.75**	**-0.68**	102	**20.62**	**22.25**	**-7.92**
33	**24.31**	**15**	**38.31**	68	**39.00**	**42**	**-7.68**	103	**32.38**	**42.75**	**-32.01**
34	**19.04**	**22.5**	**-18.19**	69	**26.34**	**22**	**16.47**	104	**41.69**	**42.75**	**-2.55**
35	**24.95**	**22.08**	**11.50**	70	**19.49**	**19**	**2.53**	105	**18.23**	**22**	**-20.67**

*** PV=Predicted Value, OV=Observed value and PE=Percentage Error**

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Humanitarian Operations and Crisis

Building social capital in humanitarian-business partnerships

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Abstract

Although NGO-corporate partnerships can bring many advantages for both the humanitarian organization and the commercial organization, research showed that these partnerships are still limited. While these NGO-corporate partnerships can easily be compared with buyer-supplier partnerships in business supply chains, the literature specifically indicates several additional challenges to achieve effective and efficient partnerships between humanitarian organizations and business corporations compared to commercial partnership contexts. To overcome these challenges, our research wants to understand how value can be gained, in terms of resources and assets, from these partnerships. We also aim to analyse the required relationship characteristics and partnership mechanisms that support the management of these partnerships. Through a social capital lens, we study the particularities and contingencies that affect the effective development of cross-sector partnerships between NGOs and business corporations. From a practitioners view, we do not only want to acknowledge the complementarities of NGOs and business corporations for implementing socially sustainable supply management practices, but also understand how NGOs and corporates could successfully implement these understudied cross-sector partnerships.

Keywords: Social Responsibility, Partnering, Case Studies; Qualitative Data Analysis

Introduction

Across the world, humanitarian relief and development challenges call for collaborative endeavors by all potential actors. As the problems are multifaceted, wicked and resource demanding, these challenges are known as complex and turbulent (Van Wassenhove, 2006). Moreover, scholars and leaders agree that dealing with climate changes, urbanization, poverty, natural disasters and conflicts are not a duty of a single government or a traditional humanitarian actor. While dealing with these relief and development challenges was traditionally the role of national governments and humanitarian organization, it is nowadays acknowledged as a common responsibility. Depending on the severity of the disaster or development challenge as well as the resource of the government, the affected country could also call for international humanitarian actors as well as businesses to contribute to the relief and recovery operations. These organizations might provide access to infrastructure and experiences in timely delivering goods to beneficiaries. Therefore, different types of organizations should be sought-after to

contribute in managing these worldwide disasters and developing challenges (Demiroz and Kapucu, 2015). In other words, inter-organizational collaborations, and in particular NGO-corporate partnerships, are becoming essential to deal with these complex and turbulent disasters and development challenges (e.g., Kovacs and Spens, 2007; Nurmala et al., 2018).

Although NGO-corporate collaborations are believed to be important for improving the effectiveness and efficiency of humanitarian activities, there are only limited numbers of successful cases (Maon et al., 2009; Rueede and Kreutzer, 2014). This evaluation should not only be based on financial contributions of business corporations, but also on the potential transfer of knowledge and expertise from the business sector to the NGOs and vice versa. From a supply-chain perspective, partnerships between commercial and humanitarian organizations are a reasonable thought as most supply chain elements are similar in business and humanitarian sectors. Therefore, academics believe that these and methods developed for business supply chains could be adapted to humanitarian relief chains (Beamon and Balcik, 2008; Van Wassenhove, 2006). Additionally, the involvement of the business sector in relief operations could enable faster response times as some critical infrastructures that affect public well-being are owned by the business sector (Stewart et al., 2009). While in business organizations, supply patterns are generally stable, inventory can be easily monitored and lead times are predictable (Oloruntoba and Gray, 2006). Consequently, humanitarian organizations can learn about quality, productivity and efficiency from working with business organizations (Jensen, 2012). This will help them to improve the effectiveness of their distribution network, inventory management and technology (Rueede and Kreutzer, 2014; Pettit and Beresford, 2009). Meanwhile, business supply chains can learn from humanitarian organizations how to increase the flexibility and reliability in uncertain ad hoc environments. Time pressure in humanitarian operations is for instance high as high risks are involved, while demand and supply patterns are unpredictable (Kovacs and Spens, 2007). However, NGO-corporate partnerships are still far from straightforward (Nurmala et al., 2018), despite the multiple endeavors from NGOs. For example, statistics show that the contribution of business corporations to NGOs are currently still limited to 6.6% of the total contribution (Global-Humanitarian-Assistance, 2016).

The difficulties in setting up NGO-corporate partnerships motivate us to look at some successful NGO-corporate partnerships to shed light on opportunities, as well as the challenges. As such, the aim of this paper is to understand contingencies and impediments within these NGO-corporate partnerships to enable our knowledge on how to set up successful partnerships among actors with different goals, challenges and objectives. As setting up inter-organizational relationships has its roots in social capital theory, our research is analyzing how different NGOs and corporates are setting up relational, structural and cognitive capital to support this endavour towards successful partnerships.

Challenges for NGO-Corporate Partnerships

Humanitarian–business partnerships are still far from effective. Recent research (e.g., Nurmala et al., 2017) identified several challenges to achieve effective and efficient partnerships between humanitarian organization and business corporations.

The first challenge for humanitarian organizations relates to differences in mandates and goals. Humanitarian agencies are mandated by their vision of saving lives (Van Wassenhove, 2006). As such, the strategic goals of managing humanitarian supply chains relate to cost reduction, capital reduction and service improvement (Beamon and Balcik, 2008). On the other hand, business organizations are instructed by their vision of acquiring profit. The strategic goals of the business sector are described based on the

financial returns for shareholders (Beamon and Balcik, 2008). These conflicting goals may create challenges for these humanitarian-business partnerships. For example, humanitarian organizations may find it difficult to select partners in time-pressed situations (Kovács and Spens, 2009).

A second challenge relates to image and customer's perceptions. Although humanitarian organizations want to receive resources and knowledge from business organizations, they also want to be independent (Rueede and Kreutzer, 2014; Thomas and Fritz, 2006). Meanwhile, business corporations might worry that a partnership with a humanitarian organization might be seen as a simple solution and as such being perceived as a lack of capabilities and professionalism (Rueede and Kreutzer, 2014; Thomas and Fritz, 2006).

A third challenge relates to differences in working rhythms and culture. For humanitarian organizations, partnerships with business corporations could bring cultural and technical problems (Haigh and Sutton, 2012). While humanitarian organizations view supply chain management as an individual responsibility, commercial organizations are used to manage supply chains with multiple partners. Consequently, humanitarian organizations can learn from commercial organizations how to collaborate with other partners in the supply chain and become more effective by relying on partners in the supply chain (Schulz and Blecken, 2010).

A final challenge relates to the resources available for developing and maintaining these crucial partnerships. As NGOs and business corporations feel sometimes uncomfortable with upfront payments for uncertain event (e.g., earthquakes, tsunami, etc.), funding often only starts after the occurrence of the event. As such, there is little effort and money allocated to building partnerships in the preparedness phase (Fawcett and Fawcett, 2013; Tatham and Pettit, 2010), resulting in ad hoc decisions when unexpected disruptions happen (Fawcett and Fawcett, 2013). On top, humanitarian organizations have little resources to invest in IT solutions, which might enable humanitarian organizations to create visibility in their supply chain.

Theoretical Background: Social Capital Defined

Social capital represents the "assets and resources made available through partnerships within the social structure of the collective that can be utilized by the collective" (Payne et al., 2011, 497). It thus provides a theoretical perspective from which to understand the value gained through social networks (Carey et al., 2011). Social capital can accumulate value, which represents the "sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit" (Nahapiet & Ghoshal, 1998, 243).

Social capital has also been defined as an antecedent of collaboration and coordination, which can eventually increase the performance of teams or organizations (Adler & Kwon, 2002). Among the benefits of social capital are the generation of positive economic and emotional returns (Gulati & Gargiulo, 1999) and the establishment of value and competitive advantage through collective and effective relationships among organizations (Nahapiet & Ghoshal, 1998; Villena et al., 2011).

Nahapiet and Ghoshal (1998) propose three dimensions of social capital, namely, the structural, relational, and cognitive dimensions. These concepts closely relate to the concepts of reach, richness, and receptivity at the network level, as described by Gulati et al. (2011).

Relational Capital

Relational capital refers to qualities of the relationship that enable collaboration and the sharing of resources among partners. By enduring, frequent and intense interactions, partners can build up strong ties. Often these interactions are complex in nature, i.e., involve different persons and different forms of communication and exchanges. The relational dimension describes the quality of connections by characteristics such as trust, reciprocity, and intimacy (Nahapiet & Ghoshal, 1998). Trust is considered a core element of successful buyer–supplier relationships and reduces the risk of opportunism (Morgan & Hunt, 1994; Uzzi, 1996; Krause et al., 2007).

Relational capital is specifically important for communicating knowledge that is difficult or impossible to codify (Hansen, 1999; Reagans & McEvily, 2003). This positive affect that comes with strong relationships is also associated with trust (Krackhardt et al., 2003), reducing the need for formal control systems and contracting, as well as extensive monitoring (Adler & Kwon, 2002). Strong relationships are more committed to maintain the relationship, to recognize its importance and to make adjustments for ensuring its continuity. Strong ties also increase the willingness to share resources (Lin, 2008), including the sharing of tacit or sensitive information (Nahapiet & Ghoshal,1998; Gao et al., 2015), or leverage the diverse knowledge assimilation and recombination (Gao et al., 2015) and the collaboration in complex problem solving activities, such as product innovation (Carey et al., 2011; Villena et al., 2011).

Structural Capital

The structural dimension refers to the configuration of a network and is used to examine the extent to which people in the network are connected as well as the patterns and usefulness of these connections (Bolino et al., 2002). Carey et al. (2011, 279) indicated that structural capital "describes the extent to which actors are linked in a relationships and how they come to understand 'who knows what'." Structural capital refers to the degree to which an actor's network is expansive and diverse, as grounded in theories pioneered by Granovetter (1983) and Burt (1992). It looks for instance at the reach of the network, i.e. how partners increase the direct and indirect connections to different communities.

Cognitive Capital

The cognitive dimension concerns the degree to which connected parties share a common perspective. Cognitive capital is often measured as shared vision, which is further conceptualized as the "collective goals and aspirations" that affect knowledge transfer among members in a network (Inkpen & Tsang, 2005, 157). In a supply chain setting, the common goal is often set by the focal firm (Krause et al., 2007). In addition, Tsai and Ghoshal (1998) discuss the cognitive dimension as the existence of a common code of understanding.

Cognitive capital allows partners to have a common understanding of goals and develop common goals (De Carolis and Saparito, 2006). As a result, it enables coordination among partners (Handfield and Nichols, 1999), forming a synergy among partners' activities to work towards the shared goals (Villena et al., 2011), facilitates the exchange of resources and information among partners (Nahapiet and Ghoshal, 1998; Tsai and Ghoshal, 1998; Preston et al, 2017). The lack of collective goals may result in conflicts among partners (Inkpen and Tsang, 2005; Rossetti and Choi, 2005).

Interaction between Social Capital Dimensions

While previous scholars often focused on one dimension (e.g., the relational dimension)

(Cousins et al., 2006; Yu & Huo, 2018) or two dimensions (Lawson et al., 2007) of social capital, Krause et al. (2007), Carey et al. (2011), and Whipple et al. (2015) studied all aspects of social capital simultaneously. Besides examining the effect of each dimension on the performance of inter-organizational networks or dyads, these scholars specifically call for exploring the interaction among social capital dimensions (Gulati et al., 2011, Jonhnson et al., 2018).

Although Tsai and Ghoshal (1998) emphasized potential interdependency among the three dimensions, such interaction was relatively underexplored (Carey et al., 2011). Acknowledging the multidimensional nature of social capital, Carey et al. (2011) proposed that the relational dimension mediates the association among structural and cognitive dimensions and the performance of buyers in buyer–supplier relationships. Gulati et al. (2011) propose a moderation relation among the three dimensions. For instance, the rich (structural capital) increases the impact of richness (cognitive capital) on the network performance, or receptivity (relational capital) enhances the partners' ability to use the potential value of inter-organizational network, but their success depends on richness (cognitive capital) of accessible resources.

Method: Data Collection and Analysis

Given the limited theory on NGO-corporative partnerships, case study-based methodology is the appropriate choice to refine theories (Siggelkow, 2007), to develop frameworks and ideas (Edmondson and McManus, 2007; Mahapatra et al., 2010; Martinez et al., 2011; Yin, 2014), and to provide practical insights for humanitarian donors and managers (Greenwood and Levin, 2006). More specific, multiple case study design is used for investigating a selected number of focal NGO-corporate partnerships. To understand the dyadic nature of the partnership, nested case study analysis is conducted in which the unit of analysis is a partnership between an NGO and a firm acting as a corporate partner.

To set our sample of European NGOs, we consulted the member lists of the International Council of Voluntary Agencies (ICVA) and the Voluntary Organizations in Cooperation in Emergencies (NGO Voice). In total, 18 NGOs accepted our interview invitation. In our first interview with these NGOs, we talked about partnership formation with corporates. The NGOs provided an overview of all the partnerships. This enabled us to check whether these partnerships are strategic in nature, i.e. not solely rely on short-term financial support or entail long-term commitment of both partners on activities such as mutual consulting (e.g., CSR or risk management), knowledge sharing, product development and/or capacity building. From these interviews, we learned that NGO-corporate partnerships at the strategic level are rather rare. Many NGOs reported transactional collaborations with customized projects, but not strategic in nature. In the end, we were able to identify 13 NGO-corporate partnerships. To investigate the dyad, we also contacted the corporate partner for an interview. Four corporate partners have not replied to our interview requests. As a result, nine NGO-corporate partnerships were investigated, in which both the NGO and the corporate were willing to collaborate and provide in depth information. To validate our findings, we compared our data with four collaborations that are not strategic in nature. To gather this similar dyadic information, we consulted NGOs as well as corporates as respondents for our control cases.

We interviewed 27 managers, with responsibilities in setting up and/or maintaining these partnerships: 13 managers from the NGO side and 13 Managers from the corporate world. Throughout the case studies, we collected data through interviewing informants, studying documents, meeting notes, presentations, and websites and news articles. As such, we used several alternative data sources for triangulation purposes (Jick, 1979): (1)

corporate materials, including corporate CSR reports, home pages, and other Internet sources; (2) documents provided from the interviewees; (3) interviews with NGOs to acquire a more in-depth understanding of the institutional context of each NGO and its specifics regarding humanitarian products or services; and (4) publicly accessible reports and statistics on the humanitarian context. These additional data sources also helped us to validate the insights that we received from our main informants.

Our analysis started by understanding the timeline and resources invested for each dyad. This is called the within-case analysis. Next, we determined the patterns across dyads, equivalent to a cross-case analysis. The purpose of our within-case analysis was twofold: deeply understanding the underlying research phenomenon, and building an explanation of how partnerships are set up within an NGO-corporate setting. The cross-case analysis was used to compare and contrast the explanations of each dyad in order to establish a replicated pattern of how successful partnerships are build (Yin, 2014).

While the first round of interviews focussed on identifying the partnership relationship development trajectory and the different social capital dimensions, later interviews, through a replication logic, were used to classify the social capital resources required for developing towards these partnerships. Finally, these patterns and social capital elements were compared with dyads characterized as non-strategic collaborations. This analytic strategy allowed building a theoretical framework of social capital resources required for setting up partnerships between NGOs and corporates. Similar as in the coding phase, the results of two researchers performing the analyses were compared, while disagreements were discussed.

Results

While we investigated 9 NGO-corporate relationships, we will describe in this paper only the 3 most advanced partnerships (given the page limitations). However, in formulating our results, we also took the other cases into consideration.

For each of the cases, a small description of the evolution of the partnership, the collaborative practices and the aim of the partnerships are described. Table 1 represents the social capital dimensions for each of the cases.

NGO 1-Corporate 1

In 2013, the top management of NGO 1, the leading global independent children's organization, and corporate 1, a science-led global healthcare company, formed an ambitious and strategic global partnership. As the corporate strategy states that 20% of profits from developing countries should be reinvested in those developing countries to support local healthcare systems, the corporate decided to partner with NGO 1 on a more strategic level than previously. While these institutions have collaborated for many years, their collaboration was purely philanthropic and project-based. The main concern of this collaboration was to raise funding and to create awareness. From the beginning onwards, both partners have stressed the importance of clearly articulating the aspirations and expected outcomes of the partnership. Using their combined expertise, resources and influence, the partnership aim is to help to save one million children's lives. More specifically, the partners are looking for new ways to help reduce child mortality with a specific focus on the health of children below the age of five. This vision was written down in a contractual agreement that is renewed every three years. Reporting is performed on an annual basis with clear objective measures and is supported by an open communication policy.

Both the local office and the coordination center of the NGO have dedicated teams focusing on this partnership. At the corporate, the partnership touches almost all areas of

the business, using expertise in R&D, immunization and supply chain logistics to help save children's lives. Their on the ground presence and expertise in child survival provides a local perspective on child mortality to help the partnership reach some of the most vulnerable children with life-saving interventions. With the large global footprint of both organizations, the partnership intends to scale up and replicate its successes for the benefit of communities most in need. To date, the partnership has already reached 2.6 million children. They focus on reducing child and infant deaths by developing child-friendly medicines, by more vaccination, by better training of health workers and by helping children affected by humanitarian crises or disasters in terms of health. In total, ten work streams, ranging from R&D, purchasing and communication to supply chain management, were formulated for working together. Another example is a negotiation training that the corporate organized for the purchasing team of the NGO. Through universal panels, the platform also aims to raise awareness in order to influence other corporates around the world.

NGO 2-Corporate 2.

This partnership started based on short-term programs in the life saving response and recovery phases of humanitarian operations to support the needs of communities close to their own businesses and communities. The corporate runs an initiative called Shelter in a Storm. This initiative aims to provide assistance to victims and is funded by both the corporate and its employees. Using the expertise of the NGO in disaster relief enables IHG to deliver aid (accommodation, financial support or needed supplies) in efficient and effective ways when disaster strikes – either directly or through appropriate partners in the affected area.

As the partnership has grown, its scope has been extended to cover long-term programs in disaster preparedness and longer-term community resilience. The partnership supports both the business goals and values of the corporate and in addition assists the NGO in reaching its global program goals.

NGO 3-Corporate 3.

In 2010, these members began a global collaboration including a wide range of projects. A key target of these collaborative initiatives is to address youth unemployment worldwide. In this vein, the NGO has a Youth Economic Empowerment program to support youth with skills and training. The corporate also has a corporate citizenship initiative, which aims to assist more than three million people worldwide in developing skills to get a job or build a business. The partnership allows them to build on the corporate's core strengths, utilizing their technical skills, research expertise and global networks, and the NGOs grassroots presence and local knowledge on youth employment programming. In another project, the corporate supports the development of a digital birth registration system to ensure all children are counted and can access their rights. That collaboration has included large youth employment programs in, for example, Indonesia, Philippines, Vietnam, and in Eastern Africa.

Since 2013, these partners started more indepth collaborations, which was formalized by a three-year contract in 2016. The corporate has engaged in organizational development and knowledge management projects supporting the NGO in improving its organizational processes. Both partners also find it important to present the collaboration initiatives at each other's relevant forums or stakeholder events.

Table 1. Social capital dimensions for each of our cases

		Dimension and sub-dimensions		
	Relationship type	**Structural capital** – **Pattern and frequency of connections** – **Pattern and frequency of communication** – **Interaction initiatives**	**Relational dimension** – **Trust and trustworthiness** – **Reciprocal commitment** – **Friendship, respect, and reciprocity**	**Cognitive dimension** – **Shared vision** – **Shared language**
NGO1 – Corporate1	**Partnership**	– Both organizations stress the importance of a global (similar) reach. – They conduct frequent exchanges through site visits, roundtable meetings and feedback rounds, and writing blogs. – They conduct intense interactions to work together on projects, knowledge, and capabilities. – They have long-term project commitments in multiple disciplines (communication, purchasing, emergencies, innovation, etc.) – Corporate employees work on projects with NGO – A central coordination office in the NGO links the different projects together. – Different pillars with different managers involved create cross-functional collaboration among the partners. – The partnership enables the NGO to reach and convince other pharmaceutical companies and to influence political choices.	– Both organizations have dedicated people to work on the partnership. – They are pro-active helping one another. – Trust and open communication are the keys to a successful partnership. – The partners rely on each other's competence and knowledge. – The corporation respects the ethical standards of the NGO. – They adapt to work as a team. – Their communication and soft skills have increased. – Benefits go both ways (win–win situation	– The partnership supports the priorities of both organizations. – The partners have a deep understanding of how each other's organization works. – The partners communicate well on how the partnership benefits both parties.
NGO2 – Corporate2		– Both organizations have more than 80 local offices. – They are interested in partners operating in similar global areas. – They have the ability to collaborate across the global supply chain. – They work closely with each other. – They have a good communication flow among their partners (e.g., Web sessions to exchange information). – They have a joint presence at external round tables.	– Both organizations have a constant and continuous engagement with each other. – They spend time and resources to understand the values, core competencies, and needs of their partners. – They adopt a long-term approach in which they exchange information and learn from each other. – They have honest and transparent communication. – They are in a win–win situation.	– Both organizations have common interests. – Their influence has become greater by being together. – The added value to what they do individually is crucial in the collaboration. – Their projects are attached to their core business. – The partners understand each other's working methods and environments. – Both organizations obtain much sectoral knowledge.
NGO3 – Corporate3		– Both organizations have a global presence (operations and market). – Both organizations have regular calls and meetings to evaluate the partnership. – Company matches the partnership goals and activities within its global social initiatives.	– Both organizations have mutual trust. – They have developed a transparent partnership – The partners work closely to achieve the agreed outcomes. – The partners are open to taking risks.	– The partners consider the partnership to be unique. – The end result can affect the world. – They have an overarching vision for the partnership. – The partners understand each other. – They communicate in a similar language. – They have similar mission statements. – Their messages are similar.

Discussion

Non-governmental organizations (NGOs) conduct emergency relief operations or implement development programs to save or enhance the quality of life in developing countries or countries affected by disasters. NGOs are confronted with challenges such as responding to the complexity and increasing demands of disaster and development management—a function that extends beyond their limited supply chain capacity. If these organizations want to systematically deal with such complexity and demands, they need to join or form cross-sectional partnerships with corporates. On the basis of a supply chain-oriented lens, corporates can enhance NGO capacity by providing donations, in-kind supplies, pro-bono resources, low-cost consulting, transportation services, or sharing knowledge on supply chain processes and digitalization. All this extra support from corporates advance the operations of NGOs while increasing the impact of the projects. On the other hand, scholars suggest that NGOs are part of companies' supply chains and influence the sustainability efforts of these firms (Hyatt & Johnson, 2016). Collaborating with NGOs can therefore serve as a means of overcoming environmental and social challenges within the global supply chain of corporates. These relationships can also affect companies' core businesses (resilience, innovation, market development) and enhance the response of both partners to social issues.

We argue that these cross-sectional partnerships present benefits for firms and NGOs, depending on the type of partnership established and the contribution of each partner to the relationship. As more and more NGOs are engaged in cross-sector partnerships and incorporate supply chain thinking and engagement into their approach, there is a need to study the approaches towards partnership arrangements, in relation to social capital formation and performance outcomes (Johnson et al., 2018). To analyse the ideal circumstances in which these NGO-corporate partnerships can operate smoothly, this study adopts a meta-level view of the short- and long-term cross-sectional programs through which NGOs and corporates collaborate. These cross-sector initiatives were analyzed using a supply chain perspective, and NGO–corporate partnerships were scrutinized on the basis of social capital theory. The current research contributes to scholars in supply chain management by examining the antecedent of value creation within cross-sectional interactions. Specifically, we categorized NGO–corporate relationships within socially sustainable supply management using the dimensions of time orientation and value creation. We employed the social capital perspective to explain the factors that influence the formation and performance of different cross-sectional relationships, as an extension to previous studies at the individual (Stolze et al., 2018), functional, cross-functional (Frankel and Mollenkopf, 2015) and firm level (Autry and Griffis, 2008) andas a response to the call made by Johnson et al. (2018) and Rodríguez et al. (2016).

The study reveals that either NGOs or corporates can initiate cross-sector relationships and that their interactions can take place at different levels.

Previous research also showed that there is a turning point and that too much social capital also has a destructive impact on the performance of the partnerships (Villena et al., 2011). While these findings were found in collaborations among commercial corporations, these results do not seem to be valid for NGO-corporate partnerships. It seems that these NGO-corporate partnerships who succeed in lifting the partnership to a strategic level are able to build extra social capital that can be translated into impactful sustainable actions, valued by both partners in the supply chain. These strategic partnerships also make clear that the benefits of relational, structural and cognitive capital might reinforce one another in a stronger way than for commercial partnerships, as earlier suggested by Gulati et al. (2011). Our research for example shows that NGO-corporate

partnerships who succeed to increase their relational capital might also increase their performance by working together on a broad scale of projects, even in collaboration with other partners, i.e., adding the structural capital to the partnership, will release additional benefits of social capital that are more than the sum of the individual forms of capital.

In addition, our research clearly distinguishes how specific characteristics of the partnership can be established. More specifically, our cases show that continuity i.e., the ongoing, long-term commitment, fosters cognitive capital, while the reciprocal supply chain capability building efforts accommodates the development of structural and relational capital.

On top, social capital building within NGO-corporate partnerships also creates a shift in the focus of joint initiatives from responsiveness to preparedness. This additionally improves the resilience of communities in facing disasters or development issues and creates additional value in for all partners in these cross-sector supply chains.

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The Hunger of Nations: Gender Inequality, GDP and the Environment

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Abstract

The UN Food and Agriculture Organization (FAO) estimated that 815 million people suffered from chronic undernourishment in 2016, and named poverty the principal cause of hunger. According to the World Bank, 767 million people live on less than $1.90 per day, i.e. below the international poverty line. Other causes of hunger include conflict, political instability, food and agricultural policies and climate change. To these causes, this paper adds gender inequality. The study uses regression analysis of secondary data to test the influence of gender inequality, income and environmental performance on hunger. Results confirm interrelationships among several sustainable development goals (SDGs).

Keywords: Hunger, Gender Inequality, Environmental Performance

Introduction

There are hundreds of millions of hungry people in the world today. Inspired by the SDGs and the triple bottom line (TBL), this paper investigates the influence of national income, gender inequality and environmental performance on the hunger of nations, focusing on the developing countries.

The second section defines hunger, discusses its causes, and links these causes to the SDGs and the TBL framework. Next, the third section describes the variables and outlines statistical testing methods. Sections four and five present the statistical results and offer a summary discussion, focused on implications for public policy and academic research, respectively.

Hunger

What is hunger?

According to the National Research Council (2006, p. 48), *hunger* is an individual-level concept. It is a "potential consequence of food insecurity that, because of prolonged, involuntary lack of food, results in discomfort, illness, weakness, or pain that goes beyond the usual uneasy sensation." Beyond the hunger of any individual, the problem can be aggregated to the community, the nation and the world.

Insufficient intake of nutrients needed by the body leads to malnutrition. The most critical type of malnutrition is protein-energy malnutrition (PEM), i.e. a lack of calories and protein. The human body converts food into energy; energy contained in food is measured by calories. Protein is necessary to perform many bodily functions, including development and maintenance of muscles. PEM can be lethal. It is the primary concern in discussions on world hunger (https://www.worldhunger.org).

For the individual, the hunger end-game is *starvation*, which is a severe deficiency in the calories needed to maintain the body, for a prolonged period of time. The starving body takes measures to moderate its metabolism and re-allocate energy distribution to its vital systems to survive. Non-essential processes slow down as caloric expenditure is reduced. With the lack of nutrients, organs such as the heart, lungs, ovaries and testes weaken and shrink. Blood pressure lowers as the heart rate slows and *heart volume* – the volume of fresh blood pumped per beat, lowers. The immune system becomes impaired and kidney function is reduced. The individual starts to feel cold, as the body's heat regulation demands are lowered. Less energy is deployed toward rebuilding muscles, and physical exhaustion ensues (Lieberson, 2004).

A typical healthy man who weighs 70 kilograms has sufficient fuel reserves in the form of carbohydrates, fats, and muscles, to starve and still meet caloric needs for 1-3 months (Berg et al., 2002). During these periods of caloric deficiency, the body has an agenda of energy sources to prioritize. It switches from readily available glucose, to stored carbohydrates, to fat derivatives, and then on to proteins. In the final stages of starvation, the body begins to eat itself through *catabolysis* – the breakdown of fat and muscle tissue to stay alive.

The first priority of the metabolism is to provide enough glucose to the brain and tissues that are dependent on the fuel, like red blood cells. In the early fasting state, blood-glucose levels drop, decreasing insulin secretion and causing the pancreas to secrete more glucagon. This is the signal for the *starved* state. Without readily available blood glucose, carbohydrates stored in the liver as *glycogen* are used for fuel. Glucagon acts as the stimulator for the breakdown of glycogen into glucose. The only other potential glucose source comes from amino acids, produced in the breakdown of proteins. This is very hazardous because it can cause muscle atrophy and loss of organ function. Thus, as a second priority, starved metabolism preserves protein by shifting its fuel source from glucose to fatty tissue. Fatty acids and *ketone bodies* are compounds produced during the metabolism of fats. Within several weeks, ketone bodies become the major fuel of the brain. Once fat stores become depleted, the only remaining fuel source is protein. Degradation begins with the proteins that have a rapid turnover rate, such as those in the intestinal lining. In the late stages of starvation, the metabolism accelerates protein breakdown to the muscles, heart, liver and kidney. At this point, the body is at risk of organ failure and death (Berg et al., 2002).

What are the causes of hunger?

The FAO and its partners have identified the following causes of hunger: poverty, war and conflict, political instability, food and agriculture policy, and climate change (FAO, 2017; FAO et al., 2018). This sub-section briefly discusses each of these causes.

Poverty is the principal cause of hunger. The causes of poverty are lack of resources, unequal distribution of income, war and conflict – and hunger. By compromising health, energy levels and mental functioning, hunger fuels poverty as it reduces an individual's ability to learn and earn money by working.

Conflict interferes with food production, due to destruction of the land and logistics infrastructure. It also often increases the cost of food, making it less affordable for

hungry people. Political instability typically brings economic decline, reducing strength of a nation's currency, yielding higher food prices and lower availability. Job losses further compromise the affordability of food for individuals and families.

Lack of adoption of more productive agriculture technology in lower-middle-income countries contributes to large differences in the volume of food production compared to higher income countries. Further, agricultural policies and practices designed to increase crop yields have had unintended consequences in terms of land and soil degradation, as well as depleting or polluting available groundwater. This affects future food production capacity, as these resources may be non-renewable.

Climate change is yet another cause of food shortages and hunger. Unstable weather patterns can bring drought. On the other hand, hurricanes and cyclones cause flooding, along with harm to livelihoods, reduced agricultural production and rising local food prices. Climate change also contributes to political instability and mass migration.

Ecofeminism lays a theoretical foundation for the link between gender inequality and environmental degradation. According to Metz (2008), "ecofeminism embraces the idea that the oppression of women and the oppression or destruction of nature are closely connected;" i.e. that gender discrimination is related to exploitation of the environment. Parsons (2011) argues that eco-feminist and Indigenous ethos intersect on themes of respect for women and the earth. One fundamental concept tying these two perspectives together is *inseparability* and an *economy of affection*, as opposed to separateness and an economy of exploitation (Kelly, 2018). Separateness of nature and humans, and of women and men, endorses environmental exploitation and gender inequality. In turn, environmental harm and discrimination against half the population enables movement away from, rather than toward, the goal of zero hunger.

Sustainable Development Goals (SDGs)

The causes of hunger reveal important interrelationships among the following SDGs (UNDP, 2019).

- Goal 1: *No poverty* – end poverty in all forms and dimensions by 2030. The UNDP links poverty to reduced access to nutritious food, clean drinking water and sanitation.
- Goal 2: *Zero hunger* – end all forms of hunger and malnutrition by 2030. Extreme hunger and malnutrition are huge barriers to development in many nations, often partly due to environmental degradation, drought and biodiversity loss.
- Goal 5: *Gender equality* – "end all discrimination against women and girls is not only a basic human right, it's crucial for sustainable future." The UNDP notes that 35 percent of women have experienced physical and/or sexual violence. In addition, women earn only 77 percent of what men earn for doing the same work.
- Goal 13: Climate action – to mobilize US $100 billion per year by 2020 to enable developing countries to better adapt to climate change and invest in low-carbon development. Average annual economic losses from climate-related disasters are estimated to be hundreds of billions of dollars.

Triple Bottom Line (TBL)

The three principle causes of hunger considered in this study also represent the TBL dimensions of sustainability: social, environmental and economic. These dimensions are frequently referenced as the three Ps: people, planet and profits. Slaper and Hall (2011) discuss challenges and opportunities of measuring the TBL, whether as an index or from a total cost perspective. It is not easy to measure people and planet in the same units as profits, i.e. in terms of dollars (Anonymous, 2009).

Theoretically, the TBL attempts to account for total costs of operations. Thus, it is akin to the balanced scorecard. The idea is: what is measured will receive managerial attention. Organizations that measure their social and environmental impact are more likely to become socially and environmentally responsible. Traditionally, cost-cutting and the "bottom line" were the top priorities of business, to the neglect of environmental and social costs of moving production and service operations to nations with low costs, and lax social and environmental standards; leading to exploitation of cheap labor and natural resources (Anonymous, 2009).

Methodology

The methodology involves regression analysis of secondary data. This section describes the dependent and independent variables, along with their sources.

Global Hunger Index (GHI)

The dependent variable is the International Food Policy Research Institute's Global Hunger Index (von Grebmer et al., 2016). GHI measures hunger at the global, regional and national levels each year, using four indicators:

- Undernourished people as a percent of the population;
- Proportion of children < 5 who are wasted (have low weight for their height);
- Proportion of children < 5 who are stunted (have low height for their age);
- Mortality rate of children < 5, which reflects poor nutrition and sanitation.

The index does not include "rich" countries, such as Sweden and the United States, where the prevalence of hunger is assumed to be very low. The 2016 GHI is available for 118 nations.

Gender Inequality Index (GII)

According to the United Nations Development Programme (UNDP), gender inequality is a major barrier to human development. Women and girls face ongoing discrimination in terms of health, education, political representation and labour market participation, with negative impact on development of their capabilities, along with their freedom of choice. Constructed by the UNDP, the Gender Inequality Index (GII) estimates gender inequality across three important aspects of human development: health, empowerment and labour market participation (http://hdr.undp.org/en/content/gender-inequality-index-gii). Higher GII scores imply greater gender inequality. The 2016 index is computed for 159 countries, revealing gender gaps and pointing to possible public policy options for overcoming obstacles faced by women.

Environmental Performance Index (EPI)

The EPI rates national performance on environmental matters in terms of protection of human health and ecosystems. It scores performance across nine issue areas, made up of twenty specific indicators. These nine issue areas are: health impacts, air quality, water and sanitation, water resources, agriculture, forests, fisheries, biodiversity and habitat, and climate and energy. The EPI uses primary and secondary data from multilateral organizations, government agencies and academic collaborators. All its data sources are publicly available. The Index enables cross-country comparisons and comparisons over time. According to Hsu et al. (2016), the EPI "was created with the aim to shape data-driven environmental policymaking."

The EPI report contains only two mentions of "gender in(equality);" arguing that "poor sanitation degrades the quality of life for millions of people, exacerbates gender inequality, and stunts economic development" (Hsu et al., 2016, p. 55). The report notes

a positive relationship between EPI and GDP/capita among included countries. It also suggests something other than economic development may be important for improving environmental performance. Perhaps this "something" includes gender equality. The 2016 EPI is calculated for 160 countries.

Results

Table 1 reveals the regression results. The three independent variables (GII, EPI and log (GDP/capita)) explain 72 percent of the variance in GHI (adjusted R-square = .718) and overall fit between the data and model is significant (F = 69.713; p-value = .000). The results provide evidence indicating a lack of issues of autocorrelation in the regression residuals, as the Durbin-Watson statistic (1.968) is close to 2.0. Table 1 also shows the variance inflation factors (VIFs) to assess possible issues of multicollinearity among the independent variables. According to Akinwande et al. (2015), VIF between 5 and 10 indicates high correlation that may be problematic, and VIF > 10 suggests the regression coefficients are poorly estimated due to multicollinearity.

Table 1 – Regression Results

Model*	Std. Beta	t-statistic	p-value	Tolerance	VIF
(Constant)		6.131	.000		
GII	.253	2.826	.003	.434	2.305
EPI	-.336	-3.070	.002	.292	3.430
log(GDP/capita)	-.345	-3.315	.001	.322	3.104

*Dependent variable = GHI

This regression confirms support for the link between gender inequality (GII) and the global hunger (GHI). The t-statistic (2.826; p-value = .003) is significant at the .01 level of alpha. Gender inequality and the hunger of nations appear to go hand-in-hand. Environmental performance (EPI) is also significantly related to hunger (t = -3.070; p-value = .002). Poor environmental performance is another friend of hunger. Finally, as expected, the link between GDP/capita and hunger is also significant (t = -3.315; p-value = .001). This evidence supports the close connection between poverty and hunger.

In summary, results based on regression analysis support the following relationships:

- Gender inequality is linked to the hunger of nations.
- National income (GDP/capita) is inversely linked to hunger.
- Environmental performance is inversely linked to hunger.

The results confirm important inter-relationships among the sustainable development goals (SDGs); specifically no poverty (SDG #1), zero hunger (SDG #2), gender equality (SDG #5) and climate change action (SDG #13). Reducing poverty, promoting gender equality and addressing climate change are steps on the path toward zero hunger.

Implications

For policy

Regarding concepts such as the SDGs and the TBL, Slaper and Hall (2011) suggest that: "Policy-makers use these sustainability assessment frameworks to decide which actions they should or should not take to make society more sustainable."

Study results confirm important inter-relationships among several of the sustainable development goals (SDGs). In terms of public policy and sustainable development, the

findings suggest government policy makers and NGO leaders and donors should include a focus on eliminating gender inequality as they work to end poverty and hunger. This is the long game, solving a lingering large problem rather than treating its symptoms. In addition, investments in climate change mitigation can facilitate movement toward zero hunger. While sending food and money may reduce hunger this month, eliminating exploitation of women and nature may be needed to eliminate hunger by 2030.

For research

Future research is needed to better understand the interplay between hunger, obesity and food waste. The World Food Program (WFP) lists food waste among the causes of hunger (http://www.wfp.org/hunger/causes). Over-eating and obesity can be viewed as a form of food waste. Further, there appears to be a paradoxical link between obesity and food insecurity (Dhurandhar, 2016), which leads to hunger.

This study may be among the first to include both environmental performance and gender inequality in the world hunger conversation. One future research opportunity would involve including more variables (e.g. elements of national culture) among the predictors of hunger. Another opportunity is to focus on individual nations or a small group of nations to understand unique cultural and political challenges in the fight against poverty, hunger and gender inequality.

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Climate science and humanitarian supply chain: The use of climate information in humanitarian relief efforts

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Abstract

This paper provides a systematic literature review of the state-of-the-art applications of climate information in humanitarian relief efforts in order to further the understanding of how climate science can be better integrated into the decision making process of humanitarian supply chain. By delivering an overview of the current applications and challenges of climate information, this literature review intends to develop a conceptual framework as well as research agenda for future contributions.

Keywords: Disaster management, Humanitarian logistics, Sustainable supply chain

Introduction

In the past few decades, the threats of climate change have been identified and understood thanks to the numerous researches conducted on climate risks. A report published recently by the Centre for Research on the Epidemiology of Disasters and UNISDR (2018) reveals that in the last twenty years, climate-related disasters have resulted in direct economic losses amounting to $2245 billion, which make up 77% of the total economic loss of all disasters. 91% of all disasters were due to extreme weather events, the frequency and severity of which increased by climate change (CRED & UNISDR, 2018), which has become a pressing challenge for supply chain resilience (Papadopoulos et al., 2017).

Humanitarian supply chain, responding to disasters including climate related disasters but in the meanwhile affected by climate risks (Halldórsson and Kovács, 2010; Kovács and Spens, 2009), calls for an updated design in order to adapt to climate change (Kovács and Spens, 2011). One of the recommendations for humanitarian supply chain to achieve better performance is to utilize "technology and emerging best practice" (Majewski et al., 2010), in particular climate science in order to cope with complications resulting from climate change (Braman et al., 2010). A review study on sustainable humanitarian supply chain has also acknowledged that climate change adaptation should be integrated into sustainable humanitarian supply chains (Dubey and Gunasekaran, 2015).

However, even though given the research gaps identified in the past years, the number of contributions to sustainable humanitarian supply chain in the face of emerging threats remains relatively small (Dubey and Gunasekaran, 2015). There are examples of using climate applications in the field, such as that taking climate factors into account in decision support systems in warehouse location selection (Charles et al., 2016), but a state-of-the-art review is yet to be conducted.

To fill this gap, this article provides a review of the current applications of climate information in humanitarian relief efforts in general and to draw links between applications in humanitarian relief efforts and existing as well as potential applications in humanitarian supply chain, as humanitarian supply chain is a key ring of humanitarian relief efforts.

The article aims to answer two research questions:

- How is climate information being used in humanitarian relief efforts and humanitarian supply chain?
- What are the challenges encountered by the current applications and the potential solutions to these challenges ?

By answering these research questions, the article intends to develop a research agenda for future contributions to the field.

Methodology

Systematic literature review, originally used in medical science as an evidence-based approach to improve the quality of literature review (Tranfield et al., 2003), has been also applied in the field of management studies because of its transparent and inclusive principles that enables a more comprehensive inclusion of literature selected by a relatively objective and replicable manner (Denyer and Tranfield, 2009).

Systematic literature review is used here because it can effectively prevent the loss of knowledge which is already available (Tranfield et al., 2003). Because of the fact that humanitarian supply chain is a young field and that to best knowledge of the author, the number of research conducted which is directly relevant to both climate information and humanitarian supply chain is not large, each relevant article may provide valuable insights and should not be neglected if possible.

Initially, a number of search terms were developed by the author by brainstorming process. The list was later modified and refined based on recommendations and advice from experts in the field. A final list includes two sets of strings. Set A includes “climate information”, “climate science”, “climate forecast”, “climate prediction”, “climate service”, “seasonal forecast” and “weather forecast”. Set B includes “humanitarian”, “disaster relief”, “supply chain” and “logistics”. Each of the strings in Set A was then combined with each of those in Set B by using the boolean “AND” (e.g. “climate information” AND “humanitarian”), resulting in 28 search terms in total. These search terms were them applied to databases to generate the initial search results.

The databases used for the search are Emerald Insight, Springer Link and Science Direct. The rationale for using these databases is that the focused issue concerns a transdisciplinary study that requires to take researches from supply chain and operation management as well as research from climate science into consideration, and the databases mentioned above represent a good mix of both areas.

The inclusion criteria for this study is based on that used by Collicchia and Strozzi (2012) in their review:

- Select articles are journal articles in English published between 2000 and 2018
- The title or abstract of the select article must contain at least one of the string of the search term (e.g. "climate information" OR "humanitarian" should be found in either the title or the abstract)
- Articles should be excluded if only concern narrow aspects or context
- Articles should be of substantive and empirical relevance

The rationale for setting the time range of the literature to be between 2000 and 2018 is that humanitarian supply chain is a relatively young field, and therefore there is very little literature available before the year 2000.

The 28 search terms returned in total 1149 items. After screening, applying the inclusion criteria and excluding the identical results, 41 articles were selected.

Findings and Discussion

Current applications of climate information

There is no unified definition of climate information, which in a broad sense refers to all kind of climate related information, for example precipitation and air temperature. The common applications of climate information in humanitarian relief efforts are in the form of forecast, in different time ranges and developed to aid different stages of disaster preparedness and response (Goddard et al., 2014; Fall et al., 2007). The stages covered by climate forecast can be from early warning to recovery (Alfieri et al., 2018). Climate information is also applied across spatial contexts. Even though the most literature found focus on rural context, climate information based decision support systems to mitigate disaster risks are not just developed for rural areas, but also for urban contexts (Baklanov et al., 2018).

Climate forecast is used to monitor risks of varied types of disasters. Rainfall forecast is a common way to provide information on drought and flood risks, using predictors such as sea level pressure, air temperature and relative humidity (Djibo et al., 2015). The development of geospatial technologies based on climate information can help monitor drought (Vicente-Serrano et al., 2012) and flood risks in real time (Koriche and Rientjes, 2016). It may provide insights for decision making in inventory levels (Taskin and Lodree, 2011) warehouse location (Davis et al., 2013; Morrice et al., 2016) in the face of hurricane and storm threats.

Climate information is applied both in a macro, long term scale, such as to map the hotspot of humanitarian crisis and therefore direct more attention to the more vulnerable regions susceptible to climate threats for better preparation (de Sherbinin, 2014), and in a micro, short term scale, such as to help public health systems to address weather-related emergency (Runkle et al., 2018) or just to be in understandable terms that can be accessed shared on social media to mitigate damage of natural disaster (Mesmar et al., 2016). Weather and climate information can also be applied using big data techniques (Ali et al., 2016).

In the recent years, climate information has been directly integrated into the operations of humanitarian organizations. A forecast based financing scheme is developed to distribute funding to humanitarian organizations in advance to the actual materialization of the disasters based on climate forecast in an automated manner, and

thereby enabling humanitarian organizations to adopt early actions (de Perez et al., 2015, cited in Lopez et al., 2018). The scheme of forecast based financing is further developed by Lopez et al. (2018) by introducing a valuation approach to select the forecasts to trigger humanitarian actions to help various types of users to determine what thresholds should serve as the triggers for early actions.

Challenges and potential solutions

Even though there are multifold benefits to apply climate information in humanitarian relief efforts (Tall, 2010), there are also many factors that hinder the use of climate information and prevent it from being applied in some cases.

One commonly found factor that hinders the use of climate information is the discrepancy in perception. Humanitarian organizations, the end user of products developed based on climate information, may not perceive the value of these products the same way as the climate scientists, the developer and provider of these products (de Perez and Mason, 2014). This may be due to the their different perception of climate risks. People who lack awareness or accessibility to such information, or if they have received false information in the past tend to be indifferent to weather forecast (Hossain and Paul, 2018). In addition, risk is perceived in relativity and the political context would also influence decision making. Therefore, it is suggested that other than the climate forecast, the context and disaster setting are also very important (Ramírez and Briones, 2017). In some regions the perception towards climate risks is politicized and thus hinders a just judgement of climate information by decision makers (Oloruntoba, 2013).

The potential solutions include helping end users organizations better understand the usefulness of climate products (de Perez and Mason, 2014; Tall, 2010; Njau, 2010), providing information in a understandable way for practitioners (de Perez and Mason, 2014; Tall, 2010; van Aalst et al., 2008), facilitating partnership between science workers and humanitarian organizations (de Perez and Mason, 2014; Hansen et al., 2014; Tall, 2010). Examples include a serious game developed to help humanitarian workers better understand the value of climate information (Parker et al., 2016). Communication is not only done between science workers and local organizations, but also between climate information providing scientists and scientists from local communities at risks (Lyon et al., 2014).

Discrepancy also exists between what end users want and what scientific community is able to offer (Giannini et al., 2016). A mismatch between what is provided and what is needed or can be used by the local organizations and communities has also been identified (de la Poterie et al., 2018; Carr and Onzere, 2018) which is due to the communication gaps between science workers, the provider of climate information, and the local communities, the end users of climate information (Baudoin and Wolde-Georgis, 2015). Such gaps also exist between science workers and humanitarian organizations (Parker et al., 2016). It can be dangerous when end users misunderstand the climate information and make decision based on the misinterpretation (de la Poterie et al., 2018). Climate information may also only exist in forms that are incomprehensible and therefore not usable for local communities (Tschakert et al., 2010). A discrepancy between how climate risks is perceived and how local communities respond to the perceived risks. Even though the climate risks have been

recognized by certain communities, very few plan to integrate newly developed climate information into their hazard mitigation plans (Stults, 2017).

Therefore, it is essential to provide training for end users of the products based on climate information (Vicente-Serrano et al., 2012). The mode of training provided by climate scientists to practitioners also switches to user-driven. End users of climate information are involved in the early stage of the training to ensure that the training is designed in a way that the local needs are met (Mantilla et al., 2014). This mode of early engagement of user communities has also been confirmed to be important by the stakeholders (Giannini et al., 2016).

To better address this problem, scientists also call for a different approach in terms of knowledge production and climate products development and design. A bottom-up approach is also suggested to facilitate community based risk reduction (van Aalst et al., 2008). Co-production of knowledge is encouraged. Local traditional climate knowledge should also be incorporated into the co-production of knowledge to better tailor the climate information products to meet local needs (Egeru, 2016). Hazard information is found to be most useful and more likely to be used if combined with local information (Alfieri et al., 2018). A study identifies the main challenges faced by co-production of actionable climate science as the scattered information flow within organization and between humanitarian organizations and scientific community (DeCrappeo et al., 2018). A deeper mutual understanding is yet to be between the local communities and scientific workers. It is crucial to understand how the vulnerable groups respond to disasters (Tschakert et al., 2010). Pressure hindering applications of climate information also comes from peers, who are more conservative to embrace new ways of practice, within the community. Understanding how to alleviate this pressure is critical to the usable design of products based on climate information (Carr and Onzere, 2018).

Accessibility is another challenge for climate information applications. The availability and access of climate information is absent in some parts of the world, especially the rural communities and therefore a decentralization of climate information dissemination is needed (Njau, 2010). Digital platforms on which climate information is made available and accessible for non-climate specialists are developed to aid humanitarian works (Blumenthal et al., 2014), Some scholars also advocates a real time release of climate information (Vuillaume et al., 2018). However, channels to disseminate climate information should adapt to local conditions. For example, community meeting is a better channel to disseminate climate information than radio in some communities (Egeru, 2016).

Furthermore, the definition of the “end user” of climate information varies. In some studies, the end user of climate information refers to humanitarian organizations (de Perez and Mason, 2014). While in some other studies, the end user of climate information refers to local communities (Baudoin and Wolde-Georgis, 2015). Another study identifies three types of end users, namely the local communities, the humanitarian managers who make policies and large-scale policies, and the humanitarian workers who do not make decisions themselves but apply policies made (Djenontin and Meadow, 2018). The different positioning of end users may affect the design approach and prioritization of interest.

Across regions, stakeholders perceived the effectiveness early warning system based on climate information quite differently, and the results contradict that of certain official

reports (Lumbroso et al., 2016). It can therefore be indicated that the effectiveness of climate information based systems should be further evaluated in different regions to obtain a better idea of what can be improved. The evaluation of the performance of products based on climate information is also key to build trust between providers and end users, which will further facilitates the use of climate information based products (Alfieri et al., 2018). Some techniques are still in development and not very mature. For example, downscaling seasonal forecast, originally aiming to provide forecast at a higher solution for local uses, is found to be sensitive to region and dataset and not as reliable as the coarser resolution forecast in place (Nikulin et al., 2018). In locations where the conditions do not allow good enough forecast, decision makers should be cautious before making decisions based on climate information (de la Poterie et al., 2018). It is therefore recommended that decision makers should clearly identify local needs and determine if and to what extent climate information should be applied.

There is a lack of "interoperability" among government bodies and NGOs working to relieve disasters (Shareef et al., 2018). Institutional and informal setup are crucial to determining the best approach to address risks (Vicente-Serrano et al., 2012).

Recurring themes

From the findings above, several systemic elements are found to be recurrent and can be clustered in to a theme. Three themes have been identified, namely collaboration, usability and coordination, which can be considered to be construct a conceptual framework for future research.

For the purpose of this study, collaboration is defined as: "the ability to work across organizational boundaries" (Fawcett et al., 2008). In this context, the interoperability between governments and NGOs, the partnership between scientific communities and humanitarian organizations, the improved accessibility and schemes for information sharing are challenges and solutions of collaboration.

For the purpose of this study, usability is defined as "how science is produced and how it is needed in different decision contexts" (Dilling and Lemos. 2011). In this context, the co-production of knowledge, the mutual understanding process and the trust building among scientific workers, humanitarian organizations, local governments and communities are challenges and solutions of usability.

For the purpose of this study, coordination is defined as "managing dependencies between activities" (Malone and Crowston, 1994). In this context, the actionability of plans and perception alignment and compromise are challenges and solutions of coordination.

Conclusion

Even though not without challenges and risks, climate information is being applied in various ways in humanitarian relief efforts. However, researches focused on applications of climate information in humanitarian supply chain in particular are still rare. There are very few examples found to be directly related to humanitarian logistics. It is recommended that more researches that connects humanitarian supply chain with climate science to be conducted. Three recurring themes have been identified from the literature review, namely collaboration, usability and coordination. These recurring themes can be considered to be used to construct a conceptual framework.

Limitations

Limited by the subjectivity of choosing a limited number of search terms, the article may not represent an exhaustive review of the field. By including more search terms to widen the literature, the review results may be different. Further research is needed to draw a conclusion that reflects a more comprehensive perspective of the field.

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Sustainable Innovations for Humanitarian Operations in Refugee Camps

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Abstract
Refugee camps were originally built up as temporary emergency relief 'safe spaces' assuming that refugees may return to their home country in the short-term. However, statistics show that refugees stay in camps for an average of 17 years, which means that the management of camps is a medium to long-term commitment that requires specific strategies and operational resources to be sustainable. By means of case study research in two refugee camps in Jordan, we examine major operational innovations and their sustainability effects, potential trade-offs and dilemma situations that arise from restricted resources and conflicting goals.

Keywords: sustainable innovations, humanitarian supply chain management, refugee camps

Introduction
"Being well prepared before the refugees arrive is key in order to welcome and treat them with dignity." (Camp Management, Organisation A)

There is a need to develop innovations towards sustainability (Tidd & Bessant, 2014). On the one hand, the lifestyles in countries of the global North use the resources of 1.7 planets (Watts, 2018). If the emerging countries follow the same path, a resource use of 2.5 planets is predicted for the year 2050 (WWF, 2010). On the other hand, many important external energy and raw material resources are becoming more and more scarce (Brown, 2011). War, persecution and climate change are among the triggers for forced migration. As a consequence, host countries, like Jordan, set up refugee camps to manage high influxes of refugees. Refugee camps were originally built up as temporary emergency relief 'safe spaces' assuming that refugees may return to their home country in the short-term. However, statistics show that refugees stay in camps for an average of 17 years, which means that the management of refugee camps is a medium to long-term commitment that requires specific strategies and operational resources to be sustainable (Lahn & Grafham, 2015; Oloruntoba & Banomyong, 2018; Ossenbrink et al., 2017).
We studied the sustainability of these camps by means of case study research in two refugee camps in Jordan, we examine major operational innovations of the last past five years and their sustainability effects as well as potential trade-offs and dilemma situations that arise from restricted resources and conflicting goals (Hall, Matos, Gold, & Severino, 2018). This paper aims to answer the following research questions:

1. What are the major operational changes of the last past five years that help to make supply chains in refugee camps more sustainable?
2. What are the performance implications of these solutions on the economic, environmental and social performance dimension?
3. Are there any trade-offs that cause dilemma situations?

Literature Review

According to the Brundtland Commission (1987) sustainable development is defined as "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". In the economic field, the concept of sustainability was later operationalised by the Triple Bottom Line (TBL), which requires an even and simultaneous pursuit of the social, environmental and economic dimensions of sustainability (Dyllick & Hockerts, 2002). Slack & Lewis (2008) developed the operations strategy matrix for the private sector (Annex A). It brings together the two perspectives of market requirements and operations resources. The latter can acquire different capabilities through accumulation of their resources and skills. The organisation's operations shape these capabilities by making a number of decisions over time. The matrix describes and visualises an operations strategy as the intersection of a company's performance objectives (quality, speed, dependability, flexibility and costs) with its decision areas (capacity, supply network, process technology, and development and organisation). Performance objectives address customers' needs and the general classification by which competitive factors are grouped. Operation strategy decision areas are groupings of decisions that shape the operating resources. An operational strategy reflects how an organisation creates value for its customer, itself and the ecosystem it is embedded in, through the specific combination of performance objectives and those decisions areas that affect, or are affected by, the company's strategic resources. (Slack & Lewis, 2008) While there is an urgent need to lead operations strategies towards sustainability, (sustainable) innovations are key drivers for creating value in the long-term. The word *innovation* comes from the Latin word, *innovare*, and is all about change. Tidd & Bessant (2014, p.3), defined *innovation* as "[…] the process of creating value from ideas." According to Silvestre & Tirca (2019), there are four types of innovations in sustainable development (Fig. 1), categorized along the dimensions "Social Emphasis" and "Environmental Emphasis".

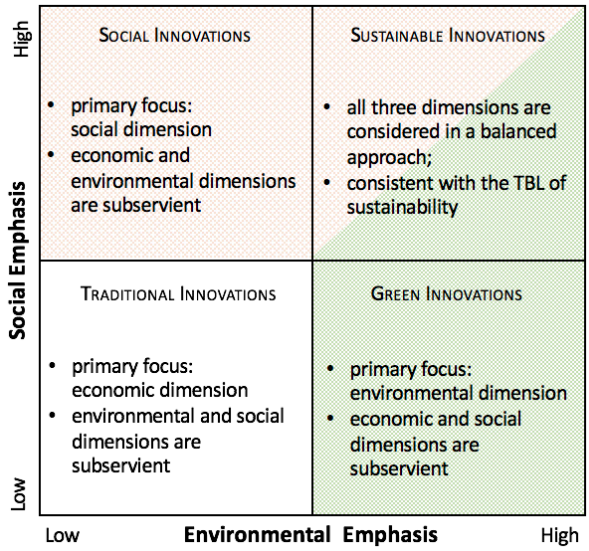

Figure 1: Typology of innovations for sustainable development by Silvestre & Tirca (2019)

Depending on their nature and the primary challenges they aim to address, the different types vary in terms of low to high emphasis on environmental and/or social challenges and their

implications for the planet. *Traditional Innovations* (low/low) have a primary focus at the economic dimension and associated concerns and neglect the ecological and social components. While the focus of *Green Innovations* (low/high) mainly lies on the environmental dimension (e.g. low-carbon), *Social Innovations* (high/low) contribute, for example, to the welfare of society, improvement on social capital and trainings and empowerment (Linnenluecke & Griffiths, 2010; Silvestre & Tirca, 2019). *Sustainable innovations* (high/high) consider all three dimensions as equally important and are consistent with the TBL of sustainability (Elkington, 1997). The latter type is more difficult to achieve, due to its complexity, dynamics and uncertainty, e.g. its wider range of stakeholders or more ambiguous and contradictory demands of different parties (Silvestre & Tirca, 2019). At the same time, more holistic innovation approaches are needed to uncover opportunities that include solutions to resource instability and scarcity, energy security and system efficiency for their supply chains (Nidumolu, Prahalad, & Rangaswami, 2009; Silvestre & Tirca, 2019).

Theoretical framework: Operations strategy in the context of a refugee camp

Based on the operations strategy model of Slack and Lewis (2008) and the sustainable development innovations framework by Silvestre & Tirca (2019), this research study investigates operation innovations in refugee camps. An operations strategy of a refugee camp must be aligned with the short and long-term humanitarian needs, as well as the resources available to humanitarian organisations. (Kunz & Reiner, 2012; Seifert, Gold, & Kunz, 2018) Alignment is the state where an operation's capabilities match the operation's requirements (Slack & Lewis, 2008). Alignment should be achieved through reconciliation of the humanitarian needs and humanitarian operations resources. Continuous alignment results in sustainable performance over time (Kunz & Gold, 2017). Existing trade-offs could complicate such alignment. The attempt to strengthen the balance between humanitarian operational capabilities and the special needs in the field through an innovation process is referred to as a 'dynamic approach to sustainability' (Slack & Lewis, 2008). The extent of alignment within an organisation's operations strategy can be assessed by analysing it using the operations strategy matrix.

Since refugee camps cannot be compared with organisations in the private sector that compete in the marketplace, we adjusted the initial framework by Slack & Lewis (2008) accordingly. International (humanitarian) organisations, such as UNHCR are usually managing refugee camps. Thus, we adapted the performance objectives by using the UNHCR's global strategic objectives (UNHCR, 2009, 2017b) and aligning them with the humanitarian needs in the field. *Reaction Speed* is the amount of time it takes to respond to needs. It leads and coordinate humanitarian operations. Humanitarian organisations strive to respond to the needs of beneficiaries in the shortest possible time. *Operations Costs*: A good cost management is important for (humanitarian) organisations involved in camp and project management. Due to limited financial resources and the dependence on donor funding (Seifert et al., 2018), efficient OM/SCM processes are essential to secure financial resources of organisations. With *Safety and Security* precautions, humanitarian organisations ensure that refugees have access to safety and are protected from return into situations of harm in the short- and long-term (UNHCR, 2017b). According to the international humanitarian law that applies in armed conflicts, refugees have a right for special protection under the Fourth Geneva Convention and Additional Protocol I (ICRC, 2015). *Reliable* communication and information are important when delivering assistance in emergencies and development aid operations to beneficiaries and host communities. Policies and sustainable standards for humanitarian operations in refugee camps have to be set up by international organisations and national authorities (UNHCR, 2017b). To have a perspective for a job, to participate in further education or to build up resilience and empowerment as well as integration and long-term inclusion in the host societies are decisive long-term *Qualities of Life* for refugees. Instead of focusing on the four initial decision areas (Capacity, Supply network, Process technology, and Development and

organisation), as proposed for organisations in the private sector by Slack and Lewis (2008), we concentrate on the two decision areas *Supply network* and *Process technology*, since we believe they are the most relevant dimensions in respect to refugee camps. Although the survival of the involved organisations is important, too, their performance against competitors does not lie in the focus as much as the well-being of beneficiaries and host-communities. Therefore, we amended the overall goal 'market competitiveness' with 'mitigation of the suffering of forcibly displaced persons'. The framework of the matrix for operations innovations in refugee camps is shown in Figure 2. The initial operations strategy model by Slack and Lewis (2008) can be found in Annex A.

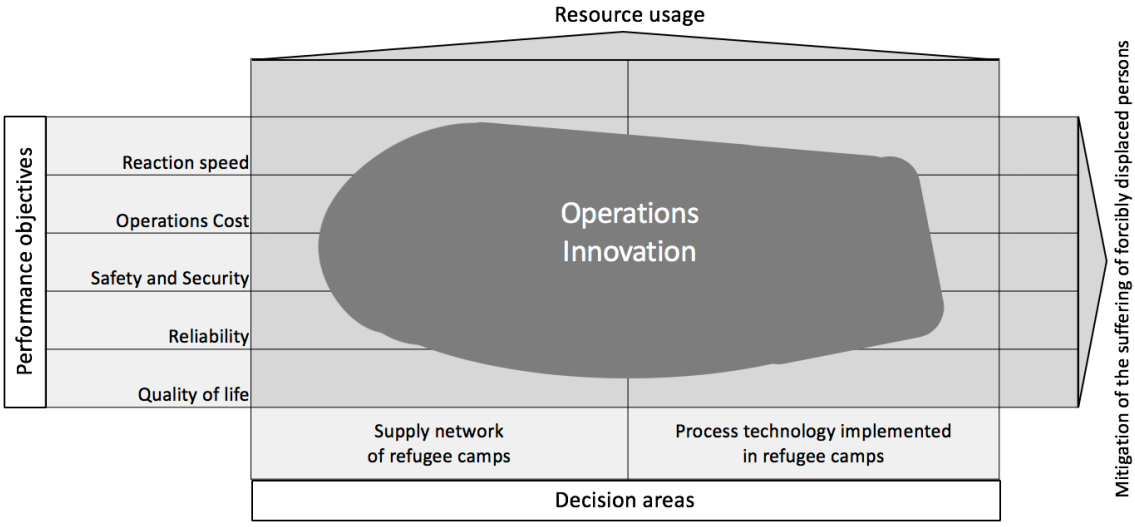

Figure 2: The Operations Innovations framework for refugee camps

Design/methodology/approach

Selection of Method

Innovation in refugee camp operations is a complex and context-specific subject that has been rarely investigated on empirical grounds, amongst others due to challenging field access (Seifert et al., 2018). Therefore, we use an explorative multiple embedded case study approach. The two largest refugee camps in Jordan, the Zaatari and the Azraq camp, represent our cases, and operation-related innovations are the units of analysis. The explorative multiple embedded case study approach is considered suitable for investigating complex subjects within their specific contexts (Yin, 2009), such as operations strategies and incorporated sustainable innovations in different refugee camps. Such a methodology allows to investigate particular situations in-depth (sustainable innovations) and immerse into complex social phenomena in order to develop an understanding about the operation strategies in refugee camps and their interconnected actions and relationships (Yin, 2009). As a basis for the empirical analysis, we have developed a theoretical framework that locates humanitarian operations innovations within major operations management decision areas and conceptualizes its effects on various sustainability performance dimensions. This framework has been derived from key literature (Silvestre and Tirca, 2019; Slack & Lewis, 2009) and adapted to the specific features of refugee camps. It served as a foundation for the development of the interview guide.

Sampling

Syria and Jordan belong to the "Fertile Crescent" in the Middle East, the birthplace of agriculture, where the rich and fertile soils irrigated by the Tigris, Euphrates, Nile and Jordan. Important crops such as barley and wheat are cultivated there (Salamini, Özkan, Brandolini, Schäfer-Pregl, & Martin, 2002). This area feeds millions of people (Jaradat, 1998), however,

the situation is changing since recent droughts and rising temperatures continue to affect once fertile soils (Kitoh, Yatagai, & Alpert, 2008). Jordan and Syria are the countries most affected by the current decline in precipitation (Erian, W., Katlan, B. and Babah, 2010). Due to multi-faceted causes of climate change, unemployment, food insecurity, corruption and repression (EJF, 2017), the war in Syria started in connection with the Arab Spring in March 2011 (Azmeh, 2014). Since then, a full-scale civil war has impelled around 13 million people to flee the country or to be forcefully displaced within the country (OCHA, 2017; UNHCR, 2017a). To date, the Syrian war is already in its ninth year and has resulted in more than 500.000 deaths (IamSyria, 2016), Besides the millions of people that have been internally displaced (IDMC, 2017), some hundred thousand emigrated to Europe and over 5.5 million people are residing in camps in neighbouring countries (IRC, 2017), such as Jordan. Jordan was selected as our focus country since it is one of the neighbouring countries of Syria that is most effected by the Syrian civil war and the associated refugee movement. With a Gross National Income (GNI) per capita of 3920 USD in 2017, Jordan is considered as a 'lower-middle income country' by the World Bank (Bank, 2017). It manages the second highest proportion of refugees compared to the world population, 89 refugees per 1,000 inhabitants (UNHCR, 2018). Some 670,000 Syrian refugees are registered in Jordan, most of whom live in the Amman governorate (UNHCR, 2019). Recent figures show that only 126,131 refugees live in camps and the remaining 83.2% of refugees live outside the camps in urban areas near the border to Syria (Healy; & Tiller, 2013; UNHCR, 2018). To reduce the impact of the influx of refugees into the cities, Jordan established the Zaatari camp (Mafraq Governorate) in 2012 and the Azraq camp (Zarqa Governorate) in 2014 beside other smaller camps (Healy; & Tiller, 2013; UNHCR, 2019). For our multiple embedded case study, we selected the two largest refugee camps in Jordan, Zaatari and Azraq, as cases since they are particular important for investigating operations innovations. Since we draw conclusion on how to improve operations in camps, we define the units of analysis as the multiple innovations for sustainability. The embedded units are the organisations as well as employees belonging to the ecosystem of the camps and having a focus on running camps in a sustainable way. Numerous humanitarian organisations are active in both refugee camps, working in logistics, supply chain and operations management. Prior to the empirical data collection, we analysed the humanitarian organisations that are managing and implementing projects in the camps and whose work is linked with camp operations. Interviewees were selected based on their role in camp management and by using the snowballing technique (Bryman & Bell, 2015).

Data Collection, analysis and quality

In the course of the field work, data was collected through participatory observations and semi-structured interviews with selected refugee camp staff, logistics and operations managers, following a key informant approach. By means of a prior developed interview guideline, 21 interviews were conducted with humanitarian organisations in Jordan between January 24th and March 03rd 2019. A summary of the interview notes is shared with the interviewees for accuracy checks. Annex B provides the list of interviews, including the organisation, function and level of interviewees. Secondary data were gathered from global institutions in order to realise an appropriate analysis of sustainable innovations and the operations strategies in camps and to facilitate data triangulation (e.g., Hakim, 2000). By means of the software Atlas.ti, data is analysed through qualitative content analysis, following a combined deductive-inductive approach that departs from the framework developed from literature as described above (Mayring, 2000). We followed a structured and reliable research design to ensure valid and reliable findings. Each case, the associated challenges and the gained insights are discussed and coded among three researchers. The units of analysis are presented following a similar structure, including background and their implications on economy, environment and society, in particular the five pre-defined performance objectives as well as potential trade-offs and dilemma situations.

Empirical findings and analysis

This section presents the data collection and analysis in Azraq and Za'tari camp. First, we examine the influencing factors for the development of both camps, which also provides explanations regarding the forms of various innovations. Then, we analyse the relationships between each performance objective and decision area of sustainable supply network and process technology innovations as well as challenges and trade-offs we identified during the field work. In the following we present an excerpt of the results. For the presentation at EurOMA2019 we will provide the detailed analysis and results.

Za'tari and Azraq camp

Both camps have been set up according to the Sphere standards that concern Water, Sanitation and Hygiene (WASH), food security and nutrition, shelter and settlement as well as health (Sphere Association, 2018). Za'tari and Azraq provide similar products and services to beneficiaries, however, the different configuration of the two camps is based on their developments and that the experiences of Za'tari were taken into consideration in the development of Azraq. Za'tari started as a transit site with *District 1* and *2*. Up to 3000 people a day have arrived in Za'tari during the emergency phase. UNHCR provided tents and later caravans and built communal latrines and kitchens according to the Sphere guidelines. After reaching 140'000 refugees in Za'tari, the Jordanian government decided to build the second camp, Azraq, in which they incorporated the lessons learned from Za'tari. After a construction time of around one year, Azraq has finally a capacity of twelve villages (140.000 people). Since Azraq is located in the middle of the dessert and exposed to cold winters and hot summers, a special isolated T-shelter (transitional, sealed shelter in cement) has been developed that can't be dismantled or moved. Compared to Za'tari where some facilities can only be found in certain districts, each village in Azraq includes a police station, community centres, schools, hospitals and markets, mosques. Another challenge represents the so-called spaghetti structure in Za'tari camp. Refugees relocated their shelters at night to create the environment they like. Due to the large number of people who arrived daily during the emergency phase at Za'tari, the camp management were not able to handle the relocations of shelter and hence, the modification of camp layout. The spaghetti structure of roads led, for example, to a delay in rapid response to an emergency. Furthermore, the management had to face challenges when implementing the water network and water-waste-management process. In the Azraq camp no communal facilities, like kitchens and bathrooms have been built as they were not being accepted by the refugees in the Za'tari camp. *"[…]in Za'tari all the communal facilities have not been used properly or have been rejected by the refugees because of cultural preferences." (Head of Technical Unit, Organisation A)*

Process technology innovations

(1) Iris Scanning

"The Iris Scan is a very complex system. It helps to speed up the service processes, and to avoid mistakes from our side, but also to avoid fraud or duplication, since every eye is unique. […] Iris Scan is used in the registration centers, supermarkets and distribution area. Beneficiaries scan their eyes and automatically have access to their file. They can print their birth certificate or any other personal document. It is like a kiosk." (Logistics Manager, Organisation B)

The Iris Scanning and EyeCloud scanners are used for biometric registration and the delivery of financial assistance to refugees (Leo, 2018). More than 2.3 million Syrian refugees in Jordan and the region are registered with the *irisguard* system, allowing them to scan their eyes to withdraw cash at ATMs from the Cairo Amman Bank or pay for goods in camp supermarkets. Refugees often do not have access to a traditional bank account to access benefits, save money, or make payments. By registering for Iris Scanning, refugees are granted access to a bank account and a system that will provide them with all their personal and official documents. In

addition, Iris Scanning replaces the usage of cash, vouchers and e-cards since it has been implemented in supermarkets of both camps by the World Food Programm (WFP).

- *Reaction speed*: Iris Scanning has increased the responsiveness of organisations and reduced the waiting time of refugees to a minimum. The verification of refugees' identity and payment at the checkout is faster than with e-cards or vouchers. Operations staff have reported that they had to make overtime in the past without the Iris Scanning and were only able to handle half the cases per day. *"Initially, we had to check the person, his proof of registration and had to compare the information with our shared desk. It took a long time to identify the eligible cases and that the person in front of you is the right person who should receive the items." (Distribution area staff, Organisation C)*
- *Operations costs: "This process is faster, much more efficient, reliable and safer." (Operations Manager, Organisation C)* In addition to minimizing working time and saving overtime, UNHCR also benefits from the database and the reports and evaluations it generates. The data allows conclusions to be drawn about the preferences of beneficiaries and enables UNHCR to adapt its operations processes to the needs of refugees as well as save operations costs.
- *Safety and security*: With Iris Scan fraud is minimised. *"[…] Very often people come with an ID and a name to pick up the items. But the same person can come again, just with another ID to get wrongly more items. […] or people share their kids to increase their family size and to receive more items. But now with the Iris Scan you can't cheat." (Head of Technical Unit, Organisation A) "The refugees have real trust in this system. if you ask them, they'll say 'yes you can trust me but we're happy that you're using iris on everybody else because A.T.M. cards are traded and sold'. There is a big black market for them. So, they are, first of all, pleased with a no cash in hand type of transfer. Because they trust an A.T.M. machine over somebody handing them cash. And they trust the iris that it's giving the money to the right people and that we care enough to ensure that there's no fraud in that." (Head of Humanitarian Assistance, Organisation A)*
- *Reliability*: *"So, we can say that Iris Scan has an impact on reliability, since all important documents are always available and accessible and stored in one place that is only accessible by the specific person him or herself." (Operations Manager, Organisation C)*
- *Quality of life*: *"Iris scan increases the comfortability. It is easier for the refugees, too. Their waiting time is much shorter."*
- *Challenges*: In addition to the positive feedback, Iris Scan is also heavily criticized regarding how power is exercised by institutions over individuals. With the Iris Scan and the generation of codes, identities are created and imposed on individuals. This approach enables institutions to categorize individuals in order to integrate them into management systems (Schoemaker & Currion, 2018). The attributed legal identity of the "refugee" allows access to services for those in need, but also limits their mobility. For example, refugees must always apply for an exit permit when leaving the camp.

Expected findings

Through our theoretically framed exploratory research design, we aim to increase our understanding in how far changes of operations (i.e. innovations) affect operational, economic, ecological and social performance of the humanitarian operations, which means in how far they may be categorized as "sustainable innovations" (Silvestre & Tirca, 2019). In addition, we aim to generate knowledge under which conditions innovations contribute to various performance dimensions or lead to trade-offs and dilemmas (cf. Hall et al., 2018). More precisely, we strengthen insights on how operation innovations of a refugee camp affect: reaction speed, operations costs, safety and security for refugees, reliability of processes as well as quality of life for refugees and host communities.

Our research investigates successful, partly successful and unsuccessful operations innovations in the two Jordanian refugee camps and provides advice to camp management on planning and implementing innovations that simultaneously benefit various performance dimensions.
We propose future research on how humanitarian organisations can 'do better' by implementing sustainable innovations in camps and on how they may rethink their underlying knowledge architecture to continuously improve processes and management structures.

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ANNEX A

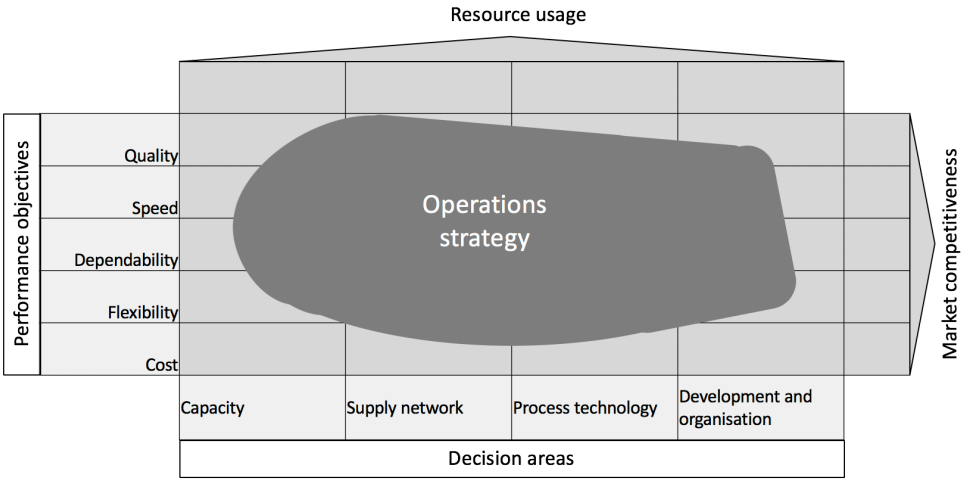

Figure 3: The operations strategy matrix by Slack and Lewis (2008)

As visualised in Figure 3, the matrix emphasizes the intersections between what is expected of the operation function and the way the operation attempts to achieve this through the set of decisions (and capabilities developed) in each decision area.

ANNEX B

	Organisation	Role	Years of experience	Location
1	B	Logistics Manager	17	Amman
2	A	ICT Specialist and Connectivity for Refugees Coordinator	15	Amman
3	C	Logistics and Fleet Manager Za'tari and Azraq camp	10	Amman
4	C	Project Officer Za'tari and Azraq camp	9	Amman
5	A	Infrastructure and Camp Design Associate	6	Za'tari Camp
6	A	Field Engineer	9	Za'tari Camp
7	A	WASH Associate	7	Za'tari Camp
8	A	Supply Associate	6	Za'tari Camp
9	A	CDC Team Leader	15	Za'tari Camp
10	A	GBV Manager	9	Za'tari Camp
11	A	Senior Supply Officer	20	Amman
12	A	Supply Officer	6	Amman
13	A	Humanitarian Assistance (CBI)	18	Amman
14	B	Deputy Logistics and Security Director	12	Amman
15	C	Project Manager	15	Azraq Camp
16	D	Associate Professor (RefuGIS)	16	Za'tari Camp
17	A	Senior Technical Officer	18	Amman
18	A	Supply Associate Azraq Camp	6	Azraq Camp
19	E	Health Coordinator for Azraq and Za'tari Camp	8	Azraq Camp
20	A	Camp Management	35	Azraq Camp
21	F	Project Manager WASH	13	Amman

Motivation and job satisfaction of humanitarian logisticians

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Abstract

The turnover of logistics staff is significant challenge for humanitarian organizations. Understanding what motivates logisticians to join the humanitarian sector, which factors influence their motivation and job satisfaction could help the organizations to struggle with the extremely turnover they have to face. Up to now, the performance of humanitarian logisticians and needed skills were examined. Also, the motivation of humanitarian workers are noticed in previous research. Therefore, the aim of this research is to extend the knowledge about the human resources in humanitarian sector.

Keywords: Humanitarian Logisticians, Motivation, Job Satisfaction

Introduction

Each humanitarian operation is reliant on logistics. Effective procurement, knowledge of transport conditions and the needs of the affected population, or the arrival of supplies at the right time are essential for the success of humanitarian operations. At the same time, growing number of disasters together with failure of humanitarian aid lead to rising attention about humanitarian logistics (Meduri, 2014). Logistics activities are always connected with logistic staff. For effective functioning, it is crucial to "hire, develop and retain the 'right' person at the 'right' time in 'right' numbers" (Meduri, 2014, p. 139).

Humanitarian workers operate in complex environments with various challenges and demanding working conditions. Up to now, the performance of humanitarian logisticians (Chaikin, 2003) and needed skills were examined (Kovács and Tatham, 2010; Kovács et al., 2012). Previous research has revealed importance of functional logistics skills, as well as additional skill sets related to the context of humanitarian operations (Kovács et al., 2012). Remington and Ganapati (2017) examined the required sets of skills of recovery workers in general. Authors recognized five main categories of skills that are needed in post-disaster context – communicative skills, leadership skills, emotive skills, technical or job specific skills, and field experience. Already in 1999, McCall and Salama found that vital characteristics of emergency workers include leadership skills, e.g. adaptability, flexibility, and technical expertise as well.

One reason why identifying the required logistics skills, together with motivation and job satisfaction, is important is the low level of permanent staff in the humanitarian sector. Indeed, staff turnover in humanitarian logistics is extremely high; workforce rotation of field logisticians can reach 80% (Thomas, 2003). In the end, the turnover has negative impact on the performance of organizations. However, "optimal turnover is not the lowest turnover that can be achieved" (Loquercio et al., 2006, p. 2). According to Loquercio et al. (2006), humanitarian agencies welcome a degree of workforce rotation due to e.g.

more flexibility in relocating staff. The retaining workers who have lost their motivation is harmful for the organizations (Loquercio, 2006) as well.

On the other hand, motivation of humanitarian workers (mostly medical workers or volunteers) has been examined before. Previous research reveal motivators as 'compassion/imparting love to those in need', 'God's calling to help others', 'giving back' (Putman et al., 2009), 'solidarity', 'feeling compelled to address the rights of others', 'charity and philanthropy' (Asgary and Lawrence, 2014), 'a desire to make contribution', 'a desire to make a difference' (Bjerneld et al., 2006), 'altruism' (Bjerneld et al., 2006, Oberholster et al., 2013), 'career development', 'international experience', 'escapism', and 'outsider support' (Oberholster et al., 2013). Participants of Asgary and Lawrence's study also mentioned that "a sense of personal responsibility driving their humanitarian work" (2014, p. 3) and "values from family, community, early education, or experiences with colonial history" contribute to their motivations (p. 4). Albuquerque et al. (2018) track the changes of motivators of nurses over time. At the beginning, the participants of authors' study wanted to discover new things and feel the worthiness. On the other hand, nurses with more experience wanted to continue to challenge themselves and they enjoyed stimuli from the fieldwork.

Identifying the differences motivation of humanitarian workers can support the effective recruitment, training and career management (Oberholster et al., 2013). These aspects are crucial especially because one of the main challenges for humanitarian organizations is a high workforce rotation (Albuquerque et al., 2018).

Methodology

In this research, combination of qualitative and quantitative research has been used. The data are obtained through the semi- structured questionnaire. This questionnaire is completely anonymous and consists of 40 questions and can be split into six parts: (1) general information (e.g. sex, age, education), (2) work-related information including information about training (e.g. current position and job placement, work experience), (3) motivation and job satisfaction (e.g. the reason why participants have decided to join this sector, which factors affect their motivation and job satisfaction), (4) statements (14 statements in total), (5) perception of their job, (6) trauma events and mental health. Some of the questions are relevant only for workers with field work experience or address the previous question. Therefore, the number of answers to various questions or parts of the questionnaire can vary. In some questions, respondents have to indicate how much they agree or disagree with the statements using a 7-point scale according to Diener et al. (1985). The questionnaire reflects the previous research about motivation, job satisfaction or psychological conditions of humanitarian workers (Bjerneld et al., 2006, Imai et al., 2010, Oberholster et al., 2013, Jones and Williamson, 2014, Akintola and Chikoko, 2016). Therefore, it is possible to compare the results of logisticians with other workers in humanitarian sector. The questionnaire was piloted, and the minor changes were done.

To ensure the completely anonymity of the participants, the statements of the participants will not be linked up with their affiliation or any other personal information from the first section of the questionnaire. The questionnaire was distributed to international, national non-governmental organizations, UN agencies, International Federation of Red Cross and Red Crescent Societies, Logistics Cluster, and Humanitarian Logistics Association with request to ask logisticians to get involved in this research. The data collection has begun in the middle of November 2018. Only logisticians with at least one year of work experience can participate in this research.

In total, four research questions and three hypotheses were defined:

- RQ1: What is the motivation of humanitarian logisticians?
- RQ2: Which factors influence the level of job satisfaction of humanitarian

logisticians?
- RQ3: How do humanitarian logisticians perceive their job?
- RQ4: How does the immediate family and friends influence the humanitarian logisticians?
- H1: The salary negatively influences motivation of humanitarian logisticians and the job satisfaction as well.
- H2: The organization can influence the motivation and job satisfaction of logisticians through the culture and conditions within.
- H3: The stance of family members or friends mostly negatively affect the level of motivation of humanitarian logisticians.

The results of parts number four and six of the questionnaire which are focused on the statements and mental health will not be presented in this paper. These information are not focused directly on motivation and job satisfaction of humanitarian logisticians.

Results

In total, 79 participants filled out the questionnaire. Two of these responses, P1 and P70, had to be excluded from the analysis due to unclear answers of the respondents. As a result, 77 participants participated in this research. Most of the respondents are men (51 overall; 66.2% compare to 26 women, 33.8%). The average age is 42 (maximum 72, minimum 23). The Table 1 represents the results of first part of the questionnaire.

Table 1 – General information (personal collection)

Sex	**Overall (percentage)**				
male	51 (66.2%)		female		26 (33.8%)
Marital status					
married	35 (45.4%)		in relationship		13 (16.9%)
single	24 (31.2%)		divorced		5 (6.5%)
Education					
high school	11 (14.3%)	university	42 (54.5%)	postgraduate	24 (31.2%)

Most of the respondents are married (29 men, 6 women), followed by respondents without any relationship (10 men, 14 women), people in relationship (3 men, 5 women), and 5 respondents are divorced (4 men, 1 woman). No respondent is widowed. In total, 42 respondents graduated from university (28 men, 14 women), followed by 24 respondents with postgraduate education (13 men, 11 women), and 11 respondents with high school education (10 men, 1 woman). Participants stated 33 countries of origin. The average amount of years of work experience is 17.3 years with minimum 2 years and maximum 52.5 years. The respondents work in average for 2 organizations and on their current position are in average for 3 years. This average is driven by 14 respondents with more than 5 years on the current same position. However, the highest number of participants has been on their current position for one year (24 overall) or two years (13 overall). One respondent did not answer this question. Table 2 includes other results from the second part of the questionnaire.

Table 2 – Work-related information (personal collection)

Current organization		**Overall (percentage)**	
UN agency	15 (19.5%)	IFRC	1 (1.3%)
INGO	56 (72.7%)	NNGO	7 (9.1%)
Current job placement			

field	60 (77.9%)	HQ	7 (9.1%)	both	10 (13%)
Formal training					
yes		45 (58.4%)	no		32 (41.6%)
Feeling well trained for current position					
strongly agree		19 (24.6%)	agree		30 (39%)
slightly agree		15 (19.5%)	neither agree or disagree		5 (6.5%)
slightly disagree		3 (3.9%)	disagree		4 (5.2%)
strongly disagree		1 (1.3%)			
Field work					
expat	63 (81.8%)	local worker	11 (14.3%)	without experiences from field	3 (3.9%)
Work experience from business sector					
yes		63 (81.8%)	no		14 (18.2%)

Most of the participants work for international NGOs and in the field. Two respondents responded they work for INGO and for UN agency at the same time. Most of the respondents with field work experience are expatriates (63 overall; 81.8%), compare to 11 local workers (14.3%). Three respondents do not have work experience from the field.

In total, respondents mentioned 46 various position they currently hold, for example hospital logistician, logistic coordinator, cluster logistic coordinator, supply chain advisor, logistic manager, all round logistician, logistic assistant, storekeeper, water and sanitation manager, logistic project manager etc.

RQ1: What is the motivation of humanitarian logisticians?

In the third part of the questionnaire, the respondents firstly answered on question "What was the reason why you have decided to join humanitarian organization?". Respondents have 11 defined options. They were able to choose more than one option or mention other motivators because the question was open-ended. Their most important motivator was 'the chance to help people', 'the chance to change the world and make some contribution', and 'the chance to gain international experiences'. Table 3 includes the full lists of answers.

Table 3 – Motivation to join humanitarian organization (amended from Bjerneld et al., 2006, Imai et al., 2010, Oberholster et al., 2013, Jones and Williamson, 2014, Akintola and Chikoko, 2016; personal collection)

	Overall	**Percentage**
The chance to help people	46	59.7%
The chance to try something different (gain new work experience)	16	20.8%
Career development	12	15.6%
The chance to gain international experiences	24	31.2%
The chance to get away from difficult personal situation or relationship	2	2.6%
The effort to justify one's life and pay back society	21	27.3%
The chance to change the world and make some contribution	29	37.7%
The opportunity to test my own limits	14	18.2%
The opportunity to know me better	12	15.6%
Curiosity and the opportunity to search for adventure	18	23.4%
Perception that my current job is routine and boring	11	14.3%

11 respondents also gave their own answer, for example: "*the interest of discovering the supply chain management of NGO*" (P11), "*believes that practises in humanitarian jobs are more transparent*" (P15), "*dream of my youth to spend a few years for humanitarian work*" (P18), "*fed up with corruption and exploiting staff in my previous position*" (P23), "*to step out of the capitalistic system*" (P52) etc.

Another question was "What keeps you involved?" followed by "Have you had periods when you have struggled to stay involved? Why? What has kept you involved?". The answers of the respondents can be splited into some groups. The first group includes participants who want to help people, and this is the main motivation for them, e.g. "*the needs are still there, I am still motivated*" (P7), "*motivated to help the people…*" (P60). The second group includes people who are motivated by their job itself, e.g. "*The fact that I am living my dream of being a humanitarian loggie in an emergency response.*" (P55), "*… I have realised that supply chain functions are very important to the success of any humanitarian operation.*" (P69). Other workers keep themselves motivated by their co-workers, e.g. "*…the feeling that I can do a great job with the rest of the team together*" (P18), "*the good spirit of my team*" (P19). Some other respondents displayed the desire for challenging work environment, e.g. "*the challenges faced constantly*" (P64), "*I love the constant challenges of the job…*" (P67). Another often stated reason was the humanitarian organization participants work for, e.g. "*I have big trust in what [the organization] doing.* " (P37), "*I work for an organization that does good work.*" (P38). Some respondents mentioned also financial aspects, sometimes in the opposite ways, e.g. participant P67 stated *"…I love the fact that I am not working for money, but to contribute to the well-being of people*", while participant P23 stated "*money*" as an aspect which keeps him/her involved in this job. In total, 21 respondents (27%) stated they have not struggled while doing this job. The respondents who have experiences with struggling periods, mentioned the reason like 'the disconnection from family', 'bureaucracy', 'problems with management of organization', 'waiting too long for missions', 'stress caused by high workload', e.g. respondent P28 stated "*feeling that it is an endless job*". The main cited factor that kept them involved, where seeing results of their job.

The respondents had to choose the factors which positively and negatively affect the level of their motivation. The most cited factor with positive effect is 'the chance to help people', followed by factors 'the possibility to make a difference' and 'the reputation of the organization and the organizational culture'. Whereas factors as 'salary', 'stance of my superior', and 'the living conditions during missions in the field' affect negatively the level of motivation the most. Table 4 includes the whole list of these factors and results.

Table 4 – Factors which positively and negatively affect the level of motivation of humanitarian logisticians (amended from Bjerneld et al., 2006, Imai et al., 2010, Oberholster et al., 2013, Jones and Williamson, 2014, Akintola and Chikoko, 2016; personal collection)

	Positively (overall)	**Positively (%)**	**Negatively (overall)**	**Negatively (%)**
The stance of my superior	27	35.1%	26	33.8%
The reputation of humanitarian organization and the organizational culture	45	58.4%	12	15.6%
The unpredictable conditions in the field	26	33.8%	9	11.7%
The (limited) opportunities for career advancement	22	28.6%	20	26%
The possibility (impossibility) to make a difference	50	64.9%	16	20.8%
Job security (insecurity)	11	14.3%	17	22.1%

The (limited) chance to help people	58	75.3%	17	22.1%
The stance of my family members	11	14.3%	10	13%
The living conditions during missions in the field	14	18.2%	21	27.3%
Salary	16	20.8%	27	35.1%
The possibility and necessity to stay busy	16	20.8%	3	3.9%
The (limited) chance to be "somebody" in the community	10	13%	1	1.3%
Fear that my family or friends do not understand my decision	1	1.3%	7	9.1%
The level of recognition of my abilities by the organization	23	29.9%	13	16.9%
The potential risks and challenges of the field work	29	37.7%	9	11.7%
Concerns that insecurity would affect my work performance	1	1.3%	10	13%
Fear of being socially alienated upon returning back home	6	7.8%	14	18.2%

As obvious, these factors do not affect the motivation both negatively and positively with the same extent. The fact that factor 'the possibility and necessity to stay busy' positively affects motivation of logisticians is in compliance with statements of respondents that they 'perceive their previous job as routine and boring' one. Participants also mentioned some other factors which positively (e.g. "*to learn always new things*" (P27), "*the quality of the humanitarian programme*" (P63)) or negatively (e.g. "*…unfair treatment/unqualified leadership*" (P18), "*not getting the correct position in your mission*" (P37), "*Unprofessionalism of the organisation. Lack of qualified colleagues.*" (P45), "*waste, inefficiency, and poor leadership and management*" (P54)) affect their motivation.

RQ2: Which factors influence the level of job satisfaction of humanitarian logisticians?
The options of questions which focused on job satisfaction were defined according to Minnesota Satisfaction Questionnaire (University of Minnesota, 1977). The most important factors which positive affect the level of job satisfaction of humanitarian logisticians are 'the chance to do things for other people', 'the chance to make use of my best abilities' and 'the relationship with my co-workers'. On the other hand, the factors 'the way my boss handles his/her employees' and 'job insecurity' negatively influence the level of job satisfaction the most. Table 5 includes the full list of factors and results.

Table 5 – Factors which positively and negatively affect the level of job satisfaction of humanitarian logisticians (amended from University of Minnesota, 1977; personal collection)

	Positively (overall)	**Positively (%)**	**Negatively (overall)**	**Negatively (%)**
The chance (impossibility) to do something different every day	44	57.1%	8	10.4%
The (limited) opportunities for career advancement	19	24.7%	19	24.7%
The way my boss handles his/her employees	23	29.9%	26	33.8%
Job security (insecurity)	11	14.3%	23	29.9%
The chance (impossibility) to be important in the eyes of others	14	18.2%	5	6.5%

The policies and practices toward employees of the organizations	17	22.1%	21	27.3%
The living conditions during missions in the field	14	18.2%	14	18.2%
The (limited) chance to do things for other people	50	64.9%	21	27.3%
The working conditions	21	27.3%	14	18.2%
The possibility and necessity to stay busy	15	19.5%	6	7.8%
The chance (impossibility) to make use of my best abilities	48	62.3%	21	27.3%
Job description	9	11.7%	8	10.4%
The relationship with my co-workers	47	61%	12	15.6%
Salary	14	18.2%	20	26%
The way my boss provides help on hard problems	21	27.3%	15	19.5%
The way my job provides for a secure future	7	9.1%	8	10.4%
The chance (impossibility) to try my own methods of doing the job	29	37.7%	17	22.1%
The praise I get for doing a good job	19	24.7%	8	10.4%
The unpredictable conditions in the field	19	24.7%	10	13%
The chance (impossibility) to do things that do not go against my religious beliefs	6	7.8%	4	5.2%

Other factors that respondents stated, and which have positive effect on their job satisfaction are "*The ability to make a difference to the lives of others and not for the purposes of making money.*" (P46) or "*inclusion in team settings and decisions*" (P52). On the other hand, participants also mentioned "*sometimes long-term planning is missing…..even in short term mission we should have somehow a clear view for the future*" (P19), "*not family friendly*" (P25), "*arrogance of the leadership*" (P48), as factors which negatively influence the level of their job satisfaction.

H1: The salary mainly negatively influences motivation of humanitarian logisticians and the job satisfaction as well.

As mentioned before, 16 respondents (20.8%) stated that salary positively affects the level of their motivation, compare to 27 respondents (35.1%) who stated the opposite. Other 34 respondents (44.1%) did not find any importance in the relation to the level of their motivation. In total, 14 respondents (18.2%) stated that salary has the positive impact on the level of their job satisfaction, compare to 20 (26%) who stated the opposite. The level of job satisfaction of other 43 respondents (55.8%) is not affected by salary. According to these results, this hypothesis is proven to be false.

H2: The organization can influence the motivation and job satisfaction of logisticians through the culture and conditions within.

The factor 'the reputation of humanitarian organization and the organizational culture' positively affect the level of motivation according to 45 respondents (58.4%), and negatively according to 12 respondents (15.6%). The factor 'the policies and practices toward employees of the organizations' positively affect the level of job satisfaction of 17 respondents (21.1%) and negatively of 21 respondents (27.3%). The influence of culture and conditions within the organizations will grow if other factors as 'the (limited)

opportunities for career advancement', 'job security (insecurity)', 'the working conditions', 'the chance (impossibility) to try my own methods of doing the job' etc. will be included. According to these results, this hypothesis is proven to be true.

RQ3: How do humanitarian logisticians perceive their job?
The respondents also had to choose which factors make the job of humanitarian logisticians exacting and stressful. In total, 70 participants answered to this question and the results are obtained in Table 6.

Table 6 – Perception of the job (amended from Bjerneld et al., 2006, Imai et al., 2010, Oberholster et al., 2013, Jones and Williamson, 2014, Akintola and Chikoko, 2016; personal collection)

	Overall	**Percentage**
The level of resources (funding, human resources)	35	50%
The unpredictability	30	42.9%
The fact that your job is never done	33	47.1%
The pressure inside the organization	21	30%
The job insecurity	13	18.6%
The potential risks and insecurity in the field	21	30%
The excessive workload expected by the organization	28	40%
The disorganized environment in the surroundings of the organization	27	38.6%
The pressure in the surroundings of the organization	10	14.3%
The social alienation upon returning back home from the field	16	22.9%
The lack of training	17	24.3%
The impossibility to combine this career with family and personal life	29	41.4%
The living conditions during the missions in the field	17	24.3%
The disorganized environment inside the organization	33	47.1%

Some respondents also added other aspects, e.g. "*lack of understanding of the dangers of untrained people undertaking certain types of high-risk work*" (P40) or "*interpersonal relations, mostly on the HQ level. Cold-heartedness of managers.*" (P75) etc.

As is obtained in Table 6 above, the most exacting aspect of job of humanitarian logistician according to the respondents in this study, is the 'level of resources (funding, human resources)', 'the fact that your job is never done' or 'the disorganized environment inside the organization'. Factors 'the excessive workload expected by the organization' and 'the impossibility to combine this career with family and personal life' have also significant importance. These factors are also reflected in the previous parts of the questionnaire. Logisticians appreciate the technical aspects of the job, they are aware of the importance of logistic operations for humanitarian projects. They welcome the unpredictability and changing environment of these projects as well as the opportunities to travel and take international assignments. On the other hand, logisticians struggle with level of bureaucracy, and processes or relations inside the organizations. Some participants stated: "*abusive bossy attitudes*", "*the UN is a corrupt system*", "*humanitarian world is becoming a business*" or "*the majority of the INGOs recruitments are not based on what you know it matters who you know*" (because of the nature of the statements, author did not mention the indications of respondents neither). In general, for humanitarian logisticians is very important the culture and reputation of organizations they work for.

RQ4: How does the immediate family and friends influence the humanitarian logisticians?

The linkage between motivation of humanitarian logisticians and stance of family members or friends will be described below. However, respondents stated that the separation from their family or friends leaded to the periods of struggling. Also, one participant P33 noted he/she struggled "*due to family response*". However, one respondent mentioned that "*…have family obligations, kids school fees to pay…*" (P16) keep him/her involved. Specific aspect is possibility co combine this job with family and personal life. 41.4% of respondents think that 'the impossibility to combine this career with family and personal life' makes their job exacting and stressful. Respondent P45 mentioned that "*moving with my partner and the difficulty of being separated for long periods of time*" lead to struggling and that "*having a husband that is also [humanitarian worker] and understands the drive, needs, etc it is easier*".

H3: The stance of family members or friends mostly negatively affect the level of motivation of humanitarian logisticians.

As mentioned before, 11 participants (14.3%) stated that 'the stance of family members' positively affect the level of their motivation compare to 10 participants (13%) who felt that this factor negatively affects their motivation. Other 56 respondents (72.7%) did not choose this factor. On the other hand, only one respondent (1.3%) perceive the influence of factor 'fear that my family or friends do not understand my decision' positive compare to 7 participants (9.1%) who perceived the influence as negative one and 69 participants (89.6%) who did not perceive any influence. Also, 14 participants (18.2%) stated that 'fear of being socially alienated upon returning back home' negatively influence the level of their motivation, compare to 6 respondents (7.8%) who stated the opposite and 57 participants (74%) who did not choose this factor at all. According to these results, this hypothesis is proven to be false.

Conclusion

The presented research is still ongoing. The author would like to involve higher number of respondents, especially from national non-governmental organizations or local workers. However, the obtained data evince the degree of consistency. Respondents stated similar reasons why they have decided to join humanitarian sector, why they struggle or factors which keeps them involved. Their answers are also similar and comparable with answers of other humanitarian workers examined in previous research.

Author would like to examine the gained data through regression analysis more deeply, examine the reactions on statements of respondents, and compare it with previous research. However, this paper does not provide enough space for this analysis. The factors which affect the motivation and job satisfaction of humanitarian logisticians can be divided into two groups. The first group includes factors which organizations cannot completely influence, e.g. the unpredictability, the stance of family member or friends of logisticians, the disorganized environment or pressure in the surrounding of the organization etc. On the other hand, organization can influence factors as working conditions, the stance of managers, the job security, the pressure and disorganized environment inside the organization etc., and these factors affect well-being of humanitarian logisticians in significant degree.

The results also show that logisticians are driven not only by their will to help people, but they also want to gain new work or international experience and they reflect the possibilities for career advancement. This is necessary to reflect because human resources are crucial for humanitarian operations. Also, according to Kovács and Moshtari (2018),

the research should be motivated by practical problem. During the data collection, HR and logistic specialists stated the important of examination of the motivation and job satisfaction together with fact that turnover is a big problem for them.

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Swift trust – swifter distrust: Exploring coopetition in humanitarian supply chains

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Abstract

This paper provides insight into the context of coopetition among organisations in the humanitarian supply chain (HSC). Through the use of 44 semi-structured interviews, the study identifies various strategies used by humanitarian organisations to develop "swift trust" between those operating in the HSC, thereby improving the performance of the entire supply chain. A number of barriers to swift trust development in HSCs are also identified. A significant finding from this study is that while developing swift trust is possible within HSCs, short-term swift trust can quickly develop into longer-term distrust if humanitarian organisations do not manage their activities carefully.

Keywords: Humanitarian supply chains, Coopetition, Swift trust

Introduction

Humanitarian supply chains (HSCs) operate in a complex international environment and must link diverse actors across national boundaries and cultures (Kovács and Spens, 2007; Day et al., 2012). Against a backdrop of high uncertainty, limited institutional learning, and a lack of local infrastructure and funding, HSCs work to save lives and improve wellbeing during or following disasters (Tomasini et al., 2009; Day et al., 2012). These goals are achieved by developing cross-sector relationships with different actors (e.g. governmental, military, other non-governmental and private organisations) to harness their respective competencies and resources (Stadtler and Van Wassenhove, 2016). Managing these relationships is difficult, as actors need to develop a level of trust to facilitate coordination relating to humanitarian relief, whilst also competing for scarce resources (e.g. donations) and media attention (Van Wassenhove, 2006; Kovács and Spens, 2010). This environment can lead to coopetition; collaboration between competitors for mutual benefit (Stadtler and Van Wassenhove, 2016). To facilitate coopetition in HSCs, the notion of 'swift trust' is a key consideration; a phenomenon by which relationships are developed quickly in pursuit of a common goal (Tatham and

Kovács, 2010). An understanding of the coopetition phenomenon, particularly the logic behind these unique relationships, may help humanitarian organisations to tailor their partnership and coordination strategies to better meet the needs of beneficiaries. However, the empirical evidence for coopetition in the context of HSCs is underdeveloped.

By drawing on the theory of coopetition, we present the results of a multiple case study analysis to explore coopetition and discuss its implications for HSCs. Thus, the study aims to contribute to both HSC and coopetition literature by addressing the following research questions:

RQ1: *What does coopetition look like in cross-sector relationships within HSCs?*

RQ2: *How does coopetition influence complexity in HSCs?*

Literature Review

While our understanding of traditional commercial supply chains has improved significantly over the past 25 years, with established bodies of literature in areas such as information transparency, collaboration, and performance management (Delen et al., 2007; Ramanathan et al., 2014; Bendoly et al., 2007), HSCs have only recently become a recognised field of research. As a result, we have far less understanding of their operations when compared to their commercial counterparts.

Several key barriers to successful HSCs exist. The most obvious challenge is the time, location and magnitude of a disaster; these things are difficult to predict, and as a result the majority of disasters occur with very little warning (Oloruntoba and Gray, 2009; Tatham and Spens, 2011; Whybark, 2007). Those operating within HSCs often have limited information as to how many people will be affected by the disaster, and where those people are likely to be located during and after the disaster strikes (Heaslip et al., 2012; Scholten et al., 2010). Supplier relationships, inventory management and quality management (all of which are comparatively simple to manage and maintain in a relatively stable commercial environment) become almost impossible to efficiently manage in HSCs (Beamon and Balcik, 2008; Ilhan, 2011; Maon et al., 2009), especially when damaged infrastructure in the affected area can lead to a sheer lack of transportation options (Fawcett and Fawcett, 2013; Jahre et al., 2009; Pettit and Beresford, 2005).

Despite the need for highly accurate information in order to make key decisions within a short space of time (Yates and Paquette, 2011), most decisions in the field must be made using information that is incomplete or highly inaccurate (Maon et al., 2009; John and Ramesh, 2012; Perry, 2007). This lack of accurate information leads to uneven distribution of aid (Perry, 2007) and high levels of frustration among beneficiaries (Tapia et al., 2012). Information systems used throughout HSCs are also incompatible (Yates and Paquette, 2011; Overstreet et al., 2011), with tight budgets compounding this issue as humanitarian organisations are reluctant to invest their hard-earned capital in sophisticated technologies or unable to do so because of earmarked donations (Maon et al., 2009; Scholten et al., 2009). High staff turnover due to the stressful operating conditions is commonplace in organisations responding to disasters, with some scholars suggesting that this is as high as 80% on a yearly basis (Sheppard et al., 2013; Tatham and Spens, 2011). As a result, humanitarian organisations struggle to replace the significant experience that is lost when these individuals leave (Chandes and Pache, 2010; Tomasini and Van Wassenhove, 2009), leading to a widely held view that there is a serious skills shortage in the field (Akhtar et al., 2012; John and Ramesh, 2012).

Resources are also a challenging issue, with humanitarian organisations having to raise large amounts of funding in a short space of time once a disaster has occurred (Chandes and Pache, 2010; Oloruntoba and Grey, 2006). Donations are highly unpredictable (Day

et al., 2012; Tomasini and van Wassenhove, 2009), and donors wield significant power over where their donations should be spent (Pettit and Beresford, 2009; Sheppard et al., 2013). Finally, and perhaps most importantly, competition between humanitarian organisations is fierce (Herlin and Pazirandeh, 2012; Oloruntoba and Gray, 2006), with each organisation having to emphasise their own contribution, leading to self-interested behaviour (Fawcett and Fawcett, 2013). Competition for media coverage in particular becomes increasingly intense, with media attention likely to increase the amount of donations these organisations receive from the potential donors (Wakolbinger et al., 2013; Van Wassenhove, 2006).

Coopetition and Swift Trust

One method of overcoming these resource issues is the concept of coopetition. Coopetition is the concept of organisations cooperating with other organisations whilst simultaneously competing with them; a common form of such an act would be sharing knowledge with your competitors whilst attempting to use said knowledge to outperform them (Tsai, 2002). This relationship is well understood by all parties and is not seen as a "devious" alliance but more of a method of absorbing the skills and knowledge of other organisations in an attempt to improve the efficiency of the entire supply chain (Hamel et al., 1989). Research has shown that such relationships can offer organisations numerous benefits such as increased knowledge flows into the organisation (Tsai, 2002), increased access to key resources (Gupta et al., 1999), increased technology adoption and market expansion (Lado et al., 1997), and increased supply chain resilience (Bakshi and Kleindorfer, 2009), all of which would be useful for humanitarian organisations.

Many methods of coopetition exist, but one method that has gained significant interest within HSCs is that of "swift trust". Swift trust was first identified as a potential concept of interest in the HSC field by Tatham and Kovács (2010) who suggested that while commercial supply chains have the luxury of growing trusting relationships between organisations over a period of time, HSCs are effectively "hastily formed networks" and therefore do not have the time to create the high levels of trust between actors that are required for strong team performance. Their argument was that the concept of swift trust can be applied to HSCs if certain conditions are met; firstly information must be shared freely between the various actors within the HSC. Secondly, employees of all organisations within the HSC should be encouraged to change their mindset, allowing them to become more trusting of others. Thirdly, rules should be put in place and adhered to so as to prevent "maverick behaviour" of any HSC actors. Fourthly, organisations should seek to increase the dialogue and understanding between themselves, so as to minimise any biases or preconceived ideas of how others will act in certain situations. Finally, all humanitarian organisations should attempt to increase their employee competencies (via training and formal qualifications) so that others will trust that they are dealing with professional individuals who "know what they are doing".

Following on from this study, Hyllengren et al., (2011) identified factors impacting on swift trust within the military setting, while Curnin et al., (2015) found that clarifying actors' roles is highly important for the effective development of swift trust. Perhaps most significantly, Lu et al. (2018) empirically showed that swift trust leads to improved coordination effectiveness within HSCs; they found that being introduced to another actor in the HSC by a trusted third party can increase swift trust, while having similar rules, procedures, and organisational values can also increase swift trust development between humanitarian organisations.

Methodology

This study was conducted utilising a case study methodology, due in part to the extensive support for such a method in operations management research (McCutcheon and Meredith, 1993; Voss et al., 2002). According to Yin (2014) a case study is "*an empirical enquiry that investigates a contemporary phenomenon within its real-life context*" (p. 14). In this study, the unit of analysis was a particular event (i.e. a natural disaster) rather than a particular organisation or person (Bryman, 2012); the 2 case studies used for this research were the Haiti earthquake of 2010 and the Pakistan floods of 2010. Haiti and Pakistan were highlighted as two natural disasters in the same year that resulted in very different responses from the international humanitarian community.

The semi-structured interview approach was selected as interviews are the most widely employed qualitative research method in general (Bryman, 2012) and are among the preferred research methods of logistics researchers (Larson and Halldórsson, 2004). Interviews are also the most commonly used method associated with case study research (Yin, 2009). A broad interview guide was used to guide the interviews (as recommended by Bryman (2012) and Easterby-Smith et al. (2012)) but departures from this guide were encouraged during the interviews. In total, 44 semi-structured interviews were conducted using a combination of theoretical sampling and snowball sampling. The aim was to interview actors in a variety of roles within humanitarian organisations that might not necessarily be described as logisticians or supply chain managers (e.g. pharmacists in charge of stock-keeping and ordering medical supplies). The selected interviewees worked both in agency headquarters and in the field, as well as in a range of organisations, which provided a rich and varied picture of the humanitarian context. The interviews were recorded and the transcripts were entered into NVivo for data analysis, as recommended by Fielding and Lee (1991) and Kelle et al. (1995). Data coding followed the recommendations of Corbin and Straus (2008) and Saldanha (2016) whereby the codes initially emerged from the extant literature, before going through a 3-stage cycle whereby emergent themes were discovered from data (Miles and Huberman, 1994).

Findings

Data analysis reveals a dynamic paradox inherent in coopetition in HSCs, indicating that cooperation and competition exist simultaneously among humanitarian organisations. There are clear parallels to previous work on multi-company, commercial/humanitarian cross-sector partnerships (Stadtler and Van Wassenhove, 2016). While details vary, many of the codes and dimensions evident in the 2016 study have been found in the current dataset, particularly *Tensions*, *Behavioural Responses*, and *Task Context*. However, there was limited evidence of the dimension of *Organisational Context* as humanitarian organisations represented in the sample had little to no formal rules in regard to coopetition behaviour and there was no evidence of top management messages on the matter, or clear training and mentoring. While interviewees in the 2016 study exhibited *Paradoxical Frames* through developing nested identities or segmentation of their cooperative and competitive roles, there was no clear evidence of this in the present study.

The results are now presented under the headings of tensions, behavioural responses, and task context below. Interviewees' are anonymised and only the participant number is given after each quotation in order to protect their identities.

Tensions

Corporate profiling

Interviewees described a highly competitive landscape where "*every organisation wants to be seen as leading the way*" (#32) resulting in an inherent distrust in many humanitarian agencies, particularly less established ones who are seen to be lacking essential expertise and networks. Nevertheless, interviewees acknowledged that trust is desirable as "*a lot of projects across all agencies need the same things and if we could collaborate more, that would be easier*" (#37).

Knowledge sharing

The UN Logistics Cluster as an attempt to facilitate formation of trust was largely derided amongst interviewees who felt "*it doesn't organise anything, it's just another way for people to feel important*" (#32) and "*you're just literally going round in circles saying the same thing every meeting*" (#8). This was particularly evident from organisations that perceived themselves as being advanced in their logistics performance who felt "*it's not necessarily advantageous for us, but it can be advantageous for the others*" (#13). Smaller or newer organisations were trusted the least, with some suggesting "*only those agencies with operational experience and a proven record in the sector should be involved in cluster meetings*" (#44).

Role conflicts

Several participants described the operational context as a "*project environment*" (#20). This was emphasised because of its implications for the longer-term operations of humanitarian organisations, as interviewees felt they went "*from one project to the next and no continuity*" (#4) and that "*it looks like we are doing a lot of firefighting*." (#9) Interviewees stressed that this leads to a management approach that lacks consistency and clear, achievable performance targets for individuals as well as on an organisational or interorganisational level. Concerns were raised that this attitude is "*not necessarily focused on the long-term improvement of the process*" (#5) and as such might encourage a more competitive nature than what would be most beneficial. The planning horizon is typically severely constrained with priority being given to quick fixes rather than overall optimisation.

Behavioural Responses

Integrating

Building trust with the local population was regarded as essential and failure to do so cited as showing "*how the international aid industry [...] can create even more of a disaster*" (#27), particularly in Haiti. "*Collaborating and developing something together*" (#38) was also seen as culturally sensitive, highlighting an important dimension of trust in HL. Particularly in areas that have seen much humanitarian aid over the years, there is an awareness of the quality differences and a wariness of the intentions of the incoming organisations, so it is essential "*to prove [...] we're not fly-by-nights, we're not going to come and go*" (#8). Many organisations seek to facilitate that trust by including beneficiaries as committee members or in similar roles, particularly for continuity and sustainability, acknowledging that "*requests from the local community change*" (#18).

Seeing that there is strong competition and much distrust, many organisations bypass the issue of building swift trust by attempting to build long-term relationships. This can take the form of long-term engagement in a region, which can result in preferential treatment like an organisation that had been "*working in the country for 25 years at the time of the earthquake [...] were able to get pretty much blanket authorisation to import [...] because we were trusted*" (#35). Another area are global sourcing contracts with trustworthy partners that provide appropriate quality and quantity when needed.

Demarcating

Any form of working together *"gets political very quickly"* (#11), indicating that swift trust is not developed sufficiently, as "*it's important for every organisation to get a foot in the door, on their own, with their logo on it*" (#42). This is particularly pertinent in humanitarian responses that engender a significant media presence, such as Haiti, which makes it essential for individual organisations to have their presence noticed as part of wider competitive agendas in terms of donations. Interviewees confided that such competitive elements can overshadow cooperation in favour of raising the profile of individual institutions— "*There is so much arrogance… They all have to be seen to be pissing on all the trees*" (#11).

Task Context

Other stakeholders

Humanitarian organisations face significant scrutiny, both from donors and from within the humanitarian community. Interactions with other parties are often a matter of principle. "*Neutrality as a core humanitarian principle can be difficult to uphold amidst the realities of humanitarian responses, but can also be vital to operations as it is often...essential. You have to be impartial just to gain access to an area*" (#42). On the donor side, not aligning humanitarian work with political priorities can mean that organisations forgo governmental donations in part or entirely. Some organisations strongly assert their neutrality, saying "*we don't work with any political parties in the country that we work in. We do work with the party that happens to be in power at that moment in time*" (#19). Neutrality can be a concern in cooperative behaviours, particularly where the military is concerned and there is often an intense politicality to working with other parties: "*we are probably a more political organisation than anything else*" (#43). Furthermore, there is an inherent political impact of humanitarian work, whether that is as a showcase of values and material advantages of the donor countries over the host country or through lobbying and support. Cooperation can enhance both the risks and the impact achieved.

Social causes

Interviewees expressed a strong desire to improve the situation of the beneficiaries in each response. "*We are all about empowering people. That's very important for us and we engage with civil society for that*" (#27). While this can be an incentive for more cooperative behaviours, it can also increase competition, as working with any external partners is seen by some as a loss of focus on the beneficiaries as "*firstly you miss the neediest, because it is directed according to other priorities, and secondly, you actually make the aid itself ineffective, because the identity and perception of those who are delivering the aid becomes compromised in the mind of the recipients*" (#41).

With the significant impact humanitarian missions can have on the local economy, an added level of complexity is the long-term impact the work has on the recipient country. Humanitarian organisations often directly work with and shape the practice of institutions like the national health service, the ministry of education or the ministry of agriculture. There is clear evidence of an intense awareness of the longer-term impact of their operations. While timely emergency response was important, respondents described a quick transition into setting up projects that were developed to have a sustainable impact on the local economy and highlighted that they had to balance immediate response "*with support of local agriculture and economies as well, because potentially the amount of*

food we could buy could be a really big support to the local agricultural and economic system" (#28).

Furthermore, many organisations are advocates of societal change, but also acknowledge that cooperation with local stakeholders can hamper this. *"we will speak out about issues we encounter and often we will be the first to tell the rest of the world what is happening. That has retributions… It is not always possible to speak out. You have to balance if we'd do more good drawing attention to an issue"* (#42).

Discussion and Conclusion

The goal of cooperation is problem solving and value creation by uniting different actors' competencies and resources. HSCs require actors to work together and develop a solid level of 'swift trust' between them, while building trust with the local population is essential, as failure to do so adds greater complexity to the HSC.

Overall, the findings show that humanitarian organisations are willing to develop swift trust within the HSC, however they are very open and honest about the numerous barriers that currently limit the degree of its development. The major barrier in this setting is that actors are still relatively wary of their "competitors" as many are still of the opinion that they have to be highly visible by being "first on the scene", especially when there is a media opportunity that may garner additional donations from the public. One method of circumnavigating this issue could come from the donors themselves; given the level of influence they have, they could insist that their donations are used on collaborative efforts that include more than one humanitarian organisation. Another potential solution would be to force humanitarian organisations to pool their resources by using schemes such as shared appeals for donations; this way, the organisations are not only cooperating with their competitors, but they are also potentially increasing the amount of donations they are likely to receive.

Although swift trust has been acknowledged as desirable, humanitarian organisations also face conflicting organisational interests in a competitive setting, resulting in the phenomenon of 'swift distrust' in many humanitarian organisations, particularly less established or smaller organisations that are perceived as lacking essential expertise and networks. Similarly, the 'swift trust' that is built up between the humanitarian organisations and the beneficiaries can quickly and easily be eroded if promises are broken. In this sense, coopetition in HSCs appears as a dynamic phenomenon. That is, short-term 'swift trust' quickly develops into longer-term 'swift distrust'. In recognising that there is strong competition and much distrust, the findings highlighted that participants were bypassing the efforts involved in building 'swift trust' by attempting to build long-term relationships. Examples of such activities included long-term engagement in a region and developing global sourcing contracts with trustworthy partners that provide appropriate quality and quantity when needed. This is an interesting finding as it suggests that humanitarian organisations may feel that 'swift trust' can only develop their relationships so far; rather than wasting time developing 'swift trust', these participants seem to want to develop lasting, long-term relationships from the get-go.

The findings also highlighted some methods being used by humanitarian organisations in order to increase 'swift trust'; many organisations seek to facilitate 'swift trust' development between themselves and beneficiaries by including the beneficiaries in official roles, particularly for continuity and sustainability purposes. Not only does this make the beneficiaries feel that their opinions are being listened to (and that the humanitarian organisations are taking their situation seriously), the increased transparency allows the beneficiaries to understand exactly what is going on in the relief operation, thereby taking 'swift trust' to the next level and creating stronger bonds

between the humanitarian organisations and the beneficiary community (particularly when humanitarian organisations are working in the area for long periods of time).

This study has increased our understanding of the prevalence of coopetition in cross-sector relationships as well as the implications for HSCs. The study adds to the extant literature on HSCs by highlighting the dynamic paradox inherent in coopetition in cross-sector relationships. To promote 'swift trust', humanitarian organisations could, for example, include beneficiaries as committee members. At the same time, they also need to be aware of the fact that they are still competing with each other, a fact that could quickly lead to 'swift distrust'. Furthermore, these organisations should take heart that it is possible for them to go beyond the short-term 'swift distrust' phenomena to build effective long-term relationships, as long as they approach these relationships in the correct manner. This research also has implications for how humanitarian organisations can better tailor their partnership and coordination strategies in disaster relief operations, an important area for further work.

Future research in this area should look to further understand the relationship between 'swift trust' and 'swift distrust', in particular the activities currently being adopted by humanitarian organisations in order to maximise trust and minimise distrust. Another avenue for future research would include investigating the different models of coopetition used by the various non-governmental organisation (NGOs) operating in HSCs, as well as their opinions on how effective they believe such models are. Data collection in this field is very difficult, especially given the extreme conditions these organisations have to operate in. But if we are serious about increasing our understanding of this field to match our understanding of traditional, commercial supply chains, gaining the opinions of those in the field is of the utmost importance.

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Value co-creation in professional services: an exploratory investigation in the humanitarian context.

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Abstract

This study identifies the main characteristics of value co-creation within the humanitarian setting, analysing the key factors that enable value co-creation of professional service providers, working with beneficiaries for long-term integration programmes. The practices of co-creation are analysed and the perception of both actors are explored to determine key factors which influence the value co-creation process. Given the novelty of the subject and its intrinsic characteristics, we conducted a qualitative study through a case study. The findings of the research clearly show that the success of the programme, namely the achievement of the full integration of the beneficiary into the society, not only depends on the trust, self-motivation, cultural background and education of the beneficiary, but also on her/his level of commitment, interaction and participation with the professional service provider during the design and delivery of the service.

Keywords: Humanitarian Supply Chain, Value Co-Creation, Professional Services.

Introduction

Indisputably, the rise of the Mediterranean migration phenomenon poses new challenges to traditional integration mechanisms and processes of welcoming and reception. From 2015, more the one million refugees, migrants and asylum seekers arrived by sea and landed to the south of Europe (Greece, Italy, Malta, Spain and Cyprus) (UNHCR, 2019). This phenomenon has driven policy makers and scholars to define structured plans for beneficiaries' integration (referring to refugees, asylum seekers and any kind of people who need to socially integrate themselves into a host country) through improving the long-term integration programmes (L-TIPs) within the recovery phase of the humanitarian supply chain. L-TIPs are measures, often funded by governments, aim at ensuring the social, professional and economic integration of both migrants and refugees within the society. Through L-TIPs beneficiaries can access different professional services such as interpretation and linguistic-cultural mediation services, legal counselling, teaching of the hosting Country's language, health assistance, socio-psychological support, counselling on the services available at local level, as well as information on recreational, sport and cultural activities. However, L-TIPs are often falling short in achieving the desired outcome, i.e. the refugee integration. Furthermore, satisfy beneficiaries primary needs and delivering professional services to them is not sufficient in order to fully achieve the social integration goal; a real "welcoming" attitude and context by the hosting community is

strongly required to support and encourage beneficiaries to achieve long-term stability. Thus, services that are delivered to beneficiaries need to be properly designed to foster the integration process in a more effective way. L-TIPs involve organisations that increase the real value of the professional services they are delivering to beneficiaries, where the real value means they reach social integration.

Previous studies in the area of humanitarian operations management have manly focused on logistics aspects of disaster relief operations that deliver first aid and restore basic conditions (Galvagno and Dalli, 2014; Kovacs and Moshtari, 2018; Kumar and Kushwaha, 2018; Seifert *et al.*, 2018). However, the specificity of the humanitarian crisis related to the refugees' integration within the European society asks for a deep investigation of other operations management aspects; namely not those related to the basic services for refugees' survival but those related to the professional services delivered within the L-TIPs.

In sum, one of the main challenges in facing the Mediterranean migration humanitarian crisis is to improve the success and the effectiveness of refugees' integration programmes; while dealing with this important social challenge, this research wishes to contribute to the literature on value co-creation, in the area of professional services. Specifically, we will try to understand how the professional services, which are aimed at fostering the integration of beneficiaries within the hosting country, are designed and delivered; also, to understand the mechanisms underlying value co-creation processes of service design/delivery in the humanitarian context. Our research questions are:

RQ1. Do humanitarian professional services' providers co-create value with and for beneficiaries in the context of refugees' L-TIPs. If yes, how?
RQ2. What are the enablers of beneficiaries' participation and commitment in the value co-creation process?

In what follows, we introduce a few theoretical concepts and background where we anchored to for conducting the case study presented in this paper.

Theoretical foundation

Coherently with the aim of this study, in order to frame our research within the operations management literature, we briefly analysed three literature streams: humanitarian operations and supply chain, professional services operations management, value co-creation in service operations.

Humanitarian Supply Chain and Operations

According to Seifert *et al.*, (2018) providing assistance to vulnerable people is the core of humanitarian supply chain management. The humanitarian supply chain is composed of five phases: mitigation, preparedness, immediate response, reconstruction and recovery (Abidi *et al.*, 2013; Haddow *et al.*, 2018). The mitigation and preparedness phases aim to avoid the impact of a disaster with a strategic vision, establishing an adequate regulatory framework to manage the emergency in the disaster management cycle, impeding the reoccurrence of a disaster and/or to prevent it. The immediate response phase is characterised by short duration, high urgency and large uncertainty, thus entailing operations management challenges such as efficient purchasing, logistics of in-kind donations, etc. The reconstruction phase deals with the immediate disruption, damage, and other effects of the disaster (Asian Development Bank, 2004). The last phase, the recovery, tends to satisfy the main need of the victims to restore basic conditions. In the human migration crisis context the recovery phase includes long-term

integration programmes (L-TIPs) that differ from recovery programmes aim at restoring basic condition immediately after the emergency in other humanitarian contexts. In fact, the L-TIPs enable new opportunities to integrate beneficiaries in the local context for a new start in a hosting country. While, usually, the response phase and the recovery phase provide rescue operations and restore basic conditions and immediate needs, the L-TIPs focus on the effective integration of beneficiaries into the host country by delivering professional services such as educational support (e.g. language courses, counselling, education, vocational orientation), social support (e.g. assistance in entering labour market and legal support) healthcare and specialised services (e.g. women at risk, children at risk). In other words, the aim of L-TIPs trough their professional services, is enabling beneficiaries starting a new life in a new country and not restoring their basic conditions.

Professional Services Operations Management

In Operations Management literature professional services are defined as generic service types characterised by a high level of knowledge, with high levels of customer contacts consisting in flexible processes with low capital and high labour intensity (Schmenner, 2004; Lewis and Brown, 2012). Despite the wide range of diversity and application domains, professional services are commonly characterized by a high degree of ongoing interactions, interpersonal communications and organizational/personal relationships (Patterson, 2016; Bagdoniene and Valkauskiene, 2018). Moreover, professional services are characterized by the ability of professionals to receive information from customers and transform this information into useful services (Baltova and Baltov, 2017). Consequently, they consist on complex operations and the performance depend on the tasks' outcome of both customers and professionals (Damali *et al.*, 2016).

In the L-TIPs context, the main aim of professional services is to support beneficiaries on their integration, offering services that could allow them to increase the quality of their lives through their integration into the local context. During interaction between customer and professional, various form of tacit and explicit knowledge and personal attitudes are constantly mixed, redefined, linked and enriched from both parts. It is also particularly emphasised the "guiding, nudging and persuading" of professional employees rather than the implementation of standard operating procedures and, of course, customers play a critical role because their presence is a necessary and sufficient condition to define a production process as a service process (Sampson and Froehle, 2010).

Prior studies on business professional services focused on the role of professionals as a primary source of value co-creation, ignoring customers role, form of involvement and participation (Damali *et al.*, 2016a). Human relations in these types of services, and especially in the humanitarian setting, influence the design of processes and consequently the outcomes.

Value co-creation in service operations

Value co-creation has become a central theme in service management and marketing literature (Grönroos and Voima, 2013; Galvagno and Dalli, 2014; Vargo and Lusch, 2016). Although many scholars have focused on the study of co-creation process and have developed systematic approaches to service innovation, the concept of co-creation is still not clearly identified (Yu and Sangiorgi, 2018). Indeed, according to Oertzen *et al.* (2018), there seem not to be a shared and accepted definition about "co-creation" in services design. In few words, the idea of co-creation is to bring something into existence as a result of often coordinated actions or processes and could be considered as important manifestation of customer engagement, resulting from motivational drivers (van Doorn *et al.*, 2010; Galvagno and Dalli, 2014). In sum, it is a joint, collaborative and peer-to-

peer process where both customer and provider integrate their own resources (Prahalad, C.K. and Ramaswamy, 2004; Galvagno and Dalli, 2014; Bagdoniene and Valkauskiene, 2018), but it is also influenced by the emotional, cultural and relational experience of the customer (Grönroos and Voima, 2013; Mustak, Jaakkola and Halinen, 2013; Yu and Sangiorgi, 2018) and of course involvement and participation seem to be necessary prerequisite-forms for the co-creation of service to occur (Oertzen *et al.*, 2018). Thus, value co-creation could be considered as a paradigm describing how providers and customers are involved, like active and participant actors, in the design and development service (Prahalad and Ramaswamy, 2004), where motivational drivers seem to be key elements to reach personal, cognitive and social benefits (Oertzen *et al.*, 2018). Service value co-creation research tends to focus on the customer's role (Damali *et al.*, 2016a) and has not yet been specifically examined in the context of humanitarian organisations. In this context, however, the specificities of the customers (refugees), the complexity of the delivered services, the priority of designing and delivering effective services (i.e., reaching the refugee's integration goal), the need of actively involving the refugee and the other stakeholders for creating real value, make the exploration of value co-creation very interesting.

Research methodology

Being the empirical context under investigation specific and multifaceted and given the exploratory nature of the study (Voss, Tsikriktsis and Frohlich, 2002) the research was conducted using qualitative methodology in the form of case study. The qualitative methodology is appropriate when the researcher wants to understand comprehensively a less-investigated topic and the case study strategy is justified by the non-conventional nature of the environment (Eriksson and Kovalainen, 2015; Bagdoniene and Valkauskiene, 2018) apparently characterized by a form of closing attitude to the external elements. The case study strategy with an outgoing and kindly approach helped authors to break down current barriers, allowing and building a basic trust relationship between professional service provider's operators (mainly lawyers, medical doctors and cultural-linguistic mediators) and beneficiaries. Furthermore, the case study method is also justified by the goals of this research, providing a deep insight about the concept of value co-creation and the main factors enabling value co-creation.

The case study focuses on a professional service provider (PSP) working into the humanitarian field. The case location (Sicily), as well as the participants, were chosen using selective sampling (Teddlie and Yu, 2007). The location was suggested by the presence in this geographical region of a diffuse reception system due to the geographical centrality of Sicily within the Mediterranean human migration flow. The selected PSP, named *Centro A*, offers a complex services portfolio aimed at refugees' integration. It helps beneficiaries by delivering a list of professional services, starting from welcoming to health screening, language lectures, legal assistance, job placement assistance, cultural mediation, after-school child care to psychological assistance. Data have been collected between October 2018 and January 2019. In that period, the authors visited, deeply observed, attended at events, wrote personal notes during their visit and planned and conducted semi-structured interviews with directors, cultural-linguistic mediators, professionals and volunteers, as well as beneficiaries of these services. Authors also invited the organisation to contribute in the research. Two different research protocols, one for beneficiaries and the latter to PSP's operators were drafted. Specifically, authors conducted and recorded semi-structured interviews with 1 director, 4 professionals, 2 cultural-linguistic mediator and 4 beneficiaries, lasting from 20 to 70 minutes. The recorded interviews were transcribed and analysed with the qualitative data analysis

software ATLAS.ti. Authors performed the coding activity through labelling row data, organising them into a pattern of concepts and categories with the respective proprieties (*open coding*), then connected categories, sub-categories and dimensions (*axial coding*), finally selecting core category and systematically relating them in other categories (*selective coding*).

Additionally, authors analysed the engagement approach and the perspectives used by PSP's operators during their interaction with beneficiaries. As Dabhilkar *et al.*, (2016) suggest, studying and observing processes, as constituted by various practices, may help to develop a deeper understanding. Consequently, a case study research approach results as suitable method for attaining as much information as possible from operational activities and tasks for the purpose of exploration (Voss, Tsikriktsis and Frohlich, 2002). The study allowed authors to absorb tacit knowledge about the phenomenon from the perspective of their experience.

Case analysis

While the literature recognizes that in professional services, significant customer participation is required in order to co-create value, the mechanisms through which this is practically obtained need further investigation (Damali *et al.*, 2016). Human relations in professional services influence processes and consequently the outcomes (Jaakkola and Alexander, 2014). This is mainly due to the interaction between the provider and its customers, basically given by the high heterogeneity of the offered services and the high level of customization required. After analysing data and interactions between PSP's operators and beneficiaries, different key factors emerged as crucial to facilitate value co-creation process. Some factors are often related to beneficiaries' self-motivation and cultural background, others due to the PSP's operator attitude and capability that could have a different impact on enabling value co-creation processes. In additional to, others are related to the service design sphere.

Factors enabling value co-creation

The value co-creation process, at *Centro A*, starts getting beneficiaries involved for a first meeting. One of the PSP's operator explains the beneficiary how he/she could be involved in the activities of the centre and which types of services will be offered. In order to understand beneficiaries' needs and provide customized professional services the PSP allows interactions with each beneficiary. Before to understand the main needs and the goals that each beneficiary wants to reach, it is crucial to build trust and build a personal relationship with each beneficiary:

> <… they have recently landed... …let's say, they are muddled people who have no idea about their rights, their needs ... thus in that status, they don't really know what they have to do, where they have to go, they need to trust in someone…> (PSP's operator A);
> <… If they do not trust in me, my work becomes complicated. I am not able to exactly translate what they need to. But once trust is established, they can communicate …> (PSP's operator B).

Even from the beneficiaries' point of view, trust is recognized as a primary factor to allow participation during the value co-creation process:

> <… for me trust is important, I feel supported…> (Beneficiary A);

Thus beneficiaries could uncover their needs:

> <… once trust is established, they can communicate us their problems…> (PSP's operator A).
> <… we always start from the personality of the guys, to understand what their experience is, let's take stock of the skills to understand what their experience is…> (PSP's operator C).

Despite trust is recognised as a primary element from both PSP and beneficiary perspectives, it is reached by an empathetic and open approach in addition to fairness, relational capability and continuous interactions. Often these interactions are stimulated by the PSP's operator in order to involve the beneficiaries in meetings and events with other stakeholders. In other words, having the beneficiary engaged in the process is not always obvious and the operator has to encourage the beneficiary interaction in order to build trust thus to make her/his needs and desires come out:

> <… what we do here is to hear each beneficiary stimulating their interaction, we undercover their needs speaking, if they are looking for a job or want to go away…> (PSP's operator B);
> <… Sometimes you try to involve them for example going to the cinema, during the spring we go with them to see the botanical garden, also to make him understand where they are, in which context and we understand if our professional services match their needs…> (PSP's operator C).

Moreover, certainly the level of beneficiary's language and communication ability, but also her/his cultural background and relational attitude influence the intensity of the interactions with the PSP's operator and their participation and commitment during the value co-creation process. In fact, some of them do not like to get involved either for lack of self-motivation or because he/she does not want to integrate into the hosting country:

> <… the relationship with these people is not simple, some of them want to go away from the hosting country, they are subjected also to the pressure of their families…> (PSP's operator B).
> <… usually depends on the predisposition of the beneficiary and their cultural background, the socio-economic context…> (PSP's operator C).

Apart from the PSP's operator skill and ability to enable interactions and consequently build a trusted relationship with the beneficiary, other service design aspects of the PSP emerged to be as crucial in the value co-creation process. The first aspect is related to the number of beneficiaries that directly interact with the PSP's operators. Indeed, according to some of the operators, working with a single beneficiary or interacting with a small group of them in a family-like dimension force beneficiaries to communicate and interact with them and also increase interaction with locals outside their community, thus mainly exploring the context. This service design dimension allows providing better services:

> <… the advantage of working on small numbers allows us to achieve a better service…> (PSP's operator A).
> <…working on small numbers, this is the winning thing, working creating a relationship with people…they are integrated when they know how the local system works, they know who they can ask for help, they know where to go if they need a postal service…they must enter in a critical condition to be able to struggle> (PSP's operator D)

Another element of the provider organization concerns human resources' expertise and capabilities. Indeed, the researchers noted some elements such as participation and

customers' commitment are pushed by the expertise and capabilities of the PSP's operators:

> <… We seek to be promoters of opportunities to exchange, to try to promote the individual, the individual in a social context that is not his community…> (PSP's operator C);
> <… Integration means maintaining own identity, exploring their reality, understanding their uses, customs, working to involve them peacefully and continuously…> (PSP's operator D).

Discussion

This case study sought to comprehend the characteristics of the value co-creation processes within a third sector organisation that provide professional services to beneficiaries into the humanitarian L-TIPs. Baltova and Baltov, (2017) suggested that the concept of value co-creation was considered like a necessity than a choice for business oriented organization and could be beneficial for all engaged parties in many ways. As this case study shows, into the humanitarian setting, value co-creation seems to be a clear choice to find beneficiaries' participation and their commitment in order to deliver better professional services, potentially increasing the probability of their integration.

Centro A offers a vast list of professional services aimed at fostering the integration and inclusion of the beneficiaries in the local context. These professional services range from healthcare, legal, education and job placement requiring extensive customer inputs and interactions to be successful and effective towards the final objective, which is the beneficiaries' integration. While the professional service literature recognizes that significant customer participation is required in order to create value, the mechanisms through which this is practically obtained needs further investigation (Damali *et al.*, 2016).

The main findings of the case research are: 1) trust is a basic element to enable participation during the value co-creation processes; 2) trust is enabled by a continuous interaction between PSPs and beneficiaries; 3) interaction depends both on self-motivation, personal attitude, cultural background of the beneficiary and on interpersonal skills, experience, availability and capabilities of the PSP's operator; 4) the service design sphere could affect the service quality.

Already past studies have revealed trust seems to be a key factor to enable value co-creation processes (Aarikka-Stenroos and Jaakkola, 2012; Damali *et al.*, 2016a; Kohtamäki and Partanen, 2016; Bagdoniene and Valkauskiene, 2018), this also emerged in our case study. Howden and Pressey, (2008) state trust is an interaction driver, and fairness and capability are important sources of value in professional service relationships. Correspondingly, Strokosch and Osborne, (2016), observed that building trust is important both for consumer and service provider in business-oriented context. Nevertheless, trust is crucial to build a personal relationships with beneficiaries to ensure their participation into the value co-creation processes. These insights lead to the following proposition:

> **Proposition 1:** Humanitarian professional service providers, by building empathetic and open approach relationships with their beneficiaries (in addition to fairness and relational capability) increase their participation and commitment during the value co-creation processes.

Furthermore, interaction is the first enabling element to allow trust. Interaction is a mutual action getting involved parties in each other's practices. Many scholars (e.g. Prahalad and

Ramaswamy, 2004; Grönroos and Voima, 2013) claim that the use of interaction is the crucial element to enable value co-creation, thus identifying value as a function of interaction between operators and beneficiaries (Grönroos and Voima, 2013). In the humanitarian context the following proposition could be propose:

> **Proposition 2:** The level and intensity of interaction with beneficiaries increases when the humanitarian professional service provider organizes regular meetings and events with local society: this will help the beneficiaries feel part of a wide community.

Most of the times interactions are pushed by the humanitarian professional service provider, this asking for a high level of adaptation (e.g., the way of communicating) with respect to the beneficiary's cultural and educational background. Moreover, as Prahalad and Ramaswamy, (2004) suggest, "each person's uniqueness affects the co-creation process". A humanitarian professional service provider mainly fosters value co-creation processes thanks to the engagement of individuals increasing expertise and capabilities:

> **Proposition 3:** Cultural differences and educational background gap are avoided by the development of new professional skills (e.g. cultural, linguistic) and the adoption of new methods and tools of beneficiary involvement, allowing beneficiaries to start interaction.

The customer's self-motivation is the starting point for value co-creation in professional services (Hoyer *et al.*, 2010). Often, it is determined by the social and economic aspects of the local context (Bagdoniene and Valkauskiene, 2018). In the case study the researchers have found that beneficiary's self-motivation often depends on the emotional pressure they have in the pursuit of a job, to support their families in other countries, and on socio-economic condition of the local context. Considering beneficiary's self-motivation is an enabling factor of the interaction between PSP's operator and beneficiary, the following proposition is proposed:

> **Proposition 4:** Due to the main beneficiary concern, the development of a network of stakeholders could increase the ability to perform work experiences for beneficiaries while sharing more information about the local context.

The researchers found another crucial aspect related to the PSP during the value co-creation process. It is the service design dimension, intended as the number of beneficiaries that directly interact with the PSP's operators during the participation into the value co-creation process. Indeed, working with a small group or with a single beneficiary force him/her to estrange himself from the context in which he is hosted, starting to communicate with the PSP's operator increasing their individual autonomy and explaining own needs in an easily way, outside the community by abandoning patterns and preconceptions:

> **Proposition 5:** Abandoning a family environment or their community push themselves to interact individually avoiding cultural patterns and preconceptions, ensuring its participation

and a high degree of commitment during the value co-creation process, increasing service quality.

Conclusion

While the literature recognizes that in professional services domain, significant customer participation is required in order to co-create value, the mechanisms through which this is practically obtained need further investigation (Damali, et al., 2016), especially in the humanitarian context. The case study showed that value co-creation processes seem to be the result of a relationship based on trust, reached after continuous and intensive interactions. The relationship between actors in professional services domain will continue to shift and acquire new forms and manifestations (Baltova and Baltov, 2017). Other interesting aspects that emerged in this research are related to the PSPs' expertise and the service design. The main driver to build trust thus enabling value co-creation processes, are education, open dialogue and an open approach discovering different cultural background.

This research wishes to contribute to the body of knowledge on value co-creation by providing an exploratory view on value co-creation processes into the L-TIPs. Nevertheless, this case study has limitations that constitute possible lines of research for the future. The authors also recognise that this is as a single case study with limited diversity of involved participants. Moreover, the study is focused on a small sample selection. It would be interesting to investigate the value co-creation processes comparing different organization and investigate value co-creation process in a structured manner. In addition, related to the aim of L-TIPs could be interesting explore other mechanisms allowing service effectiveness in the humanitarian organizations hoping that could increase beneficiaries' integration into the hosting countries.

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The role of unmanned aerial vehicles in mapping and search and rescue in response to natural disasters

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Abstract

This paper intends to present the implications of deploying UAVs in assisting mapping and search and rescue in immediate response to natural disasters. For doing so, empirical data has been collected from three organizations with real deployment experience. Evaluation framework (Piotrowicz & Irani, 2010) have been used to classify the impacts. Findings indicate that on strategic level, intangible and non-financial benefits, challenges and risks dominate whereas on tactical and operational level, tangible and non-financial impacts outnumber. Considering these impacts, the study identifies areas for improvement. Moreover, it modifies and extends the evaluation framework for use in humanitarian sector.

Keywords: Unmanned aerial vehicles, mapping, search and rescue

Introduction

Every year, sudden onset natural disasters cause deaths, causalities and often result in significant economic and financial losses (Shavarani & Vizvari, 2018). For international NGOs and aid organizations, these disasters restrict their ability to access the affected areas and collect up to date information about the situation (Haavisto et al., 2016; Erdelj et al., 2017). Since first 72 hours are crucial for searching victims post disaster, therefore collecting accurate and timely geospatial information becomes critical for coordinating rescue operation and delivering need based response. Several studies indicate the usefulness of mini and micro Unmanned Aerial Vehicles (UAVs) in bridging knowledge gaps in immediate response phase and enhancing data collection and information sharing capabilities of first responders and humanitarian organizations (Sakr et al., 2016). While each methodology has different impacts, this research intends to present the benefits, challenges and risks of the using UAVs in disaster response, particularly in mapping and search and rescue.

Evaluation Framework

Since UAVs can be used to strengthen the capabilities of Geographic Information System (GIS) by collecting and transmitting remotely sensed spatial data, therefore we decided

to use evaluation framework (Piotrowicz & Irani, 2010) to identify and classify implications of the use of UAVs in disaster response. This framework takes into account the technology related flexibility and can be used to present impacts that cannot be measured through conventional evaluation techniques (e.g. cost benefit analysis).

For this research, we have the modified dimensions of framework to incorporate unique characteristics of humanitarian sector and our research aim. The dimensions of this framework are explained below.

Strategic, tactical and operational impacts

Strategic impacts are linked with the objectives of organization and represent the long term impacts. They affect performance on tactical and operational levels (Gunasekaran et al., 2001). In case of humanitarian organizations, these impacts can be affected by the time and socio-political and economic conditions of the country in which disaster strikes (Pettit & Beresford, 2009). Tactical impacts are linked with resource, process and task requirements and affect medium (short terms) success of project. Operational impacts represent requirements that must be fulfilled on daily basis for successful completion of a project (Gunasekaran et al., 2001).

Impact characteristics

Impacts experienced at each level can be categorized based on the extent to which they can be measured indirectly or directly (Gunasekaran et al., 2001). Tangible (T) impacts can be experienced and measured in a direct manner whereas intangible (INT) impacts cannot be assessed directly (Piotrowicz & Irani, 2010). Tangible and intangible impacts may indicate financial (F), or non- financial (NF) repercussions of innovation decisions (Gunasekaran et al., 2001).

Balanced Scorecard (BSC) dimensions

Piotrowicz & Irani (2010) have used BSC dimensions to present distribution of benefits in areas such as financial, internal business processes, customers and learning and growth (Kaplan and Norton, 1996). Due to immense importance of donors and beneficiaries in humanitarian sector, several humanitarian organizations consider them as their customers. Donors provide funds and influence humanitarian decision making (Beamon & Balcik, 2008) therefore, we chose them as customers. As the main objective of humanitarian organizations is to save lives and reduce suffering of victims, their main responsibility is also towards beneficiaries (Beamon & Balcik, 2008). Thus, we also regarded beneficiaries as customers.

Unmanned aerial vehicles (UAVs)

UAVs are aerial vehicles without passengers and crew onboard. They can be dispatched autonomously or semi-autonomously to perform sensory operations (Sakr et al., 2016). In this research, we aim to analyze the implications of micro and mini UAVs because they are preferred for use in disaster response from regulatory point of view due to their size and weight (OCHA, 2014). The maximum take-off weight of mini UAV is less than 30 kg whereas that for micro UAV is less than 5 kg (Bendea et al., 2008; Giordan et al., 2018). Several humanitarian organizations and emergency management organizations such as International Organization for Migration (IOM), World Bank and Greater Manchester Fire Rescue Service (GMFRS) have used them (both fixed wing and multi-rotor) for mapping and search and rescue in immediate response to disasters (Soesilo et

al., 2016). Mini and micro UAVs can easily be transported to disaster site and perform challenging tasks such as search and rescue (SAR) (Tanzi et al., 2014; OCHA, 2014).

They are more affordable to use for mapping and SAR operations compared to other types such as High Altitude, Long Endurance (HALE) and Medium Altitude, Long Endurance (MALE). Small rotary wing UAVs cost around US$2,000, whereas high endurance fixed wing models costs around US$130,000,000 (Tatham et al., 2017). DJI's phantom (multi-rotor UAV) costs around €500-€1500 and MikroKopter's ARF OktoXL 6S12 (multi-rotor UAV) costs approximately €6,500 for mapping. Fixed wing UAVs (for mapping) range from €10,000 (Danoffice IT's Cumulus 1) to €20,000 (SenseFly's eBee). The cost of UAVs for live feeds during SAR can range from €42,000 (Microdrones' MD4-1000) to €40,000 (Sky-Watch's Huggin X1). These cost variations are due to brand, type of UAV (fixed wing or multi-rotor) and sensors used (Soesilo et al., 2016).

Limited endurance of mini UAVs (<2 hours) and micro UAVs (around 1 hour) affect their ability to fly longer (Bendea et al., 2008) and support SAR and mapping operations without a charging arrangement or extra capacity. Their limited payload capacity restrict their capacity to carry the number and type of sensors and cameras. However, the development of miniaturized and custom designed thermal sensors as well as multi and hyper spectral cameras have enhanced usefulness of these platforms (Giordan et al., 2018).

Mapping and SAR challenges in immediate response phase

Immediate response to disaster involves multi-dimensional activities to reduce disaster impact, save lives and prevent further damage. Despite the critical need to rescue victims and provide relief, humanitarian organizations have to face significant challenges in conducting immediate response activities, particularly with first 72 hours. This is because disasters most often damage physical infrastructure and cut off affected areas (Haavisto et al., 2016). Inaccessibility to affected locations coupled with inaccurate understanding of situation limit the ability of humanitarian organizations and first responders to collect up to date spatial data. Most often in response phase, humanitarian organizations are receiving information from deployed assets and reports from the community. The collected information is sometimes inaccurate or incomplete (Griffin, 2014).

Benefits of UAV assisted mapping and SAR

The availability of accurate and up to date information is critical for rescuing victims and providing relief (Griffin, 2014). In this regard, images or live video feeds streamed by mini and micro UAVs from disaster site can improve situational awareness of humanitarian actors (Shakhatreh et al., 2018). These videos can also increase the flexibility of first responders in improvising SAR operation (Tanzi et al., 2014); thereby improving SAR time efficiency (Shakhatreh et al., 2018). Sending data acquisition plan to satellites and collecting data from them takes several days whereas UAVs can be deployed on demand for multiple observations of disaster affected area. Mini and micro UAVs carrying IR camera and LiDAR can be quickly dispatched to scan the disaster affected site and collect data even during night time and adverse weather conditions (Shakhatreh et al., 2018). This can improve mapping time efficiency (Nedjati et al., 2016). UAV based images can be used to create maps and other information products (such as DTM and DSM) which can be used to conduct risk assessment, damage assessment and plan need based relief efforts efficiently (Hashemi-Beni et al., 2018). Their use can also reduce the overall response time (Tanzi et al., 2014). Up to date UAV based spatial data

can strengthen GIS and can be used to improve other immediate response activities (Gomez & Purdie, 2016).

Autonomous mini and micro UAVs can reduce operating costs of UAVs because these vehicles are less costly as compared to helicopters and airplanes (Soesilo et al., 2016). Low cost and off the shelf sensors and cameras have also reduced unit cost of these vehicles (Sakr et al.,, 2016). Moreover, autonomous systems reduce the need of trained pilots to operate the vehicles and decrease the total manpower required to perform UAV based mapping. Micro and mini UAVs can also enhance victim detection and mapping accuracy. As compared to other remote sensing platforms such as airplanes, helicopters and satellite, mini and micro UAVs can fly at low altitudes (30-150 meters) and capture high resolution images from different angles (Soesilo et al., 2016). Sensors carried by these vehicles allow them to locate and detect victims with accuracy (Tanzi et al., 2014). UAVs as a platform can overcome coverage issues due to atmospheric conditions (such as cloud cover and dust whirls) (Soesilo et al., 2016).

Deployment risks and challenges in disaster response

Regulations present a major challenge in deploying UAVs for disaster response (Gomez & Purdie, 2016; Shakhatreh et al., 2018). Every country has different regulations and several countries in which humanitarian organizations operate do not have UAV laws (OCHA, 2014; Tatham et al., 2017). Compliance with local regulations is necessary for operationalizing the technology in a safe manner. However, the lack of UAV laws can raise the level of uncertainty regarding their use in disaster response. Since UAVs can collect, store and transmit significant amount of big data, their use has raised concerns regarding data security and privacy of victims (Tatham et al., 2017). This data upon leaking or hijacking can lead to intrusive monitoring of people and observed areas and can also cause personal harm to people (Erdelj et al., 2017). In addition, UAVs have a negative image due to their prior association with the military and their use in modern warfare. For humanitarian organizations, such an image becomes a critical issue that must be managed to retain their image as an independent and impartial entity (OCHA, 2014).

Mini and micro UAVs are sensitive to heavy rains and strong winds (Shakhatreh et al., 2018). Such weather conditions can change the pre-determined flight path; thereby, affecting the coverage of observation area (Shakhatreh et al., 2018). UAV based operations required highly trained pilots and technical staff available, particularly within first 48 hours (Soesilo et al., 2016). In addition, integrating UAVs as a supplementary tool requires significant costly preparations beforehand to ensure timely results. UAV based operations also demand managing (or overcoming) long data processing and energy constraints (Shakhatreh et al., 2018). In case of UAV based SAR, managing coordination between technical team and first responders or humanitarian staff is critical for ensuring success of operation. Lack of clarity about roles and priorities can reduce the possibility to find victims in time and save lives (Soesilo et al., 2016). While the technology is still evolving, technical risks such as limited communication range, need for robust collision avoidance solutions, use of low cost and risky off the shelf components and unexpected sensor failure present challenges related to public safety (Erdelj et al., 2017).

Methodology

Empirical data has been collected from a purposeful sample of three humanitarian organizations (HOA, HOB and HOC) with actual deployment experience in disaster response. HOA and HOC are based in Central and Southern Europe respectively. HOB is based in North America. Multi-case study design has been used to enhance generalizability of findings and compare implications across cases. Constructivism

paradigm have been used to guide research process, data collection and data reporting. Altogether 3 skype based individual interviews have been conducted from 3 respondents in humanitarian industry using an interview guide. All respondents are UAV experts who have used the technology and have participated in real deployment experience of case organizations. Apart from the interviews, written communication in the form of UN reports, documents published on websites of case organizations and previous studies were used for data triangulation.

Findings

Humanitarian Organization A (HOA)

HOA use UAVs as a supplementary tool for mapping only. It uses satellites, on ground team with COBO (Company Owned/Business Only) phone or tablet with GPS and UAVs for collecting spatial data and supporting GIS analysis. Before implementing UAVs, HOA considered cost comparisons between satellites and UAVs, frequency and resolution of observations required, and finance. In addition, an assessment of best tools in terms of days or duration of project was also made. The report was first submitted to the program manager and then to the mission manager in Haiti. After gaining approval, HOA collaborated with a private company named SenseFly to source micro- UAVs and software. After receiving field validation reports from teams on ground, HOA conducted test flight with UNOSAT in the aftermath of Hurricane Sandy (2012). To make sense of spatial data, HOA collaborated with Pix4D and converted raw data or images into accurate 2D maps (orthomosaic) and 3D models (DEMs). For digitizing images and conducting GIS analysis, HOA hired a specialized team from Open Street Map (OSM). It then reduced the size of each UAV based imagery and maps (<50 Megabytes) and shared this information freely (open source) through humanitarian data exchange (HDX platform) and OSM with relevant stakeholders (volunteers, local government, humanitarian partners and civil protection bodies).

UAVs showed advantages during first deployment as it provided the data faster (29th October) than satellite (2nd November). Cost wise UAVs gave a more detailed overview as compared to satellites on km^2 basis. Upon realizing benefits from this experience, HOA began developing in house UAV capacity. It sourced more vehicles, servers and formed a specialized team in house. Later it deployed UAVs in response to Hurricane Matthew (2016) to verify satellite data, improve situational awareness, collect baseline data to identify hurricane pattern and support damage assessment and plan response (in terms of NFI and food distribution). The respondent mentioned that UAV based operations are challenging because the technology can be deployed only if the Government requests and allows their use. Their use also requires considering and complying with laws regarding data management (storage, filter information and processing). Moreover, cases in which Government receives reports of misuse of UAV sourced data, improvising the situation becomes problematic.

Humanitarian Organization B (HOB)

HOB use UAVs as a complementary tool for mapping only. HOB does not replace satellite, manned aviation assets or ground based surveys with UAVs. It uses them for data triangulation or bridging knowledge gaps. HOB prefers to use UAVs for direct live feeds or improve situational awareness of an area when satellite images are inadequate. UAVs provide high resolution images (1.5 to 10 cm) that are accurately geo-referenced. These vehicles are used when HOB has the capacity to use the technology in terms of

funds, vehicles and technical staff available. UAV are preferred for small scale (10 km) localized assessments as compared to ground based survey. An aerial image sourced from UAV can be cheap as compared to satellite images. Moreover, UAVs provide flexibility to HOB for on demand and efficient mapping. However, the preparation for UAV based operations can be very costly in terms of acquiring the technology, permits and developing or hiring technical staff. Regulations for UAVs are more restrictive than satellites in terms of data management and use of vehicle. If preparations are not done before deploying UAVs in immediate response then, UAV based response can take long time. Even with preparations done, data processing stage can be significantly time consuming if HOB is covering large areas with UAVs. Thus, with 72 hours, it is hard to conclude that UAVs can be effective in delivering the maps. It can be useful with 72 hours provided the vehicle streams live video feeds to the team. Furthermore, the use of UAVs requires collaborating with the technical team or technology providers on site. Challenges and risks mentioned by the respondent deals with ethical implications (such as privacy of victims, data protection and management), lack of uniform standards, long processing time (e.g. 3-4 days to map 10 square kilometers), harsh weather conditions, overhyped product capabilities, costly preparations, lack of experience of technology providers in emergencies and regulatory restrictions. She mentioned that some countries do not even have UAV regulations and several do not have streamlined processes to gain approval for UAV, pilot and operator. It usually takes several weeks to go through several registration processes and certifications.

Humanitarian Organization C (HOC)

HOC has been using UAVs as a supplementary tool for mapping and improving visibility of national partners at lower costs. However, it has been supporting local Governments, National Disaster Management Organizations (NDMOs) and first responders in SAR by prepositioning lower cost UAVs ($2000/ UAV) and localizing skillsets through training programs. For mapping, HOC has prepositioned equipment at six regional bureaus (Panama, Bangkok, Cairo, Johannesburg, Nairobi and Dubai). It has been conducting capacity building workshops for HOC personnel, cluster partners and the Government. For localizing UAVs, HOC is working with civil aviation authorities to get clearance.

Before deployment, HOC defined expectations at programme level in each country of operation. Decision to use the technology was based on the comparative analysis of the end product price vs methodology. End product price was measured on project or unit cost basis. For mapping HOC analyzed cost effectiveness of UAVs i.e. it compared quality and accuracy vs cost per hectare of land.

HOC have used UAVs in Philippines after Typhoon Haiyan (2013) to map out millions of damaged coconut trees and to support efforts to enable reuse of farmer lands. In Columbia, HOC used UAVs to track displaced population in the aftermath of Hurricane Irma (2017). In Mozambique, it mapped 14000 km^2 of River Delta (2018) to assess damages in the aftermath of floods (2018). In response to Hurricane Maria (2017) in Dominica, HOC used UAVs to support Government and rescue teams. For map generation, HOC use LiDAR, photogrammetry software and high processing power computers to create orthomosaics, Digital Surface Models (DSMs) and Digital Elevation Models (DEMs). It then freely shares the generated information products with national partners to improve situational awareness. HOC use micro UAVs (less than 1kg) and sensors such as Near Term Digital Radio (NTDR) and Unreal Development Kit (UDK) camera for thermal imagery. For observing large areas (e.g. 500 hectares), HOC use fixed wing UAVs. The benefits reported by the respondent include workload reduction,

improvement in inter-agency coordination and information sharing and strengthening GIS. UAVs improved mapping and SAR accuracy, flexibility and capabilities. The challenges and risks that HOC reported include ensuring the appropriate equipment (UAV) for use, retention of technical knowledge and staff, timely communicating with civil aviation authorities for safe operations and assuring safe operations across the cluster.

Discussion

Table 1 & Table 2 presents classification of reported benefits, challenges and risks based on the framework dimensions (Piotrowicz & Irani, 2010). Majority of the reported benefits can be categorized as strategic and operational whereas most of the challenges and risks can be classified as strategic and tactical. On strategic level, UAVs mostly improve: inter-agency coordination and information sharing and other immediate response activities. These findings are in line with previous research (Gomez & Purdue, 2016; Soesilo et al., 2016). On tactical level, UAVs can reduce map procurement costs (HOA, HOB & HOC) and improve GIS data collection and information system (HOA & HOC) on organizational (HOA) and multi-agency level (HOC). These findings are supported by previous studies analyzing the impact on intra organization (Sakr et al., 2016) and inter-organization level (Soesilo et al., 2016). On operational level, UAVs can be used to enhance capabilities and accuracy of mapping (HOA, HOB and HOC) and SAR operation (HOC). All these findings are similar to observations made in previous studies (Nedjati et al., 2016). On strategic level, the main challenges and risks mentioned by all cases include concerns regarding: regulations and data protection. Limited resource capacity, lack of deployment preparedness and data management were found common challenges and risks among several cases on tactical level. On operational level, technical team dependence, long processing time, and weather conditions can be categorized as main challenges and risks. These findings have been confirmed by previous studies (Bendea et al., 2008; Erdelj et al., 2017). We found some new challenges and risks such as retaining technical knowledge and staff, monitoring risk and assuring safety at multi-agency level, dependency on agency request and gaining approval internally. On strategic level, intangible and nonfinancial benefits, challenges and risks were found dominant. Majority of benefits, challenges and risks on tactical and operational levels were identified as tangible and non-financial in nature. We found donor and learn and growth as main improvement areas in all organizations. Moreover, findings revealed learn & growth, internal process and beneficiary as the areas that require the most attention to reduce risks and overcome challenges.

Conclusion

Findings have revealed the difficulty in measuring benefits, risks, and challenges for humanitarian organizations on strategic level. Most of the implications on strategic level (such as improvement in inter-agency coordination and information sharing and regulations) are intangible and non-financial in nature. Although their impact is difficult to measure, these outcomes can greatly impact the performance of humanitarian organizations in immediate response. On tactical and operational level, tangible and non-financial impacts dominate tangible and financial as well as intangible and non-financial for all organizations. Evaluation framework enabled us to indicate intangible and non-financial implications of UAV assisted response. These impacts cannot be captured by conventional evaluation techniques (e.g. cost-benefit analysis) and operational measures.

Table 1 – UAV deployment challenges and risks-HOA, HOB and HOC

	Balanced Scorecard dimensions				
Levels	**Donor**	**Beneficiary**	**Internal process**	**Learn and growth**	**Financial**
Strategic	Improve other immediate response operations (INT, NF)	Improve other immediate response operations (INT, NF)		Improve other immediate response operations (INT, NF) Improve inter-agency coordination and communication (INT, NF)	
Tactical					
			Improve map procurement process (T, NF)	Strengthen GIS , proactive assessment and planning (NF, INT) Accurate and on demand information products (T,NF)	Reduce map procurement costs (T, F)
Operational					
	Enhance mapping accuracy (T, NF) Increase mapping time efficiency (T, NF) Enhance mapping capabilities (INT, NF) Improve situational awareness (INT, NF)	Improve situational awareness (INT, NF) Reduce waiting time (T, NF)	Reduce waiting time (T, NF) Increase mapping flexibility (NF, INT) Autonomous systems streamline workflows (NF, T)	Improve situational awareness on organization and multi-agency level (INT, NF) Enhance mapping accuracy (T, NF) Reduce personnel workload (INT, NF) Enhance mapping capabilities (INT, NF)	Increase cost effectiveness and efficiency (T, F)

Table 2 – UAV deployment challenges and risks-HOA, HOB and HOC

	Balanced Scorecard dimensions				
Levels	**Donor**	**Beneficiary**	**Internal process**	**Learn and growth**	**Financial**
Strategic	Data protection and privacy (INT, NF) Regulation and authorizations (INT, NF-F)	Regulation and authorizations (INT, NF-F) Data protection and privacy (INT, NF) Public safety (INT, NF)	Regulation and authorizations (INT, NF-F)	Overhyped capabilities of UAVs (INT, NF)	Costly preparations (INT, F) Regulation and authorizations (INT, F-NF)
Tactical					
	Data management (INT, NF)	Data management (INT, NF)	Data management (INT, NF) Dependency on Government and agency request (T, NF) Limited resource capacity (NF-F, T)	Data management (INT, NF) Gaining approval internally(T, NF) Resource preparation and prepositioning (T, NF-F) Monitoring and assuring safety measures on cluster level (T, NF) Retention of technical staff and knowledge (T, NF)	Limited resource capacity (NF-F, T) Resource preparation and prepositioning (T, NF-F)
Operational					
		Weather conditions (NF, T)	Limited availability of trained staff (T, NF) Weather conditions (NF, T)		Limited budget for operation (T, F)

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Value co-creation of continuous aid process in the humanitarian service triads

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Abstract

The purpose of this study is to understand how service triad members in humanitarian supply chains (HSC) contribute to the value co-creation of continuous aid process. This study implements semi-structured interviews to humanitarian service triad members. The sample from non-governmental organizations, service providers and the beneficiaries are selected through purposive sampling and snowball sampling. By identifying the best practices and bottleneck points, this study contributes to the development of an understanding in HSC literature for the continuity of aid in the value co-creation process in humanitarian service triads.

Keywords: Value Co-creation, Service Triads, Humanitarian Supply Chain

Introduction

Recent changes in the global environment has increased the importance of supply chain management, not only in commercial setting but also in humanitarian setting. Humanitarian aid services, which includes security, education, health, nutrition and human rights, is becoming more crucial in enhancing livelihoods of people in need (UN OCHA, Turkish Red Crescent Community Centers) as the humanitarian crisis has increased in terms of number and duration.

The HSC consists of several actors, such as donors, aid agencies, non-governmental organizations (NGOs), governments, military, logistics service providers and suppliers (Kovács and Spens, 2008). Besides, the beneficiaries are introduced as the end-users of the products or services, whose needs are not predetermined and must be accommodated in a limited time (Altay and Green, 2006; Kovács and Spens, 2007; Oloruntuba and Gray, 2009).

The direct contact between the service provider and end user is entailed by service triads (Li and Choi, 2009), and this concept has a unique approach in HSC, since the components of the triad does not rely on linear links; instead, extends across multiple links in the triad (Heaslip and Kovács, 2018).

Recently, the attention to the roles and contributions of the HSC members in the humanitarian aid delivery process is increased in humanitarian supply chain management (HSCM) literature (Makepeace et. al, 2017; Oloruntoba and Banomyong, 2018; Seifert et. al, 2018). However, the research on the service concepts in HSCM literature is still in its infancy (Heaslip, 2013; Heaslip and Kovács, 2018), and empirical studies are needed to advance theory on service delivery process in HSC.

HSCM involves providing services in disaster relief operations as well as in continuous aid operation with long-term goals (Kovács and Spens, 2007). The purpose of this research is to understand how service triad members in continuous aid HSC - humanitarian organizations, implementation partners of the humanitarian organizations and the beneficiaries - contribute to the value co-creation of aid process and to assess the continuity of aid services in HSCs before and after they are provided to beneficiaries (e.g. capacity building through job trainings). Thus, the research raises two research questions:

- How does value co-creation operationalized in humanitarian service triads?
- How does the benefits generated by the value co-creation utilized by the beneficiaries and sustained by the humanitarian service triad?

By identifying the best practices and bottleneck points, the research contributes to the development of a novel framework in HSC literature for the continuity of aid in the value co-creation process in humanitarian service triads. The empirical basis of the research relies on semi-structured interviews (Eisenhardt et. al, 2007; Flick, 2014) with humanitarian service triad members, that is, humanitarian organizations, service providers and the beneficiaries.

The paper is structured as follows: in the following section, the literature review on value co-creation in HSCs is discussed. Then, the relevant literature for value co-creation in HSCs is synthesized. In the methodology section, qualitative methodology adopted for the study is elaborated. In the last two sections, findings and conclusions are presented.

Theoretical Perspectives of Value Co-Creation in HSC

Recent developments and studies demonstrate that there is a shift toward service dominant logic in HSCM (Heaslip, 2013; Heaslip et al., 2018). Even with the new implementations, such as the cash-based approach, humanitarian organizations enable beneficiaries to access markets on their own (Heaslip, 2015). This also shows a transition from push principles to pull principles in HSCM, since the organizations start trying to fulfill the actual need of beneficiaries (Heaslip et al., 2018).

HSCs can be set up for various reasons, and they can have short-term and long-term goals. Following a rapid-onset disaster, such as earthquakes, hurricanes and floods, HSCs can be set up in a few days in order to provide basic relief services to the beneficiaries (Kovács and Spens, 2007). However, HSCs can also be set up for providing continuous aid, which has long-term objectives, such as for reconstruction and rehabilitation of affected regions (Matopoulos et al., 2014; Oloruntoba and Kovács, 2015), as well as for development programs. While short-term HSCs are agile (Oloruntoba and Gray, 2006; Van Wassenhove, 2006), long-term continuous-aid HSCs, or preparation and reconstruction HSCs are lean (Taylor and Pettit, 2009; Cozzolino, 2012). Although collaboration among members in HSC

has been seen as a challenge due to the different mandates of humanitarian organizations (Balcik et al., 2010), there has been a call from donors for their integration in HSC (Moshtari, 2016).

Value Co-Creation in HSC

Value co-creation and its role in a supply chain (SC) and its processes have been studied through various aspects. Furthermore, the degree of collaboration in a SC has been investigated in terms of value co-creation (Jin et. al, 2013; Sandberg et. al, 2018), and collaboration is found as one of the key antecedents of value co-creation and service delivery in humanitarian setting (Moshtari, 2016; Prasanna and Haavisto, 2018). Supply chain performance and on-shelf availability (Ehrenthal et. al, 2014; Tuan 2017) and customers' loyalty and their contribution to the overall process (Thiruvattal, 2017) were some of the topics that has been analysed under the concept of service dominant logic based on value co-creation in supply chain management (SCM) literature. In addition to value co-creation literature, Grönroos (2011) more specifically defined the customer is a co-creator of the value as well as the firms.

HSC consists of different actors providing different services to each other as well as to the beneficiaries with the aim of bettering the conditions of beneficiaries. Thus, value co-creation process can take place among the different members in HSCs. Despite being recognized as one of the key concepts in the literature, value co-creation has not been analyzed sufficiently in HSC literature until recently (Heaslip and Kovács, 2018). Heaslip (2015) highlighted the gap in the HSC literature as the value constellations to be the growing phenomenon.

Service Delivery Process and Service Triads in HSC

There are different types of HSCs (Oloruntoba and Kovács, 2015) ranging from short term to long-term continuous aid HSC, where there is more time to assess the actual needs of beneficiaries. Continuous aid HSC can be set up for different objectives such as a part of recovery and rehabilitation of affected region due to a disaster or a conflict (Matopoulos et al., 2014). There is a debate on the role of beneficiaries as the customers of HSCs; beneficiaries are not viewed as the regular customer as they have to accept what they are offered in terms of services (Oloruntoba and Gray, 2009), however there are also studies which consider beneficiaries as customers (Heaslip, 2015; Heaslip et al., 2018; Scholten et al., 2018).

On the one hand, service triads have been defined as the relationship among services buyer, supplier and the end customer (Li and Choi, 2009). Service triads cover when firms serve their customers through the third party service providers. Triadic relationships based on service dominant logic covered on purchasing and retail performance (Chuang et. al, 2016; Broekhuis and Scholten, 2018), socially responsible operations (Jung et. al, 2015) individuals with caregiving relationships with the customer (Roetzmeier-Kueper et. al, 2018). On the other hand, in HSCs, humanitarian organizations start offering services to each other (Heaslip, 2013). In Heaslip and Kovács (2018)'s study, the authors provide a service triad of implementing partners, donors and UN agencies/International Humanitarian Organizations/Logistics Service Providers, and they examine the financial, contractual and physical flow among these three.

This study focus on a service triad in a HSC setting as in Heaslip and Kovacs (2018)'s study. However, in this study, beneficiaries are included in the service triad rather than

donors. Therefore, this study focuses on a service triad of beneficiaries, service providers and NGOs in a HSC setting.

Methodology

This study has an explorative nature and applies qualitative research methodology (Flick, 2014) to humanitarian service triad members through semi-structured interviews. Qualitative methodology provides participants with flexibility and freedom to talk about their experiences and discuss implications effectively, as well as allows us to understand their contribution to the value co-creation process (Eisenhardt et. al., 2007).

The sample from NGOs, service providers and the beneficiaries are selected through purposive sampling (Palys, 2008). Statistical data gathered from UN High Commissioner for Refugees (UNHCR), International Committee of Red Cross (ICRC), International Federation of Red Cross (IFRC), The International Red Cross Red Crescent Movement (IRCRCM) and IOM (International Organization of Migration) show that İzmir is a preferable baseline to conduct the study. Therefore, data collection took place in İzmir, which is among the top ten cities with the highest amount of refugees in Turkey (Interior Directorate General of Migration Management, UNHCR Turkey). Moreover, snowball sampling (Patton, 1990) is used during data collection until a state of data saturation was reached (Eisenhardt, 1989). The interviewees are selected from the three triad categories (6 beneficiaries, 4 NGOs, 6 service providers), since each of them represent distinct components of the service triad. The first group, beneficiaries, are chosen based on their demographic features (age, gender) and the time spent as a refugee. The following group is NGOs which receive their donation through several funding sources, such as governmental, institutional or private sources (Heaslip, 2013; Oloruntoba and Gray; 2009). Last group is service providers, which act as intermediaries between NGOs and the beneficiaries (end users) of the service delivery process in HSC by providing job trainings.

Table 1 - Characteristics of the Sample

Position in the Triad	***NGO***	***Working voluntarily to aid the people who is in need and supplying psychosocial support and protection services***		
Codes of the Respondents	**Gender**	**Position**	**Age**	**Humanitarian Aid Experience**
NGO-1	Female	Project Manager	30-39 years	2-5 years
NGO-2	Female	Protection Program Officer	20-29 years	2-5 years
NGO-3	Male	Logistics Officer	20-25 years	2-5 years
NGO-4	Female	Communications Officer	30-35 years	0-1 year
Position in the Triad	***Service Providers***	***The member of the triad who is in charge of supplying the required services or products***		
Codes of the Respondents	**Gender**	**Position**	**Age**	**Humanitarian Aid Experience**
SP-1	Female	Local Institution	35-40 years	10-15 years
SP-2	Male	Head of Trade Association	35-40 years	15-20 years
SP-3	Female	Psychologist	30-35 years	2-5 years
SP-4	Female	Turkish Language Trainer	35-40 years	5-10 years
SP-5	Female	Turkish Language Trainer	25-30 years	0-2 years
SP-6	Female	Turkish Language Trainer	25-30 years	0-2 years

Position in the Triad	***Beneficiaries***	***People who migrated due to the conflict, and is in need of social aid***	
Codes of the Respondents	**Gender**	**Employment Status**	**Time spent in Turkey**
B-1	Female	Employed	8 years
B-2	Male	Employed	4 years
B-3	Male	Unemployed	3 years
B-4	Female	Seasonal Worker	8 years
B-5	Male	Unemployed	8 years
B-6	Female	Unemployed	5 years

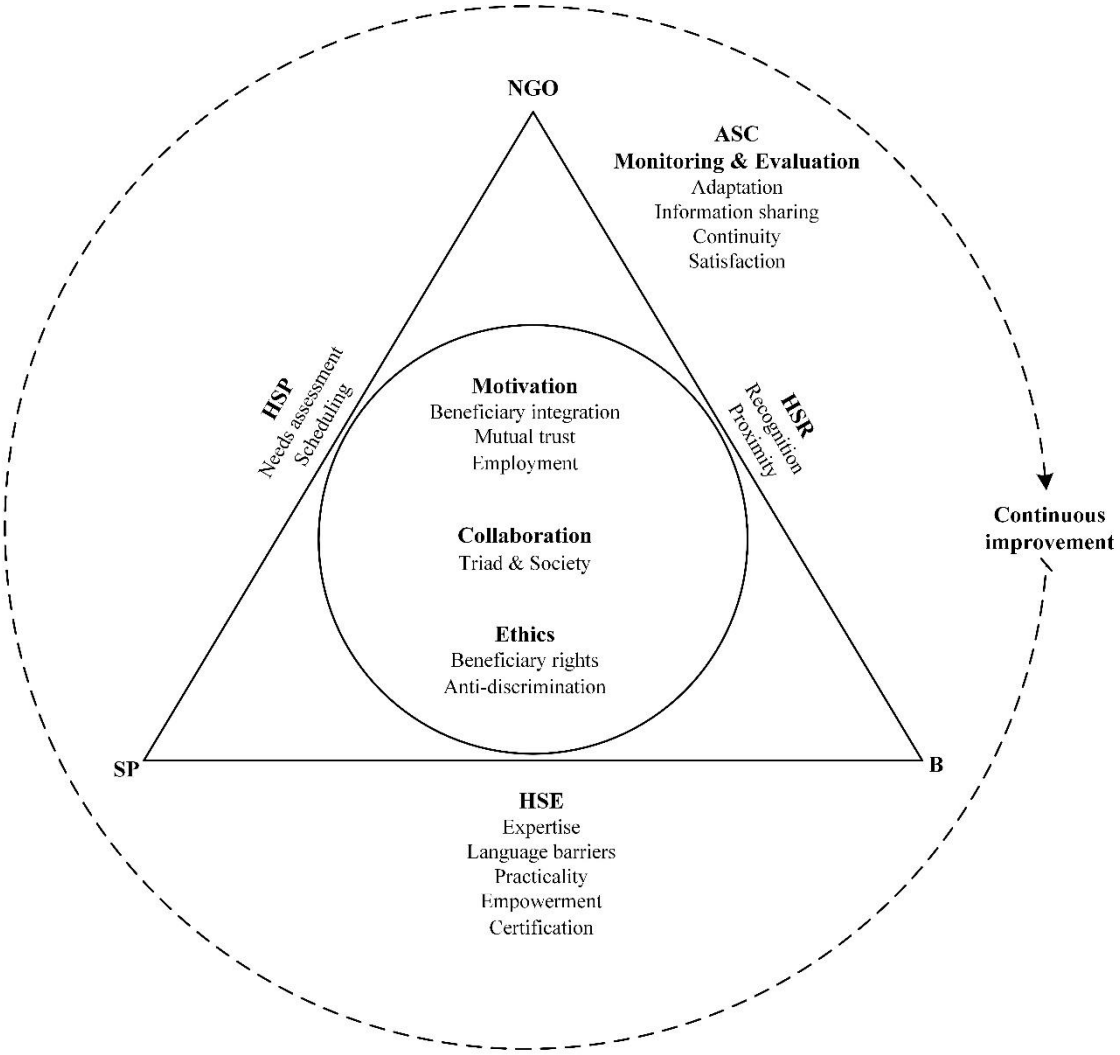
In semi-structured interviews, triad members' current practices in HSC service triad are questioned. All interviews are recorded and transcribed. Content analysis (Graneheim et. al, 2017) is used for analyzing the data. In the first stage, through a line by line analysis, the patterns, concepts and their properties are described. In the second stage, comparisons of the labeled concepts are made and grouped, if necessary (Eisenhardt, 1989, Miles and Huberman, 1994). Then, their contribution to the value co-creation in the humanitarian service triad is explored. This framework is extended towards after-service process, where the effectiveness and continuity of humanitarian aid process is further pondered, and the expected value co-creation environment in the humanitarian service triad is revealed. In order to ensure validity and reliability, the data is coded by two researchers and inter-rater agreement is achieved through "discursive alignment of interpretations" (Seuring and Gold, 2012). Further, the data is triangulated (Denzin, 2017) with observation and publicly available documents gathered from websites.

Findings and Discussion

The coding process revealed seven main categories of value co-creation of continuous aid process in humanitarian service triad (Figure 1). Among these categories, humanitarian service planning, humanitarian service reachability, and humanitarian service effectiveness are co-created as value by mutual contribution between two of the triad members. Collaboration in humanitarian services, humanitarian service motivation, ethical issues in humanitarian services are co-created with joint contribution of triad members, and enhances all value components across the triad. After care in humanitarian services is found to be a generic component, which influences other components and enhances the value co-created across the triad for the continuity and continuous improvement of the service delivery process.

Humanitarian service planning is one core value co-created across the triad, with mutual contribution of NGO and service provider. The important focus in planning is needs assessment and arrangement of services based on the concerns of beneficiaries, as the value co-created by effective planning is directly utilized by the beneficiary.

Humanitarian service reachability is another important value, co-created across the triad by mutual contribution of the NGO and beneficiary. NGO sets the link between the service provider and beneficiary for raising awareness on the service by announcing the service through various communication channels, while beneficiary contributes by spreading the service through word-of-mouth.



HSP: Humanitarian service planning
HSE: Humanitarian service effectiveness
HSR: Humanitarian service reachability
ASC: After service care

Figure 1 – Value Co-creation in Humanitarian Service Delivery Process

Humanitarian service effectiveness is value co-created during the actual service delivery to the beneficiary, and generated by mutual contribution of the service provider and beneficiary. On one hand, service provider contributes by providing quality of the service provided, which is enhanced by the expertise and experience, while beneficiary contributes by effectively receiving the service and empowering his/her skills.

It is evident in the analysis that collaboration is a critical component in humanitarian services (Moshtari, 2016; Prasanna and Haavisto, 2018). However, the integration of beneficiaries and society to humanitarian service delivery process is outlined to be an essential value for generating effective collaboration in the service triad. On the other hand, beneficiary, service provider and NGO contributes to value co-creation from different perspectives for raising motivation to humanitarian services by creating trust and satisfaction

environment across the triad. Furthermore, ethics is found to be another value co-created by joint contribution of the triad members to protect the rights of the beneficiaries, remove gender discrimination, and empower marginalized groups.

Another value component in humanitarian service is after service care, which is associated with the follow-up of the beneficiary (e.g. employment, adaptation and satisfaction) and the continuity of information sharing after the service is delivered.

The synergy created by the interactions of the value components co-created across the humanitarian service triad elevates the service delivery process in the entire triad and enhances continuous improvement.

Conclusion

This research contributes to the literature by analyzing how a continuous aid in value co-creation can be provided in such a dynamic environment of a humanitarian setting. By detecting the bottleneck points with the empirical analyses, it aims to contribute to the practice by the development of a value co-creation understanding in HSCM.

This study is one of the few studies that examines the value co- creation process (Grönroos, 2011) in HSCM that includes beneficiaries. Recently, there is an increasing trend from both practitioners and academics towards improving services in the HSCM (Heaslip, 2013; 2015; Heaslip and Kovacs, 2018. Findings of this study shed light on the understanding of services provided to end users (beneficiaries) in HSC, and advances knowledge on this concept for the continuity of the humanitarian aid process, as well as provides useful and profound information to the practitioners in humanitarian setting. For further studies, focusing on the effect of the harmonization period of the beneficiaries could be a good starting point of a phenomenological study. Current trends in HSC and considering value co-creation as a complementary part of the continuous aid process could enable humanitarian organizations further develop impact analyses in their working space.

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Integrating systematic literature reviews to develop a framework for stakeholder collaboration in disaster response

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Abstract

The disaster response faces several problems related to the management of different stakeholders. On the one hand, integrated frameworks that could support the management of these stakeholders lacks adherence to the disaster and humanitarian context. On the other hand, the Humanitarian Supply Chain Management (HSCM) research is currently composed of several thematic e independently Systematic Literature Reviews (SLR). This paper combines different thematic SLR in the HSCM to develop an integrated framework, which brings additional value not achieved by the SLRs independently. Future research embraces the framework validation and its expansion to other disaster lifecycle stages.

Keywords: Stakeholder Theory, Stakeholder Management, Process Management

Introduction

Operations in disaster response demand interdisciplinary, and a high interaction among stakeholders from the public and private sectors, and the society. Moreover, the coordination of such stakeholders depends on a broad comprehension of the stakeholders themselves, as well as the disaster response processes (Nirupaman and Etnikin, 2012; Tatham and Spens, 2016; Fontainha et al., 2017). Nevertheless, maintaining a productive relationship remains a challenge because of the large number and diversity of actors with distinct organizational cultures and structures (Caruson and MacManus, 2011; Leiras et al., 2014). The consequences of such complications in the stakeholder management are observed in increased inventory costs, longer delivery periods and other logistics inefficiencies (Tatham and Pettit, 2010). Consequently, the management of these stakeholders, of different profiles, cultures, and interests is continually recognized as a critical issue that deserves further investigation (Heaslip et al., 2012; Leiras et al., 2014; Tatham e Spens, 2016).

In a general Systematic Literature Review (SLR) in the area of Humanitarian Supply Chain Management (HSCM), Behl and Dutta (2018) observed the recurrent use of SLR

addressing a variety of emerging topics, stressing the importance of integrating these different topics to bring innovative discussions in the HSCM research and practice. Thus, this paper brings a Stakeholder Theory embedded approach to discuss the connections between four essential topics in disaster response operations. These topics involve stakeholder identification, stakeholder satisfaction, process management, and strategies for stakeholder collaboration, which can be combined into an integrated framework.

After this introduction, this paper presents the results of recent SLRs grouped in dimensions associated with traditional frameworks, more specifically the Performance Prism. Then, the paper presents the conceived integrative framework. Last, the paper gives the main conclusions and indication of future research.

Literature review

This section presents the results of SLRs in the field of HSCM associated to the dimensions of the Performance Prism, which is reflected in dimensions related to (i) the identification of the stakeholders in the HSCM, (ii) the stakeholder's satisfaction in disaster response operations of HSCM, (iii) disaster response process model in HSCM, and (iv) strategies for collaboration in the HSCM.

According to the Performance Prism structure, the first dimension to improve operations is the identification of who are the organizations' stakeholders. In this sense, Heaslip et al. (2012) explain the importance of understanding the roles of each stakeholder to build a new model, claiming that visual representations are essential tools to improve the operations, both from academics and practitioners' perspectives. Aligned with this, Tatham and Spens (2016) also noted that, despite the recent increase of research in the subject, it lacks a common understanding of the inter-relationships related to the management of stakeholders in disaster and humanitarian operations, and common vocabulary and its meanings. In the literature, there are some models discussing the engagement of all stakeholders from different perspectives, such as the ones presented by Kovacs and Spens (2007) and Balcik et al. (2010). More recently, Fontainha et al. (2017) performed an SLR to identify the patterns among the stakeholder models in the academic literature of HSCM. The authors proposed the Public-Private-People Relationship (3PR) Stakeholder Model by the identification of ten main stakeholders: government; military; legislative and regulatory; media; private sector; direct supplier; international air network; local aid network; donor; and beneficiary.

The stakeholder satisfaction is also an essential dimension discussed in the Performance Prism, which addresses the relationship between the organizations according to two perspectives: the dyadic and complex relationships. This approach is relevant for disaster response operations because organizations usually understand well only their own operations and are unaware of other stakeholders' roles (Nirupaman and Etnikin, 2012). To answer this research gap, Fontainha et al. (2018a) performed an SLR to synthesize the stakeholder satisfaction in disaster response according to the perspective of all stakeholders identified in the 3PR Stakeholder Model. This SLR synthesizes 29 satisfactions of stakeholders interacting in complex relationships.

Another dimension discussed in the Performance Prism is related to process management. In this aspect, several important researches on disaster response process models are identified in the academic literature with a broad and diverse perspective regarding modelling notation, respect to the principles of modelling, method for collecting the data or the source of the data, the extension of the model content, the disaster type and site, and the stakeholder that is the focus of the models (e.g., Oloruntoba, 2006; Charles and Lauras, 2011). Nevertheless, Aldin and Cesare (2011) explain that identifying patterns among previous models is the natural path to developing generic and

reference models to overcome such limitations. Fontainha et al. (2018b) developed a SLR on the existing process models and identified patterns among them, which served as the basis for the development of a model of reference processes for disaster response. The main processes are "Recognition of the disaster occurrence", "Assessment of the current situation", "Search and rescue", "(R)estabilishing infrastructure in the response", "Resource request for the response", "Resource transport during response", "Service to the population", "Demobilization of the operations", and "Response support operations". Moreover, Fontainha et al. (2018b) argue that the model allows different flows among these processes, since, depending on the specificity of the disaster, because some processes can be implemented or not in the response to the disaster. The authors explain that this model is the first one suitable to all stakeholders and that can be used as a reference and tool to improve the planning of disaster response.

Besides the previous dimensions, the strategy is also a dimension discussed in the Performance Prism. Regarding the ODH context, Moshtari and Gonçalves (2016) analysed the collaboration strategies between international humanitarian organizations and identify that collaboration as a strategy is affected by three groups of factors: contextual; interorganizacional; and organization. Considering collaboration strategies between international aid networks and direct logistics providers, Bealt et al. (2016) identified that the goals of involving direct suppliers of logistics in HSCM vary between strategic decisions, corporate social responsibility, publicity, commitment to help vulnerable people to start operations in the country or region, among others. Jahre (2017) analyses strategies considered by several stakeholders involved in collaboration in the HSCM and conclude that the strategies represent decisions that different stakeholders can develop when acting in response to disasters. Regarding the collaboration strategy, Jahre (2017) identified the following collaborative elements: coordination; supplier's relation; commercial-humanitarian cooperation; collaborative procurement; civil-military collaboration; adaptability; orchestrating networks.

Framework

Inspired by the work of Neely et al. (2008), the interaction of the results observed in the previous SLRs is conveyed in a four-dimension framework discussed in an integrated approach presented in Figure 1.

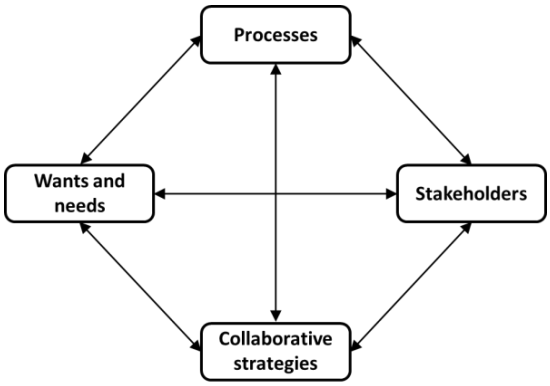

Figure 1 – Integrated framework for stakeholder collaboration in disaster response.

Besides the independent analysis of each dimension, which is already discussed in the separated researches, their interaction also brings additional value to academics and practitioners. For instance, the combination of the stakeholder and the wants and need dimensions allows the identification of which needs must be met according to the

identification of which stakeholders are involved in the disaster response. The combination of the wants and needs and the process dimensions allows a more objective understanding of stakeholders' wants and needs in the planning of disaster response operations according to a process perspective. The combination of the stakeholder and the process dimension allow the identification of which stakeholders are involved in each disaster response process. All of these dimensions and discussions are subsidiary in the debate of which and how the collaborative strategies are implemented in the disaster response, which is in the centre of the framework.

After analysing the three dimensions, it is possible to discuss the collaboration strategically in disaster response in an integrated way. At this point in the analysis of the integrated framework, the seven elements of the collaboration strategy identified by Jahre (2017) can be discussed with regard to the need to involve specific stakeholders if these elements of the collaborative strategy are affected by the wants and needs of stakeholders, and if the collaborative strategy elements are considered in the planning of the disaster response processes to be executed.

Finally, considering the nature of the models and syntheses that support the dimensions of the integrated framework, it can be considered a reference in the discussion of collaboration in disaster response. This is reinforced by the flexibility adjustability of its application to any stakeholder/organization and disaster scenario faced.

Conclusion

As discussed in the paper, the integrated framework is conveyed as an essential tool to discuss collaboration in disaster response operations in HSCM mainly for two reasons. First, the framework provides the context specificities required by practitioners in the field, as indicated by Vries and Van Wassenhove (2017). Second, the framework enables the discussion of essential issues further than the ones already discussed by the SLRs/dimensions independently. Besides, considering the integrated framework proposed in this paper, suggestions of future research are related to the use of other research methods to aid the validation and evaluation of each dimension and their combination in the integrated framework based on the perspective of academics and practitioners. An additional future research proposal is the analysis of the capacity dimension of the stakeholders, as indicated by Neely et al. (2008), and how this dimension can help to improve the discussion of stakeholder collaboration in disaster response.

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Humanitarian Supply Chain Configurations and Strategies for Managing Unsolicited Donations

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Abstract

The convergence of unsolicited non-priority in-kind donations has been coined as the second disaster wave. It hampers the delivery of critical supplies to disaster-affected locations and obstructs efforts in meeting demand with supply in humanitarian emergencies.
Based on eliciting the opinions of two expert panels, the present research puts forward potential combinations of supply chain configuration-strategy that allow better management of unsolicited donations. The paper identifies supply chain capabilities and related practices needed in each combination. As such, supply chain researchers and practitioners can prioritise the most relevant supply chain capabilities, considering the constraints of the prevalent conditions.

Keywords: Humanitarian Supply Chain, Supply Chain Configuration, Supply Chain Strategy

Introduction

In August 2005, hurricane Katerina struck the Gulf Coast of the United States, affecting Louisiana, Mississippi and Alabama. Buildings, infrastructure and facilities were severely damaged to an extent that communication infrastructures were not reliable to guarantee effective coordination between different organisations (Wachtendorf et al. 2010). With a death toll of over 1300 casualties and an estimated $96 billion dollars of property damage, an overflow of unsolicited in-kind donations started to converge at the disaster-affected locations. There was lack of a functional system able to register the requests for supplies, and the information about the donations or requested supplies delivered to disaster-affected areas was scarce (Holguín-Veras et al. 2007). Given the absence of the communication infrastructure, media messaging was the main source of information (Holguín-Veras et al. 2007), yet low control over the information disseminated in the

media, has led to a surge of unsolicited non-priority donations, making Katerina one of the catastrophes where the convergence of unsolicited donations generated huge damages (Wachtendorf et al. 2010), and earned the label 'the second wave of disaster.' This phenomenon exists in the aftermath of almost every disaster, where there is often a spontaneous flow of supplies from multiple sources to the disaster-affected area that is known in disaster management literature as *material convergence* (Fritz and Mathewson, 1957). The magnitude of the implications of such phenomenon has encouraged the United Nations Office for Coordination of Humanitarian Affairs and the Logistics Cluster to establish a strategic plan for limiting the flow of unsolicited donations and developing tools for a better management of donations in disaster-affected locations (OCHA, 2013).

Though the convergence of unsolicited donations has attracted the attention of practitioners, it is still an unexplored topic in humanitarian supply chain literature, as put by Holguín-Veras et al. (2014, p.2) as *"the most unique, overlooked, and poorly understood disaster phenomena."*

To this end, this study investigates the phenomenon of unsolicited non-priority in-kind donations from a humanitarian supply chain perspective (for simplicity, henceforth referred to as *unsolicited donations*). The findings of our literature review on such phenomenon suggest that managing unsolicited donations needs a holistic approach that incorporates supply chain design and strategy. Hence, the decision to explore the potential combinations of configuration-strategy of humanitarian supply chain to manage the surge of unsolicited donations. In this paper we attempt to investigate the main research question, RQ1; *How potential combinations of supply chain configuration and strategy can allow better management of unsolicited donations?* Answering the main research question has helped us in addressing the secondary one, RQ2*; What is the level of supply chain capabilities utilised in each potential configuration-strategy combination?* The research respects the context-sensitivity of managing such phenomenon according the varying disaster characteristics. Hence, our analysis considered the disaster characteristics and potential disaster scenarios.

Literature Review

Our approach for this literature review is twofold. On the one hand, we wanted to explore the supply chain configurations that could be adopted for better mobilisation of resources and positioning of stocks, and the supply chain strategies that are better suited in emergency situations. On the other hand, we also wanted to identify the supply chain management practices and capabilities that can help manage (mitigate or eliminate) the material convergence phenomenon. We noticed academics, especially those in disaster management literature stream, tend to use the terminology 'material convergence', while most practitioners in the humanitarian logistics tend to use the terminology 'unsolicited donations' to refer to the same exact phenomenon. Hence, the decision to use both as keywords in our literature search "material convergence" OR "unsolicited donations" AND "manag*". For configuration-strategy combinations we used "humanitarian supply chain strategy" OR "humanitarian supply chain design", "humanitarian supply chain configuration", "humanitarian logistics strategy", "humanitarian logistics design", "humanitarian logistics configuration". Scopus and Google Scholar databases were used for the purpose.

Managing the convergence of unsolicited donations

A high percentage of in-kind non-or-low-priority donations arriving to the humanitarian site gets classified as unsolicited if they were not requested by any humanitarian actor or local authority, hence, usually they do not meet the exact needs of the affected population

(FEMA, 2003). Further, their existence creates stagnation issues at the entry points, especially if the humanitarian site has a single point of entry (Holguín-Veras, 2014), or as in the case of catastrophic disasters such as hurricane Katrina where the infrastructure was almost completely destroyed (Wachtendorf et al., 2010). The consequences are time delays and problems of storage, space and congestion. Furthermore, there were excessive delays caused by a lack of training of field personnel and of proper purchase agreements with suppliers (Holguín-Veras et al., 2007), hence, leading to impeding the efforts to deliver critical high-priority supplies.

Given the high complexity of the phenomenon, and the issues it generates, the literature review was focused on the identification of supply chain practices that can help managing unsolicited donations. The first practice introduced is donations management. Its importance is recognized by different authors who consider it a critical success factor in humanitarian logistics (Yadav and Barve, 2015) for providing guidelines to match the needs with the donations (Holguín-Veras et al. 2014, Arnette and Zobel 2016). A closely linked practice to donations management is how to manage the excessive unwanted received donations, hence, the relevance of waste management practices (Trivedi et al., 2015). Further, Vaillancourt (2016) and Mutlu et al. (2010) found that the adoption of material consolidation practices improves the management of material donations producing benefits in terms of costs and time. Moreover, other authors stress the importance of making needs assessment even before a disaster occurs (Tomasini and Van Wassenhove, 2009), training the staff to provide them the necessary skills to help the beneficiaries and to handle unwanted donations (Yadav and Barve 2015, Varella and Gonçalves 2016) and of developing a plan for responding to a crisis before it arises (Kovacs and Spens 2007, Natarajarathinam et al. 2009). Therefore, actual needs assessment, training & skills and planning for effective response are introduced as supply chain practices that can mitigate material convergence.

Given the heterogeneity of the actors involved in a disaster response, different authors recognize the importance of improving collaboration (Tomasini and Van Wassenhove 2009, Yadav and Barve 2015, Varella and Gonçalves 2016) and communication among them (Houston et al. 2014, Yadav and Barve 2015, John et al. 2018).

Supply chain configuration and strategy

The configuration settings of a supply chain shape the inter-organisational relationships between its members, determine the physical flow, how upstream or supply network is designed, as well as how the delivery of products/services to the end customer, downstream or distribution networks are designed, and therefore, it impacts on supply chain performance (Chandra and Grabis, 2007). Configuring supply chains as networks of interconnected companies, can be challenging. The configuration (or design) of supply chains need adequate flexibility, and configuration decisions should be as dynamic as possible to cope with the changes in their environment (Sabri et al., 2018). In the humanitarian supply chain context, the configuration largely impacts the level of preparedness and response (Kunz and Reiner, 2012). Further, logistics represent a huge part of the costs of humanitarian supply chains, hence, it becomes necessary to focus the attention on how the supply chain could be configured (Tomasini and Van Wassenhove, 2009b), while considering the need to simultaneously respond quickly and being cost efficient (Jahre et al., 2009).

Humanitarian supply chain configurations can be identified as a dichotomy from centralized to decentralized (Salvadò et al., 2016, Gatignon et al., 2010). The adoption of a centralized or decentralized structure is based on deciding which resources and activities can be kept in a central geographical location, and which ones in a decentralized hub.

Gatignon et al. (2010) explain how the International Federation of Red Cross Red Crescent Societies (IFRC) moved its supply chain configuration from centralized to decentralized. In a centralized configuration, a Field Assessment Coordination Team (FACT) is in charge of assessing the needs of beneficiaries and operates in central Head Quarter (HQ) in a developing country. Further, FACT collects all the necessary information and manages the operations in the sites that are far from the field (Salvadò et al., 2016). All the information was centralized in a Relief Mobilization Table at the IFRC Geneva headquarters and then was transferred to suppliers, National Societies (NSs) and donors. Materials flow from suppliers to the affected population through different country coordinators. The centralised configuration results in a slow fulfilment, risk of receiving the same items since donors send materials independently (Gatignon et al., 2010).
The IFRC has redesigned its supply chain towards a decentralized configuration in 2006, where three Regional Logistics Units (RLUs) were established to support the distribution. The RLUs are placed in strategic locations around the world (in Panama, Dubai and Kuala Lumpur), and centrally managed by a team based in Geneva. They act as intermediaries between the field, suppliers, NSs and the IFRC's Geneva headquarters (Gatignon et al., 2010). Each RLU has to provide the logistics services within the geographical area of reference, and it "has preparedness capacity to deliver a range of relief items" (Jahre et al. 2009, p.1016). RLUs are in charge of supplies procurement, mobilisation, stocking, warehousing and fleet services, each in its respective geographical location (Gatignon et al., 2010). The decentralised approach proved success as prepositioned stocks are closer to beneficiaries (Jahre et al., 2009) and can be delivered in 24-48 hours after the disaster (Salvadò et al., 2016), also local sourcing and competences are favoured due to the presence of skilled staff at regional level (Jahre et al., 2009).

Humanitarian supply chain follow different strategies regardless the configurations settings, how they fit together and the impact on preparedness and response is an area that needs further research. There is a number of strategies in humanitarian logistics literature, such as, collaboration, flexibility, postponement and speculation (Jahre, 2017). These strategies are mostly on the operational level. The most supply chain strategy adopted is the cluster strategy starting 2005 (OCHA website accessed 27 May 2018). The cluster strategy is based on allocating areas of intervention for each involved humanitarian organization, where the roles and responsibilities are clearly defined and formalised (IASC, 2015). Moreover, a central coordinator is present to manage the interaction and the exchange of information between the different parties. UN OCHA defines this strategy as "clusters are groups of humanitarian organizations, both UN and non-UN, in each of the main sectors of humanitarian action, e.g. water, health and logistics" (OCHA, 2012). The aim of the cluster strategy is to improve "the effectiveness of humanitarian response by ensuring greater predictability and accountability, while at the same time strengthening partnerships between NGOs, international organizations, the International Red Cross and Red Crescent Movement and UN agencies" (IASC 2006, p.1). It is about strengthening the preparedness and the prioritization of the resources thanks to the division of the labour and a clear definition of roles and responsibilities. Thanks to the presence of Humanitarian Coordinators, the approach is applied in different countries (IASC, 2006). For instance, the Humanitarian Coordinator has to ensure coordination and information-sharing amongst different groups and avoid the duplication and overlap among sectors.

The alternative strategy is what we termed *the aggregated* approach. It refers to the situation in which a central coordinator is not present for managing inter-organisational activities or coordinating the work done by the organizations involved in the disaster response. Looking at the humanitarian supply chain literature it is evident how

coordination represents an important part of the humanitarian response but at the same time how it is a key challenge for the success of humanitarian supply chains (Van Wassenhove 2006, Tomasini and Van Wassenhove 2009, Chandes and Pachè 2009, Yadav and Barve 2015, Varella and Goncalves 2016).

According to Byman et al. (2000) one of the main problems of the humanitarian supply chain is the lack of planning that causes high inefficiencies like the congestion produced by the high volumes of unneeded items. Some humanitarian organizations can focus more on receiving donations from donors, rather than providing help to beneficiaries. As a consequence, they prefer to not share information and to avoid collaboration without considering the benefits that could be generated because to the adoption of a collective strategy. Therefore, given the presence of an environment characterized by the absence of a clear command and control, the lack of profit incentives and the changing priorities, coordination represents a challenge (Tomasini and Van Wassenhove 2009a). The result is a disorganized supply chain due to the limited collaboration, "the lack of recognition of the importance of logistics, the shortage of professionalism of the teams, the lack of use of technology (in particular, this refers to information systems)" (Chandes and Paché 2009, p.337).

Theoretical Framework

Supply chain capabilities to manage unsolicited donations

Given the complexity of the material convergence phenomenon and the issues generated, it emerges the necessity to identify those approaches, that, if correctly implemented, contribute to the management of material convergence. From the literature, we built on Sabri et al. (2018) work in which eight main supply chain practices were identified; Donations management, Waste management, Material consolidation, Actual needs assessment, Training & Skills, Planning for effective response, Collaboration and Communication. The degree with which these practices suit the preparedness, response and recovery phases of humanitarian supply chain (Kovacs and Spens, 2007) will be explored theoretically and tested in the empirical part of the research.

The first supply chain capability is Material Flow Management. Donations management is linked to Material flow management since the implementation of donations management practices can help in providing guidelines to donors (Holguín-Veras et al., 2014b), and thus, in managing the flow of materials reducing the amount of low priority and non-priority items. Moreover, this is linked to the importance of introducing Waste management and Material consolidation practices to avoid serious congestion problems along the humanitarian supply chain.

The second supply chain capability is Agility which is defined as quickly "respond to sudden and unexpected changes in markets" (Lee 2004, p.4). The possibility to perform accurate actual needs assessment before and during the first stages of a disaster can improve the agility of the humanitarian supply chain. Furthermore, if stronger effort is put to improve the skills of personnel and train them on how to handle the unsolicited donations, the capacity to recognize the needs will improve, and a faster response can be implemented. As such, planning for effective response and relief operations can be implemented faster, and delays will be reduced.

The third supply chain capability selected is Alignment– that is, to "align the differing needs and dynamic roles of many players" (Van Wassenhove 2006, p.486). This can be achieved acting on collaboration and enhancing communication between the humanitarian actors involved (UN and non-UN). Supply chain capabilities are depicted in Table 1.

Supply Chain Configuration-Strategy Matrix

We developed a 2x2 matrix combining supply chain configuration with supply chain management strategy in order to identify potential different profiles. The idea behind the development of the matrix is to understand the mix of capabilities that different configuration and strategy combinations offer to manage unsolicited donations. Moreover, what are the supply chain practices and capabilities most needed in each configuration-strategy combination.

This has resulted in identifying four combinations as depicted in Figure 1; *CS1* decentralized configuration and aggregated strategy, *CS2*: decentralized configuration and cluster strategy, *CS3*: centralized configuration and aggregated strategy, and *CS4:* centralized configuration and cluster strategy. Then, each one of the four identified quadrants will be linked to the supply chain capabilities outlined above.

Table 1 – Supply chain capabilities needed to manage unsolicited donations

Supply Chain Capabilities	**Supply Chain Practices**	
Material Flow Management	**Donations management**	Practices required to match the needs with the donations and reduce the possibility that donors donate unneeded items (Arnette and Zobel, 2016). It depends on donors' characteristics like the donor behaviour, awareness, location and type.
	Waste management	Practices for managing and disposing of the wastes present (Trivedi et al., 2015).
	Material consolidation	Grouping of materials that have something in common to improve the performances (Vaillancourt, 2016).
Agility	**Actual needs assessment**	Evaluation of the possible needs to have an idea of the items and services needed when a disaster occurs (Tomasini and Van Wassenhove, 2009).
	Training & Skills	Training of the actors involved so that they have the necessary skills to operate when a disaster happens (Varella and Gonçalves, 2016, Van Wassenhove, 2006).
	Planning for effective response	It is part of the preparedness phase and is based on the development of a plan for responding to a crisis (Natarajarathinam et al., 2009).
Alignment	**Collaboration**	Collaboration practices between the stakeholders involved in the emergency response since they have different interests, mandates, capacity etc (Yadav and Barve, 2015).
	Communication	Exchange of information between the actors involved. It includes messaging to media and donors (Houston et al., 2014).

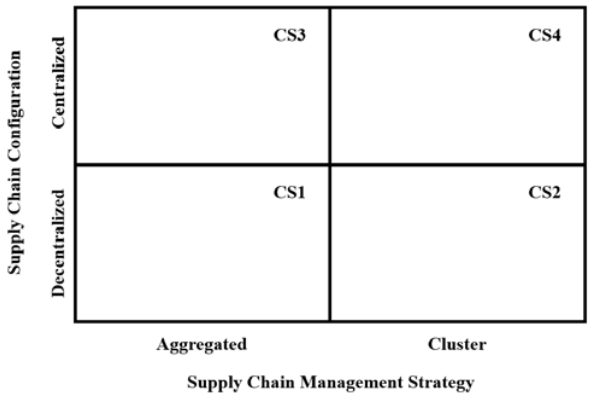

Figure 1 – Supply Chain Configuration – Strategy matrix

First, the level of supply chain practices and resources (i.e. capabilities) utilised in each potential configuration-strategy profile will be explored theoretically and will be given a score on a scale (Low/Medium/High) as follows; i) *Low*: just one of the supply

chain practices is addressed; ii) *Medium*: 2 out of 3 supply chain practices are addressed; and iii) *High*: all the supply chain practices are addressed.
Second, following the same above-outlines score, the resulting theoretical matrix will be tested empirically and afterwards refined based on expert practitioners' responses, as explained in the following section.

Methodology
In this study we applied a Delphi-like approach that enables us to elicit experts' opinions and analyse these opinions in a structured fashion to test the appropriateness of the developed framework. Prior to commencing the Delphi study, we performed an extensive literature review to identify possible humanitarian supply chain configurations and strategies as depicted in the previous section.

Our Delphi-like approach was composed by multiple rounds and follow-up interviews. The first step was the development of a structured questionnaire that was dispatched to a group of emergency management experts with a profound knowledge of the humanitarian field, and mainly involved in preparedness and planning phases. The questionnaire addresses the severity of material convergence phenomenon and the importance of the eight supply chain practices in different disaster scenarios. It allows to access the knowledge that comes from different sources since experts belong to different organizations and institutions, have different backgrounds and are located in different geographic areas. It consists of a set of questions aimed at collecting the opinions of experts from all over the world about a phenomenon for which incomplete knowledge is present.

Then, the second step is based on interviews to a selected panel of humanitarian logistics experts in humanitarian aid organisations to refine the findings of the first round of the questionnaire. Moreover, the interviews provide insights on the reasons behind the results obtained and on how further actions can be implemented.

Findings
Each one of the four configuration-strategy combinations is analysed and supply chain capabilities are explored in all quadrants. The matrix is updated with the score of the supply chain capabilities (Low/Medium/High) according to the number of practices needed in each quadrant, as depicted in Figure 2. The identification of the most important practices allows to define the configuration and strategy to adopt in each scenario. It is evident how the adoption of the cluster strategy allows dealing larger number of practices. The responses from the interviewees emphasize the usefulness of the cluster approach for achieving a better management of unsolicited donations; since it acts on favouring the collaboration and communication between the actors involved, it enables stronger coordination mechanisms among them.
CS1 is characterized by a decentralized configuration and aggregate strategy that allows dealing with donations management practices since acceptance guidelines for in-kind donations are formalised. Most of the items are collected in the RLUs, grouped and transported in smaller batches thus generating cost and time savings, hence material consolidation is considered. *CS1*, similar to the IFRC's decentralized supply chain, favours the introduction of standardised processes for activities, hence, structured needs assessment is usually performed. Moreover, the importance of improving training & skills of the staff due to the aggregate strategy, for instance defining periodical training sessions. This configuration-strategy combination lacks focus on collaboration and improving the communication due to the aggregate strategy, hence, there is high attention on being prepared for disasters, rather than reacting after a crisis occurs. Indeed, thanks to presence of prepositioned stocks, planning for effective response is improved. As such, *CS1* is very

agile, yet scores medium in material flow management, and lacks in alignment between the different humanitarian actors. Similar to *CS1*, *CS2* has a decentralised configuration, yet with the cluster strategy more capabilities are developed, specifically collaboration and coordination. In *CS2* information and resources are shared among the actors involved, thus guaranteeing flawless communication and messaging. Moreover, communication and coordination with stakeholders are important factors that affect the implementation of disaster waste management programmes.

CS3, the centralised configuration and aggregated strategy, prioritises three supply chain practices. Donations management practices are implemented, but, for sure, they should be improved since organisations do not have clear strategies for the management of unsolicited donations. Regarding the actual needs assessment, it is a practice that was present in the case of the IFRC's centralized supply chain because it defined a Field Assessment Coordination Team (FACT) in order to assess the needs of beneficiaries and centrally manage the information. Moreover, a well-trained staff was present in order to communicate where, when and what items were needed, thus recognizing the importance of improving the training & skills. *CS4* and *CS3* share three practices. The difference between them is linked to the adoption of the cluster strategy in *CS4* that prioritises collaboration, communication and waste management. Cluster strategy acts as a preventive plan since strategies and plans are defined before a disaster occurs to determine the area of intervention. Thus, there is a focus on planning for effective response recognizing the importance of preparation and pre-positioning of resources.

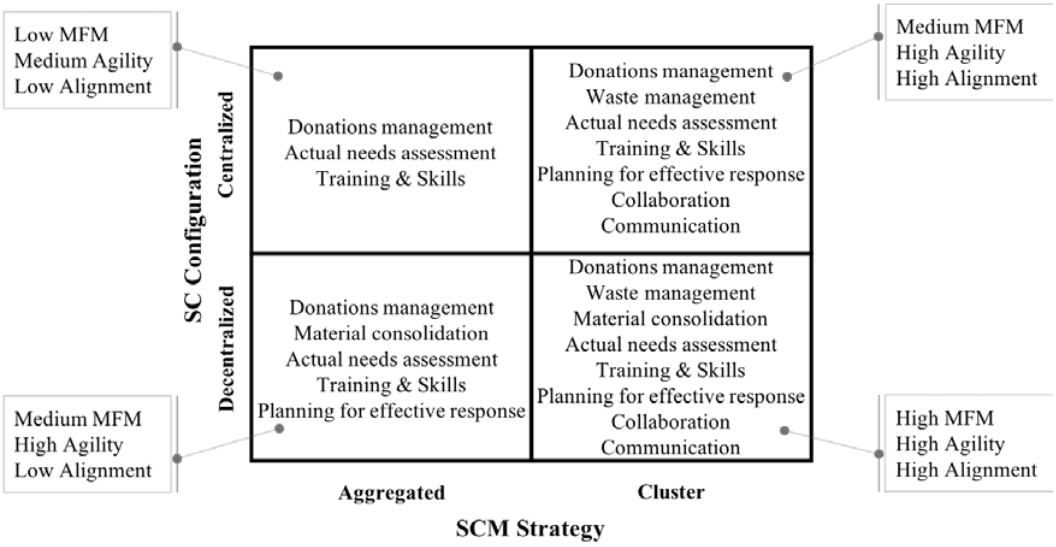

Figure 1 – Supply chain Configuration, Strategy and Capabilities

The difference between CS2 and CS4 is linked to the possibility to deal with material consolidation practices. In the decentralized configuration, items are grouped in small batches and then delivered to the affected areas. In contrast to the case of centralized configuration, that is not well focused on material consolidation. In this case, the items are just assembled in large batches, thus generating high costs and delivery times. The decision could change from country to country according to factors like the capacity of being prepared or the impact that political and security constraints have on the mobilisation of resources. For instance, in a country that usually faces the same type of disaster, it is preferred the adoption of a decentralized configuration with availability of stocks at regional level. Instead, in cases where the disaster hits a country that is not well prepared, the adoption of a centralized configuration could result easier, since it involves the management of a single warehouse.

Discussion and Conclusion

The high importance of agility (i.e., communication and collaboration) emerges from the analyses of the questionnaire and interviews. Most of the experts recognize the relevance of improving communication among the involved humanitarian actors and to implement a coordinated communication strategy with the aim to keep everyone involved and to spread the same strong message (e.g., cash donations are better than in-kind donations). Moreover, it emerges the importance of planning for effective response and thus of being prepared before a disaster occurs. As highlighted by some experts, an important part of the communication strategy is represented by needs assessment. It is not only linked to the definition of the needs as soon as the disaster arises, but to their identification beforehand the emergency. The analyses suggest that different configuration-strategy combinations can suit different types of disasters. This can help us focus the efforts on developing the needed capabilities that are most relevant to the configuration-strategy-disaster characteristics.

For instance, the combination in *CS1* is more suited for addressing unsolicited donations in repetitive regional/local disasters with limited geographical dispersion and high local coping capacity. *CS2* is more suited to address disasters where there is short response time, geographically dispersed affected-areas and low local coping capacity with the emergency. Therefore, the implementation of a decentralized configuration will reduce the time needed to manage the emergency and the cluster strategy will improve the capability to cope with the high volumes of items present by enhancing collaboration and communication. *CS3* is very agile and there is high alignment, therefore, it can be suited for disasters that need the involvement of a large number of local and international humanitarian actors, this means there is medium-low local coping capacity with the disaster. *CS4* combination is suited for disasters that are geographically dispersed or that do not strongly affect the local coping capacity. The adoption of a centralized configuration could result easier in cases where the disaster hits a country that is not well prepared.

This study makes several contributions to humanitarian supply chain literature and practice. Considering how valuable (and often scare) are the resources needed to develop capabilities especially in a humanitarian emergency setting, the study provides guidelines to prioritise the relevant capabilities in potential supply chain configuration-strategy configuration. First, we extend the findings of prior literature to identify proper combinations of supply chain configuration and governance strategies. The matrix provides novel insights to reduce the flow of unsolicited donations and to manage their impact. The analyses presented here guides humanitarian supply chain practitioners on how to better configure humanitarian supply chains and select their strategies, and to identify the most relevant capabilities needed to be developed whilst considering the constraints of the prevalent conditions.

Although all care was put to provide a comprehensive analyses, the present study was limited to the opinions of the members of the 2 expert panels, who mainly belong to international humanitarian organisations. Therefore, an avenue for future research is to further explore this matrix with respondents representing different humanitarian actors. Further, another topic for future research is to deepen the analysis by taking into consideration the situational environment of the disaster-affected location – that is, to link and customise the matrix according to different disaster characteristics.

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Innovation, Product and Service Development

Open innovation using satellite imagery - Viability assessment of solar photovoltaic projects

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Abstract

One of the responses to the fight against climate change by the developing world has been the large-scale adoption of solar energy through the installation of photovoltaic farms. The realization of solar energy producing sites involves complex decisions and processes in the selection of sites. The knowhow on this is not available with all the stakeholders supporting (e.g. banks financing the project) the industry value chain. In this paper, we answer how open innovation using satellite imagery based big data analytics can deliver objective assessment of technical, economic, social, and environmental aspects for stakeholders of solar industry value chain.

Keywords: Open innovation, Satellite imagery, Solar industry value chain.

Introduction

Solar energy industry has been touted to be a beacon of hope for a clean-energy future across the world and has received special attention by developing countries such as India which have put in place investments and enabling policies for large scale adoption of renewables to address their rising energy requirements (Kapoor et al., 2014). However, the high initial investment cost associated with solar energy infrastructure is one of the primary barriers that has to be tackled to accelerate its adoption for production of renewable energy (Ansari et al., 2013).

To overcome such barriers, policymakers in the solar photovoltaic sector have constantly fiddled with creating catalytic policies as instruments to induce market growth. Inducing market growth was expected to trigger investments by firms operating in technology adoption and innovation sector (Hoppmann et al., 2013). Even with such elaborate efforts to solve persistent problems, new bottlenecks continued to arise. For instance, unaware of the workings of novel technology-based industries, stakeholders

who had to invest in the solar photovoltaics value chain (e.g. banks) often viewed the investments as risky and were therefore reluctant to allocate capital (Wilkins, 2002). Acknowledging the importance of the expansion of renewable energy, the policymakers in developing countries like India have been continuously attempting to tackle these bottlenecks using policy interventions which can incentivize investments by the private sector in solar photovoltaics (Jolly & Raven, 2016).

Financing landscape is a bottleneck for solar energy projects and acts as a key barrier to scaling the production of renewable energy in India (Kar, Sharma, & Roy, 2016). One of the key issues contributing to financing landscape bottleneck is the lack of reliable and objective data (e.g. irradiation data over time for different sites, history of performance of commercial solar projects, etc.) in the solar energy industry. Lack of objective data negatively influences the perception of bankers and their risk attitudes towards financing commercial scale solar energy plants (Umamaheswaran & Rajiv, 2015). This negative influence constraints local commercial banks from financing the solar energy projects and thereby pushes the projects to find foreign sources of capital for execution (Sarangi, 2018). The phenomenon aligns with research in the policy landscape of renewable energy projects which suggests that the cost of capital increases with a perception of risk which then significantly influences the business case of a project (Noothout et al., 2016).

Satellite imagery is a unique source of data that has the ability to provide global coverage. The notable transition of the space industry from an open innovation perspective is the move from its controlled nature of national space programmes which shackled satellite data with restrictions or made it expensive to procure to a new era of open-access satellite data (Wulder & Coops, 2014). Examples of this include the 2008 decision of the US Geological Survey (USGS) to provide open and free access to the world's largest archive of Earth imagery collected by its Landsat satellite series which goes back to the 1970s (Wulder et al., 2012), and Europe's efforts to make its Sentinel satellite series data openly accessible (Malenovský et al., 2012). These radical shifts in making data available have enabled the exploitation of satellite big data to create socio-economic applications (Kitchin, 2014).

In our paper, we are interested in answering the research question 'how open innovation using satellite big data analytics can plug information gap for the stakeholders supporting the adoption of solar photovoltaics'. We use a case study of proposed solar photovoltaic site in the Bangalore region to demonstrate how satellite imagery contributed to removing the bottlenecks present in the financing landscape of solar energy projects. We document how satellite imagery helped in independently assessing the technical, economic, social, and environmental viability of projects. The satellite imagery combined with other data sources such as yearly radiation, dew point temperature, wind direction and wind speed were subjected to multi-criteria selection analysis to derive an overall suitability index score for a solar photovoltaic site.

Data and Analysis

We utilize the methodological foundations laid down by Eisenhardt (Eisenhardt, 1989) and Yin (Yin, 1994) in case studies. We study and document the assessment of potential photovoltaic sites in the Bangalore region in India to answer the research questions. Despite various normative nature of methodological points, case studies provide grounds to study the effect of information systems on users, organizations or the society (Kaplan

& Duchon, 1988). In our case study research, the open innovation of using satellite data for assessing the potential of photovoltaic sites is based on understanding the contribution of the data to the research question itself (Siggelkow, 2007). Our choice of a single-case study in this paper allows us to answer different form of research questions such as "how", "what" and "why" through which we are able to analyses the operational challenges in assessment of photovoltaic projects faced by institutional investors in India.

The case study features an assessment of sites for the installation of photovoltaics in the Bangalore region in India. The primary sources of information for the assessment of photovoltaic projects used in this case study are the satellite imagery and data provided by Landsat 8 and Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) satellites. Landsat 8 is a satellite in the Landsat program, which is run by the United States for four decades now. The Landsat represents the world's longest continuously running collection of space-based data which was made open to public access in 2008 (Wulder et al., 2012). Similarly, ASTER is a joint US-Japan satellite flown in 1999 to gather data for creating detailed maps of the Earth's land surface temperature, reflectance, and elevation. Similar to Landsat's public access declaration, ASTER's data products have been made available to open access since 2016. Our case study showcases how such openly available satellite data products can enable their adoption in developing countries who otherwise may not have had the resources or the intellectual property to build such complex systems that can offer information continuity for past several decades.

From the perspective of assessment of the power generation using photovoltaics, a broad range of parameters that encompass climatic conditions, geological features and land access affect the decision making. Table 1 provides a list of key parameters and the source from where the data have been taken for the assessment of photovoltaic projects. The geological and access condition data were sourced from Landsat 8 and ASTER satellites respectively. The climatic conditions data is sourced from both ASTER and Automatic Weather Station (AWS) data, which is again a mix of both satellite-based and ground-based measurement of key weather parameters. The AWS data in the case study was procured from a commercial vendor.

Table 1 - Key parameters affecting installation of photovoltaics

Assessment	**Parameter**	**Source of Data**
Geological	Land use and land cover	Landsat 8
	Height	ASTER
	Slope	
	Aspect	
Climatic	Solar Radiation	Automatic Weather Station
	Dew point temperature	
	Wind direction	ASTER
	Wind speed	
Access	Road network	Landsat 8
	Water resources	

The satellite data provides information extracted for various geological and climatic parameters captured by the sensors onboard the ASTER satellite over the Bangalore region and plotted according to the geographic area of the city. The data from the sensors which have recently been made available openly form the basis of accurately quantifying

the geological and climatic parameters. All the geological and climatic parameter captured within the satellite data over the terrain. The variations include the total radiation received on the ground, height over the terrain of the region above mean sea level (captured through digital elevation model), changes in the slope of the terrain over the region, the airborne water vapor captured as dew point temperature, compass direction that a slope faces captured as aspect, variation of the wind speed, and the wind direction over the Bangalore region. The underlying data is geo-referenced (i.e. tagged with latitude and longitude) and provides accurate mapping of the changes over the Bangalore region for the parameters in question. The geo-referenced satellite data for the Bangalore region is transformed into 70749 segments with area of 2225 m^2 per segment using a combination of data classifier algorithms including Gaussian Naive Bayes, linear support vector machine, kernel based support vector machine, decision tree, and random tree (Qian, Zhou, Yan, Li, & Han, 2015). Each of the segments have codified identifiers which translates back into a location in Bangalore. We intentionally do not focus on describing the technicalities of using data classifiers to calibrate and derive the baseline data for the attributes recorded in Table 1 from the underlying satellite data. Within the purview of this case study, we believe it is more meaningful to discuss as to how the baseline data post such technicalities is operationalized in the decision-making process to arrive at an assessment of proposed photovoltaic sites rather than describing the standardized computation techniques in satellite image processing. The underlying data from the geo-referenced satellite data as illustrated in The satellite data forms the basis of extracting the quantitative values of parameters listed in Table 1. The geological parameters in the figure such as slope, aspect and height captured against the incident radiation directly affect the interaction between the radiation from the sun and surface of the Earth which in turn affects the output of the photovoltaics (Nguyen & Pearce, 2012). Similarly, local weather variables such as local radiation flux, temperature, wind speed and direction have a bearing on the thermal operating environment, which affect the output of the photovoltaics (Skoplaki & Palyvos, 2009).

Within the list of the parameters recorded in Table 1, no single parameter will be sufficient enough to arrive at a decision on the proposed installation of photovoltaics. The synthesis of wide array of parameters listed in Table 1 pose information processing complexity in the decision making. To address this complexity in decision making, the firm processing the satellite and allied data chose a Multiple Criteria Decision Analysis (MCDA) procedure to derive a decision-making algorithm. Within the MCDA framework, the Analytic Hierarchy Process (AHP) has been utilized to assign weights to each of the parameters listed in Table 1 on the basis of the relative importance to power generation using the photovoltaics. The baseline quantitative data for the AHP process is derived through the satellite data, which captures the data over the Earth's surface according to the latitude and the longitude. Therefore, the open data from the satellites form the foundation of the MCDA process and aid providing crucial information in identifying a number of functional parameters and assessing their comparative importance for a potential site for the installation of photovoltaics. We intentionally do not detail the AHP process since it has a well-established theoretical (Saaty, 1990) and case study history (Ho, 2008) in management literature. The final computation of the site suitability index based on the AHP process generates end weights which lies between 0 and 1, corresponding to the "worst" and "best" sites, respectively. From a methodological perspective of connecting the AHP to the problem at hand, the Simple Additive Weighting (SAW) is used to arrive at this evaluation criteria. SAW is an established

metamodel for multiple criteria decision analysis (Kaliszewski & Podkopaev, 2016), which in this case study is utilized to aggregate the weights to arrive at an overall site suitability index based on relative importance of each of the functional parameters listed in Table 1.

Results and Discussion

As we discussed in the data and analysis section, the assessment of a potential photovoltaic site cannot be based on the key metric of how much power it produces alone. Factors such as the distance to road access, water access, height and slope of land have a bearing on the initial infrastructure and operating costs of the photovoltaic installation. Therefore, the end analysis using the open satellite data allows to consider comprehensive factors that affect the overall investment and operations rather than produce an assessment based on a prominent output metric. The proposed solar photovoltaic installation sites vary from 2 MW to over 200 MW of energy on the power generation parameter, but their overall site suitability scores range from 0.35 to 0.22 respectively. The limited range of the overall site suitability index against the possible range between 0 to 1 can be attributed to a combination of geological and climatic conditions of the Bangalore region, and the land rights attached to the site (i.e. some latitude and longitudes might turn out to have higher site suitability but the ownership or the right to those lands may not be available to the promoters of the solar photovoltaic installations). Giving due consideration to factors such as topographic, local weather parameters and access to the sites, it is found that several of the high power generating proposed sites have a lower overall site suitability score than their smaller installation counterparts. We have organized the discussion of the results and its implications from the perspective of stakeholders supporting the solar industry value chain.

The assessment conducted by utilizing the open data from satellites has specifically helped loan case officers of banks in Bangalore who now have a basis of relying on the scientific results generated through the data analytics process to make informed decisions. Previously, the case officers who faced bottlenecks due to an insufficient lending experience within their institutions had to engage with external expertise to get such assessments performed. This often led to a practice of clubbing several projects into project volume before submitting to external consulting firms to reduce the per-project cost of assessment. This in-turn caused delay ranging between 3-4 months for the photovoltaic industry loan seekers and at the same time led to increased loan servicing costs which were recovered by offloading to the applicants. The reduced transaction time and costs attained through open innovation using satellite imagery brings more certainty for the industry in planning and operationalizing their roadmap for procurement and installation of photovoltaic modules. This clearly demonstrates that the fundamental value of liberated data is its influence within the transactions between stakeholders supporting the value chain as well as external technology exploitation based on open innovation (Lichtenthaler, 2008). Breaking the shackles of expensive or restricted access to new generation satellite data enables the adoption of the insights generated by the stakeholders supporting the photovoltaic industry value chain. Therefore, the open innovation based on satellite big data allows invoking an independent source of truth, which otherwise might not have been possible owing to the barriers of access.

The firm which has developed the solution discussed in this case study also enabled cloud-based deployment of the final results of the site assessment for the Bangalore

region. Providing basic training to the loan case officers on how to access and interpret the end results of the data analytics process will build up institutional capacity within the banks. The cloud-based integration of the data analytics platform helps case officers to seamlessly integrate the platform into their daily workflow routines. The combination of open satellite data analytics with the cloud-based deployment clearly lubricates the overall process of exchange of information between the stakeholders. It also provides a foundation to scale-up the use of the end results in the overall lifecycle of the lending and recovery process of the banks. For example, once the assessment of the proposed site is completed and a positive decision to provide credit has been made, the open satellite data with the cloud-based delivery insights can also be used to monitor the use of the credit by the borrowers. The open satellite data in this case allows for the periodic monitoring of the invested asset with the capacity to keep track of changes in construction and its alignment with the projected milestones in the use of the credit by the industry borrowers. Therefore, the applications are not just limited to the initial assessment of the potential photovoltaic sites but there is definite scope for scaling up of use of open satellite data for a deeper deployment in the entire cycle of credit lending and recovery. This represents the horizontal scalability of the underlying innovation.

With the global rise of development of large-scale solar parks, there is an emerging policy and investment decision conflict based on land use that is expected to emerge. (Späth, 2018) has underlined the tension that may emerge between renewable energy development using large-scale on-field photovoltaic generation and the preservation of agricultural land. This conflict may especially be of interest in developing countries since several of them have dense populations. We believe that the case study sheds light on how innovation using novel technologies such as big data analytics based on open data can be leveraged to tackle these emerging problems by providing holistic information to policymakers. The modelling of the utility of land based on the type of land, its current usage, and access to it has been taken into consideration in the site suitability assessment conducted in this case study. There is potential to extend the utility of land use classification model via satellite big data analytics to derive assessments to balance energy policy against the land preservation charter. This extension will provide a basis for decision making by policymakers that will be inclusive and informed of natural environment.

Research indicates that cyclical peddling of policymaking may arise to treat new bottlenecks as impetus is provided for pushing the adoption of novel technology innovations, which may lead to compulsive policy-making (Hoppmann, Huenteler, & Girod, 2014). Adoption of open innovation based technology solutions from lateral sectors (in this case, space industry solutions into energy industry) can alleviate the bottlenecks by removing the information gaps. This in-turn has the potential to avoid compulsive policy-making and ensure effective functioning of stakeholders who support the value chain. Our study indicates that it is important for policymakers to be aware of liberalization of data sources in allied sectors that were previously locked away in the form of lack of access due to sharing restrictions or being too expensive to adopt. Post liberalization of such data sources, the legacy value to the information in such data source may lead to disruptive open innovations which hold the potential to remove previously existing bottlenecks in the processes within the value chain. The case study demonstrates how open data with new sources can lead to taking a comprehensive approach than just taking the obvious or most prominent (e.g. total power) factors into account for decision making.

Our case study explores one of the ways in which open innovation using satellite data can be deployed to create value for stakeholders in an industry value chain by overcoming the legacy barriers for adoption. The results of the case study should provide motivation for practitioners in developing countries to exploit outside-in open innovation based innovation strategy (Bagherzadeh et al., 2019) in building services by combining the liberalized open satellite data and other data sources to support stakeholders in several other industry sectors (e.g. agriculture, infrastructure). We believe there is scope for adoption of products and services using open data from satellites by stakeholders tackling socio-economic or humanitarian challenges such as disaster management, climate change, food security, etc. Open innovation using satellite big data combined with other data sources also have the potential to help support achieving sustainable development goals especially in the context of challenges faced by developing countries.

Within the realm of research based on open innovation, our case study only deals with the pre-installation of the photovoltaics. There is scope to study the effects of open innovation post-installation of the photovoltaics since power monitoring systems are expensive and have a bearing on the operational life of the installation (Triki-Lahiani, Bennani-Ben Abdelghani, & Slama-Belkhodja, 2018). Open innovation based on allied technologies such as Internet of Things (IoT) have the potential to provide solutions to such monitoring problems (López-Vargas, Fuentes, & Vivar, 2018). Moreover, with the emergence of application of novel technologies such as artificial intelligence into the solar photovoltaic industry (Mellit et al., 2009), a larger kaleidoscope of service research on such technologies operating at scale and across the industry value chain on the basis of open data can be explored. From the standpoint of building on top of the existing open satellite data, there are implications to be explored for policymakers and supply chain practitioners based on the implementation of newer technologies such as machine learning. Implementation of these new technologies is expected to deliver better results in various activities within the photovoltaics value chain such as designing higher efficiency solar power plants (Şahin et al., 2014) and large-scale installed capacity monitoring (Assouline, Mohajeri, & Scartezzini, 2017).

Conclusion

Satellite big data based open innovation creates a foundation for invoking of an independent source of truth in assessing proposed photovoltaic sites. The tailored assessment conducted using open data has demonstrated the potential for loan case officers of banks in Bangalore to make informed independent decisions for the proposed photovoltaic installations. The proposed solution discussed had a positive bearing on the working of the stakeholders supporting the photovoltaics industry value chain through its ability to reduce the transaction time and costs between the financial institutions and the entrepreneurs. The ripple effect of this catalytic process is the greater certainty for the Indian photovoltaic industry in planning and operationalizing their roadmap for procurement and installation of modules. The utility of satellite big data within the relationship between the bankers and the industry has scope to scale-up by considering the overall lifecycle of the lending and recovery process of the banks. The study demonstrates the potential for using open innovation on the basis of liberated data to resolve bottlenecks in transactions between the stakeholders supporting the photovoltaics industry value chain. The utility of open innovation based on satellite big data analytics with the cloud-based deployment has potential to scale horizontally and vertically within

the solar industry value chain. Exploring such scaling opportunity has the potential to help policymakers solve socio-economic, techno-managerial and environmental challenges in the Indian renewable energy penetration context including management of current power assets, future project planning, management of incentives, deepening of rural electrification and preservation of agricultural land.

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Challenges and opportunities for innovation in the big data era

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Abstract

The proliferation and implementation of technologies that provide data has opened up a myriad of opportunities and previously not exploited sources *of* and *for* innovation. The purpose of this paper is to provide an up-to-date review of the literature on data-driven innovation with a specific focus on its opportunities and challenges. A critical analysis is performed with the aim to define a research agenda and the most prominent key actions that could give directions useful for researchers and practitioners.

Keywords: Innovation, Development, Data, Big Data, Artificial Intelligence, Data-driven innovation

Introduction

While innovating in the field of innovations might sound a paradox itself, it is certain that the field is in constant evolution both in practice and in research, reaching however a rather mature status quo. Meanwhile, the proliferation and implementation of technologies that provide data has opened up a myriad of opportunities and previously not exploited sources *of* and *for* innovation. Big data, artificial intelligence, Industry 4.0 are only some of the trends that are gradually being implemented and integrated in the operations of the different actors forming the innovation eco-system.

While in practice big data facilitators' diffusion is ongoing, we question the current status quo of research by raising the question of *what, if anything, big data brings to the field of innovation.* Finding the right answer might be difficult, especially taking into account the still fuzzy conceptual limits of the big data term, situated at the confluence of social science - where is often more useful- and computer science, a vital component for generating and exploiting it.

It is in this context that we aim to contribute with our research by providing a holistic conceptualisation and an up-to-date review of the literature on data-driven innovation with a specific focus on its opportunities and challenges. A critical analysis is also performed to draw a research agenda and to formulate possible key actions that could give directions for researchers and practitioners.

To the extent of our knowledge, our contribution is the first review to attempt and elucidate the link between *data* and *innovation*. Its originality consists in putting a balanced emphasis on both terms, since the existing literature is abundant in analysing them separately.

Method

The field of innovation is abundant in systematic literature reviews, among the most comprehensive ones we mention Keupp et al. (2012) on strategic management of innovation, and Bagno et al. (2017) a review of innovation management models. A series of publications are also available for certain specific topics in relation to innovation, as examples see measurement in the software industry (Edison et al., 2013), product-service systems (Boehm and Thomas, 2013), family firm (Duran et al., 2016), open innovation (), or even more specific barriers to open innovation (Oumlil and Juiz, 2016) to mention just a few.

According to various authors (Budgen and Brereton, 2006; Boehm and Thomas, 2013) a systematic literature review implies three distinguished phases: i) review protocol for defining the objective and scope, ii) a search strategy for encountering relevant literature, and iii) documentation and analysis to answer the question what can be learned from a rigorous analysis. The different authors agreed on the technical details of each phase. Two researchers worked separately and in parallel, but following the same methodology in order to search, select and analyse existing sources of interest for the present contribution. A tabulated spreadsheet template has been used to categorise the selected papers. When finished, the results have been gathered in a unique file while shared and commented among all the authors.

The technical details of the process are visually represented in Figure 1. The authors centred the attention on a unique database, namely Scopus, considered one of the most inclusive databases including all scientific fields. Since 2004, Scopus has delivered a comprehensive overview of the world's scientific research output across all disciplines (Elsevier, 2019). Being the largest abstract and citation database of peer-reviewed literature, and considering the central focus of our task, we do not consider relevant to contemplate other alternatives (Google Scholar, and or discipline-specific databases).

No exact timeframe was set-up and we left open all possible extremes (lower end to nowadays), even including publications from 2019, ongoing. The main reason underlying this decision is that we aim to capture, indifferently of time, all publications focusing on data and innovation, being able to detect possible transformations of terminology or a different understanding attributed to the analysed term.

A total of 1018 documents have been identified with the less restricted search terminology. While the focus is on novel approaches, additional search terms have been added resulting in 344 documents. All abstracts have been reviewed in order to make sure that no important source is left out of the review.

A final selection of 30 articles that most fit the purpose of the present review are analysed in detail and presented in the second part of our Results section.

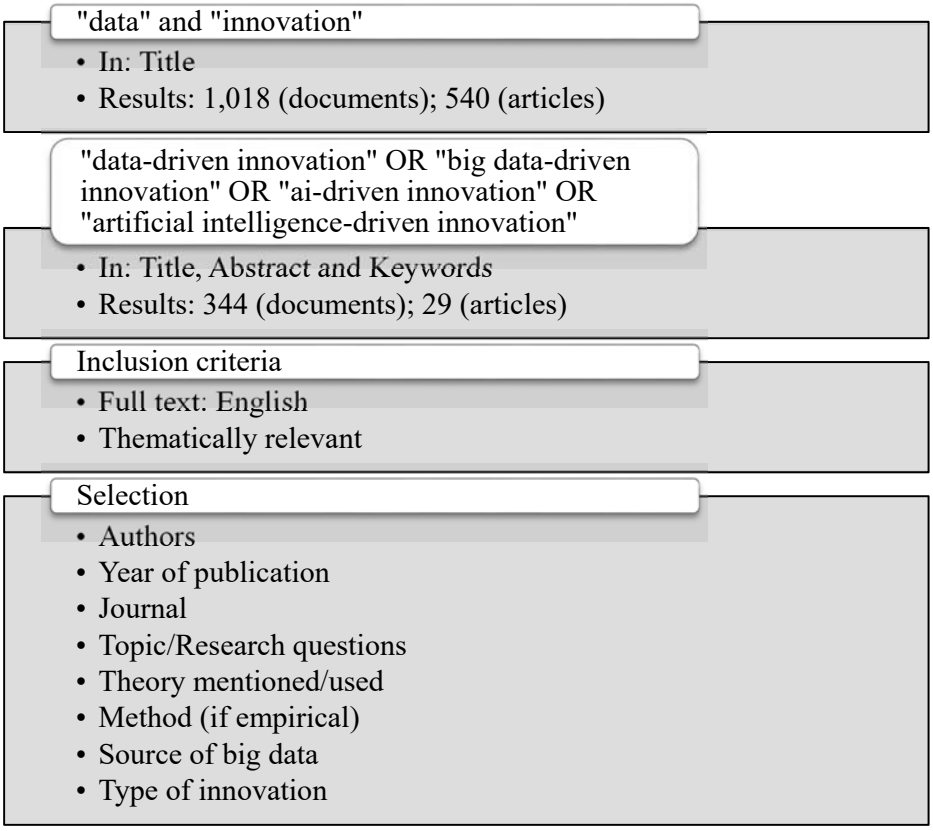

Figure 1 – Methodological process and inclusion criteria

Results

In this section, the results of our review are presented and organised according to relevant aspects including a general overview referred to 344 sources, followed by a more detailed and specific review of a selection of 30 articles that we considered highly relevant for the present review.

The information showed in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 are commented globally, allowing for some general highlights. Table 1 contains a summary of the selected sources according to the reviewed items.

Compared to more mature fields, but also to other recent trendy topics (like *open innovation,* the *sharing economy, or gamification in education*) research on relating the concepts of data and innovation is (still) embryonic. This finding is somehow surprising since technological advancements and solutions exist, hints on their implementation are also present, and it is believed that exploitation potential is infinite.

In the past decade the body of knowledge has been exponentially growing reaching a total of 344 scientific publication, out of which 114 have been published in 2018 (Figure 2). However significant, the number of scientific articles falls far behind the huge interest raised by the relationship of big data and innovation in real practice.

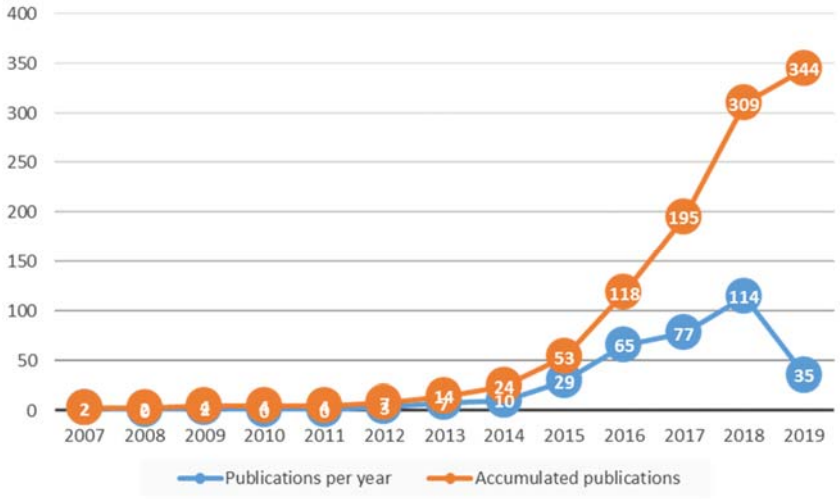

Figure 2 – Chronological evolution of publications by year

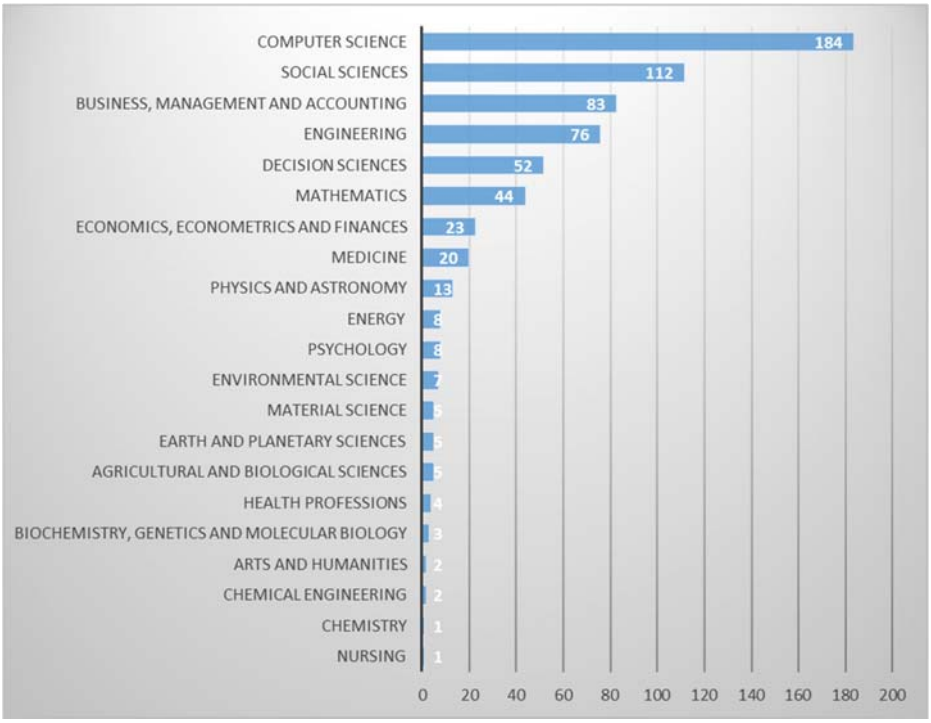

Figure 3 – Classification of publications by discipline

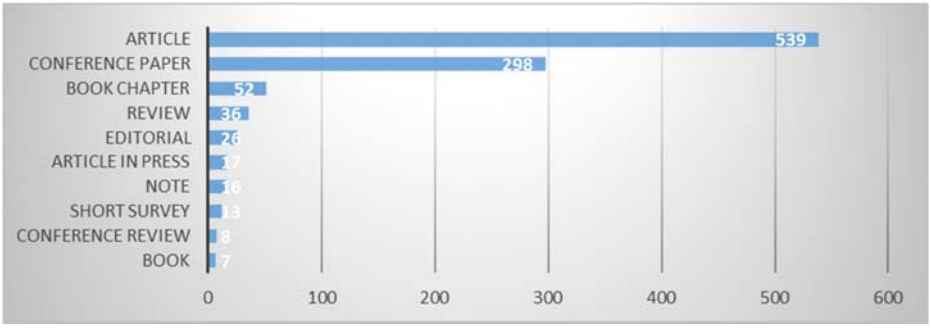

Figure 4 – Classification of publications by type

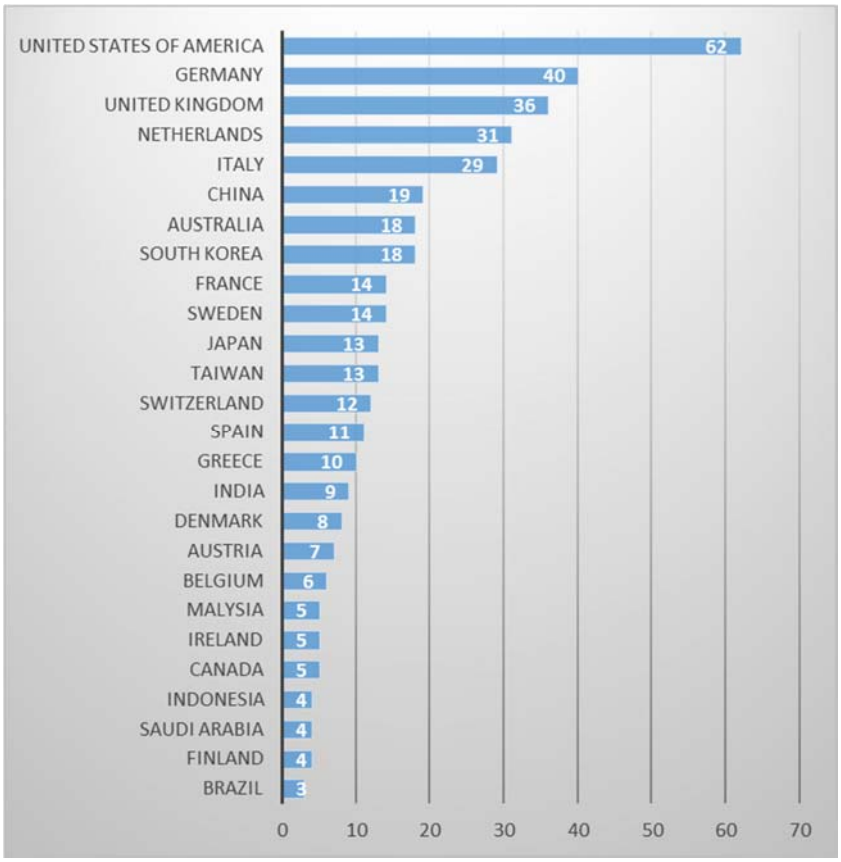

Figure 5 – Classification of publications by country

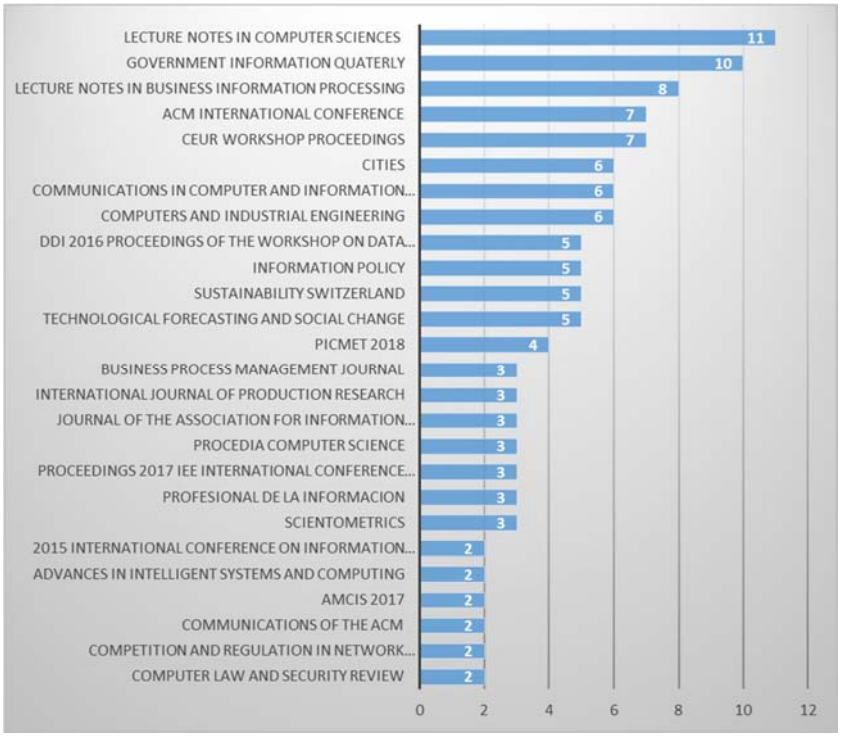

Figure 6 – Classification of publications by journal

Further it is interesting to observe, that a classification of the scientific outputs by discipline (Figure 3), shows the predominance of the computer science field (184), followed by social science (112) and business, management and accounting (84) which if summed up equal the amount of the top-ranked field, followed by engineering. These results are illustrative of the fact that possibly the technological component and the (big) data matter is the protagonist and its novelty, complexity and scientific discovery and value makes it worth for researchers to publish their results in specialised journals. In addition, all other disciplines appear to be fields of application, contributing to the body of knowledge by describing the phenomena, envisaging possible uses and benefits, expressing opinion, reflecting on the evolution, presenting some experience, among others.

Out of the 1,018 scientific documents found (Figure 4), c outcomes are predominantly in form of articles (539), followed by conference papers (298) and relatively few book chapters (52), with authors' affiliation (Figure 5) in the US (62), and followed by Germany (40), UK (36), the Netherlands (31), Italy (29) and China (19). When classifying the outcomes by publications, we find a series of well-known and strongly established conference publications and journals (in italic), on the top positions situating Lecture Notes in Business Information Processing, *Government Information Quarterly*, Lecture Notes in Computer Sciences, followed by *Sustainability* and *Technological Forecasting and Social Change* journals. The observation relative to Figure 6 is that the majority of publication appeared in Conference Proceedings which confirms again the field's emergent nature, while also putting in evidence the journals that concentrate the reviewed scientific outcomes.

Due to space limitations the detailed review of selected publications can not be included. It consists in a 30 rows x 6 columns, where each row represents a paper and the columns are paper author/s; topic, focus, aim; theoretical framework used or mentioned; method; source of Big Data; type of innovation. The table is available upon explicit request from the authors.

The status-quo of research in relating big data to innovation can be summarised in the following points:

- Existing work is basically defining the concept and generic
- The approach is predominantly centred on technology, while the field of application and resulting outcome (in the form of innovation) is not explored
- Theories and theoretical frameworks considered as classics in the general field of innovation are neither mentioned or used in the reviewed publications
- Empirical evidence is scarce and anecdotic
- The few empirical papers when giving details on the type of innovations resulting from data are predominantly focused on product innovation; other typologies (service, process, business model, etc.) are missing
- Traditional and established innovation surveys do not include relevant details to capture the existence and relation to data
- Sound and proved argumentations and justifications of the relationships between data and innovation are missing
- The relationship on how data brings value to innovation is not elucidated

Research agenda

When drawing a possible research agenda we opt for a two-step approach. First, we select and show the reviewed publications in terms of challenges and opportunities (Table 1) and, second, based on our own interpretation and expertise in the field, we

formulate a resulting research agenda that covers 8 issues which are relevant for the future.

Table 1 – Review of selected publications

	Big data Chall.	Big data Opp.	Research conceptualization	Big data Impact	Development of methods, approaches towards data driven innovation
Pub_1	✓				
Pub_2			✓		
Pub_3		✓	✓		
Pub_4					
Pub_5		✓			
Pub_6	✓	✓		✓	
Pub_7					✓
Pub_8				✓	
Pub_9					✓
Pub_10	✓		✓		
Pub_11	✓				
Pub_12				✓	
Pub_13					
Pub_14					✓
Pub_15					
Pub_16				✓	
Pub_17					
Pub_18				✓	
Pub_19		✓			✓
Pub_20	✓		✓		
Pub_21		✓			
Pub_22	✓				
Pub_23			✓		
Pub_24				✓	✓
Pub_25		✓	✓		
Pub_26				✓	✓
Pub_27			✓		✓
Pub_28	✓				
Pub_29			✓		✓

Pub_30		✓			
Abbreviations: Pub = Publication; Chall.= Challenges; Opp.= Opportunities; Note: numbers are showed in parenthesis in the reference list					

As a research agenda to explore the connection of data to innovation, we propose the following areas for research:

1. Generating a common understanding of the Big Data concept
2. Theoretically grounding research on Big Data
3. Overcoming the research-practice gap
4. Conducting valid evaluations (integrating data-sources into innovation surveys and/or conducting independent topic specific evaluations; conducting relevant case studies)
5. Generating data and communicating the benefits of data-driven innovation with valid examples
6. Exploring other innovation types beyond product innovation
7. Connecting and balancing big data and innovation
8. Motivating innovation researchers to collaborate with computer scientists in the framework of international, multidisciplinary collaborative projects

Conclusion

The present contribution aimed to offer a state of the art on data-driven innovation, first by identifying the existing and related scientific publications, reviewing them in terms of aim, theoretical foundations, methodological approaches present in the field as well as uncovering research gaps and setting up future research agenda. Additionally, our contribution could be considered valuable by novice researchers who aim to position and start their research in the field of innovation and big data, in giving them an overview on the field with respect to "*what we have*" and "*what we lack*".

Although some years have already passed since, according to Wamba et al. (2015), the extant literature identified 'big data' as the 'next big thing in innovation' (Gobble, 2013), this statement remains valid nowadays. Consequently, all pillars in the innovation ecosystem need to co-work and further elucidate what is the roadmap to follow in order to truly achieve making 'big data' as the 'next big thing in innovation'. In this way, there will be a contribution to the body of knowledge on the topic, which is vital in a field still in its early stages. The global question is not *if* but rather *how* organisation can benefit from the value of big data.

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How are the new digital services developed and deployed?

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Abstract

The purpose of this research is to reveal the process of new digital service development, and explore the deployment strategy of digital services, in order to shed more light on the mechanisms of service innovation in the digital age. An in-depth case study is used to identify the digital NSD process and investigate the contingencies of digital NSD. Digital NSD is entrepreneurship intensive and in fast clock-speed. Outsourcing is highly popular and valuable in digital NSD. Digital NSD processes have to be extremely agile to the dynamic context, meeting with ever-changing customers' needs and fast updated technologies.

Keywords: Digital Services, New Service Development, Service Innovation

Introduction and Purpose

The purpose of this research is to reveal the process of new digital service development, and explore the deployment strategy of digital services, in order to shed more light on the mechanisms of service innovation in the digital age. New service development (NSD) is largely conceived and characterized by previous research as less stable, ad-hoc and informal processes (Santos & Spring, 2013), which are more apparent in the e-services context (Riedl et al., 2011).

The service sector, also known as the tertiary sector, is the third of the three economic sectors, where the others are the secondary sector (referring to manufacturing) and the primary sector (referring to raw materials). The significant role of services in nowadays economy arouses academic researchers', practitioners' and entrepreneurs' interests and surging attention to NSD (Santos & Spring, 2013; Zomerdijk & Voss, 2011). Though NSD stems from new product development (NPD), academic researchers are increasingly exploring and comprehending how NSD is distinctive from NPD (Johnson et al., 2000; Menor et al., 2002; Santos & Spring, 2013; Zomerdijk & Voss, 2011). Moreover, the assortment of services in the tertiary sector also suggests that distinctions exist between the development mechanism of different types of services, such as experiential services, traditional services, and digital services etc. (Menor et al., 2002; Zomerdijk & Voss, 2011). This research mainly focuses on digital services.

Servitization and digitalization, as two megatrends, is bringing about a revolution to the contemporary economy (Häikiö & Koivumäki, 2016). Digital services are growing rapidly with the "transformational development of information and communication technologies" (Barrett et al., 2015, p.135). In 2018, the worldwide revenue in the digital services amounted to approximately $18.7bn USD and was predicted to show an annual growth rate (CAGR 2019-2023) of 9.0 % (Statista, 2019). This growth rate shows that digital services are creating new markets.

Digital services, also known as electronic services (e-services), are the service offerings delivered via "electronic network formats", such as internet and wireless networks (Rust & Kannan, 2003, p. 38). Digital services are different to traditional brick-and-motor services in terms of barriers to entry, continuous improvement, cost structure, cyclic and iterative development, disintermediation, a high degree of outsourcing, modular architecture, and transparency (Menor et al., 2002; Riedl et al., 2011). As a result, these contingencies create managerial challenges and new research opportunities. For instance, the high clock-speed and short time-to-market nature of digital services renders the management of new service development (NSD) and service innovation challenging (Bowman et al., 2010).

Theoretical Background

NSD research has historically focused on the creation of the service from a marketing or innovation management perspective (Mendes et al., 2017; Papastathopoulou & Hultink, 2012). Whilst less attention has been placed on the systems or processes that are co-created to support the introduction and provision of the service (Mendes et al., 2017). Informing NSD research from the operations management is highly suggested by many scholars (Mendes et al., 2017; Menor et al., 2002; Papastathopoulou & Hultink, 2012)

The definition of a new service is contingent upon the newness of the service offerings or service process, which differentiates between radical innovations (offerings not formerly provided) and incremental innovations (changes to existing offerings) (Johnson et al., 2000). The management of NSD has become a central concern for sustainable development in substantial service industries (Johnson et al., 2000; Menor et al., 2002). Although NSD derives from the plethora of rigorous studies on the NPD. NSD does differ from NPD in plenty of key aspects, due to special characteristics of service (Papastathopoulou & Hultink, 2012). NSD processes are verified to be a lack of formality and rigidity, compared to NPD (Menor & Roth, 2008). NSD remains immature among the least researched and comprehended subjects in the service management literature (Mendes et al., 2017).

NSD is an entrepreneurial process that narrates the value mechanisms and integrates resources and capabilities to define, design, and implement service (Tatikonda & Zeithaml, 2002). According to Johnson et al. (2000), the NSD process cycle consists of four fundamental phases (namely design, analysis, development, and full launch), which is highly iterative and non-linear/cyclic in nature (Bonomi et al., 2013; Menor et al., 2002). The NSD process cycle identifies the essential NSD stages revolving around the design and configuration of the service concept elements and recognizes the operational resources and capabilities in the development process (Santos & Spring, 2013).

The emergence of the Internet and then digital services further complicated the NSD research (Riedl et al., 2011). This is because NSD research is now divided into traditional brick-and-mortar services (such as healthcare, hospitality, financial banking, and transportation) and digital services (such as web-based or Internet-based service) (Bitner et al., 2000; Geum et al., 2016). Substantial researchers necessitate the exploration of NSD in the digital age (Barrett et al, 2015, Riedl et al., 2011).

There are substantial differences between traditional services and digital services, for instance, the transparency of service feedback, improvement status (continuous or discrete) of services, cost structure (fixed and marginal costs), degree of outsourcing, and development speed of new services (Geum et al., 2016; Menor et al., 2002). Digital services are dependent upon the user-interfaces, layout, and the location of menus, regarding the approaches to identify the functional characteristics (Santos, 2003). While traditional services are dependent upon customer participation (Geum et al., 2016). Digital services can be much easier to design and deploy than their physical-service equivalents in NSD processes, since the majority of the service processes happen in the back-office (Menor et al., 2002). Moreover, the interactions between customers and digital services themselves become more transparent, especially in the back-office (Menor et al., 2002; Riedl et al., 2011).

The search and transaction costs and variable costs of service provision and service realisation are reduced via electronic disintermediation (Menor et al., 2002; Riedl et al., 2011). Digital services tend to be decomposed generally contingent upon modular architecture, while traditional services are contingent upon service process (Geum et al., 2016). General delivery or modular components can be easily and rapidly turned over to third-party service suppliers, due to the nature of modularity of digital services (Geum et al., 2016). In turn, outsourcing is highly popular and valuable in digital services sectors (Geum et al., 2016; Menor et al., 2002). distinctive features of digital services should be considered, when exploring NSD in the digital age.

As a result, these contingencies make the e-service industry more dynamic, uncertain, highly competitive, and a higher risk of imitation (Geum et al., 2016; Menor et al., 2002; Riedl et al., 2011).

Methodology

An exploratory case study approach (cf. Eisenhardt, 1989; Yin, 2009) was adopted, as it enables an in-depth understanding of the complex and contemporary phenomenon in the real-life digital context. Although multiple research cases are typically welcomed, which is considered to augment external validity and reduce observer bias (Voss et al., 2002; Yin, 2009). Single case studies can provide in-depth analysis to develop meaningful insights (Beltagui, 2018; Dubois & Gadde, 2014) in this specific digital context, where NSD is considered as complex and dynamic (Papastathopoulou & Hultink, 2012; Santos & Spring, 2013). Moreover, academic researchers can capture complex interactions and a better understanding of the dynamics with a single case (Beltagui, 2018). The study was underpinned by abductive reasoning where the researchers iterated between theory and data (Kovács and Spens, 2005).

Since we investigated the development and deployment of digital services, the unit of analysis is the digital NSD process. The case organization need entail NSD and involve information technology with a network of suppliers and partners that take part in the provision of digital services via the Internet. Case organization in this research mainly provide information services via the Internet (including the activities of web search portals, data processing and hosting activities, as well as other activities primarily supplying information) (UNSD, 2008).

Our research followed a three-phase approach. First, the prototype of the interview protocol was developed based on the extant literature. Then, the protocol was refined with feedback from academics. Second, pilot interviews were conducted with Case Education in March 2018. The further amendment was developed for the protocol to mitigate the ambiguities between academics and practitioners. Third, we investigated the focal organizations between July to September 2018. At the same time, the case study protocol

was kept updated iteratively in light of the emergent data and field notes. The abductive way to develop the protocol was appropriate, as we investigated a nascent phenomenon (Chakkol et al., 2014).

At last, 6 formal semi-structured interviews were conducted and recorded with the focal organization (Table 1). Because of ethical consent, focal organization were anonymized with an alias. The focal organization was visited in person and interviews were conducted face-to-face supplemented with observations. Formal interviews were also triangulated with informal chatting and secondary data such as documentation, which increased the reliability and validity of the results (Voss et al., 2002)

All of the 6 interviews were transcribed verbatim. Each interview and related document were coded and analysed using NVivo. In the coding processes, we followed the guideline of Gioia Methodology (cf. Gioia et al., 2013. Emerging data from the different cases were progressively incorporated into the analysis, allowing for the systematic combining of the transpiring issues and the ongoing development of the interview protocol (Dubois & Gadde, 2002). An iterative approach, moving between the emerging data set and the extant literature, will be adopted in order to make sense of the data and place it in the appropriate theoretical context.

Table 1- The list of interviews

Organisation	Role	No. of Formal Interviews	Average Interview Duration (mins)
Platform. Co.	*Product Manager*	1	67
	Assistant of Product Manager	1	62
	Senior Algorithm Engineer	3	63
	Junior Algorithm Engineer	1	49
In Total		6	62

Case study

In September 2018, I got a chance to investigate one of the leading E-commerce companies in China. Platform.Co. is China's largest online retailer and the biggest Internet companies by revenue. Its unrivalled nationwide fulfillment network provides standard same- and next-day delivery covering a population of more than 1 billion, a level of service and speed that is unmatched globally. As a technology-driven company, Platform.Co. builds reliable and scalable platforms that bring value to partners and customers in sectors such as e-commerce, logistics, Internet finance, cloud computing and smart technology.

Platform. Finance was founded under the name of Platform.Co. and began operating independently in October 2013 in the field of digital finance. Platform. Finance has launched innovative products and services, covering consumer finance, payment, wealth management, crowdfunding, insurance, securities, etc. Platform. Finance aimed to create a trustworthy and inclusive digital financial experience for individual customers.

In November 2018, Platform. Finance was expanded to Platform. Digital, which witnessed the transition from the business model of B2C into B2B2C. At the beginning of the establishment of Platform. Finance, its business model was B2C, which directly provided financial services to individual customers. Then, it began to transform into a "B2B2C model, providing data and technology services to financial institutions" (CEO, Platform. Digital), based on previous experience and accumulated competence with consumers and suppliers.

"The essence of digital technology is to develop cutting-edge technology as the driving force and focus on the unbounded integration of 'industry x technology' based on the existing knowledge and data. Digital technology promotes the industrial internalization, digitization and intelligentization, which ultimately achieves lowering the industry costs, improve customer experience, increase industry revenues and upgrade business models." (CEO, Platform. Digital)

With the core technologies of big data, artificial intelligence (AI) and Internet of thing (IoT), Platform. Digital has completed the "open ecosystem" (CEO, Platform. Co.), the comprehensive arrangement in the fields of digital finance, digital city, digital agriculture, digital marketing and digital campus. Furthermore, Platform. Digital has enhanced the convenience of life by the union of individual customers, business partners and government agencies. The value proposition of Platform. Digital is to implement digital technologies into financial and manufacturing industries, which helps these industries to improve the level of digitization and promote the development of the economy.

The interviewees were mainly in the Natural Language Processing (NLP) Group under the Basic Technology Development Department. NLP is a subfield of computer science, information engineering, and artificial intelligence, concerned with the interactions between computers and human (natural) languages. In particular, NLP solves the problem of how to program computers to process and analyze large amounts of natural language data.

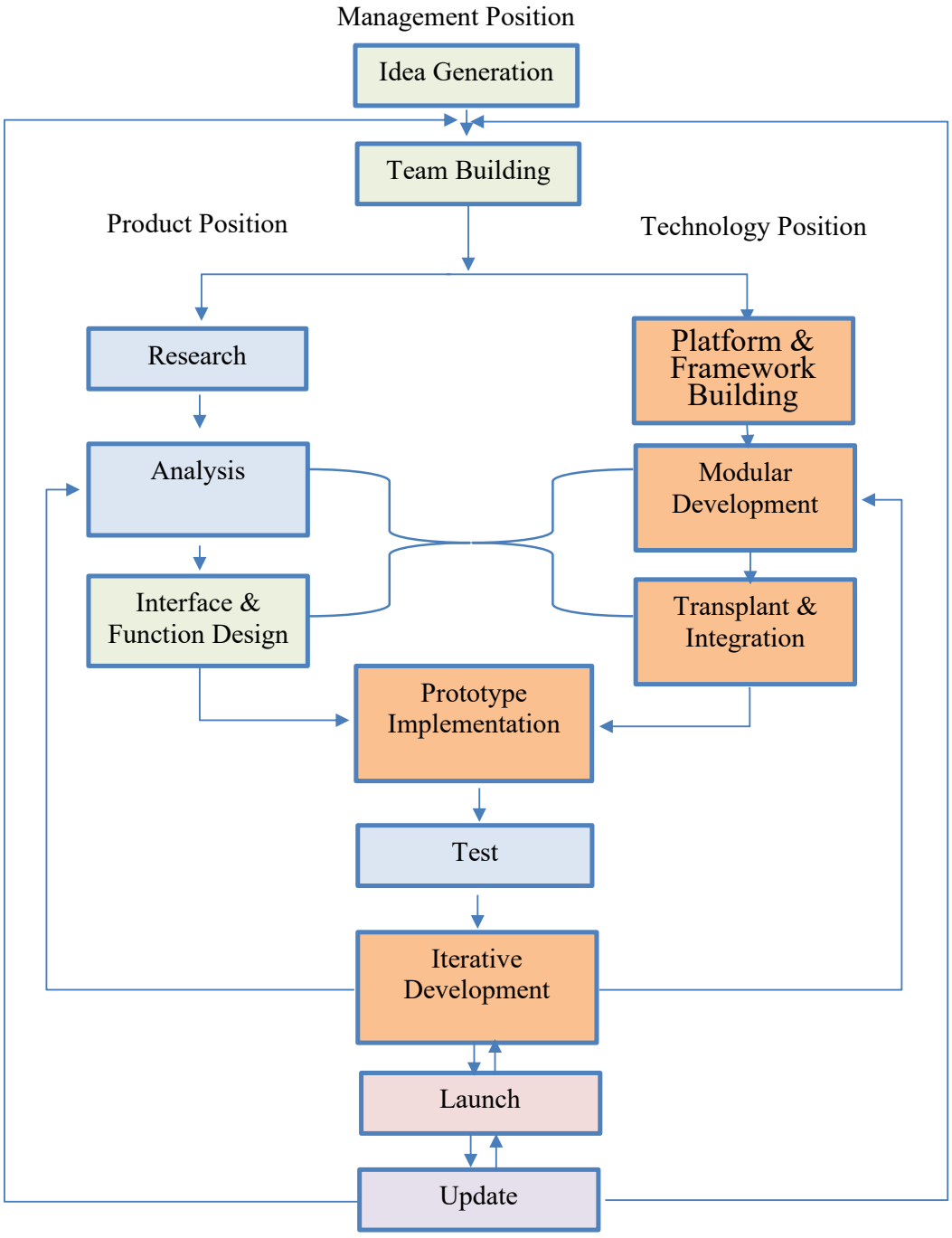
During the period of fieldwork, there were two main projects under the NLP team, focusing on the development of customer service chatbots for different purposes. One targeted on providing the customer service for the presale of investment fund, and the other for the comprehensive aftersales. Customer service chatbot is a smart online robot, developed by the company to reduce the cost of human resources and adapt to the needs of the market. Chatbot can answer frequently asked questions with a satisfied accuracy rate, and replace manual labour to a certain extent. The chatbot is one of the crucial services in Platform. Digital and in delivering intelligent customer service. The service blueprint of the basic customer service request by users is illustrated in the Appendix.

NSD process

In the era of AI, many industries have been subversively developed, and customer service is one of them with AI chatbot. For a long time, customer service has become a bridge between enterprises and customers, and its importance is self-evident. However, there are "many pain points in customer service in the long-term development process" (Product manager, Platform. Digital). For example, from the perspective of enterprises, the cost of customer service investment is very high, but the value return of most jobs is very low; From the perspective of customer service employees, the work is boring, and the career development of customer service is narrow. AI has subverted the development of the customer service, and customer service robots (chatbots) have become really smart.

The NSD process commenced in response to the decision made by the high-level management team in 2017, developing chatbot for the aftersales customer service. A new team was built under the NLP Group to develop customer service robot with the application of AI in-house. A simplified NSD process of Chatbot was depicted in Figure 1. There were mainly five stages of NSD process, namely design, analysis, development, launch, and transition. The activities in the green frame (e.g. idea generation, team building, and interface and function design) belong to the design stage. The activities in the blue frame (e.g. research, analysis, and test) belong to the analysis stage. The activities in the orange frame (e.g. platform and framework building, modular development, transplant and integration, prototype implementation, and iterative development) belong to the development stage. The activities in the pink frame belong to the launch stage. The activities in the purple frame belongs to the transition stage.

Figure 1. NSD process of Chatbot



This chatbot team consisted of three different positions, namely Management (M), Product (P), and Technology (T). There were different levels of each position ranking from 1 to 10. The staff in a higher level position had higher salaries and more power. Staff in management position tackled with the issues related to the management side, such as leading the scrum meetings, communicating with a higher level of management etc. Though staff in product position and technology position worked on different tasks separately, they communicated to each other frequently during the NSD process of

chatbot. Staff in product position played a role as a communicator between the market and staff in technology position. For instance, the product manager led staff in product position to conduct a research about the total markets, analyse the customer needs to generate a "needs pool" (Assistant of Product Manager, Platform. Digital) and designed the interfaces and specific functions in different context. On the other hand, Staff in technology position (mostly called Algorithm Engineers) built the platform firstly. At the stage of platform and framework building, Staff in technology position didn't need to have detailed information from staff in product position.

Based on the analysis and design from staff in product position, staff in technology position tried best to meet the requirements of some specific functions of the chatbot, "where a lot of problems emerged and need to be solved" (Senior Algorithm Engineer I, Platform. Digital). Due to the limitation of the AI technologies, staff in technology position could not always meet with the "ideal and surrealistic" needs from staff in product position (Junior Algorithm Engineer, Platform. Digital). A lot of compromise, trade-off and negotiation happened between staff in product position and technology position. In some occasions, the debate even went intensively, where algorithm engineers did not think staff in product position understand the technologies at all.

The stage of the modular development and framework building sometimes happened "in parallel" (Senior Algorithm Engineer II, Platform. Digital). Because some functions could be referenced from open coding resources and only need to be transplanted and integrated with the new platform. After the implementation of the Chatbot where staff in product and technology position came to an agreement on the prototype, the team did the internal alpha test initially, and then the external beta test. Based on results and feedbacks of the tests, "especially keen on the accuracy rate" (Senior Algorithm Engineer III, Platform. Digital), the team followed the iterative and incremental development process, where all the staff in product and technology position went back to the stage of analysis and modular development respectively. And then the whole team followed a similar process again to improve the results of tests. After the high-level management group was satisfied with the final version of the chatbot and approved it, a new type of chatbot was launched as V 1.0.0. Even after the launch of the Chatbot, the whole team still worked on the project, providing maintenance, fixing the bug, catering to the new needs from users, providing solutions to higher management requests. Thus, at the update stage, there were reversed processes going back and forth from the iterative development stage. Among these processes, the versions launched were marked as V 1.1.0 or V 1.1.1 depend on the degree of improvement. Occasionally, if there was a breakthrough of technology or huge changes from high-level management team, the process went back to the initial team building stage even. These kinds of new launches were marked as V 2.0.0 or V 3.0.0 etc.

Findings & Discussions

The LR suggests that there are four different stages in the NSD process, namely design, analysis, development, and launch (Menor et al., 2002). Interestingly, this study identified another additional stage called transition apart from the four traditional NSD stages, which formed a key part of the digital NSD process. In the transition stage, the digital service was kept updating and optimizing iteratively. The NSD process is cyclic and modular in nature, which implies highly iterative and non-linear (Santos & Spring, 2013; Chai et al., 2005; Menor et al., 2002), as shown in Figure 1.

"The mobile application or the official website acted as the core platform, and other subordinate services or functions were gradually developed and modularly added to it." (Senior Algorithm Engineer III, Platform. Digital).

Moreover, the exemplary NSD process of chatbot in Figure 1 shows cyclic and iterative features between five different NSD stages. For instance, the mobile application

has already launched version 7.4.6 and at least seven launches with dramatic breakthroughs went through the five NSD stages (analysis, design, development, launch, transition) iteratively and non-linearly.

The high clock-speed context of digital services incubated NSD faster with the technology explosion, where new digital services replaced the old offerings more frequently and iteratively. The Digital NSD process is in fast-clock speed. Within only a few months, a new service can be launched.

"We prefer to take a short time to develop a simplified prototype and keep testing and iteratively updating after the official launch, rather than to take a long time for a perfect version." (Senior Algorithm Engineer I, Platform. Digital).

Because the barriers to entry for new digital services are lower than traditional services due to the lower development cost and opener resources for design. The digital NSD emerges at a much greater rate with radical innovation than traditional services. Entrepreneurial processes are likely to occur in digital NSD, which is much more "entrepreneurship intensive" than traditional NSD (Menor et al, 2002, p.148). The decisions and transformation from the high-level management team played a significant role in the NSD of chatbot.

"Currently, we are in the transition from the business model of B2C into B2B2C, which was proposed by CEO Chen. Actually what we do in our chatbot project is just like we are running start-ups. As we changed our name from Platform. Finance to Platform. Digital. Now we are not only developing customer services chatbot for the financial products, but also providing solutions and services to the other financial institutions. We are transiting form retailers to the digital technology company." (Product Manager, Platform. Digital)

Outsourcing was highly welcomed at the early beginning of a new service for an organisation in the digital context. At the early stage, the resources and capabilities were quite limited. When the new service became more mature and gained great future potential for profits, the focal organisation could start to develop the resources and capabilities to operate the services in-house. Or the focal organization could also merge the outsourcing partners, where a transition from external partners into internals happened. The in-house operations could help the focal organization have better control and maintain the consistency of quality and build the brand.

Though the NSD itself as a specific dynamic capability helps the organizations better adapt to changes and develop sustainably in a dynamic environment (Gutierrez-Gutierrez et al., 2018). It is still difficult to maintain sustainable competitive advantages in a fast clock-speed context. Further investigation will be conducted.

Conclusions

This study contributes 1) by addressing the lack of NSD research in the digital age, 2) by exploring the development and deployment of digital NSD, 3) by identifying and describing efficient mechanisms for the innovation of digital service.

Digital NSD is much more entrepreneurship intensive than base-line NSD. Second, Digital NSD is in fast clock-speed. Third, outsourcing is highly popular and valuable in digital NSD, as general delivery or modular components can be easily and rapidly turned over to third-party service suppliers. Forth, Digital NSD is more likely to outsource service to a relatively remote site. Fifth, digital services can be much easier designed and deployed than their physical-service equivalents in NSD processes, since the majority of the service processes happen in the back-office. Sixth, a newly burgeoning area of NSD is "electronic disintermediation", where the traditional manufacturing firms can bypass conventional distribution channels and establish relationships with end customers directly. Seventh, digital NSD processes have to be extremely agile to the dynamic context,

meeting with ever-changing customers' demands, fast updated technologies, and hyper-aggressive competitors.

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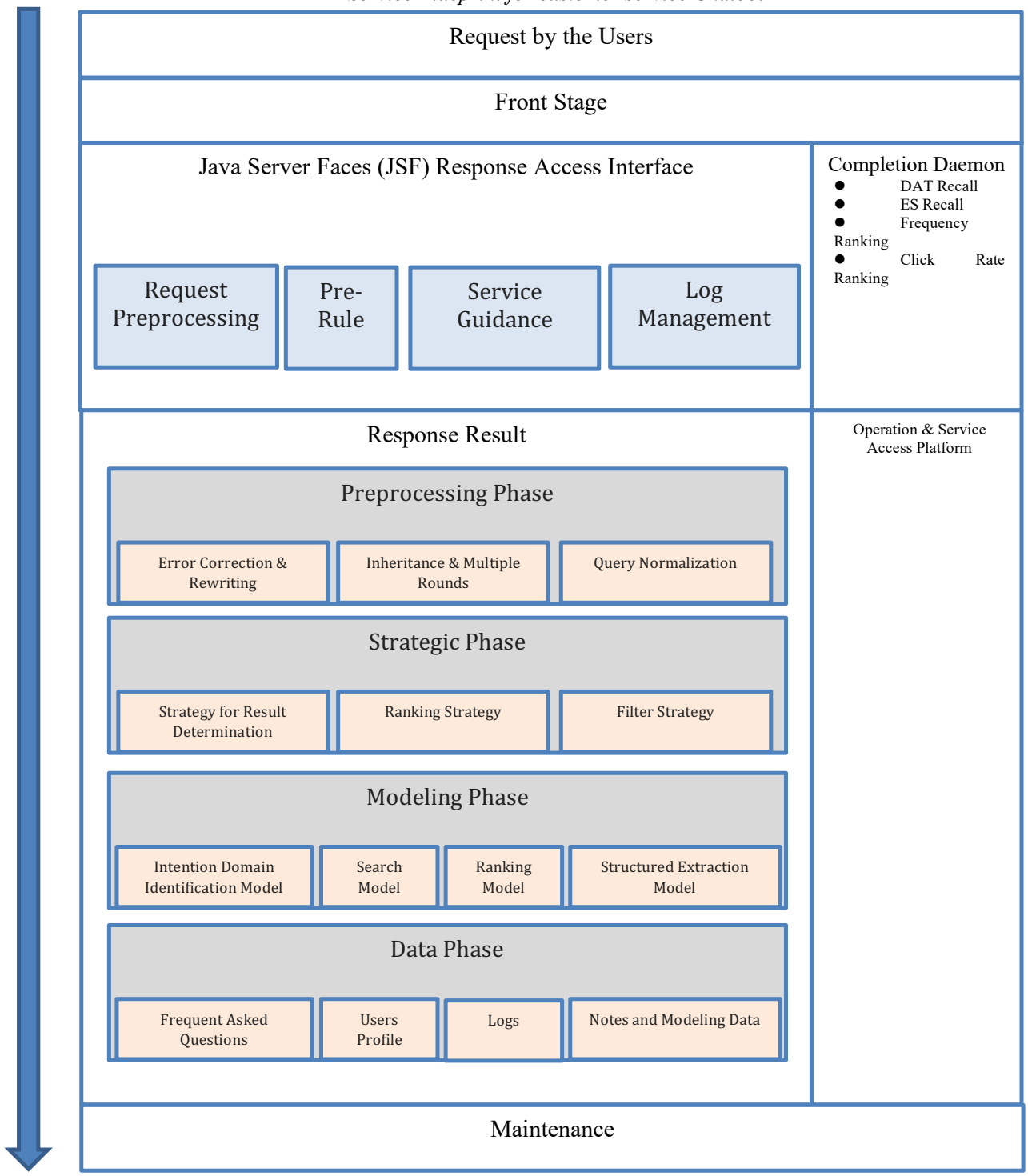
Appendix

Service Blueprint for customer service Chatbot



Supply Chain Involvement in new product development and new product performance: the role of team rewards.

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Abstract

This paper analyze the impact of team rewards (TR) on NPD success. In particular, we analyzed whether the use of TR affect the success of NPD team projects not only by accomplishing for their work as a team and the performance their perform but also considering the enhancement of the involvement of internal functions and external actors (suppliers and customers) in these projects. Using SEM we observed that TR do not produce a direct effect, but do it through the involvement of SC members in the early stages of NPD. Without involvement, it is not possible to obtain desired NPD success.

Keywords: New product development; Team Reward; Involvement; Supply Chain

Introduction

New product Development (NPD) is a critical concern for manufacturers in an increased global competition. Literature on NPD success has mainly been positioned in the domain of supply chain management (SCM) (Mazzola, Bruccoleri and Perrone; 2015). The most cited references in the field advocate for the involvement of suppliers and customers in NPD process (Flynn et al. 2010) and also to look for complementarities involving internal functions in a collaborative way to achieve NPD success (Homburg and Kuehnl, 2014).

Involving heterogeneous actors in NPD allows firms to enhance the value of knowledge-based resources (Cabrera and Cabrera, 2005). In this sense, evidences has shown that combination of broad and varied information and points of view is positively related to new product performance in terms of cost, time to market and quality (Mishra and Shah, 2009) and also with firm innovation capabilities, and firm performance (Petersen, Handfield and Ragtz, 2005). Nevertheless, some researchers also highlights the costs and challenges of collaborative competences in NPD among SC members (Fawcett et al, 2015), referring to what is known as the "dark side" of collaborative NPD process (Villena, Revilla and Choi, 2011).

As a result, the debate is open, and more research is needed to improve the understanding on how to involve a number of SC agents in the process of developing new products (bringing them closer and involving them), and how to design mechanisms to promote this process (Yang and Wagner, 2017). More specifically, researchers in the field have made a call to analyze organizational issues that promote SC relationship in order to overcome dark-side effects of involving external and internal sources of information and knowledge to achieve NPD success.

With this framework, the aim of this paper is to analyze the impact of team rewards (TR) on NPD success. In this context, an interesting question is whether the use of TR affect the success of NPD team projects not only by accomplishing for their work as a team and the performance their perform but also considering the enhancement of the involvement of internal functions and external actors (suppliers and customers) in these projects.

Overall this study makes three important contributions to the extant literature. First, this study advance in the study of TR on NPD success considering TR as a tool to work in-group involving different and distant actors in the process of NPD. This approach is aligned with the new trends in the field of R & D that recognizes the need for openness and integration of different sources of information and knowledge, providing a clear vision about the importance of adopting integrative strategies as the best way to achieve innovation performance (Crisquuolo et al., 2017). Second, the analysis consider different dimensions of NPD success distinguishing between time to market, technical issues and cost of manufacturing, usually considered in an aggregated way. Third, empirical evidence use an ample database including a more than three hundred of manufacturing

companies from fourteen countries, including developed and developing countries, and from three industry sectors, thus giving more relevance to the results found.

Theoretical background.

Team Reward in New product Development Projects

A reward system entails the use of the pay system to guide, control and affect the behaviors and efforts of individuals and sub-units toward the achievement of organization´s strategic goals (Gomez-Mejia and Balking, 1992). Total reward is defined as the combination of both the financial and non-financial rewards made to the employees and usually includes basic salary, variable pay, pension benefits, death-in-service benefits, long-term disability benefits, private medical insurance, vacation entitlement, and others (see Jiang et al., 2009).

The group-based incentive plans, such as profit sharing, gainsharing, and team-based reward, may provide an effective means of linking pay to performance in work settings where high-powered individual incentive plans are difficult to implement. Sarin and Mahajan (2001), based on the principles of the organizational control literature proposed to distinguish TR in process-based rewards and outcome-based rewards. Process-based rewards are tied to the accomplishments of procedures, behaviors and other means of achieving desired outcomes, while outcome-based rewards are defined as the degree to which team rewards are tied to the bottom-line profitability of the project. Process controls are exercised during the execution of a task while output controls are exercised after a task is completed. Researchers highlight the both types of rewards may have positive effects on team performance but depends on contingencies of projects.

Team Rewards and NPD success

Empirical evidences exploring the relationship between TR and NPD is scant and varied in terms of the measures of TR and performance measures used and mixed in terms of findings. Bonner et al. (2002) considered TR in three ways: financial rewards, internal promotion and recognitions for successful performance. They measure project performance in terms of adherence to budgets and costs, meeting schedule and ask managers to rate for product performance and team functioning performance. They find out no statistical significant relationship between TR and project performance, but all measures were treated in an aggregated way as additive indexes. Chang et al. (2007)

analyzed the effects of joint rewards on NPD performance. The authors distinguished five types of joint reward systems (reward allocation, process-based reward, outcome-based rewards, risk-free of participants, and over-reward incentives) as antecedents of NPD performance. In this case, performance refers to innovation performance in terms of sales, profits and market share, and comparing this measure with regard to competitors, and finally performance in term of the overall profitability. They find out that the overall joint reward system was positive and significantly related to NPD performance. However, only two types of overall reward systems were significant: reward allocation and risk-free to participants, but no significant effect was observed for process-based reward or outcome based rewards.

More recently, Carbonell and Rodriguez-Escudero (2016) analyzed the impact of both process control and process-based rewards (based on procedures and activities) on new product performance and job satisfaction. They find out mixed results since find out a negative association between process-based rewards and quality of new products, a positive association of rewards and the adherence to project schedule and not significant with project budget. The authors also looks for interaction between process control and process-based rewards, but results were not significant to explain project performance, but positive interaction between both tools to explain the quality of new products.

In this paper, we focus on "internal" NPD success measures, considering technical performance, time to market and manufacturing cost (Mishra and Shah, 2009). The adoption of TR is expected to be positively associated with NPD success. Rewarding all team members according with achieving project goals reinforce the perception of workplace justice, avoiding opportunistic behaviors and encouraging cross functional and interfirm collaboration. As a result, the application of TR it is expected that affect team project promoting to work hard to achieve NPD goals.

According with this arguments, we propose the following hypotheses:

H_{1a}: Team rewards positively impacts on technical performance.
H_{1b}: Team rewards positively impacts on time to market.
H_{1c}: Team rewards positively impacts on manufacturing cost.

Team Rewards and the involvement of SC members on NPD

In this section we analyze the effects of adopting TR onthe involvement of SC members in early stages of NPD. In particular, we consider bundles of practices in hand of the NPD team, both internal and external, aimed to involve SC members in providing valuable information and ensuring their effective participation in the decision-making process in the early stages of NPD. External involvement (EI) include practices fostering the coordination of decision making and the implication of suppliers and customers in providing valuable information. Internal involvement (II) of manufacturing function encompasses practices concerned with matching design requirements and process capabilities.

The resource based view-RBV (Barney, 1991) suggest that integrating heterogeneous interdependence and complementary source of knowledge is beneficial for all partners involved in NPD processes (Zhao et al., 2011). Related studies have suggested the benefits of adopting bundles of practices aimed to involve complementary sources of information from external and internal SC actors. However, involving internal and external SC members in NPD is a paramount, mainly due to knowledge sharing risk and the hidden cost of coordinate and support relationships with SC actors (Um, Ki-Hyun, and Sang-Man Kim, 2018), which sometimes generates socio-structural resistance by the different members implicated (Fawcett et al., 2015).

In addition, the social capital theory highlight the value of capital as those resources inherent in social relations which facilitate collective action. Related literature stated the positive effects of social capital among the supply chain, promoting cooperative behavior between members, sharing vision, trusting relations, and social ties and reducing the likelihood of conflicts. Nevertheless, some scholars find out the risks and potential negative consequences associated with social capital, which have been recently named as the dark side of social capital (Villena, Revilla and Choi (2011).

From a different perspective, the expectancy theorycons iders the effort of employees as a function of the perceived value of a reward and the perceived effort-reward probability. As a result, NPD team members will strive more in the search of collaboration of the SC agents if the companies have established a reward system based on the achievement of the objectives of the project especially if these objectives are achievable.

According with this arguments, we propose the following hypothesis:

H_2: Team rewards positively impacts on involvement practices of SC agents

Involvement of SC members and NPD success.

Evidences analyzing the process of NPD suggest the benefits of adopting involvement practices with all SC actors in early stages of NPD. Researchers highlight the absorptive capacity of team members, defined as the ability of companies to effectively acquire and exploit both external and internal knowledge to achieve innovation success, as one of the main reasons behind the success in NPD in manufacturing firms (Laursen and Salter, 2006). While firms learn from their external partners, they need to have the internal absorptive capacity to enhance their innovation performance. Hence, Daghfous (2004) highlight the importance of internal mechanisms to learn, to disseminate, and to exploit knowledge to enhance NPD performance.

Thus, practices aimed to involve SC actors are determinant to resolve manufacturing issues in early stages in order to achieve easy manufacturing and improving manufacturability. Johnson and Filippini (2009) comparing collaborative NPD practices such as CI, SI and II across the world on performance, stated that the use of internal involvement is more emphasized than external integration and this was translated into better product performance. In the same way, Ragatz et al. (1997) suggest that the effective integration of suppliers into NPD processes can yield benefits through reduced time to market an improved access to the application of technology). Similarly, involving customers in early stages allows NPD team to know customer assessments in early stages.

According with these arguments, we propose the following hypotheses:

H_{3a}: Involvement positively impacts on technical performance.
H_{3b}: Involvement positively impacts on time to market.
H_{3c}: Involvement positively impacts on manufacturing cost.

Methodology

Sample

The data used for empirical analysis was collected from the fourth round of the High Performance Manufacturing Project (HPMP), a research project conducted by a team of researchers working in different universities all over the world. The survey was conducted during 2013-2015 in manufacturing plants operating in three industry sectors: machinery, electronics and automotive components (SIC codes: 35, 36 and 37, respectively) and located in different countries: China, Germany, Sweden, Japan, Korea, Spain, Italy, Israel, Brazil, Finland, Austria, Taiwan, United Kingdom and Vietnam). The final data set consists of 309 responses. In table 1 we can observe the profile of the sample for the different countries and for the three industries.

Measures

We used 16 items to measure supplier involvement, customer involvement and manufacturing involvement in the NPD process. The items included in the scales have been used by other researchers who have addressed the issue (Mishra and Shah, 2009). The annex shows all these items, to which respondents indicated their agreement/disagreement on a five-point Likert-type scale (from 1 = strongly disagree to 5 = strongly agree). The survey included also other questions related to the country where the companies are located and its activity sector.

We model involvement as a reflective second order construct to capture complementarities arising from the three first order constructs (.suppliers, customer and manufacturing). This second order, involvement construct accounts for multi-lateral interactions and covariances among the first order constructs. The use of second order construct to represent complementarities among first order constructs has been well documented in existing studies (Shah and Ward, 2007).

NPD success is assessed using three commonly used items reflecting time-to-market, technical performance and unit manufacturing cost. NPD project managers were asked to rate the success of the product development project relative to the set goals and objectives on the three measures on a 5-point Likert-type scale ("How successful were the new products in terms of reaching their goals?").

In order to check for common method variance we used Harmann´s single factor test (Podsakoff & Organ, 1986). This test was conducting using principal component analysis and loading all 20 items (variables of interest) on one factor. The 33,8 % variance explained by a single factor shows that the common method bias is not a major concern in this study (less than 50% cut-off point).

The methodology was developed in two stages. First, the validation of the assessment scale for involvement was settled. The second stage was the assessment of the. hypothesized structural relationships of our model .The analysis was conducted using Structural Equation Modeling (SEM) techniques, also with EQS 3.0 software , The seminal works of Baron and Kenny (1986) and Zhao et al. (2010) have inspired the analysis of the mediation role of involvement. Results are summarized in Table 1.

Table 1. Decomposition of the parameters of the research model.

	Total effect	Indirect effect	Direct effect
Team Rewards □ Involvement	0.614 (4.51)	-	0.614 (4.51) (H_1 Accepted)

Involvement □ Technical performance	0.574 (4.19)	-	0.574 (4.19) (H_{2a} Accepted)
Involvement □ Time to market	0.494 (3.73)	-	0.494 (3.37) (H_{2b} Accepted)
Involvement □ Manufacturing cost	0.453 (3.18)	-	0.453 (3.18) (H_{2c} Accepted)
Team Rewards □ Technical performance	0.202 (1.175)	0.352 (2.48)	-0.150 (-1.810) (H_{3a} Refused)
Team Rewards □ Time to market	0.279 (1.622)	0.303 (2.37)	-0.024 (-0.267) (H_{3b} Refused)
Team Rewards □ Manufacturing cost	0.284 (1.512)	0.278 (2.15)	0.006 (0.064) (H_{3c} Refused)

Standardized parameter (t-value).

Findings confirm the first hypothesis that team rewards have a positive impact on involvement; the overall involvement construct is directly influenced by team rewards and the standardised coefficient is 0.614. First hypothesis is then confirmed. In its turn, involvement impact on positive and significantly on the three NPD success items considered, hence the hypotheses H_{2a}, H_{2b} and H_{2c} are also confirmed. One the other hand, neither of the last three hypotheses (H_{3a}, H_{3b} and H_{3c}) can be confirmed.

Conclusions

New product development (NPD) is critical for firm competitive (Brown and Eisenhardt 1995). Studies analyzing NPD success factors have neglected the study of how to involve SC members in early stages of NPD process through the use of motivational practices.

The estimations results shed novel evidence. The main finding shows that TR positively affect NPD success in terms of cost, quality and TTM, but, surprisingly, this effect are throughout the involvement of SC members. For NPD projects, linking rewards to the output produced by the team (outcome-based rewards) has a positive influence on SC agents involvement and finally on the internal dimensions on NPD success. Regardless of the type of reward implemented, if team rewards are used to motivate the members of the NPD team, it will be easier to achieve the objectives regarding quality, unit manufacturing cost of products launched and, also, the time to market of new products.

In sum, all the impacts of team rewards on NPD succeed are achieved through the mediation of involvement, which highlights the paramount importance of this construct (involvement). On other words, no effect of TR is achieved without the mediation of involvement.

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The relationships of dimensions of competence in the development of new services and the companies' performance in the development of them

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Abstract

New service development (NSD) had been seen as a result of luck or intuition. However, the need of NSD planning and greater managerial understanding so that companies can achieve the expected performance. Four NSD dimensions were considered: process focus; market acuity; strategy; and culture; plus Information Technology. Exploratory factor analysis and multiple regression analysis were used, it was found that four dimensions can be considered responsible for 30% NSD performance. It is noteworthy that *market acuity* was found to have more effect on performance. However, *NSD strategy* could not be evaluated as their variables were eliminated during exploratory factor analysis.

Keywords: New service development performance. Knowledge-intensive service.

Introduction

The service sector is fostered by the evolution of the world economy. The changes that occurred in the last decades of outsourcing of activities and processes contributed to the transition from a manufacturing-based society to services (Chase & Apte, 2007; Sampson, 2000).

The companies that provide services are inserted in an environment of globalization, of constant technological progress and of a dispute for better offers and new clients. This competition scenario therefore demands that they constantly seek to develop new services, whether they are highly innovative or only improvements in those already offered to customers (Brentani, 2001; Noori et al,, 1997; Stevens; Dimitriadis, 2005). A new service can be considered as an offer not previously available that results from an addition to the current mix of services as well as from a change made in the delivery process (Menor; Roth, 2007).

The NSD has already been seen as a mere event that was made possible by luck or intuition. Many authors have already studied the difference between developing new services and new products. Some believe that the DSN literature and innovation in service deserve greater attention because of its characteristics (Griffin, 1997; Kelly; Storey, 2000).

The statistics presented may reflect the lack of awareness of the importance of NSD or even have not been raised to the strategic plan and seen as a competitive factor by companies. This leads to the lack of a greater understanding on what can differentiate a company that reaches the success of one that has its service rejected by the market. It was under this approach that Menor and Roth (2007) explored a way to verify NSD success through a competency model spanning five dimensions: i) Focus on the NSD process; (ii) Market acumen; (iii) NSD strategy; iv) NSD culture; and v) Experience in Information Technology (IT).

It is known that financial services companies have been the most analyzed in relation to the NSD (Papastathopoulou & Hultink, 2012), however there are other types of services that also deserve to be mentioned, such as the services intensive in knowledge (SIC), or knowledge-intensive business service (KIBS) that involve activities based heavily on professional knowledge and are needed when there are situations that demand external knowledge (Milles, 2005, Smedlund, Toivonen, 2007). Among the group of this type of companies, it is possible to mention technical consulting firms, civil construction services, software and IT companies, tax and accounting consulting, that produce and transmit knowledge are seen as a source of innovation (Muller, Doloreux, 2009) and are referenced in this study by knowledge-intensive service companies (KISC).

In this way, the following research question is raised: What is the relationship between the competency-building dimensions of new services and the performance of companies in the development of new services?

In order to answer the research question, it was outlined as a general objective: to verify the relationship between the competency-building dimensions of new services and the performance of companies in the development of new services.

To unfold the general objective, the following specific objectives were defined:

a) Confirm the relationship between the five dimensions in the development of new services of knowledge-intensive services companies;

b) Validate the instrument of "competence model" for the development of new services proposed by Menor and Roth (2007);

c) To verify how dimensions contribute together to the performance of knowledge-intensive service companies.

Hypothesis formulation

The revealed dimensions are: (1) focus on the NSD process; (2) Market acuity; (3) NSD strategy; (4) NSD culture and (5) experience in Information Technology (IT). Each of them aggregates characteristics of the "best practices" of the companies verified in previous researches and they are identified like resources or organizational routines important for the success of development of a new service. (Jong; Vermeulen, 2003). The five dimensions gave rise to a multidimensional construct called "NSD competence". It is believed that "NSD proficiency shows the expertise that allows a company to provide resources and routines, usually in combination, to reach an end service" (Menor & Roth, 2007, p. 826) as well as "a critical precedent for performance of innovation "(p. 827), that is, it is seen as a precedent of performance in NSD (id, 2007).

Based on the literature presented, the hypothesis related to focus on the NSD process:

H1: *Focus on the NSD process* is positively related to performance in developing new services.

In studies by Oliveira and Roth (2012) the market acuity dimension was considered as an indicator within the market focus competency, which encompasses the company's ability to (1) understand its market and the need of its customers; (2) establish and manage the relationship with its customers and (3) develop new products and services. The results indicate that market acuity and NSD have a positive impact on market focus, which in turn reflects the company's service orientation.

Thus, the hypothesis related to this dimension is formed:

H2: *Market acumen* is positively related to performance in developing new services.

NSD strategy should be able to provide that the offerings of new services are in accordance with the expectations and demands of the clients. (Roth, 2007). In this way, it can be seen as an important agent of impact on the performance of the company (Cooper, Kleinschmidt, 1995, Johne, Storey, 1998).

Finally, the hypothesis related to this dimension is formed:

H3: *NSD strategy* is positively related to performance in developing new services.

In the conception of Storey and Hughes (2013), the NSD culture is characterized as an entrepreneurial culture, which focuses on the opportunity to generate new services in the external environment, the risk of entrepreneur and the search for the new. All these characteristics are positively related to the number of new services developed by the companies.

Based on this literature, the hypothesis related to this dimension is formed:

H4: *NSD culture* is positively related to performance in developing new services.

The NSD process also benefits from the use of IT as it allows the company to have access to the most accurate and real-time information, such as in the case of reporting and financial data to verify the process, in the development efforts of new services in a company or in decision-making cases where information needs to be available to all. (Fiedler et al., 1996, Froehle et al., 2000).

Finally, the hypothesis related to this dimension is formed:

H5: *IT experience* is positively related to performance in developing new services.

Methodology

This research is of a quantitative nature, characterized by the verification of a phenomenon through a technique of collection and statistical analysis (Creswell, 2009) and classified as cross-sectional because it seeks the understanding of a phenomenon in a certain period of time and space and the data are collected only once. (Collis & Hussley, 2006).

The data collection of the present study was performed through the survey method, considered as a method for collecting primary data from individuals of a sample and using a questionnaire elaborated by means of a specific software for such sample. (Hair et al., 2005).

Research Design

The next step of the research involved a more operational process of adjustment and verification of the collection instrument, consummation of data collection and statistical tests. Finally, the results were analyzed, thus enabling the verification of which hypotheses were supported and an attempt was made to interpret the

findings in relation to the existing literature. All this process mentioned above is part of the knowledge flow among the main components of a research, according to Hair et al. (2005).

The research design is presented and summarizes all steps involved in the present study: Data collection, Validity and Reliability, Regression Analysis, Results and Discussion.

Populations and Sample

The population selected for the validation of the instrument proposed by Menor and Roth (2007) consists of knowledge-intensive service companies. Companies are classified as Miles et al. (1995).

What fostered the choice of the KISCs was their importance in the world economy and for being one of the sectors that has grown the most in the service area. (Miles, 2005; Ostrom et al., 2010). With focus on Brazil, it is evident the great number of jobs generated by companies of this type, only in the activities of Information Technology, there are almost 390,000 people involved; considering technical-professional services this number increases to 871,000 people (IBGE, 2010).

As a source of search for companies, we sought associations, unions and technology parks to which they are integrated in order to ensure that the sample represents the study population with dignity (Collis & Hussley, 2006). Table 1 shows the surveyed entities.

Table 1 – Organizations researched

ABES *SOFTWARE*	Brazilian Software Entrpreises Association
ABRADI	Digital Services Developers
SDAERGS	Cutoms Brokers
SEPRORGS	IT Government Company
SESCON	Accounting service, advice, expertise and information
SOFTSUL	*Software* and related service
TECNOPUC	Information Technology, Automation, Engineering and Communication
TECNOSINOS	Information Technology, Automation, Engineering and Communication

Source: Prepared by Debora Moehlecke

The delimitation of the population of companies to send the research instrument was located in Rio Grande do Sul, Santa Catarina and Paraná. The sample consists of 239 companies related to four types of knowledge-intensive service companies, and the sector is classified as: (1) Advertising activities; (2) Engineering/architecture consultancy activities; (3) Business consulting and (4) IT and related activities. Table 2 shows this relationship.

In the research instrument, the companies were classified according to the number of employees of the company. It can be seen from Table 3 that almost 80% of the sample is from companies of 01-50 employees, which is characteristic of KISC (Miles, 2005).

Table 2 – Characterization of the companies

Sector de activity	Quantity of respondent companies	Percent (%)
Advertising	03	1%
Engineering/architecture consultants	06	3%
Business consultants	78	33%
IT and realted activities	152	63%
Total	**239**	**100%**

Source: Prepared by Debora Moehlecke

Table 3 – Characterization of companies by number of employees

Number of employees	Number of respondent companies and in (percent)
01-50	190 (79,5%)
101-200	15 (6,3%)
51-100	23 (9,6%)
More than 200 employees	11 (4,6%)
Total	**239 = 100%**

Source: Prepared by Debora Moehlecke

In order to validate the research instrument in question, the participation of the main actors involved in the development of new business was sought. One representative per company was interviewed from a total of 239 companies. It is believed that the goal of interviewing people who are really involved in the company's business and having a macro view of the market is verified since that more than 85% of the sample was made up of coordinators/supervisors, managers and directors of the chosen organizations, as shown in Table 4. This same caution in the choice of respondents was observed by Menor and Roth (2007) when they detected the right people for the data collection participation.

Tabela 4 – Respondent positions

Position in the company	Percent of companies
Auxiliary	1,3%
Assistant	7,1%
Analist	5,9%
Coordinator/Supervisor	3,7%
Manager	30,1%
Director	51,9%
Total	**239 = 100%**

Source: Prepared by Debora Moehlecke

As it is in the interest of the research to verify if the competence in developing new services contributes to the performance in NSD of the companies, it is necessary that the respondents are involved with the NSD and are aware of the results of the new developments.
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Data collection

The research instrument was composed of 29 questions, four of which characterize the company, twenty-one questions that cover the five dimensions: (1) focus on the NSD process; (2) market acuity; (3) NSD strategy; (4) NSD culture and (5) Information Technology (IT) experience and four performance-related questions. Table 5 presents the number of questions and types.

Table 5 – Type of questions de questions of the data collection

Type of question	Number of questions
Characterization of the sample	04
Dimentions of competence in NSD	21
Performance in NSD	04
Total of questions	29

Source: Prepared by Debora Moehlecke

Regarding the characterization of the sample, the respondent were: (1) number of employees of the company; (2) the company's sector of activity; (3) company name, and (4) the respondent's position.

Questions related to NSD dimensions and performance have originated from the NSD competency scale elaborated by Menor and Roth (2007) and validated in an environment of financial services companies in the United States (USA).

From the total questions of the "NSD competence" construct, there are an average of four questions for each dimension. All questions were measured using a Likert scale of 1 to 5, with 1 being: Strongly disagree and 5: Strongly agree. The questions were randomly mixed throughout the questionnaire and at no point was the interviewee quoted as referring to the dimensions.

First, the Focus dimension in the NSD process is verified through four questions found in Table 6.

Table 6 – Issues in the dimensions "Focus on the NSD process"

FOCUS ON THE NSD PROCESS
(P1) Our efforts to develop new services / products are composed of formal stages of development activities;
(P2) Our company employ resource and standardized routines in all new service development projects;
(P3) Our company employ formalized processes in all new service development projects;
(P4) All new service development projects are planned according to a planning of predetermined sequence of development activities.

Source: Prepared by Debora Moehlecke

In order to verify the Market Acuity, four questions were also asked as quoted in Table 7.

In order to identify how NSD Strategy contributes to NSD competence, four questions have been considered and are mentioned in Table 8.

Table 7- Issues in the dimension "Market Acuity"

MARKET ACUITY
(M1) Our company actively seeks out information about our business environment; (M2) New service offering are designed based on actively collected information about market changes and customer demand for such offer; (M3) Our company uses the information collected to respond quickly to changes in the competitive environment; (M4) Customers, both internal and external, are seen as potential and valuable sources of new ideas of supply and opportunity.

Source: Prepared by Debora Moehlecke

Table 8 – Issues in the dimension "Strategy of NSD"

STRATEGY OF NSD
(E1) The internal capacity available for the provision of services is one of the critical factors in the decision to "accept / reject" the development of new services / products; (E2) The ideas for developing new services products are largely driven by the global business strategy; (E3) Our strategy for developing new services and making new offer decisions is always formulated with the overall business strategy in mind; (E4) Senior managers are always willing to commit resources to promising projects to develop new services / products.

Source: Prepared by Debora Moehlecke

In order for the NSD Culture to be verified, four more questions were addressed in Table 9.

Table 9 – Issues in the dimension "NSD Culture"

NSD CULTURE
(C1) Our company encourages entrepreneurial efforts and accepts the risks stemming from these efforts; (C2) What keeps our organization together is our commitment to innovation and the development of new services/products; (C3) Our company values its human resources and a high cohesion and motivation of these resources in the activities of development of new services; (C4) Our company uses other forms of reward, such as recognition of the best employees, to reward the development of new services.

Source: Prepared by Debora Moehlecke

Finally, the IT Experience was covered by five questions listed in Table 10.

Likewise, the four questions were measured using a Likert scale of 1 to 5, with 1 being: Significantly low/below expected and 5: Significantly high/Meeting expectations. They were inserted in the text at random between the questions of performance/competence. Table 11 addresses the questions considered.

Data collection

Data were collected through a survey applied to the people involved in the development of new services. It was sent 990 emails in the first stage with only 39 companies answers. Then, it was decided to hire a company and two people, properly trained and guided about the purpose of the research, conducted 200 interviews. The chosen method of approach was to send emails to all those who had already been sent by the author in the first stage. After this stage, it was contracted professionals called the companies and identified themselves, questioning if they had received the presentation email with the link of the electronic questionnaire and whether the survey had already been answered. If not, I was asked if I would like to do it over the phone.

Table 10 – Issue in dimension "IT Experience"

IT EXPERIENCE
(T1) Information Technology (IT) is used to accelerate the introduction of new services and products;
(T2) Information Technology (IT) is used to identify and diagnose customer needs;
(T3) Information Technology (IT) is used to share the information that coordinates the development activities of new services / products;
(T4) Communication within the new service/product development groups is facilitated through channels using Information Technology (IT);
(T5) Our company uses technology to facilitate the flow of information among professionals who participate in the process of developing new services.

Source: Prepared by Debora Moehlecke

Table 11 – Issues related to "Performance/Competence"

PERFORMANCE
(D1) Considering the last 03 years, it can be said that the speed of development of new services in our company was ...
(D2) Considering the last 03 years, the percentage of new services that were successful in the market was ...
(D3) Considering the last 03 years, it can be said that the new services launched by our company that have succeeded in meeting the demand were ...
(D4) Considering the last 03 years, the overall performance of the new services of our company compared to the new services of competitors was ...

Source: Prepared by Debora Moehlecke

Descriptive statistics

Descriptive statistics were used to demonstrate the means and standard deviation of each of the 21 variables selected by Menor and Roth (2007) in their study and now applied to the KICS of the study. Data analysis was performed through statistical procedures using SPSS software version 19.0.

Conclusion

Given the importance of the service sector to the world economy and the rise of the number of knowledge-intensive services companies, it sought to understand in this study how these companies are developing their new offerings and how they can improve what is already being done, acting strongly on what has the greatest effect on the performance of an NSD program.

The main objective of this paper was to verify the relationship between the competency dimensions in the development of new services and the performance of the

companies in development of new services. To achieve what was foreseen, some specific objectives were stipulated.

It is believed that the purpose was reached, since through the multiple regression analysis, it was possible to verify the relationship of the competence-forming dimensions in the development of new services and the performance in NSD. It was found that, with the exception of the NSD strategy that was discarded from the analysis through the exploratory factorial analysis, all dimensions have a positive influence on the NSD success of knowledge-intensive service companies.

The first specific objective sought to confirm the relationship between the five dimensions in the development of new services of Knowledge Intensive Business Service (KIBS). It shows that all variables are positively related to the significance level of 0.01, not considering the NSD Strategy dimension, since it was previously excluded.

The second objective included the validation of an instrument of competency model for NSD). It is believed that it was possible to test and validate this instrument on the competence of companies in developing new services,

Finally, the third objective was to verify how the dimensions contribute together to the performance of KIBSs. It shows that the four factors can be considered as responsible for 30% of NSD performance and this result, although positive, indicates that there are other dimensions that also contribute to the success of a development project. a new service and that they can be explored at other times, thus enriching NSD research.

Focusing on knowledge-intensive service companies, it is believed that this paper contributes to the studies of this segment that is so prosperous these days. The analyzed dimensions that have been shown to have an impact on the development of new services can be used for further analysis in other companies with the same profile as the ones examined.

The importance of the KIBS in being in tune with the market and its customers is highlighted as managerial implications in order to seek information about their business environment and be prepared to respond quickly to changes in the competitive environment. This all represents the Market Acuity that has been listed as the greatest effect dimension in NSD Performance and can be achieved through information gathering through market research, and participation in fairs and events.

Likewise, the use of IT to share information among all those involved in the NSD deserves evidence. There are many data exchange tools that facilitate communication and allow activities to be performed more quickly, clearly, and securely.

More importantly, the results show that, although the NSD Process Focus is necessary, companies need to be careful about very formal stages of development because they can bureaucratize and hamper the progress of the project. By employing standardized resources and routines, unnecessary effort and time can be expended and the loss of momentum needed in this business environment can occur.

Although these contributions may be relevant, both for the Academy and for the business community, it is understood that this research presented some limitations. First, the research tool was applied to some types of KIBS, with a predominance of IT service companies and related activities. Therefore, this study used the sample to generalize the NSD profile of KIBSs in the Southern region of Brazil. It is known that other results could be found if the focus were, for example, on companies that provide technical tests and analyzes or surveys of area development of health.

Finally, this paper aims to stimulate further studies on the development of new services in Brazil and in emerging countries and was done with much dedication to serve as a reference for future research.

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Design for additive manufacturing: Motivations, competencies and performance impact

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Abstract

32 secondary cases on Design for Additive Manufacturing (DfAM) and expert interviews were used to identify motivations, required competencies and performance impact of AM. Findings suggest that weight reduction motivation coupled with topology optimization competency helped in reducing weight and the number of parts. Material choice competency helped in reducing weight or in improving part functionality or quality. Weight reduction also required design simulation. Choice of appropriate AM process parameters was needed to reduce production time. 8 case studies indicated a collaborative process between DfAM partners.

Keywords: Design for AM, motivation, competencies, performance impact

Introduction

Additive manufacturing (AM) technologies produce objects from computer-aided design (CAD) model data, usually adding layer upon layer, in contrast to conventional subtractive manufacturing methods that involve the removal of material from an initial stock (Gibson et al., 2010). AM provides new benefits that cannot be obtained with conventional production technologies like injection moulding, machining or casting. The capability to extend design freedom is one of AM's most important advantages (Levy et al., 2003). Trying to produce a part, originally

designed for conventional manufacturing using AM may not be beneficial and some of the benefits of AM can be obtained only if the parts are designed or redesigned for AM. These benefits can be user-fit requirements, improved functionality, parts consolidation and aesthetics (Campbell et al., 2012;Maidin and Campbell, 2011)

To take full advantage of AM, use of specialized computer-aided design software is required. Moreover, structured design tools and procedures are also necessary (Friesike et al., 2018). At the same time, product designers also need to be educated to take full advantage of the benefits which AM offers. Thus, the conventional knowledge, methods, and skills for component design have to be rethought, as product designers currently working in industry are trained to design for traditional manufacturing technologies like injection moulding, casting, machining etc. (Flores Ituarte et al., 2016).

In AM, designers should be encouraged to ignore the “design for manufacturing” limitations (Campbell et al., 2012). Furthermore, the conventional product design process is often conducted in a sequential manner considering a limited amount of discipline related variables but not evaluating across the entire product lifecycle (Mottonen et al., 2009). Boothroyd and Dewhurst (1996) pioneered design for excellence with their concept of design for assembly (DfA) which minimises the number of parts (Gershenson and Lai, 2008). DfA later expanded into design for manufacturing (DfM) including broader manufacturing aspects. Now, DfM is further referred to as DfX where X stands for considerations such as manufacturing, assembly, testability, reliability, disassembly, and cost (Gehin et al., 2008). DfX reduces time-to-market and cost as well as increases product quality (Gungor and M. Gupta, 1999)

Design for AM (DfAM) and DfM may have some similarities. However, manufacturing firms, utilizing conventional manufacturing may need to develop unique competencies to design products for AM. Currently, DfAM exercises in companies are primarily driven as individual exercises without developing a strategic perspective. This results in a scattered approach without full understanding of the competencies which need to be developed to achieve the specific performance objectives. Additionally, the performance impact of DfAM is not obvious as there are still multiple challenges associated with AM that include a limited choice of materials, design rules for different AM technology categories as well as post-processing requirements to make AM technology fit for end use. In the view of the challenges, there is a need to understand the motivations of the manufacturing firms to design or redesign parts for AM, the competencies which are needed to excel in DfAM and the performance benefits that companies are expected to obtain. Thus, the objective of this research is to address the following research questions:

1) What motivates manufacturing companies to design or redesign parts that are suitable for additive manufacturing (AM)?
2) What competencies are needed to excel in Design for AM (DfAM) and how do those differ from traditional design for manufacturing (DfM)?
3) What performance benefits can companies expect in adopting DfAM?

Literature Review

The literature review included scholarly journals from multiple databases by using these search strings: "design for additive manufacturing" OR "design for 3D Printing" OR

"design for manufacturing" OR "design for X". Using these search strings, 18 articles were chosen for further review.

We can understand DfAM as a new sub-category within the overarching DfX paradigm, which is in line with DfM but applied to AM technologies. The interesting fact is that DfAM is currently gaining momentum, as AM technology has become a reality as a manufacturing solution (Schmidt et al., 2017). In this regard, there is a need to predict that parts can be built using AM equipment, withstand the forces and other environmental conditions as well as achieve the necessary quality requirements (Gibson et al., 2010). This has fuelled interest in DfAM. Ideally, DfAM must consider: (i) novel design opportunities related to AM technologies including design rules, (ii) material and process constraints related to the different technology categories and (iii) a product lifecycle perspective including supply chain aspects, cost accounting and delivery time (Thompson et al., 2016).

AM and the understanding of DfAM provide new opportunities related to the design of complex geometries, which allows enhancing products by reducing its weight and improving its performance. For example, this is reflected in a number of cases to produce complex hydraulic manifolds (Chekurov and Lantela, 2017) or optimized heat exchangers (Chekurov et al., 2018). DfAM opportunities also relate to part-consolidation, which is the process of simplifying product assemblies by means of consolidating its parts into a minimal set of elements while maintaining its functionality (Flores Ituarte et al., 2019).

AM provides opportunities to reduce product development costs, production costs, costs over the entire value chain or provides some combination of these benefits (Thompson et al., 2016). The opportunities for DfAM are not only limited to enhancing products. Thus, in industrial settings AM allows to digitalising the manufacturing process to gain productivity, especially when there is a need for mass-customisation of assembly elements in an automotive gripper (Flores Ituarte et al., 2018).

Remixing i.e. the creation of new models on the foundation of existing design elements can also be a relevant possibility for DfAM resulting in better design process outcomes in terms of quantity and diversity of designs (Friesike et al., 2018). There are also opportunities for the application of machine learning to provide feasible conceptual design solutions for inexperienced designers by recommending appropriate AM design features (Yao et al., 2017).

However, new possibilities often necessitate new competences. While designing or re-designing a new component for AM, product designers have to ignore limitations from conventional DfM. They need to use their creativity to create product designs which are both functionally improved and geometrically complex in order to benefit from AM (Campbell et al., 2012). In DfaM, the design competences, engineering software tools, manufacturing process rules, and methodologies can become substantially different in comparison to traditional DfM.

To develop DfAM excellence, a methodical approach to formulate design rules with modularity for AM in mind is needed (Jee and Witherell, 2017; Adam and Zimmer, 2015). Competencies needed for DfAM include the ability to use finite element analysis combined with design automation, which can accommodate complex functionally graded materials and topology optimized structures while predicting material layout and part performance in accordance with desired outcomes (Boddeti et al., 2018;Vaughan and Crawford, 2013).

Choosing the appropriate material and processing technology combinations for the particular design is often challenging (Kretzschmar et al., 2018). Different AM technologies have different operating principles, processing characteristics, and compatible material types. The consideration of process-specific variables during the design process is critical for DfAM as those have impact on achievable mechanical properties as well as operational implications in terms of manufacturing time. A supporting competency to decide whether AM is feasible or not included the ability to estimate AM part costs based on few parameters early in the design process (Baldinger et al., 2016). Chiu and Lin, (2016) also demonstrated how DfAM and Design for Supply Chain need to be considered together for customized products.

In summary, this review showed a wide area of opportunities to benefit from AM integration. However, such benefits can only be realised if new competences are developed. Moreover, the opportunities related to DfAM differ from industry to industry and also for different applicants wihtin the same industry. Consequently, performance benefit of DfAM implementation is expected to be different from company to company. We fill this research gap by providing a comprehensive understanding of the motivations, the competencies, with which firms can excel in DfAM as well as the performance benefits, which firms can expect from DfAM.

Research Methodology

The first stage was to analyse the DfAM case studies published by AM service providers, equipment manufacturers, and specialised trade journals. The included cases document DfAM cases of successful AM implementation describing how companies benefited from the technology. Table 1 shows the overview of the included cases, the columns represent the industrial sector. Whereas, the rows show the DfAM service providers involved in the cases. In the second stage, semi-structured interviews with AM experts were conducted. For this paper, we could conduct 2 such expert interviews – one with an industrial products manufacturer as an user of AM and another from an AM service provider.

Table 1 – Distribution of secondary cases across industry and service providers

AM Service providers	Aerospace	Automotive	Industrial Products	Consumer products (toys and jewellery)	Cycle manufacturing	Telecom.	N/A
3D Systems				1			
Autodesk		1					
EOS	2		5				
Materialise	1	2	4	2		1	
Renishaw			2		2		
SLM Solutions	2	1	2				
Stratasys			1				1
Voxeljet		1					
Altair, Materialise and Renishaw							1

Out of 65 case studies, 32 cases explicitly covered DfAM aspects. These 32 cases were included as secondary data, from where 5 cases were related to aerospace, 5 cases related to automotive, 14 cases were related to industrial product companies, 3 from consumer products (toys and jewellery), 2 from bike manufacturing and 1 from telecommunication while there was no information about the industry for 2 cases. In summary, 7 of the 32 cases were for production tools like jigs, fixtures or grippers while the remaining were for parts or components of end products.

In summary, the literature review is followed by the collection of relevant secondary data of DfAM cases to conduct cross-case analysis of the motivations, competencies and performance improvements. The semi-structured interviews helped in understanding the competencies required to achieve benefits from DfAM implementation, the role of collaboration between partners and to specify the differences between DfAM and DfX. Data from the secondary cases and the interviews were analysed using text-mining techniques using Nvivo software.

Findings

Analsysis of secondary DfAM cases

The findings from the secondary data and included case studies show that the primary motivations for companies to implement DfAM were (i) weight reduction, (ii) development and production of complex parts, (iii) product customization and (iv) reduction of development and go-to-market times. The key competencies identified for DfAM are choice of appropriate materials and related technologies, topology optimization, conducting design simulations and determination of appropriate process parameters. 8 case studies explicitly indicated that a collaborative process between specialized service bureaus offering DfAM and end customers is needed. As the motivations for conducting the DfAM showed the intentions for the companies, the compoanies were able to achieve performance improvements directly associated with the motivations but also got some additonal or secondary performance improvements. The predominant performance improvements obtained were weight reduction, development time reduction, reduction in production time, customization, fewer parts and reduction in manufacturing costs. Thus for example, where weight reduction was the primary motivation, apart from achieving that, reduction in number of parts, improved functionality and development time reduction were also obtained in some cases.
We also conducted analysis by industrial sectors and found that for aerospace companies, the primary motivation for DfAM was weight reduction, the most frequently mentioned competency was topology optimization and the performance improvements obtained were weight reduction, reduction in production time, material consumption reduction and reduction in the number of parts. For automotive companies, the primary motivation was weight reduction and customization opportunities, the most frequently mentioned competencies were topology optimization and application of 3D geometry at slice level instead of at the STL (Standard Tessellation Language) file level where the performance improvements obtained were in weight reduction and improvement of product functionality and performance. Use of slice-based technology helped in keeping to keep the files light, by postponing the calculations of the full design until the slicing step

For industrial product companies, motivations were difficulty in machining the original part, development, and production of a complex part, customization of parts, reduction in development lead-time and weight reduction. The competencies mentioned were choice of appropriate materials and determination of the optimal process parameters.

The most frequent performance improvements obtained were weight reduction, enabling customization, reduction in development time

The text analysis of the motivations, competencies, and performances in terms of coding similarity across the secondary data reveal the following relationships:

- The motivation of weight reduction coupled with competency of topology optimization results in performance improvement in terms of weight reduction.
- Choice of materials as a competency results either in weight reduction, improved functionality or improved quality of the part while design automation and topology optimization are also needed to achieve weight reduction.
- Similarly, the choice of appropriate AM process parameters is needed to achieve reduction in production time while automating design process results in cost reduction.
- Application of 3D geometry at slice level results in improved product functionality and performance.

Analysis of the 8 cases which specifically mentioned collaboration between different partners revealed that the AM service providers provided expertise in choice of optimal process parameters and in improving the design. In turn the service providers learnt a lot about the needs and challenges faced by the customers.

Insights from interviews

The expert from industrial products industry mentioned that the competencies needed for design from AM from their perspective are topology optimization, choice or development of appropriate materials, developing multi-functional parts and simulation as for complex geometries, as it is quite difficult to simulate the performance. He mentioned *"Material considerations are extremely important because we design our component with a minimum 15 years of life time. We need to make sure that this 3D printing material they can really stand this."* This also validates our findings from the secondary cases.

To develop design for AM competencies, we learnt from our expert that their company organizes workshops where they co-developed a design rules catalog for engineer teams and R&D teams covering four different AM technologies. They also conduct two-day trainings with an external partner. The industrial product companies reported benefits in terms of weight reduction, reduction in development time and production time, reduction in manufacturing costs and in number of parts. He also mentioned that improvement can be in terms of product efficiency improvement through merging of functionalities in the product and the ability to customize products according to customers' needs in low volume.

Companies use design for AM for designing or redesigning parts as well as tools. The industrial products company where our expert works has designed press tools, which can be 3D printed, which reduced the costs of producing the tools and also ensured that the tools are more precise. They are also co-developing generic grippers in collaboration with another company, which also needs grippers in their production process, to cover a wider range of sizes for the components, which the grippers can pick.

An expert from a service provider pointed to a balance between having an open mindset towards AM while keeping a realistic eye to the limitations of AM as a key competence beyond the required skills of design skills such as CAD/CAM and other

software skills. A drawback with AM adoption can be if managers excessively try to exploit the speed and cost benefits of AM leaving too little time and budget to improve the product using the possibilities of AM.

Research Implications/Limitations

AM promises the creation of unique parts and products with functionality that was hitherto impossible using conventional manufacturing technologies. However, product designers need to rethink their restrictive design mindsets to explore the full potential of AM. This also requires the development of unique competencies and stronger collaboration with internal and external partners. Limitations of the study are that we have used 32 publicly available secondary case studies but managed to conduct only 2 expert interviews at the time of writing the paper. We plan to include more case studies across service providers in our database and conduct more interviews. It should also be noted that all the secondary case studies did not report the motivations, competencies and the performances.

Conclusion

Analysis of the secondary DfAM cases and the interviews with experts revealed that companies design or redesign both parts and production tools for AM. Though some similarities exist in terms of motivations, competencies and performance impact of DfAM across sectors, there are also some differences. We could also identify some specific linkages between motivations, competencies and performances. Hence, companies having similar motivations and desire for particular performance improvements should develop the required competencies or engage service providers which can provide those competencies.

This research has been explratory in nature. For future research, potential theoretical perspectives such as contingency theory, design science and knowledge management can be used to analyse the secondary cases and the interviews to compare the cases across industries, across service providers and across applications eg. parts and production tools. Future research should also be directed in developing a competency framework for DfAM, analysing how service providers and customers can collaborate to develop those competencies and for empirically validating the relationship between motivation, competencies and performance impact of DfAM using survey data.

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Data-driven Proposal Preparation

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Abstract

Constructors of special plants are often developing new plants from the scratch without the economic knowledge of old offers flowing into them. Although rules on technical feasibility or the like are typically taken into account, no conclusions are drawn from the success of historical offers systematically. The paper is going to examine possibilities on how to improve sales representative work using data driven technology. Innovative planning processes are supposed to help design and offer new plants based on knowledge extraction and insights from historic data.

Keywords: Analytics, Big Data, Business Process Management

Purpose

Companies in plant construction and mechanical engineering plan and manufacture customized products. Quotations are created individually based on customer specifications. There are many different possibilities in degrees of freedom for the design of a system's structure, when planning and using technical components. Due to the high diversity, sales representatives are principally involved in configuration work. In addition to the effort in the planning procedure, calculation of costs as well as lead time and production time must be taken into account. From the IT point of view, planning processes uses appropriate databases for technical components and materials as well as software-tools for quoting. Special manufacturing software is used to evaluate automatically the plant design via rule-based verification to check the feasibility of system requirements.

It is possible that specific requirements in certain areas recur over time, however, currently it can only be identified based on the experience gained by the plant designer. That means the new quotations might lead to increased diversity in plant design based on the employee's planning capabilities and inclinations. Requirements are reconsidered and thus reconfigured. There is also a lack of systematic feedback to the extent that a system configuration has proven to be successful – in the interest of the customer as well as timely and ultimately profitable completion by the system manufacturer. Some companies try to counter diversity with strict standardization. On the other hand, however, standardization slows down technical developments and is very costly.

Quotations accepted by customers culminate in an order and trigger all necessary manufacturing and value-added processes in the factories. A project order generates a large quantity of information in the processing phase and precisely reflects the actual production processes and material requirements. Relevant information is generated during order processing as a data record by various planning systems and is stored for a long period of time.

This provides a basis for a reflected consideration of all past business processes and can be used as a foundation of experience for future planning during the quotation process. In the long term, data-driven project planning information can help to integrate the successful planning and strategies of the past into new quotes and, in addition to process optimization, can also offer better chances of acceptance to order.

Investigation

Nowadays almost every bigger industrial enterprise is storing a lot of business and process data by the use of well established enterprise systems, such as ERP. Core requirement for such systems is to store data confident and secure in table structures in a Database Management System (DBMS). The management is going to ask questions about how to make use of these already stored data to accelerate and improve plant offering processes. Comprehensive and complex analysis is needed to answer these questions by use of plant information of past orders. A process mining is required to use event data to extract process-related information (van der Aalst, 2016). For optimization of planning processes through of configuration proposals, extensive knowledge of the data landscape of the manufacturer is required. The focus is on identification and processing of relevant data from the planning systems. With lot of different kind of data in bigger size and structure, analysts are confronted with huge virtual data rooms and the need of systematic information discovering process, such as ETL (Extraction, Transformation and Loading) and mathematical basements like pattern recognition algorithms to carry out how data can be used to solve future business problems. By compressing and enriching the data, the opportunity to implement new Business Intelligence (BI) analytic tools in business operations is created. The paper is showing selected work of preparation mechanisms and giving ideas of how to examine data from different sources and complexity.

The underlying structure of the investigation is shown in *Figure 1*. It shows an abstraction model referring to plant building processes. This model defines any project as a plant. Each of them is going to be separated into panels. Plant sizes variate between 5 and 20 panels depending on the customer needs. In the next level panels contain appliances and material which are varying in amount up until hundreds of pieces. They have lot of detailed information about article number, assembly lines, costs and origin data. The quantity increases the more functionality is requested by customer requirements. The whole functionality has to be fitted into an external case with space limitations. Configuration options are high because of so many possibilities to combine different functionality in different panels.

In summary a plant carries out a finite set of functions. That provides a starting point for doing research on the possibilities of a comprehensive description of plant functionality based on all the stored information about already realized projects from the past. The paper shows the investigation and results about the ability to analyze and extract functional groups out of data and gives ideas on use cases where proposal preparations increase the value in planning situations for manufacturer in sales representative work. The following sections describes the necessary steps from data extraction to finally present transformed data in an innovative planning process.

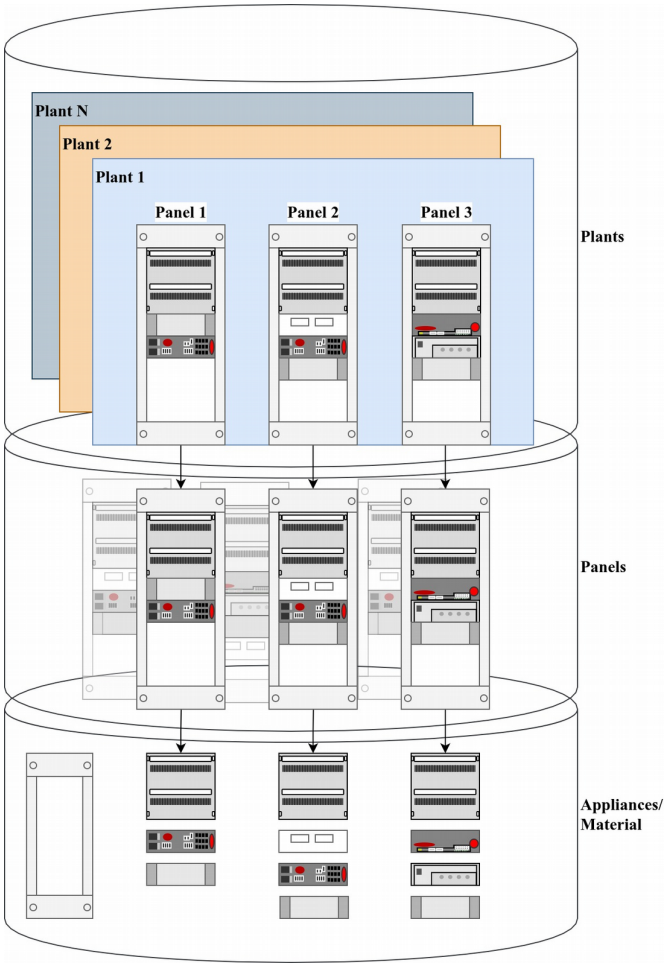

Figure 1 – Level of Abstraction

Process of Extract, Transform, Load and Display

"ETL was born on the first day that a programmer constructed a program that takes records from a certain persistent file and populates or enriches another file with this information. Since then, any kind of data processing software that reshapes or filters records, calculates new values, and populates another data store than the original one is a form of an ETL program" (Vassiliadis, 2009). ETL is part of a design process and the architectural fundament where data is gathered, cleaned and transformed. The automated exposition of information and knowledge out of business data is a holder of value. By the use of information technology, data from different sources with different structure is collected, transformed and finally loaded into a highly compact data room where analysis can start to figure and show reality out of historical data in charts and graphs. The process is consolidated as Extract, Transform, Load and Display process (ETLD). For the development phase the Big Data Integration needs specific technology and tools to handle data right before it can be consumable for effective decision making (Bansal, 2015 | Kandogan, 2013).

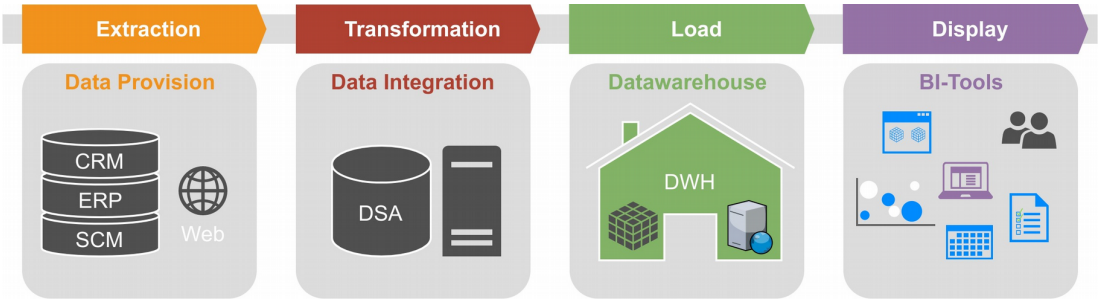

Figure 2 – ETLD Process

Figure 2 is going to show the data flow from different sources to a final centralized storage, so called Data Warehouse (DW), where the analyst benefits on the results of having well structured data with the ability to extract insights and expert knowledge for re-use in operations and generating reports and graphs. The steps in between as main part of ETL are usually extensive but a very important work to establish a Data Staging Area (DSA), where the meaning and understanding of information is extracted out of raw data sets. The main goal for the engineer is to design a DW in a meaningfully powerful software environment. During the research the analytic tool KNIME (Konstanz Information Miner) was used to load large data sets from different kind of sources and to start developing and doing analysis on data collections (Berthold, 2018). One big advantage by the use of open-source client software KNIME Analytics Platform that it is a useful tool for analysis even without or less programming skills. The individual steps of calculation can be done by drag and drop of nodes by using a graphical interface and all the work can be separated into different workflows. It is a modular and highly scalable processing platform. The software has been placed in the leader category in Gartner's 2018 Magic Quadrant for Data Science and Machine Learning Platforms (Gartner, 2018).

Data extraction

"Data provisioning constitutes the prerequisite for any Business Intelligence (BI) project" (Grossmann, 2015). The first step is to collect data from storage locations like legacy systems, files under any format, web pages or various kinds of documents (Vassiliadis, 2009). The many of different data sources has its distinct set of characteristics that need to be managed. Extraction processes needs to be effectively, while the integrated systems have different platforms, such as varying DBMS, several operating systems or a variation of communication protocols (Shaker, 2011). All the information about orders (actual costs, plant configurations, parts lists, purchasing and logistic details, production sequence) in a period of the last two to three years is a basement for extensive data analysis. The pool of information should reflect the current possible plant configurations as good as possible to avoid planning with outdated functionalities. During ERP research data from already processed orders has to be identified. Every information about costs, design conditions, material and production sequence of each order is important and required to maximize the ability of analysis. After the selection every relevant source of raw data is saved separately into file systems like CSV. The possibilities on how and where to store the input data depends on the system environment and restrictions of the company.

Data transformation
Data preprocessing can be seen as a collection of calculation tasks. All the single data sets have to be cleaned and examined in detail. Unnecessary information is filtered out and many additional computational steps like grouping, pivoting and sorting take place. After these preparation steps, related data has to be joined with each other. Therefore identifiers like the order number is necessary to enable connection. *Figure 3* is showing an example of joining two lists from different sources and afterwards grouping the result by project ID while calculating the sum of single material price and storing ID and description of material in an array. A collection of data is created, which reflect the original data in compact form and represent project insights in summary. In order to increase information content, key figures are processed to enrich the analysis with more contextual knowledge like the sum of material costs for each panel or the quantities of material input for specific functional solutions in plants.

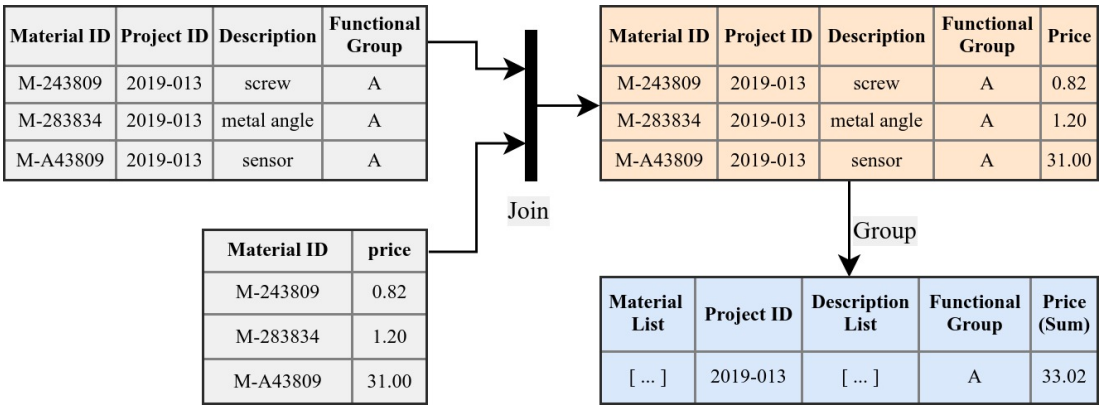

Figure 3 – Joining and Grouping data

Data loading
The developed data landscape is stored permanently in a data warehouse (DW). Data records for data mining procedures are retrieved from this storage, which leads to the development of planning instructions. Searching and understanding the structure of planning processes is the main task during the analysis. It needs a deep understanding about the manufacturing process in general and product line information in particular. The structured data sets are holder of value about plants, panels and material from already closed orders as a historic summary based on ERP data. They include technical insights of each plant, configurations and listings of components of value. The data now can be evaluated in different abstraction levels as shown in *Figure 1*. The higher the degree of abstraction, the better analysis is going to build on.

Display
After preprocessing and storing the possible interesting data, various algorithms can be used to analyze large data sets to find coherence, rules or similarities in context of appliances, configurations, panels and plants. Afterwards the collected information is taken as valid basement for proposal needs in future planning processes. The findings are transferred and displayed in new services for a business intelligence environment.

- *Prediction and Classification*
  In many applications of Data Mining data sets are compared with each other to divide them in sensuous groups. This division can be determined by Distance and

Similarity (Cleve, 2014). On this occasion the similarity between data sets is assignable by calculated distances.

- Distance $dist(x, y)$
- Similarity $simil(x, y)$

To determine the distance of data points a distance function is required. During the research the Euclidean Distance is used. Therefore in advance the interesting nominal data (plant characteristic with specific value) have to be transformed into metric normalized data. Most algorithms for pattern recognition require normalized data (Shmueli, 2017). Similarity between two data sets is greater the smaller the distance between them. If the distances of all several data points takes the value down to zero, similarity becomes identical.

Similarity between two data-points (1):

$$simil(x, y) = f(dist(x, y))$$

Euclidean Distance (2):

$$dist_E(x, y) = \sqrt{\sum_i (x_i - y_i)^2}$$

One possibility for a planning note is the detection of similarities in the plant configuration. To be able to generate these suggestions, the planner specifies various project characteristics by entering customer requirements or research criteria (starting point of each analysis for proposals). Within existing project collections, records are searched for these characteristics. An algorithm computes the Euclidean distances between the planner's entered characteristics and the prepared project data from the data set. This procedure is referred to as Similarity Search (see *Figure 4*) and replicates similarities, which are then proposed (displayed) to the planner.

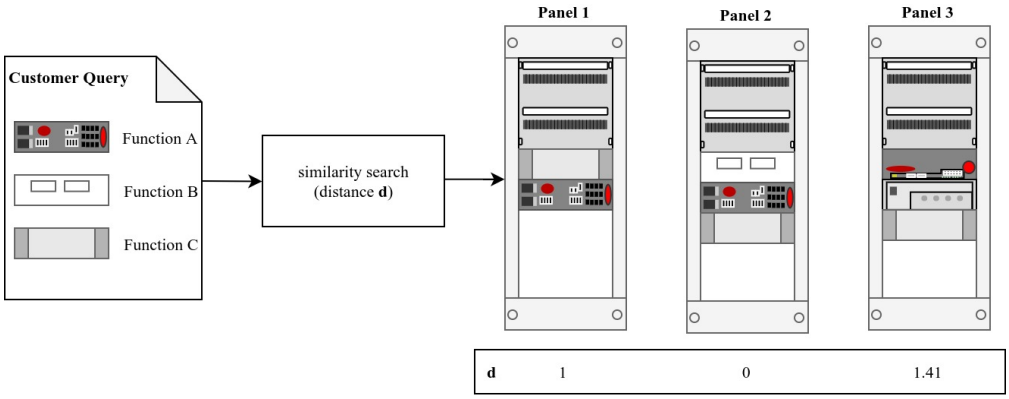

Figure 4 - Similarity Search in given realm of experience

Table 1 is showing an inquiry of a customer in a way of a summary of functions to fulfill the requirements to a specific panel. The closest panel configuration is shown with a distance of zero. It does not matter how many functions are requested. Important for the analysis is always the most possible fulfillment.

Table 1 - Distance of matching criteria

	Function A	Function B	Function C	Distance
Customer Query	1	1	1	0
Panel 1	1	0	1	1
Panel 2	1	1	1	**0**
Panel 3	0	0	1	1.41

Results of a search ideally provide information about the planning structure (design data, parts lists, material scope) and production costs. If tracked, the ability to improve the insights by showing building and delivery times. This process speeds up the quotation planning process and increases the accuracy of pre planning of the offered content. Even processes during the execution benefit from the higher accuracy in the offer phase. Different planning steps can be partly automated in the future by the knowledge extraction.

- *Relationships Among Records (Item Sets)*
  Another possibility of providing project planning support is the usage of association rules explored out of a frequent item set mining process. If individual items showing up together in many transactions, an association between them is going to identify. These learning over transactional databases is also called as affinity analysis or market basket analysis (Cleve, 2016 | Shmueli, 2017). Association rules are often used by online retailers to give customers recommendations in topics of "frequently bought together".

  With usage of the Apriori algorithm it is possible to discover the appearance of frequent itemsets out of large transactions (Agrawal, 1993). "Determining what qualifies as a frequent item set is related to the concept of support. The support of a rule is simply the number of transactions that include both the antecedent and consequent item sets" (Shmueli, 2017). The analysis is discovered with the fast calculating algorithm of Borgelt, called "Item Set Finder" (Borgelt, 2002). KNIME has an implementation of this algorithm as a workflow node. For the needs in planning situations the analysis helps to show up associations between appliances and material, where it comes to specific functional requirements.

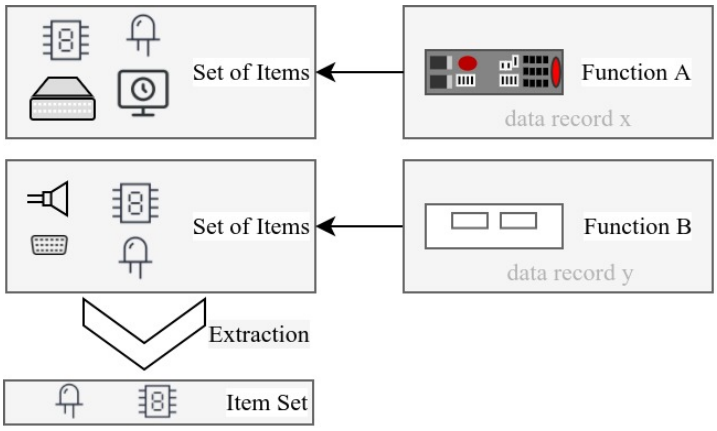

Figure 5 – Extraction of Item Set

If a plant planning process is thought as a fulfillment of functionality (functional groups), item sets can be extracted out of already processed solutions from the past and displayed during new planning situations. Therefore, the Apriori algorithm is used to determine the frequency of occurrence of material combinations. *Figure 5* is showing a simple example what the algorithm is calculating out of given data records (x, y, ...). Any Function (A, B, …) represents a list of material as a data record, which is contained in past orders. If a new customer query with subsets of information (items) is given, proposals of design solutions appearing during the planning. In *Figure 6* a given item selection is taken as input parameter and the analysis is given back all possible solutions in terms of functionality (Function A or Function B includes both items).

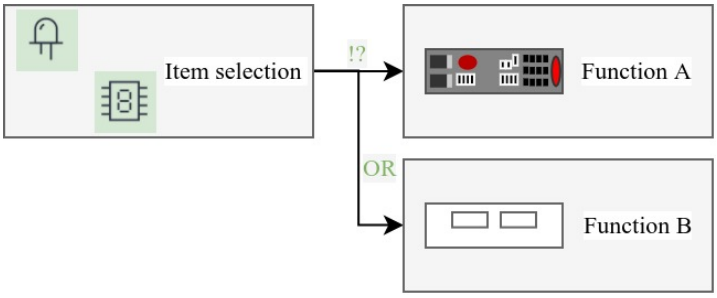

Figure 6 – Proposals of functions

Once the possibilities of searching and recognition for patterns are developed, a graphical interface is needed and some form of interactions with the user to benefit from the intelligent search algorithms. *Figure 7* shows a possible setup of such a use case. After passing the functional requirements into a summary list for each individual panel, the algorithms in behind take the information and discover the most similar planned panels with detailed business and plant configuration insights.

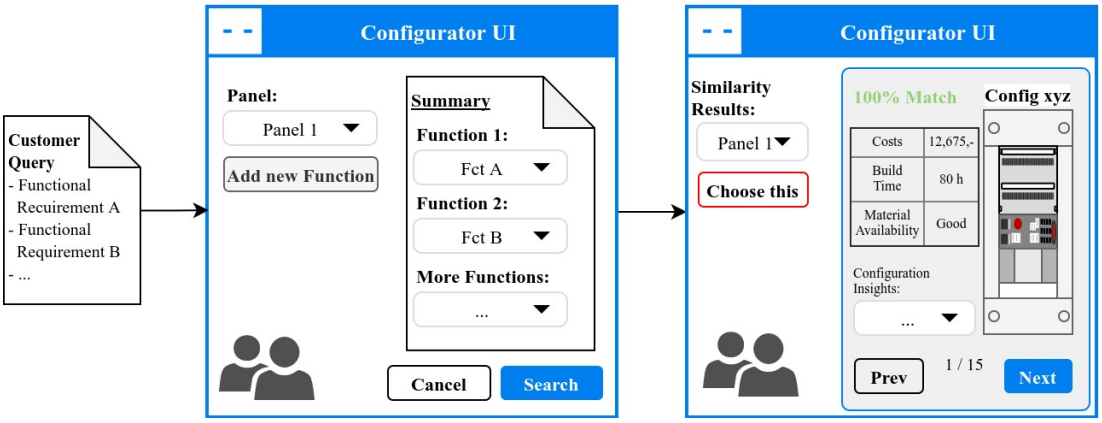

Figure 7 – Display proposals in User Interface

Nowadays the rapid technical evolution of internet technologies gives reason to believe in web application development in analytical based processes. During the research different web application frameworks like Ruby on Rails and React where included into technical implementation. The biggest advantage is the use of a powerful Back-End Server to solve large machine-learning problems, while the Front-End Client (User) only needs to

open a specific URL on the browser to get shown the already calculated results of the data-driven technology without installing any new software on the computer.

Discussion and Conclusions

The present result motivates to focus in a fully automated offer planning process in plant production situations if the management is looking for standardized solutions. The possibilities to extract already planned solutions of plant designs are high by the use of data-driven technology. Every successful solution in planning situations can be tracked, analyzed and showed. In future scenarios there must be a way to serve a configuration tool directly to the customer to ask for their needs as a function based query process. Therefore the customer is guided to all possible solutions – a kind of "soft" standardization. This increases a higher planning comfort to both, the manufacturer and the customer while the inquiry of needs is based on a more structured planning process in less time.

If it is possible to implement an automated configuration process based on criteria from customers and historical data, it should also be possible to highlight information about current factory workload, availability and delivery times for required material and much more (even external) scenarios with the ability to use analytical insights in all departments of the factory to improve the business process in general.

Midsize and large companies with plant manufacturing background are encouraged to discover their data lakes. Doing research on data-driven process management gives many possibilities to return information from already worked out solutions into future operations, especially in planning processes. The velocity and power of intelligence software environments help companies to improve their needs in digitization and Industry 4.0 context.

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A procedure for finding key factors for new product development evaluation; a conceptual model

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Abstract

This paper develops a conceptual model for finding key factors for new product development (NPD) evaluation. It builds on the work of the most cited and published authors on innovation management, but transfers attention from advertising aspects and efficiency, to factors identified within the NPD process such as new product project definition, a firm's resources, organisation-product fit, and commercial entity, that would lead to success. This paper exhibits a summary of the results, that is based on these authors' work with their corresponding correlation coefficient between the factors and outcome measures. Further, analytic hierarchy process (AHP) was used to evaluate results.

Keywords: New product development (NPD), New product project, Project evaluation.

Introduction

In recent years innovation has become an important element of economic growth in industrialised countries and is also considered as an essential component of an organisation's processes which are needed for long-term prosperity and survival.

A key function which contributes to the innovation process is new product development (NPD) (Harris & Trainor, 2009). Two critical questions need to be addressed by managers of any new tangible product project when selecting the most promising new products; what determines the success or failure of new products, and what differentiates between a new product's success and failure? (Cooper & Kleinschmidt, 1987). Although many organisations allocate a substantial amount of financial, human capital and other resources to ensuring the effectiveness of the innovation function, projects can still fail. Failure is not necessarily caused by the lack of commitment of managers and other employees, but, conceivably, by a lack of understanding of the key drivers of NPD (Pisano, 2012).

The purpose of this paper therefore, is the creation of a procedure to determine the key factors for NPD success, to aid the evaluation of NPD projects within the manufacturing industry. The creation of a new conceptual model is the foundation of the process.

The first time that a conceptual model was used for uncovering key factors of NPD was in Cooper's 1979 study, Project New Prod I (Cooper, 1979). Cooper argued that conceptual models aid in the determination of new product outcomes and allow for deeper recognition of factors that might influence NPD performance.

Additionally, this paper frames the factors and sub-factors of NPD based on rational planning and problem-solving perspectives of research. The focus of the rational planning of research is to determine the factors that affect the financial performance of the new product project. The problem-solving stream looks at the implications of development teams, suppliers and team leaders, which influence the NPD process. This stream was based on a Japanese development discipline, which has at its core a cognitive theoretical orientation, which embraces flexible and different problem-solving methods first applied in Japanese project teams (Song & Noh, 2006).

These two streams of research complement the novel theoretical framework that this paper's conceptual model uses, which is a resource-based view (RBV) of organisations. RBV aims at determining the influence of a firm's resources such as, people, product development, product testing and launch on the financial performance of the NPD projects. All assets, capabilities, processes, and organisational attributes such as information and knowledge are considered as resources, which are needed for the development of strategies that enable firms to be effective and efficient in their creation of a new product project (Calantone et al., 2006).

Thieme (2007) ranked the leading authors' work in the field of innovation by the number of publications across 14 leading journals on technology and innovation management, marketing, and management, between 1990 and 2004.

This paper's conceptual model focuses on work of the leading authors recognised by Thieme, and was derived by critically evaluating the work of Robert Cooper and Elko Kleinschmidt (ranked by Thieme as 2nd and 5th respectively), Michael Song, (ranked 1st), and Roger Calantone (ranked 3rd).

Conceptual models

Cooper's 1979 conceptual model, known as project New Prod I, was used to evaluate the impact of different factors on the outcome of the new product projects. In this model Cooper organised the factors under different categories, such as the nature of the project, its environmental category and "commercial entity". Cooper suggested that the success or failure of a new product project is based directly on the relationship of its "commercial entity" with the market; other categories mainly influence the commercial entity directly, therefore affecting the overall outcome indirectly. (Cooper, 1979)

Song and Parry (1997) expanded on Cooper's project New Prod I conceptual model by creating eight hypotheses that considered the direct and indirect relationships of the factors underlying Cooper's three categories:

H1 The positive effect of competitive potency level on 'Market and competitor intelligence' but negatively affects 'New product competitive advantages' and 'Degree of new product successful out-come'.
H2 The positive affect of firm's marketing skills and resources on 'Market and competitive intelligence' and 'Proficiency of marketing activities'.
H3 The positive impact of firm's technical skills and resources on 'Market and competitive intelligence' and 'Proficiency of technical activities'.
H4 The positive effect of cross-functional integration on 'Market and competition intelligence', 'Marketing activity proficiency', 'Technical activity proficiency' and 'New product success'.
H5 The positive affect of marketing and competition intelligence on 'Market activity proficiency', 'Technical activity proficiency', and 'New product success'.
H6 Market activity proficiency positively affects 'product competitive advantage'.
H7 Technical activity proficiency positively affects 'Market activity proficiency' and 'Product competitive advantage'.
H8 Positive affect of the product competitive advantage on 'the new product success'.

Cooper and Kleinschmidt's (1987) conceptual model was based on Cooper's previous research and empirical evidence, and demonstrated the relationship of the environmental factors with the new product strategies and implementation. They defined new product strategies as the new product itself, namely, product design, product advantages, and the launch of the new product into the market. The product strategy is the outcome of the new product process from the idea generation to product launch. The relationship between environmental factors and new product strategy is that the latter is executed within the organisation's environment.

Song et al (2003) proposed a conceptual model, which examines the relationship of project management characteristics, consisting of factors such as project management style, project manager skills and senior management support, with structural and process dimensions that has factors such as cross-functional integration and planning proficiency.

Calantone and other's (2008) conceptual model combines the key factors of NPD recognised Cooper and Kleinschmidt's and Song et al., by determining the direct and indirect impact of proactive strategic orientation of an organisation and organisational structure on the successful outcome of the NPD process. Calantone et al (2008) explain the proactive strategic orientation of an organisation as the aggressive action and

strategies of an organisation, and the organisational structure as the work allocation and administrative aspects that directs activities, resources and coordination of these aspects of the NPD process. They also considered environmental turbulence such as market, competition and technological changes as a moderating factor for the relationship of the interorganisational aspects that is not under managerial control. The impact that environmental turbulent has on the relationship of the factors may influence the outcome of the NPD project.

Methods

In 1979, Cooper examined which factors lead to success or failure and collected data from 177 manufacturing companies from a variety of industries in Canada. He collected data by telephone initially, and then a questionnaire followed by mail. The first part of the asked each organisation to choose two of their new products, one successful and one unsuccessful product. This was followed by a more detailed questionnaire in which a list of 77 statements, formed from the factors of the conceptual model, were presented to the managers, who then were asked to agree or disagree with the statements on a scale of 0 to 10. Cooper used two statistical measures for evaluating the relationship of these variables; the analysis of variance (ANOVA) and the correlation coefficient. (Cooper, 1979)

In 1997 Song and Parry started by creating a questionnaire and inviting 28 new product teams; 16 from Japan and 12 from the United states. They pre-tested their questionnaire thoroughly by sending samples to four Japanese organisations. Finally, 792 companies, traded on the Japanese stock exchanges in Tokyo, Osaka and Nagoya, were surveyed.

From the survey, Song and Parry recognised that 611 companies had introduced manufactured goods to the market since 1990. They then selected randomly, 500 manufacturing organisations from these, and sent-out personalised letters with two copies of questionnaires in each and they received 788 usable questionnaires from 404 of the companies. Multi-item scales were then used to measure all constructs, which are the factors and sub-factors mentioned in their eight hypotheses. Performance measures, such as profitability and sales volume, were used for determining the success of the new product in its market. (Song & Parry 1997)

Cooper and Kleinschmidt's 1987 project, New Prod II, determined which aspects of new product projects affect which success measures and whether there are different dimensions of success. The study focused on two major problems; the extent to which the success of the new product project can be measured, and the perspectives by which it can be measured, and whether such independent measurements exist, and; what the different aspects of identifying the success of the new product project are, and whether there are there similarities between them.

To do so, Cooper and Kleinschmidt gathered 200 new product project cases from 125 various manufacturing organisations. Out of the 200 cases, 120 were successful projects and 80 were not. They conducted interviews with managers and project leaders assigned to these projects. The interview was conducted around 5 important aspects; the nature of the product and the advantages that it offers; the product's target market and the attractiveness of the market; the risk related to the purchase of the product by the consumer; the product organisation fit or synergy, that is, does the new product project fit with the firm's resources, skills and experience, and; the organisational commitment to the new product project and how well defined were the protocols for engaging for its

development. Between seven and ten questions were formulated for each aspect, resulting in a total of forty questions, with responses based on a scale of 0-10, in order to understand fully the nature of the new product project. (Cooper & Kleinschmidt, 1987)

In comparison, Song et al's 2003 study focused on data received on 64 and 128 new product projects from Japanese and Korean OEMs respectively. These products were tangible and were from industries producing for example, semiconductors, electronics, computer, instrumental, audio-visual and communication products. Each product manager selected four relevant new product projects, which were representative of the firm's newest technologies and operational methods. Again, the questionnaire responses were on a scale of 0 to 10 and some verification of the data garnered was conducted from company records. They tested their hypotheses in two stages, a measurement model and a path model. (Song et. al, 2003)

Calantone et al's 2008 study was conducted on 346 manufacturing organisations from the Fortune 500 list. The questionnaires were sent to managers of new product projects or managers of special business units. The response rate for this research was 58%, were from 41 different industries and comprising of products produced within the last 5 years. To analyse the results, they used a two-step approach for the separation of the measurement model from the structural model. (Calantone et.al 2008)

Results

Cooper's environmental category was divided into three factors; the market, the firm's resources and the nature of the project. Cooper concluded that the category had no major impact on the outcome of the projects, contradicting the importance that he initially put on this category in his conceptual model and could be said in most screening models as well. However, firm's resources had the most impact on the outcome of the new product projects. Four of the most influential sub-factors were sales force or resources and skills distribution, the personnel and skills of the marketing research division, skill of management and the resources and skills of the promotion and advertisement division. (Cooper, 1979)

"Proficiencies of processes" according to Cooper's analysis is the most important and noteworthy major factor on outcome of the three other controllable variables. The three most significant sub-factors of this factor were market lunch, prototyping with consumer input and test marketing-trial selling. Therefore, it could be said that the most influential sub-factor that has an impact on the success or failure is the marketing aspect of the new product project process. This aspect was further supported by information acquired factor with three most influential sub-factors were knowledge of consumer price sensitivity, understanding the buyer's behaviour and knowledge of consumer needs and wants, and the technical aspects needed for the new product. From these most influential sub-factors, it could be concluded that having greater knowledge of the consumer based on their price preferences, behaviour, wants and needs according to Cooper's finding have a significant impact on the success or failure of the new product project. (Cooper, 1979)

Moreover, Song and Parry's 1997 work examined that in the case of new product selection; evaluating competitive environment, marketing and technical synergies are important. Furthermore, cross-functional integration is highly important for the successful development of the new product project and its overall success in the market. They confirm Cooper's 1979 study that impact of marketing and competitive intelligence, market activity proficiency and product competitive advantage on the project management aspect of the new product project programme. However, in Japanese firm

the market activity proficiency, which directly affects new product competitive advantage and new product success positively, is less important. (Song & Parry 1997)

Cooper & Kleinschmidt's 1987 shown that product cases when went through the 10 performance measures, three critical dimensions effecting the outcome and performance of the new product project that were: Financial performance, Opportunity window and Market impacts. Furthermore, according to them, some of the new product project characteristics were not affecting the any of the three performance measures, these were low priced, financial synergy in terms of resources, market size, purchasing nature by the consumer and new product design. (Cooper & Kleinschmidt, 1987)

On the other hand, Song and other's 2003 study, examined three sub-factors of the planning that contributes to the survival of the new product project within the market, which were detailed planning, all team member contributing to the planning process and autonomy and flexibility of the project teams. Detailed planning could increase the efficiency of the development process that in turn could impact the efficiency and overall performance of the new product within the market. (Song et. al, 2003)

However, Calantone and other's observed that environmental turbulent, which consists of technological uncertainty and market turbulence, acts as moderator for their model. However, they assessed that only a moderate relationship exists between innovativeness and market intelligence on the outcome of the new product project. Hence, during low-turbulent environment market intelligence had a positive impact on the successful out-come rather than the relationship between innovativeness and success that occurs during highly -turbulent environments. Furthermore, a positive relationship between proactive strategy with innovativeness and marketing intelligence has been observed by their model. (Calantone et.al 2008)

Summary table and analysis

Table 1 illustrates the summary of the results obtain by the authors with their corresponding correlation coefficient between these factors and performance measures of financial, market share and window of opportunity performance outcomes. The factors and sub-factors have been organised based on Cooper's 1979 categorisation of the key factors. However, the firm's strategy factor has been added based on Calantone et. al, 2008 study.

Moreover, the table exhibits analytic hierarchy process (AHP) that was comprised of the correlation coefficients of sub-factors adjusted by the ranking of the authors according to Jeff Thiems' 2007 study. The table illustrates the mean of AHP results for each key factor. The formula that the AHP used is shown in Equation 1:

$$WK_i = \frac{\sum_{j=1}^{n} R_j K_{ij}}{\sum_{j=1}^{n} R_j} \qquad \text{(Equation 1)}$$

Whereas Weighted Key sub-factors (WK) represents the correlation coefficients of sub-factors adjusted by the ranking of the authors. (R) represents the ranking of the authors that this paper assumed by a scale of 1 to 10. Finally, (K) represents the correlation coefficients of each sub-factor.

Key factors	Key sub-factors	Cooper 1979	Cooper & Kleinschmidt 1987	Song & Parry 1997	Song et. al, 2003*	Calantone et. al, 2008**	AHP
Market environment (Mean= 0.09)	1.Customer need of the specific product	r= 0.329	r= 0.313	r= 0.01	N/A	N/A	0.13
	2.Market growth rate	r= 0.221	N/A	r= 0.01	N/A	N/A	0.05
	3.Satisfaction of costumers about the new product compared to the competitors	r= 0.141	N/A	r= 0.01	N/A	N/A	0.03
	4.Degree of customer needs changing in the market	r= -0.122	r= 0.299	r= 0.01	N/A	r= 0.676	0.2
	5.Markets that have many new product introductions	r= -0.024	r= 0.296	r= 0.01	N/A	N/A	0.06
	6.Foreign markets dominant in the total of the market	N/A	r= 0.331	r= 0.01	N/A	N/A	0.07
Firm's resources and Product- organisational fit (Mean= 0.2)	1.Sales force or resources and skills distribution	r= 0.374	r= 0.301	r= 0.16	N/A	N/A	0.17
	2.Personnel and skills of the marketing research division	r= 0.372	r= 0.332	r= 0.16	N/A	N/A	0.17
	3.Technical skill of management	r= 0.316	r= 0.466	N/A	r= 0.47	N/A	0.26
	4.Marketing skill of management	r= 0.316	r= 0.466	N/A	r= 0.525	N/A	0.27
	5.Managerial skill of management	r= 0.316	r= 0.466	N/A	r= 0.48	N/A	0.26
	6.Cross-functional integration	N/A	N/A	r= 0.63	r= 0.783	N/A	0.31
	7.Resources and skills of the promotion and advertisement division	r= 0.305	N/A	r= 0.16	N/A	N/A	0.09
	8.Resource and skills of firm's R&D and product development	r= 0.142	r= 0.387	r= 0.27	N/A	N/A	0.16
	9.Firm's engineering skills and resources	r= 0.213	r= 0.329	r= 0.27	N/A	N/A	0.16
	10.Firm's costumer services skills and resources	N/A	r= 0.256	N/A	N/A	N/A	0.05
	11.Rigid reporting style	N/A	N/A	N/A	N/A	r= 0.756	0.13
	12.Flexible reporting style	N/A	N/A	N/A	N/A	r= 0.756	0.13
	13.Formal managerial style	N/A	N/A	N/A	r= 0.395	r= 0.726	0.21
	14.Participative managerial style	N/A	N/A	N/A	r= 0.5	r= 0.726	0.23
	15.Managers were motivating	N/A	N/A	N/A	r= 0.64	N/A	0.14
	16.Formal procedures	N/A	N/A	N/A	N/A	r=0.694	0.12
	17.Informal procedures	N/A	N/A	N/A	N/A	r=0.694	0.12
	18.Few people had authority on the project	N/A	N/A	N/A	r= 0.4	N/A	0.09
	19.Highly supportive top-level management	N/A	N/A	N/A	r= 0.725	N/A	0.16
	20.Top-level management involvement	N/A	N/A	N/A	r= 0.7	N/A	0.15
Nature of the venture (mean= 0.09)	1.Innovativeness of the product to the market	r= 0.199	N/A	N/A	N/A	r= 0.730	0.17
	2.Newness of the customer need served to the firm	r= -0.169	N/A	N/A	N/A	N/A	-0.03
	3.Newness of the product to the firm	r= -0.163	N/A	N/A	N/A	r= 0.730	0.1
	4.Mechanical and technical complexity of the new product	r= 0.032	N/A	N/A	N/A	r= 0.734	0.13

Key factors	Key sub-factors	Cooper 1979	Cooper & Kleinschmidt 1987	Song & Parry 1997	Song et. al, 2003*	Calantone et. al, 2008**	AHP
Commercial entity (mean= 0.16)	1.Degree of which the product met consumer needs better that the competition	r= 0.492	r= 0. 556	r= 0.48	N/A	N/A	0.31
	2.Quality of the product	r= 0.416	r= 0.441	r= 0.48	N/A	N/A	0.27
	3.Sales forces accurate targeting the market	r= 0.410	r= 0.378	N/A	N/A	N/A	0.15
	4.Effectiveness of the advertisement and promotion efforts	r= 0.233	N/A	N/A	N/A	N/A	0.05
	5.New product that offered unique benefits not found in the competition	r= 0.300	r= 0.342	r= 0.48	N/A	N/A	0.23
	6.New product solved customer's problem better than competitors	N/A	r= 0.318	N/A	N/A	N/A	0.06
	7.Product reduced customer cost	r= 0.378	r= 0.258	N/A	N/A	N/A	0.12
	8.Product that permitted customers to performed unique tasks	r= 0.238	r= 0.304	r= 0.48	N/A	N/A	0.21
	9.New product that used advanced technology	N/A	r= 0.249	N/A	N/A	N/A	0.05
	10.Introduction of a superior product	N/A	r= 0.421	r= 0.48	N/A	N/A	0.19
Proficiencies of processes (mean= 0.18)	1.Exploratory stage	N/A	N/A	N/A	r= 0.625	N/A	0.14
	2.Concept development	N/A	N/A	N/A	r= 0.68	N/A	0.15
	3.Preliminary market assessment	r= 0.328	N/A	r= 0.11	r= 0.775	N/A	0.26
	4.Market research	r= 0.342	N/A	r= 0.11	r= 0.775	r= 0.602	0.36
	5.Prototype testing with the consumer	r= 0.415	N/A	r= 0.11	r= 0.76	N/A	0.27
	6.Test marketing trial selling	r= 0.407	N/A	r= 0.11	N/A	N/A	0.1
	7.Market lunch	r= 0.517	N/A	r= 0.11	N/A	N/A	0.13
	8.Initial screening	r= 0.370	N/A	N/A	N/A	N/A	0.07
	9.Financial analysis	r= 0.309	N/A	N/A	N/A	N/A	0.06
	10.Trail production	r= 0.267	N/A	r= 0.43	N/A	N/A	0.15
	11.Preliminary technical assessment	r= 0.282	N/A	r= 0.43	N/A	N/A	0.15
	12.Product development	r= 0.394	N/A	r= 0.43	N/A	N/A	0.17
	13.Prototype development	N/A	N/A	N/A	r= 0.735	N/A	0.16
	14.Prototyping and testing in-house	r= 0.325	N/A	r= 0.43	r= 0.76	N/A	0.32
	15.Full production start-up	r= 0.394	N/A	r= 0.43	r= 0.655	N/A	0.31
	16.Technical service	N/A	N/A	N/A	r= 0.61	N/A	0.13
Information acquired (mean= 0.21)	1.Knowledge of consumer price sensitivity	r= 0.391	N/A	r= 0.45	N/A	N/A	0.17
	2.Understanding buyer's behaviour	r= 0.391	N/A	N/A	N/A	N/A	0.08
	3.Knowledge of consumer needs, wants and technical aspects needed for the new product	r= 0.362	r= 0.590	r= 0.45	N/A	r= 0.783	0.42
	4.Knowledge about the competition product, strategy, pricing	r= 0.331	N/A	r= 0.45	N/A	r= 0.753	0.29
	5.Knowledge about competitor reaction after new product launch	N/A	N/A	r= 0.45	N/A	r= 0.586	0.2
	6.Market size knowledge	r= 0.284	N/A	r= 0.45	N/A	N/A	0.15
	7.Understanding new products technology	r= 0.203	N/A	N/A	N/A	r= 0.667	0.16

Key factors	Key sub-factors	Cooper 1979	Cooper & Kleinschmidt 1987	Song & Parry 1997	Song et. al, 2003*	Calantone et. al, 2008**	AHP
Project definition (mean= 0.11)	1.Project concept	N/A	r= 0.420	N/A	N/A	N/A	0.08
	2.Project requirements and specifications	N/A	r= 0.329	N/A	N/A	N/A	0.06
	3.Project detailed planning and control	N/A	N/A	N/A	r= 0.625	N/A	0.14
	4.Participation of all project team members in planning	N/A	N/A	N/A	r= 0.72	N/A	0.16
	5.Rigid hierarchical reporting in relationship to planning	N/A	N/A	N/A	r= 0.565	N/A	0.12
Firms'Strategy (mean= 0.12)	1.Level of aggressiveness toward competitors	N/A	N/A	N/A	N/A	r= 0.666	0.12
	2.Firm's behaviour in respect to action	N/A	N/A	N/A	N/A	r= 0.713	0.12
	3.Degree of risk taking in respect to decision-making	N/A	N/A	N/A	N/A	r= 0.696	0.12

Table 1 (Summary table of authors results with AHP)

The proposed conceptual model

The AHP analysis, establishes the information acquired as the underlying key factor, which has a mean (r) of 0.21. The most influential sub-factor of this factor is a knowledge of consumer needs, wants and technical aspects needed for the new product with r equalling 0.42.

Other significant factors were a firm's resources and organisation-product fit, proficiency of processes, commercial entity, firm's strategy and project definition with mean (r) equalling to 0.2, 0.18, 0.16, 0.12 and 0.11 respectively.

Thus, based on the results obtained, Figure 1 represents the basis of this paper's conceptual model.

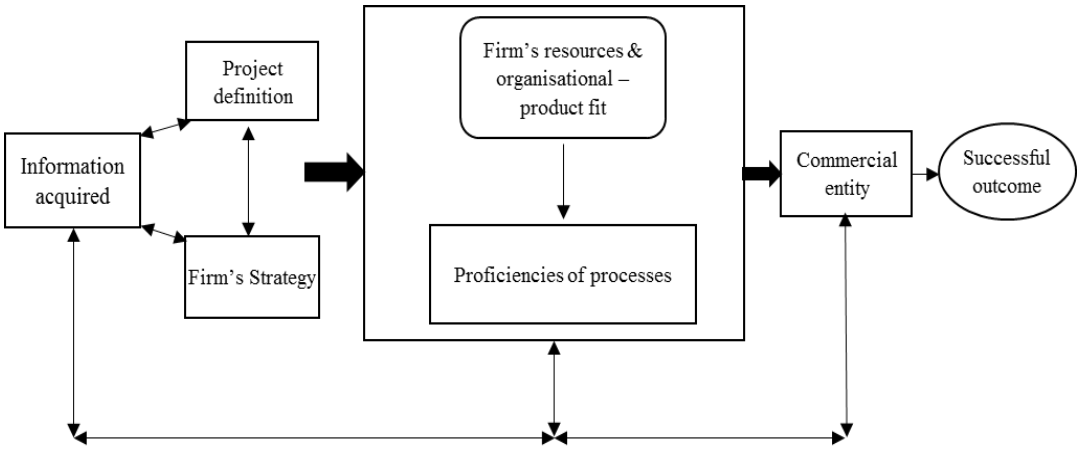

Figure 1: The proposed Conceptual model structure

According to the conceptual model, a successful outcome of a new product project is directly influenced by the commercial entity factor (with its corresponding sub-factors). This factor is the output of a transformation process, which in this case were proficient NPD processes. For the NPD processes to be proficient, the model determined that a Firm's resources and organisational-product fit has a direct impact on this factor.

Furthermore, the inputs of this transformation process were considered as being the project definition and the firm's strategy, and that both factors influence each other. Finally, the information acquired was assumed as a factor at the beginning of the process, and directly influences the project definition and a firm's strategy. Moreover, it links to other factors in the model by collecting and sharing information for each stage of the NPD process. The factor was considered as the underlying key factor, as it effects the successful outcome of an NPD project.

Future of the research

This research will continue with the application of a quantitative approach to test the factors and sub-factors found of the proposed conceptual model. The results attained from this scrutiny will validate or reject current factors or identify new key factors and sub-factors for the proposed conceptual model.

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Strategy to market innovations: Systematic literature review on the different approaches

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Abstract

Among the various models for innovation, there is a constant shock between the technological incentive and the market demand approaches, with a controversial strategy choice, there also occurring a growing interest for mixing them. Seeking to fill in this knowledge gap, a systematic literature review, combining bibliometrics, networks and content analysis, was applied, exploring the determinants of the market orientation strategy choice, in a 105-publication sample. Highlighting a continuous mixed organizational alignment, between technological incentive and market demand approaches, seeking to take advantage from both, but with an inclination toward one or the other, depending on some organizational perspectives.

Keywords: Strategies to market innovations, Technological incentive, Market demand, Systematic literature review.

Introduction

Innovations can be brought to market through two different approaches, Technological Incentive Strategy (TIS) or Market Demand Strategy (MDS) (Peters et al. 2012). The TIS, is technology-oriented, whereby the company pushes the potential customer to the market, through the areas of research and development, operating the sales team, without necessarily considering the customers' needs (Baumers et al. 2016). Conversely, in the MDS (Horbach et al. 2012), a company can create innovations, understanding the market needs. The choice between these two strategies determines the company Strategy to Market Innovations (SMI), directly connected to the process by which a company produces new products and is organized, playing an important role in companies' success (Dosi 1982).

These two strategies are well covered in the literature, but there is a research gap regarding the processes of choosing between them and a growing interest in mixing them (Costantini et

al. 2015), in which innovations are first designed through a technological bias, while demand allows innovations to adapt to market needs, to facilitate their adoption and diffusion (Stefano et al. 2012). This line of mix strategies can be found, for example, in the Lean Startup approach (Blank 2013), in which there are alternating cycles of innovation pushed to the market, and validation with the customers, for constantly improving the product or service developed. The choice of the SMI has several important consequences, because the improper choice can negatively affect the company's results, reducing overall sales, conducting to customers' dissatisfaction and leading to the discontinuation of projects with low return over investment (Brem & Voigt 2009).

Thus, this paper proposes to answer three main research questions: *What factors determine the choice between the strategies to market innovations? How do companies position themselves in relation to these strategies to market innovations, considering their market segment, the company's structure and business model?* And *What conduct companies choose of strategies to market innovations?* In this scenario, this work aimed to investigate the determinants for choosing SMI (Bernstein & Singh 2006). To address these issues, the methodological approach was the systematic literature review, combining bibliometrics, networks and content analysis. The sampling used as a reference was collected from the Web of Science, Scopus and Elsevier, being composed for 105 papers. This study seeks to identify and to analyse the most relevant papers and authors, from the context of TIS and MDS, besides their perspectives for the SMI, highlighting the determinants of choosing SMI.

This research has six main sections. Section one introduces this research, also justifying its relevance. Section two presents the theoretical background. Section three details the methodology. Section four presents this research results. Section five discusses the results, and section six concludes this research.

Theoretical Background

One of the major challenges for the study of Technological Incentive (TI) and Market Demand (MD) is the lack of consistency and uniformity in the understanding and use of terminologies. Many terms emerged to describe the internal process of TI, such as *technology push* and *science push* (Schmoch 2007), while the process of innovation from MD have already been termed as: *market pull*, *marketing pull*, *need pull*, *demand pull* and *communication pull* (Chidamber & Kon 1994; Oncioiu 2013). Leading to a scenario of greater difficulty in understanding and use these terminologies, damaging this subject research and practice. The TI and MD are especially present in interdisciplinary areas, involving the use of multiple contexts, such as project management as in Aritua et al. (2009) and supply chain management as in Hinkelman (2005). This research considered all the studies concerning the subjects, regardless of the term used.

Market Orientation

Market orientation concept can be considered the result of the deep discussion about the marketing concept implementation (Kohli & Jaworski 1990). In the literature, we could also find near concepts of market orientation such as *customer orientation* (Berthon et al. 2004) and *marketing orientation* (Payne 1988). Shapiro (1988) discussed the three previous concepts, and concluded that they were so close that there could hardly be any distinction between them. Day (1992) and Kohli and Jaworski (1990), summarized the construction of the market orientation strategy as a customers' information collection (market demand) and the competitor, disseminated throughout the company and exploited to satisfy the market current needs. The relationship between the market orientation strategy and the business performance was confirmed in different studies, such as Deshpande et al. (1993) and Kohli and Jaworski (1990).

The market orientation division into two complementary approaches, reactive (close to MD) and proactive (close to TI), introduced by Schumpeter (1934). Slater and Narver (1998) suggested that in a turbulent market environment, focusing on the customer latent needs can lead to better results than focusing on the existing customer needs. Thus, in the reactive market orientation, also known as *customer obligated* (Day 1992) and *customer led* (Narver et al. 2004), the company places its effort in discovering the current situation and expresses its customer's needs. In contrast, the proactive market orientation focuses on the customers' latent needs, needs which the customers can still ignore. Thus, depending on how a company intends to adopt the TI and the MD, the company can position itself more reactively or proactively, in a given market (Narver et al. 2004).

Technological Incentive (TI)

The first TI in large-scale is connected to the increase of the industrial activities and of Research and Development (R&D), after the II World War (Schmoch 2007). The first favourable argument about this paradigm predicted the basic science knowledge progression applied to the commercial product development research. Then, Dosi (1982) attributed the importance of this line of reasoning to some innovation process characteristics: science growing importance in the innovation process, increasing complexity requiring a long-term view, strong apparent correlations between R&D with the innovative production and innovation process inherent uncertainty. One of the main technology incentives arguments is a criticism in which it does not consider prices and other economic conditions changes, which affect the innovations profitability. Another criticism is that the emphasis on a one-way progression in the innovation process stages is incompatible with the subsequent development, which gives importance to feedbacks and interactions (Freeman & Louçã 2001).

Subsequent researches offered a less deterministic version of TI, while still giving importance to the role of science and technology. Some researchers argued that the availability of exploitable *technological opportunities* plays a role in determining the innovations rate and direction, and that it may depend on the field *science strength* (Rosenberg 1974). Companies must invest in scientific knowledge to develop their *capacity to absorb* knowledge, by exploiting emerging opportunities of the state of the art elsewhere (Freeman 1982). Other researchers support issues regarding the relationship between the technological system and the importance of knowledge flows among the different company's fields (Rosenberg 1974). Finally, there is a line that characterizes this model of innovation as a *linear* model, advocating the *sequential* characteristic of the technological incentive (Rothwell 1994). The concept of TI that emerged and was widely used in the mid-20st century was slowly side-lined to the detriment of a counter-flow perspective, to observe market needs and to act reactively to meet those needs.

Market Demand (MD)

In the 1950s and 1960s, several studies argued that MD drives the innovations rate and direction. The changes in market conditions create opportunities for companies to invest in innovations to meet customers' unmet needs. This demand guides companies to work on certain problems (Rosenberg 1969). Price changes, geographic variation in demand, as well as the identification of *latent* demand and potential new markets, affect the size of the reward in successful innovation investments, thus increasing the importance of considering the market for strategies outlined by a company.

Critics of this paradigm of market demand highlight three main points. Academically, the definition of *demand*, in general, was considered a very broad concept to be useful (Mowery & Rosenberg 1979; Chidamber & Kon 1994). Another criticism line explains that the change in market vision, as well as the technological one, is incremental and does not cause radical

changes, making the most relevant innovations impossible (Mowery & Rosenberg 1979). A third reasoning addresses the assumptions of the company's capacity arguments, expressing scepticism about: (1) how companies can identify the *undisclosed needs* of a near-infinite set of possible human needs; (2) the extent to which companies in general have access to a stock of techniques large enough to meet the variety of needs one might expect to emerge, and (3) to what extent companies can venture into existing *routines*, to meet non-satisfied demands. However, the concept of MD is widely used in the literature and applied to companies (Schmoch 2007).

Methodology

We applied a systematic literature review to identify and to synthesize the current literature in Technological Incentive (TI) and Market Demand (MD), as different market orientation strategies, answering this study research questions. The systematic literature review was conducted in three main steps, as suggested by Dybå & Dingsøyr (2008):

- (1) Criterions for including and excluding studies, research strategy - ensuring the sample quality, we only considered publications that underwent review process, filtering the results by articles or conferences publications from the Web of Science (WoS) database. Chosen because the database covers the results of greater relevance journals (journals with Journal Citation Report - JCR) from other databases. We also not exclude high impact studies from journals without JCR, also considering, the Scopus and the Elsevier ScienceDirect databases (Fleury et al. 2016).
  This research encompasses all the different nomenclatures for TI (technology push, science push) and MD (market-pull, marketing-pull, need pull, demand pull, communication pull), finding 543 papers in the databases (200 WoS, 257 Scopus and 86 Elsevier ScienceDirect), resulting in 326 papers after eliminating duplicity;
- (2) Sample filtering criteria to select the most relevant studies – only the studies with relationship with this research subject were selected (Karlsson, 2010), 105 papers.
- (3) Studies models' analysis – data analysis includes bibliometrics, networks and content analysis (Fleury et al. 2016), in three steps. Step one the bibliometric analyses were applied identifying the main subject trends and journals, also highlighting the publications evolution over time. Step two the networks analyses were carried out, using the software VOSviewer 1.6.5. Always using the sample of 105 papers. The first two steps can provide an updated broad overview of existing research, which can be used as a starting point for academics who want to research this area of knowledge. Step three, perform the content analyses, only the most relevant articles were selected, according to their impact factor. The calculation of the impact factor considers the average number of citations (Cm) and the impact factor of the journal, JCR, also being applied a Pareto' analysis, resulting in 12% of the papers (13 papers) representing more than 80% of the total sample representativeness, as done in Takey and Carvalho (2016). The content analysis applied systematic procedures to standardization and synthesis the content, with the purpose of answering the research questions (Bardin 2011).

  Equation (1):
  $Fi = Cm * (JCR + 1)$

Results

Bibliometric and Network Analysis

The journals *Research Policy*, *Technovation* and *International Journal of Technology Management* are the main journals publishing papers about TI and MD together, with each one published six papers. Figure 1 evidences the papers evolution over the years.

#	Source title	JCR	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	%
1	**Research Policy**	**3.47**				1										1		1		1				1	1	6	14%
2	**Ecological Economics**	**3.227**														1				1				1		3	7%
3	**Technovation**	**2.243**													2			2		1						5	12%
4	IEEE Transactions on Engineering Management	1.454									1															1	2%
5	TRENDS IN FOOD SCIENCE & TECHNOLOGY	5.15									1															1	2%
6	International Journal of Technology Management	0.867	1	1								1	1		1					1						6	14%
7	JOURNAL OF PRODUCT INNOVATION MANAGEMENT	2.086													1											1	2%
8	Information and Management	0.683	1						1																	2	5%
9	Journal of Retailing and Consumer Services	0																					1			1	2%
10	Industrial and Corporate Change	1.327															1									1	2%
11	Journal of Evolutionary Economics	0.753												1				1								2	5%
12	Journal of Strategic Information Systems	2.595													1									1		2	5%
13	International Journal of Innovation Management	0																1							1	2	5%
14	Technological Forecasting and Social Change	2.678																							1	1	2%
15	European Journal of Marketing	1.088															1						1			2	5%
16	Long Range Planning	2.936										1												1		2	5%
17	Structural Change and Economic Dynamics	0.829																					1			1	2%
18	Euphytica	1.618																				1				1	2%
19	Strojniski Vestnik/Journal of Mechanical Engineering	0.677																	1						1	2	5%
20	Journal of Applied Economics	0.182																1								1	2%
		Total	2	1		1	0	0	1		2	2	1	1	5	2	2	6	1	2	2	1	3	4	4		
		%	5%	2%	0%	2%	0%	0%	2%	0%	5%	5%	2%	2%	12%	5%	5%	14%	2%	5%	5%	2%	7%	9%	9%		

Figure 1 – Publications evolution over the years

The network analyse allows the evaluation of subjects' trends and relationships. In Figure 2 the lines connect the most cited keywords and the line thickness evidences the relationship strength between them. The most cited keywords were: *market pull*, *technology push*, *industrial management* and *innovation*, respectively, evidencing the intersection of *market pull* and *technology pull* with the *industrial management* and *innovation*. With *innovation* and *innovation process* more related to the TI approach, being aligned with the study of Stefano et al. (2012), what can occurs for the TI be more based on the companies' ability to manage the internal production for new innovative products and services, while MD is more related to companies' external factors, such as governmental environmental policies, patents, eco-innovation and environmental technologies, evidencing that companies that use MD strategy are more susceptible to external influences, such as customer brand perception and regulations.

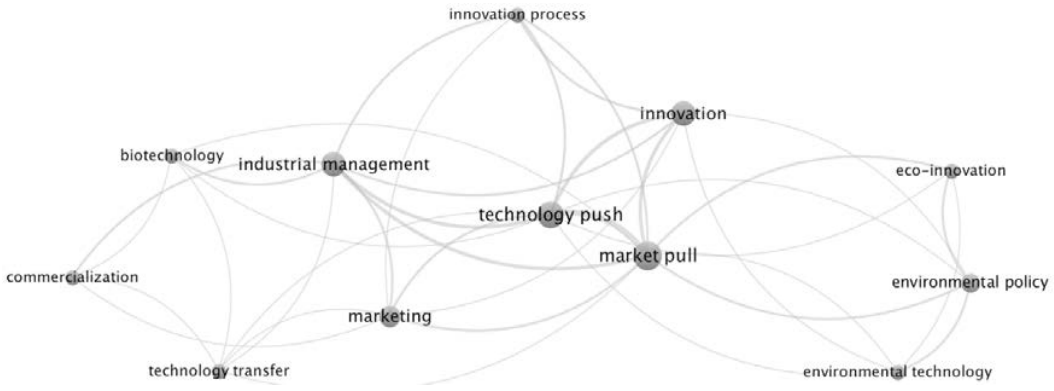

Figure 2 - Keyword co-occurrence network

In Figure 3, the lines connect the papers that share bibliographic references and the line thickness determines the sharing intensity. It is possible to highlight three clusters. Cluster 1 - focus on reduction of impacts on the environment, innovations related to sustainability and eco-innovation, with a great correlation between Horbach et al. (2012) and Rehfeld et al. (2007), that shares one of the authors and are related to eco-innovation in Germany. Cluster 2 - characterized by literature review studies. Cluster 3 - dealing with the biotechnology field.

This network assists the papers interpretation in the content analysis, useful to find similarities in the determining factors for choosing the market orientation strategy.

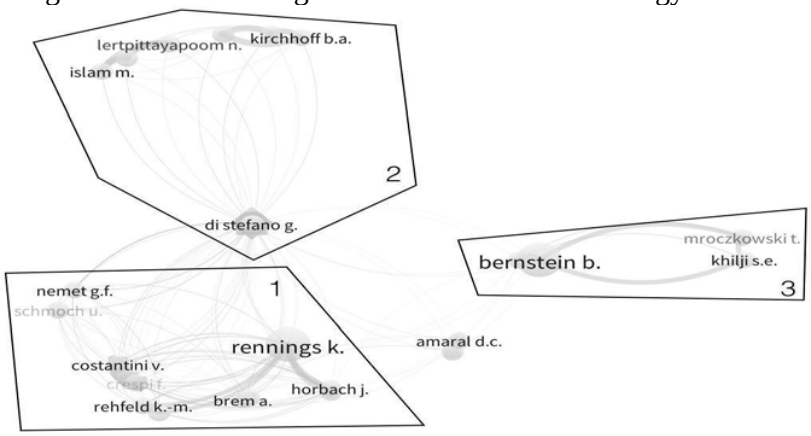

Figure 3 – Authors co-citation network

Content Analysis

To answer: *What are the factors that determine the choice between the strategies to market innovations?* The content analysis focus on: the main factors that affect the choice of a Technological Incentive (TI), Market Demand (MD) or a mix of the approaches; the implications for the market orientation strategy; and how each market segments has to adapt itself, in this context.

It was highlight that the topic of strategy choice is still controversial in the literature. On one side, Brem and Voigt (2009), based on their innovation theoretical and conceptual models consider that the two strategies (TI and MD) are equally important for all kinds of companies. Their model supposes that none of the strategies is better and that the adoption of only one of them can sink the company competitiveness in the long term. On the other side, Pearson (1990) proposes that the use of only one predominant strategy. In this scenario, raises some determining factors for a company choose between the three approaches mentioned.

Factors for Technological Incentive (TI)

According to Kivimaa and Kern (2016) the use of technological innovation systems in the context of sustainability, allow the creation of market from the new market demand creation. This new market creation can be done by demonstrating projects, creating *bridges* between markets or massifying a market. In the context of agricultural innovations, the concept of open innovation has been shown as a potentiator of the TI model (Caetano & Amaral 2011). The open innovation allows that companies and government create cooperation and collaboration for knowledge and responsibilities sharing, allowing the achievement of shared benefits.

Environmental Management Systems (EMSs) allow the introduction of clean technologies that reduce costs by reducing the lack of information (Horbach et al. 2012). In addition to companies' systems, some factors, such as employee empowerment, senior management commitment and mapping process can make possible the creation of new processes and products that generate less pollution, being important factors of eco-innovation (Stefano et al. 2012).

Factors for Market Demand (MD)

For Rehfeld et al. (2007) the concern with customer satisfaction is the main factor that a company must consider in a MD strategy. With large manufacturing companies focusing on

market demand to ensure that their products fit the market, reducing their risk (Walsh et al. 2002).

In the scenarios such as *green* products, consumers can prioritize sustainability credentials as a primary factor and put price and performance in the background. This way in segments such as the development of sustainable products it is necessary to has a well-aligned policy with the market (Kivimaa & Kern 2016). With a contrary approach, Horbach et al. (2012) believe that there is still little demand stimulation since eco-friendly products are still often very expensive. Making the costs and final price highly relevant to the eco-innovations.

Factors for the mixed approach

Majority of studies, in the field, search for innovation through a mixed approach, where technology appears to be the central point of the innovation, while demand allows the adaption of the innovation for the market needs, facilitating its adoption and diffusion (Stefano et al. 2012). The mixed approach process is a natural flow that occurs in cycles, as in the robotics industry (Schmoch 2007). The early cycles are driven by technology and produce innovations that generate what the Gartner company calls a cycle of enthusiasm. Often due to the lack of adherence of the technology to the market, there is a disillusionment, and it opens the door to a cycle more oriented to market demand. This cycle adapts the technology created for market demands, through the creation of various services and products. Then these services and products go through a consolidation phase.

Another relevant factor that affects the approaches is government policies that may end up favouring one approach or other (Nemet 2009). These policies can reduce the private costs of producing innovation, which ultimately stimulate technology, or can implement measures that reward private initiative for successful innovations (market demand).

Discussion

To answer: *How do companies position themselves in relation to these strategies to market innovations, considering their market segment, the company's structure and business model?* And *What conduct companies choose of strategies to market innovations?* It was evidenced that in addition to the internal factors (technical competencies, organizational structure, top management vision) and external factors (public policies, price of the service or product, consumer needs) that were determinant in choosing the market orientation, it was possible to identify that the *business model*, the *organizational structure* and the *market segment* where the company operates, are also variables with great influence in the choice of strategy adoption by the company.

The *business model* and *organizational structure* influences the company marketing orientation, because companies in established or saturated markets are usually oriented to a well-known market, while companies that operate in poorly defined markets search to be guided by new technologies (Costantini et al. 2015; Stefano et al. 2012). Large companies tend to search for incremental innovations, favouring the marketing demand approach, searching to respond to present market demands, whereas small companies are usually driven by technological innovations, searching to respond for future market demands, creating new technologies (Walsh et al., 2002; Nemet 2009).

Companies whose competitive advantage is in the internal knowledge management skills tend to focus on technological development, while organizations whose competitive advantage is in the marketing and sales fields tends to respond to market needs (Horbach et al. 2012). Companies oriented to create products and services to other companies tend to search innovation in new technologies, while companies that sell to end customers tend to respond to the demands of their market (Brem & Voigt 2009). See Figure 4.

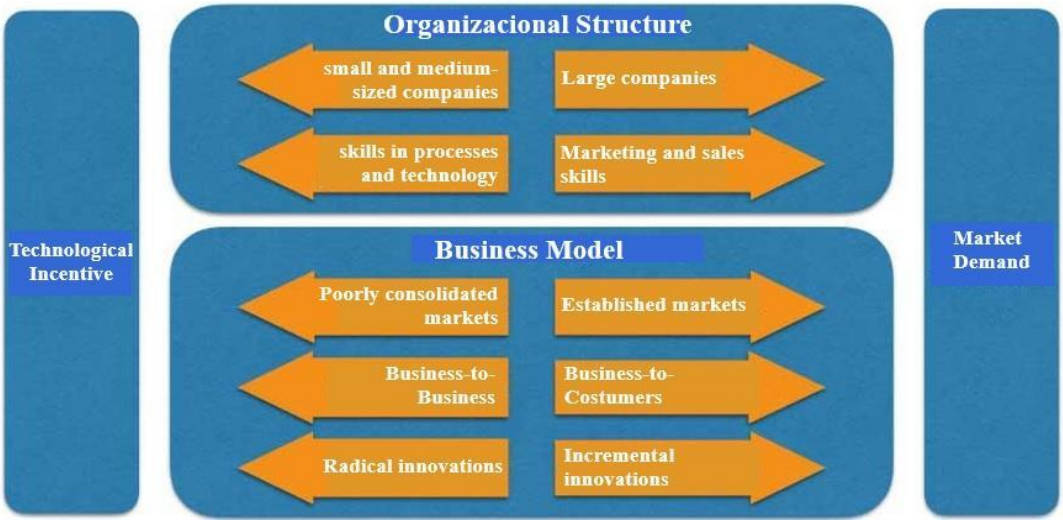

Figure 4 - Strategic orientation of innovation by business model and organizational structure

Considering the studied publications, it is possible to affirm that there is an alignment between the strategies and the *market segments*. With the TI strategy more associated with the segments of agriculture and industry software (B2B). While the MD strategy is more associated with conventional biofuels, software industry (B2C), wind power and large manufacturing companies. With the mixed strategies appearing more in segments such as advanced biofuels, food, robotics and biotechnology.

For the biofuels market, investment in R&D accelerate the transition from conventional fuel technologies (from edible raw material) to advanced fuels (from non-edible raw material) and the technical capability allied to technological knowledge are recognized as very important for the production and diffusion of eco-innovation, highlighting the importance of the technological incentive. At the same time, obtaining market incentives for the consumption of biofuels in a national scale, external investments and costs specific advantages are relevant factors for a market-oriented policy (Costantini et al. 2015).

For the creation of new functional foods, is important to balance consumer needs with technical realities, ensuring the incorporation of opportunities for advancement in technology, gaining competitive advantage (Van Kleef et al. 2002), balancing *what can be done* (customer perspective) with *what could be done* (scientific/technological perspective). Small manufacturing companies, in order to achieve disruptive innovation, use both TI and MD, with the process influenced for the optimization of the Time-to-Market (Walsh et al. 2002).

Conclusion

This study searched to fill the literature gap about the choice between the different approaches to market positioning (Technological Incentive - TI, Market Demand - MD and mixed approach). Conducting a systematic literature review to analyse the existing literature in these subjects, through a multi-method approach (bibliometrics, networks and content analysis). The literature evidenced that most of the articles that deal with one approach do not discuss the others.

The bibliometric analysis highlights the growing importance of the subjects. The networks analysis points to a greater intersection of TI with the internal issues to the organization of industrial management and innovation while the MD is more related to the external issues sustainability and government policies. Both bibliometric and network analysis contributes to theory by updating the body of knowledge on TI and MD, helping academics who want to

start looking into those concepts, to better understand which areas of study each of these topics are being further developed, if any different area can be used as reference (e.g. industrial management researchers may find relevant findings in studies on biotechnology and areas that use similar approach for SMI) and which authors can be used as a starting point for exploring the theme.

Based on the content analysis, this study compared the factors that determined the company's strategy. Evidencing a tendency for a mixed company alignment between the strategies of TI and MD, taking advantage of both, but with a more inclination towards one or other approach, depending on the: companies' structure, business model or companies' segment. The TI strategy aligns with emerging markets, in organizations with internal technological bias skills in search for radical innovations, in small and medium-sized companies and B2B businesses. The MD strategy is more associated with consolidated markets, with companies focusing on marketing and sales and incremental innovations, large companies and B2C businesses. The main objective of the TI approach is the constant relocation of the company as a technological leader in the field, while the MD allows less exposure to risks.

The findings of this research bring contributions to the literature, greater clarifying the differences between the main approaches of market position, consolidating how each company has had greater success defining its market strategy orientation. Also contributing with practitioners (strategic and marketing managers) by bringing an understanding of how better position themselves in front of the market due to organizational internal and external factors, maximizing the organizational results, improving the sales and increasing the customers' satisfaction.

This paper presents limitations regarding the number of scientific bases and the combination of keywords, presented in the method section. This research also has implications for future researchers, highlighting some authors recommendations: study the importance of greater analysis in the mixed approach models in the initial stages of product conceptualization and its impacts in the development of the product (Van Kleef et al. 2002), and the opportunity to carry out studies on open innovation and its impacts to the market demand model (Caetano & Amaral 2011).

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The structure, nature and significance of alliances in innovation networks – the case of new product development in biotechnology

Keywords: Innovation, Alliance Networks, New Product Development

Topic(s):
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Purpose

Scholars recognize the transition from exploratory innovation to commercial exploitation as a learning process (March, 1991; Yamakawa, Yang, & Lin, 2011). One unique characteristic of the commercialization pathway that the innovation literature has not rigorously assessed is the relational nature of different components in the ecosystem (Powell, White, Koput, & Owen-Smith, 2005). Powell et al. (1996) network approach finds that centrally connected exploratory R&D alliances are necessary to achieve "valued organizational outcomes". Rothaermel and Deeds (2004) exploration–exploitation framework of organizational learning suggests a causal relationship between venture alliances, that new product development depends on the type of the alliance, and that it is moderated negatively by firm size.

We build on these and other works to establish a structural model of *learning* networks via organizational alliance/ties (Figure 1), and their relative impact on new product development in the biotechnology sector.

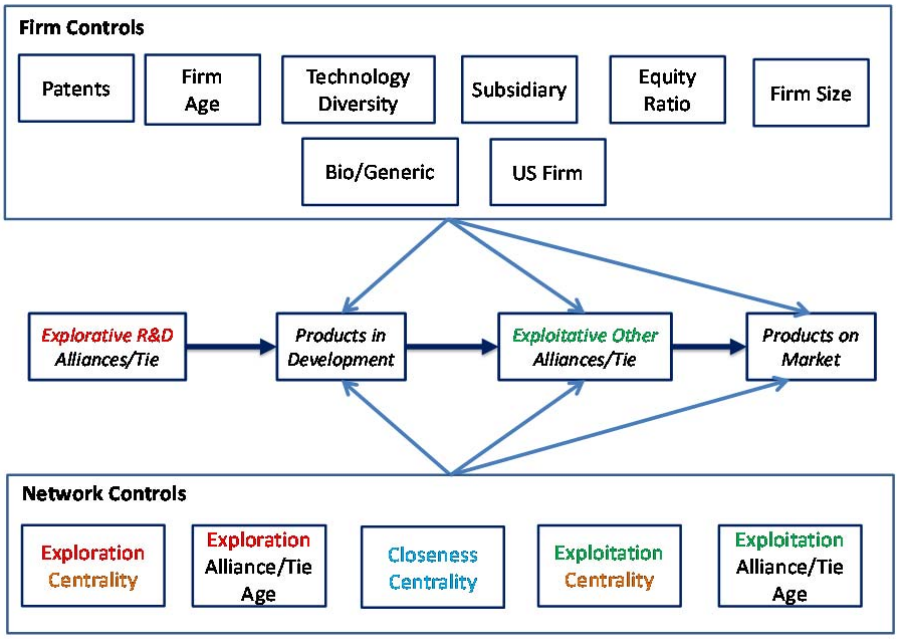

Figure 1 Structural model for commercialisation of biotechnology alliances

The confluence of these associative learning networks via organizational ties raises the following hypotheses:

Hypothesis 1: The system of new product development linking explorative R&D alliances to products on market is persistent in the biotechnology industry

Hypothesis 2: The new product development path leading from explorative R&D alliances to products on market is moderated by tie centrality and tie age.

Design

We test these hypotheses on a sample of dedicated biotechnology firms in the years 1988-2018, using a pooled, within-firm, averaged time series analysis. We identified firms dedicated to human therapeutics listed in the Cortellis Database. The companies in our data pool were collected from four segments:

– Generic Pharmaceuticals
– Specialty and Advanced Pharmaceuticals
– Biopharmaceuticals
– Biotherapeutic Drugs

This process yielded a sample of 300 biotechnology firms centred in a range of nations. We tested the model using a structural equation model built using AMOS.

Control Measures

We employed several control variables that may impact upon the new product development system (Figure 1). We control for firm structure with the usual array of

variables used in previous studies. We control for the nature of the alliance/tie network with the following variables:

- age of a firm's alliance/ties in months – longer preferred
- degree centrality - how well a firm is connected,
- closeness centrality - reciprocal sum of degree distance to each other firm
- exploration centrality - how well a firm is connected in the exploration network
- exploitation centrality - how well a firm is connected in the exploitation network

Findings

The results of our analysis are depicted in the measurement model below (Figure 2). Our results reveal a good model fit for the sampled data, with NFI, CFI and RFI > 0.96, and RMSEA < 0.026 with a 90 percent confidence interval of (0.000, 0.094). We also conduct Lagrange multiplier tests to find that no alternative specification of the parameters would have led to a model that better represented the data.
There is strong support for Hypothesis 1 that there is a robust persistent system structure of new product development linking explorative R&D ties to products on market in the biotechnology industry (as originally suggested by Rothaermel and Deeds (2004)). However unlike Rothaermel and Deeds we find little evidence that the entire new product development path is moderated by firm size, and by contrast firm age has a negative influence on exploiting potential products. We build on these works by finding the conflagration explorative tie age has on the new product development path.

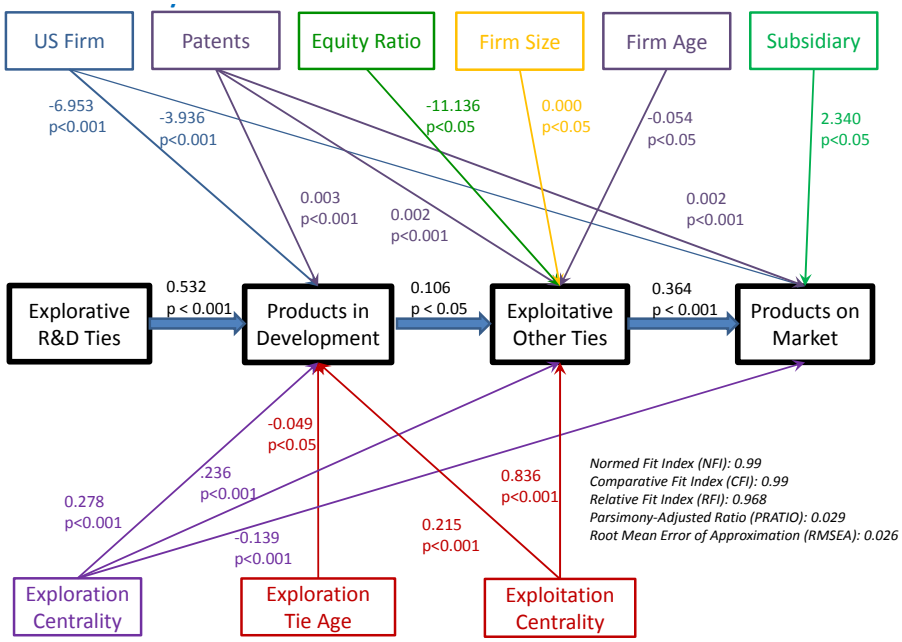

Figure 2 Measurement model for commercialisation of biotechnology alliances

We find partial support for Hypothesis 2 that the new product development path is moderated by tie centrality and tie age. In deference to Powell et al. (1996) we find that centrally connected exploratory ties are necessary to achieve "valued organizational outcomes". But rather than manifest in firm size growth, we find this influence extends through the entire network, to eventually have a negative impact on products on market.

We extend on Powell's various works by finding that exploitive tie centrality has a similar impact on the new product development path, but that the age of these ties is insignificant.

Contribution

The current study is in an attempt to better understand the commercialization pathway for innovation in the biotechnology sector. The analysis revealed that in addition to firm structural controls, the nature of network alliance/ties challenges and improves on the findings of previous inter-organizational innovation networks studies. Our theoretic contribution is to confirm that while multi stage collaboration is necessary in order to bring commercial reality to the discoveries, it is the centrality and age nature of these alliance/ties that enables effective delivery of products to market. The contribution we make to practice is to proffer a utopian commercialization pathway for discoveries in the biotechnology industry, namely one that encompasses; clusters of specific centralised expertise/learning at defined stages of development, and deemphasises the focus on large, old U.S. based firms that offer poor equity deals.

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An approach for identifying collaborative business opportunities for networked organizations: application to connected and autonomous vehicles

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Abstract

This paper presents the results of a study conducted with a network of organizations involved in the connected and autonomous vehicle's technology as an emerging trend, which aimed at developing an approach for the identification of collaborative business opportunities by deploying coopetition theory, design thinking principles, and business model theory. The purpose of this paper is twofold. Firstly, it tries to develop an approach that will enable organisations to identify collaborative business opportunities and, secondly, provides insights into the challenges and requirements for the realization of full scaled solutions for the connected and autonomous vehicles.

Keywords: design thinking, coopetition, connected and autonomous vehicles

Introduction

Emerging technologies and innovations are creating a new landscape of competition with disruptive business models being introduced into traditional industries. Therefore, it is suggested that firms should be strategically prepared to respond to emerging trends. A common strategy for that involves the transformation from separate product and service offering toward more complex value propositions that will enable firms to harness market opportunities to sustain and grow their market position. However, high uncertainty for the final offering, products' short life cycles, technology convergence and R&D expenditure intensity are just some of the reasons of why vertically-integrated resources and capabilities are never enough for a standalone firm when new industries are formed (Bengtsson and Kock, 2014). Hence, these product-service value propositions can only be realised where different actors collectively create and deliver value by integrating their resources and capabilities to overcome technological and commercial challenges.

Connected and autonomous vehicles (CAVs) are about to become a reality and, thus, automotive manufacturers have made considerable investments to make the technology more viable, affordable and safer focusing on safety case development, environmental impacts, traffic operations and infrastructure design (Talebian and Mishra, 2018). Through that, it is evident that the traditional value creation chain is shifting to an

ecosystem of multiple partners who contribute to the technological readiness and will be part of the value propositions for the emerging opportunities around CAVs. Thus, an approach that identifies collaborative business opportunities seems relevant to move forward.

This study views coopetition as an entrepreneurial process that can cope with uncertainty, explore and exploit opportunities and develop innovative solutions within a collaborative environment. Therefore, the aim of this study is twofold. Firstly, it tries to develop an approach that will enable organisations to identify collaborative business opportunities under the coopetition theory by utilising design thinking principles and the business model canvas. Secondly, empirical data is analysed to provide insights into the challenges and requirements for the realisation of full scaled solutions for the connected and autonomous vehicles.

Context

Coopetition

Coopetition - the simultaneous competition and cooperation among firms- is discussed in strategic management as an alternative for rival organisations to complement their competencies through collaboration (Bengtsson, Kock and Lundgren-Henriksson, 2018; Gnyawali and Ryan Charleton, 2018; Hoffmann *et al.*, 2018). In their review of coopetition research, Bengtsson and Kock (2014:182) provide an inclusive definition of coopetition, which is seen as '*a paradoxical relationship between two or more actors simultaneously involved in cooperative and competitive interactions, regardless of whether their relationship is horizontal or vertical'*. This definition outlines that coopetition includes relationships in both the inter-organizational and the intra-organizational level of analysis. In this paper, we discuss coopetition as the simultaneously collaborative and competitive relationship among firms in the value chain of connected and autonomous vehicles that constitute an emerging technological innovation.

Coopetition fit for opportunities and innovation

As noted earlier, high technology industries seem to face unique challenges and opportunities that require the collective contribution of different actors to be resolved and exploited, respectively. Thus, the strategic choice of coopetition seems more conductive in those industries. Scholars have emphasized coopetition strategies as the main triggers in innovation efforts as firms have used them for the development of new products (Bouncken, Clauß and Fredrich, 2016), and innovative business models (Velu, 2016). Moreover, evidence show that coopetition enriches the process of generating value-creation opportunities (Ye and Yamamoto, 2018), is a mechanism for learning and sharing knowledge (Bouncken and Kraus, 2013), and it can protect innovation projects from imitation through novelty in the business concepts and competencies (Ritala, 2012; Ritala and Hurmelinna-Laukkanen, 2013). Empirical evidence shows that being involved in coopeting relationships is essential not only to acquire new technological knowledge and skills, but it can also support the creation and access of other capabilities exploiting the existing ones (Quintana-García and Benavides-Velasco, 2004). It seems relevant to outline that radical innovations are suitable to be exploited in the setting of where more

than two firms are involved in coopetition (Yami and Nemeh, 2014). On the other hand, strategic innovations on their own can lead to increased cooperation and competition (Roy and Yami, 2009). All of the above evidence suggests that coopetition can be beneficial during the innovation process and can determine ways to move forward for the post-launch phase. Hence, it is important to be considered for connected and autonomous vehicles where new collaborative value propositions are likely to be offered in the future.

Coopetition and uncertainty

Coopetition strategies have been seen as mechanisms to cope with uncertainty (Bouncken and Frefrich, 2012). While innovation is strongly linked with uncertainty, and coopetition is a source of opportunities for enhancing innovation efforts, it is a beneficial practice under other conditions as well (Ritala, 2012). For example, the application of coopetition is relevant when industry develops swiftly, and its future is unpredictable. Firms involved in coopetition can harness multiple benefits under those conditions such as a risk of failure and cost sharing and increase their market performance (Ritala, Golnam and Wegmann, 2014). Moreover, competitors that operate in similar domains possess similar resources or complementary resources, and insights about the business environment, hence, they can better determine what these new offerings and new markets will be decreasing uncertainty. Ritala, Golnam and Wegmann (2014) suggest that in the creation of industries and offerings, coopetition is beneficial due to positive network externalities. These network externalities refer to offerings where the value that is delivered to the customer from a product or service depends on the number of other customers utilising the same product or service (Wang and Xie, 2008). For example, the mobility benefits of CAVs are expected to increase as the adoption of the technology increases in the market; therefore, competing firms are in critical roles to form a common basis for utilizing resources that work together.

Design thinking

Design thinking has different definitions as the technique has been developed simultaneously by different groups and organisations. Gruber *et al.* (2015, p.2) describe design thinking as a '*human-centered approach to innovation that puts observation and discovery of often highly nuanced, even tacit needs right at the forefront of the innovation process. It considers not just the technological system constraints but the socio-cultural system context'*. Design thinking can be practised at multiple levels by people with different capabilities since it depends on an argumentative process in which the people involved can perceive a problem and explore potential solutions gradually.

Dunne and Martin (2006) argue that management solutions use inductive and deductive logic and are acquired from a list of proposed potential solutions. Design thinking aims to think outside these predetermined answers, and to use abductive logic to attempt to see what could be. Hence, design thinking is appropriate for dealing with uncertainty when there is not available information that can solve ambiguous problems. In that sense, it fits the innovation process for connected and autonomous vehicles as within a business perspective it combines the generation of new ideas with their analysis and evaluation of how they apply in a holistic sense (Vinnakota and Narayana, 2014).

Business models

A business model has been seen as a platform between strategy and practice, describing the mechanisms of value creation and capture for organisations (e.g. Amit and Zott, 2001; Chesbrough and Rosenbloom, 2002; Teece, 2010). Essentially, a business model is a story that explains how an organisation works. To that end, business models and coopetition are linked since, in both, value creation and capture are central elements (Nalebuff and Brandenburger, 1997). Business model tools can be used to support the innovation process. Utilising the business model canvas, developed by Osterwalder and Pigneur (2011), is an effective way to understand a firm's business model by reducing complexity through a holistic analysis. Having developed a logical and tangible perspective of an organisation is important for facilitating discussion, debate and exploration of potential innovations in existing business models and promote the creation of new value through the joint resource utilisation of coopeting firms (Ritala, Golnam and Wegmann, 2014).

Approach/methodology

The 4-stages approach is based on co-creation design thinking using closed-loop processes to enable the generation of ideas based on customer aspirations and to translate them into product features and services. In particular, for emerging industries and new technologies, such as CAVs, new insights, innovations and new capabilities can be realised rapidly. The method used in this project was made up of the following four phases: discovery; design; define and ideation, and delivery phase and consisted of the following elements:

- The utilisation of the business model canvas to map organisational elements, resources, capabilities and the relationship of each organisation with its customers, suppliers and partners using semi-structured interviews with each participant organization. The business model canvas permits to visualize the main elements and was used as a guide in the ideation process (Bocken *et al.*, 2014).
- The analysis of the business model elements and the expectations for participant organisations about the connected and autonomous vehicles were utilized to design the workshop that was introduced in the define and ideation phase. This involved the visualisation of all relevant information in enabling information and knowledge transfer among the coopeting organisations informing each organisation about relevant resources, capabilities and the perception for the technology solutions around the CAV.
- Following the background work and based on resulting syntheses, a workshop was organized following these specific activities
    - Activity 1 was dedicated to helping participant organisations to understand the business model elements of their coopetitors and complement on resources and capabilities for the connected and autonomous vehicles. This facilitated a draft of the key points of the business models to assist the innovation process.
    - Activity 2 was dedicated to the development of insights about what could be enabled by the technology in the future. Hence, following a user-centred approach, participants were positioned on the role of the customers to visualise the CAVs as part of their day in the future and match their aspirations with product and service offerings.

- Activity 3 consisted of framing the problem of commuting and finding out how CAV can provide a solution to these problems. This allowed participant organizations to work for a common goal and connect product and services related to CAVs with actual problems.
- Activity 4 was dedicated to the analysis of the ideas for products and services of the previous activities to allow clustering them and combine them in relevant business opportunities.
- Activity 5 involved the discussion around which business opportunities seems more appealing from each organisation's perspective and voting for the most favourable. The participants evaluated the concepts that reached a consensus and then selected the ones as more likely to be further developed.
- Activity 6 was dedicated to exploring how competing organisations will co-create value for the most favourable business opportunities. This involved the allocation of relevant resources and capabilities of each organization to enable the development of the business opportunities scenarios.
- Activity 7 was dedicated to the identification of barriers for the realization of these scenarios considering the technical robustness and the fit with to the users. Then, mitigating actions to these barriers were defined.

- In the last phase, the documentation of the solutions and recommendations for next steps in a report allowed participating organisations to provide their feedback.

An abductive research process was followed since it is a way of working that enables data collection and theory development to take place simultaneously and fits the purpose of study that targets on a specific problem in the automotive industry (Saunders et al., 2015). Moreover, there is a clear link of abductive reasoning with the design thinking process.

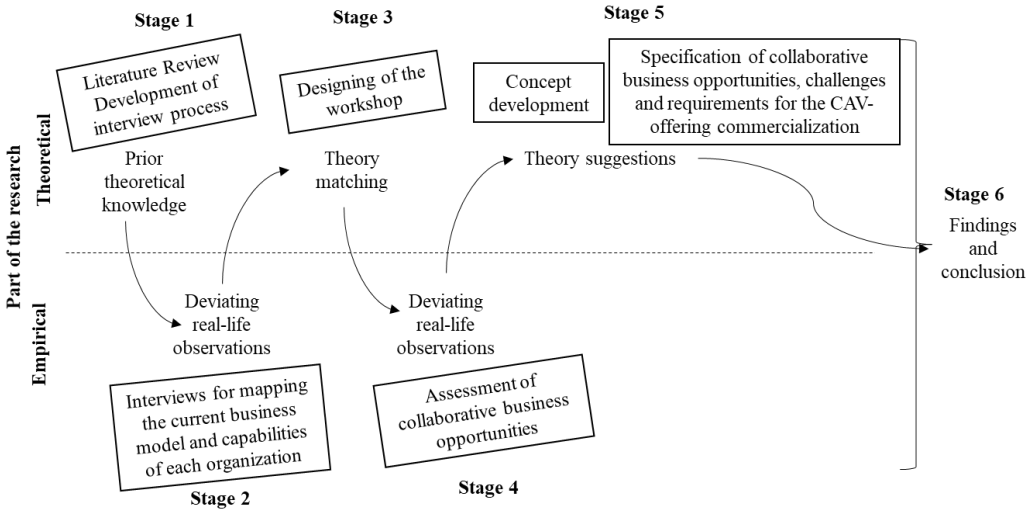

Figure 1-The abductive process adopted by Kovács and Spens, 2005

The research was built towards the development of an approach that will enable the effective exploration and exploitation of collaborative business opportunities for

connected and autonomous vehicles. A case study is the most appropriate research method since it moves away from just closing theoretical gaps through basic research and explores theory to provide a solution to a problem. To enhance the research, interviews and a workshop were selected as the most appropriate data collection tools.

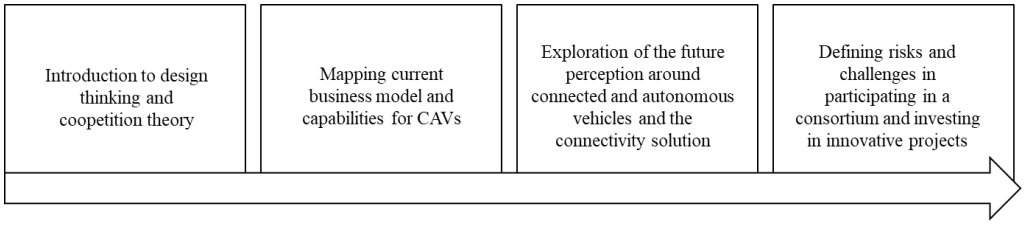

Figure 2- The interview process

All interviews were conducted via face2face meetings to secure that participant organisations were adequately informed, and their input was captured, providing them with the chance to follow-up on issues if needed. Organisations that collaborate in an established project and will be involved in the formation of commercial solutions for the connected and autonomous vehicle were interviewed. Through that, the necessary technological and market knowledge was secured, as well as, the fit of coopetition theory. Table 1 provides a full list of companies and their relevant role.

Table 1- Participant information

No.	Participant organisations	Description of their role	Interviews	Workshop
1	Automotive OEM	Car manufacturer	✓	✓
2	Infrastructure provider 1	Physical road network and maintenance	✓	✓
3	Infrastructure provider 2	Physical products and software solutions	✓	✓
4	Telecom company	Mobile connectivity	✓	✓
5	Automotive supplier	Devices and software solutions	✓	✓
6	Local authority	Urban road network	✓	✓
7	University 1	Research and development		✓
8	University 2	Research and development		✓

Findings

As illustrated in Figure 3, a new approach based on design thinking was developed, called the 4-stages modified design thinking process. The modified approach provides a strategic approach to identifying the most advantageous co-creation opportunities for an emerging industry where the final offering is still uncertain.

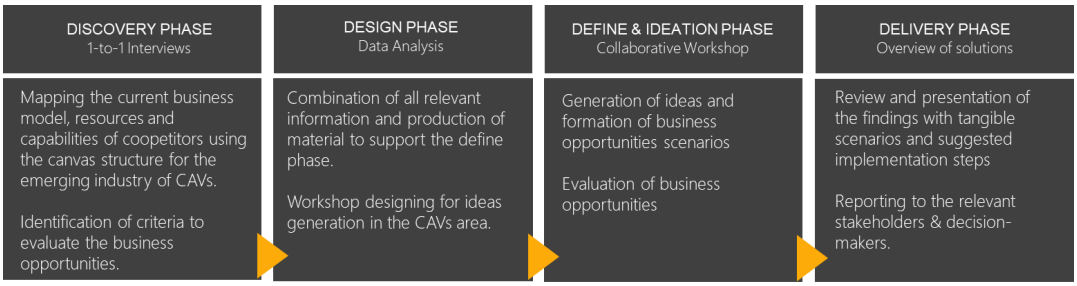

Figure 3- 4-stages design thinking process

The process utilized a modified version of the business model canvas to inform coopeting organisations on the resources and capabilities of each organisation, eliminating the inaccuracies on information gathering and transfer. This is achieved by

enabling organizations to provide feedback on the information gathered through the interviews. Moreover, the business model canvas provided an effective way for knowledge and information sharing enhancing the cooperation and allowed matching ideas for co-creation with relevant resources and capabilities of each organization (Osterwalder and Pigneur, 2011; Bouncken and Kraus, 2013).

Design thinking worked as a mean to dissolve competing relationships in the ideation stage by positioning participants in the role of the customer where details of user's lives led to new and more profound insights for offerings enabled by the connected and autonomous vehicles that were translated into products and services. A second impact during the ideation stage was observed by focusing on exploring the problem of commuting itself and, then, based on the new understandings; ideas were generated for products, services and business models to solve these problems. Dorst (2015) has argued that problem framing is one of the key design practices that make the method more likely to yield better solutions than conventional approaches to problem-solving. This stage was enhanced by having participants with different backgrounds from academics, product managers, business developers to technology specialists as different perspectives on the examined issues were combined.

Participant organizations had to collaborate in order to achieve a consensus about the most beneficial business opportunities and match their resources and capabilities to these scenarios. To achieve this, organizations had to define which technology will be used for the connectivity side. Despite that, opportunistic behaviour can be seen on determining the mix of technologies as organisations compete following their individual strategies, consensus on the resources and capabilities that are required for the realization of the final three business opportunity scenarios was found. In that sense, coopetition seems to be seen as a strategic choice for the CAVs among the networked organizations (Roy and Yami, 2009). Figure () describes the results of following the developed approach.

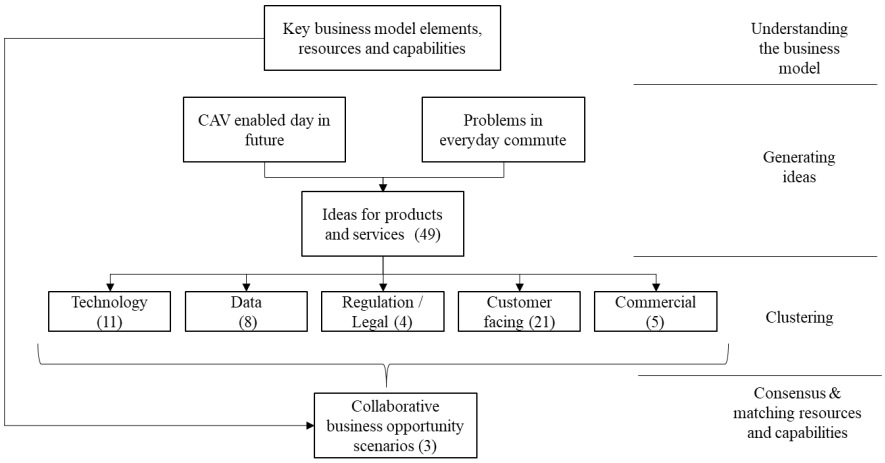

Figure 4- Results of the approach

Using a design thinking approach enabled discussions and observations that have not been identified focusing solely on the development of the technology. Hence, further insights were formed for the difficulties of commercialising CAV-enabled products and services. Except of the technological development, which is the base level in the suggested framework, data ownership and sharing issues, and incentivization were

identified as two challenges that organizations should overcome to realise the final offering of connected and autonomous vehicles. To that end, the collaborative efforts should be targeting on understanding how the customers will adopt the technology and how to demonstrate these benefits through the offerings. Moreover, the huge amounts of data that will be generated and collected as the connected vehicle interacts and exchanges data with other vehicles and the infrastructure should be classified in order to build a joint agreement about its usage and ownership. Finally, specific attention should be given around the security of the systems and the formation of an adaptive regulatory environment for the CAV technologies, products and services, with the involvement of both organisations and governments to clarify the path in all levels of commercial readiness. Figure 5 illustrates the framework for CAV commercial readiness.

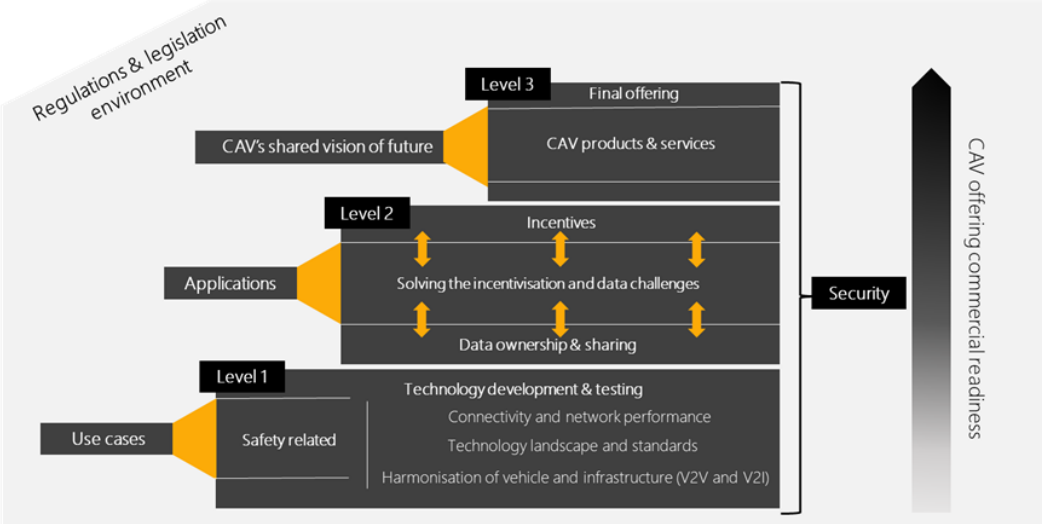

Figure 5- Framework for CAV products and services commercialization

Conclusion

To summarize, this study provides an approach for the identification of collaborative business opportunities utilizing coopetition theory, design thinking principles and the business model canvas. The case study results indicate that all three topics can be combined through the approach to enhance networked organizations in the innovation process of emerging technologies focusing on connected and autonomous vehicles. Moreover, it illustrates how competition and design thinking are valuable to provide new insights on emerging trends as they can be used for the identification of challenges and requirements that were not considered before. Finally, it provides a framework for the commercial readiness of the CAVs as the outcome of the empirical analysis. Through that, it shows that an intermediate level is required from technology development to full-scale solutions.

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How do firms manage network learning to develop solutions in global engineering services?

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Abstract
Global engineering services firms develop solutions through network learning with customers, suppliers and intra-firm engineering units, but the connection and contribution of these processes are unclear in the current literature. This paper aims to explore how firms integrate inter- and intra-firm network learning for solution development. Through the multiple case study method, it explores that firms develop solutions through an integrated inter- and intra-firm network learning process, rather than independent ones as having developed in previous studies. The integrated process is facilitated by a set of knowledge boundary spanning and governance mechanisms.

Keywords: Network learning, Solution development, Global engineering services

1. Introduction
Global engineering services (GES) firms, who provide through life-cycle project-based services to support customer businesses on a global scale, are increasingly adopting network learning for solution development to compete effectively in the changing global market (Brady and Davies, 2004; ISG, 2016; Salonen et al., 2018). Network learning is an intra- and inter-firm process that enhances firm performance through knowledge creation and reuse (March, 1991; Brady and Davies, 2004; Kotlarsky et al., 2014). Studies on network learning have found that GES firms manage network learning to acquire and develop knowledge together with customers, suppliers, and intra-firm engineering units to develop engineering solutions (Brady and Davies, 2004; Kotlarsky et al., 2014; Galbraith, 2014; Salonen et al., 2018). However, their connection and contribution to the process of engineering solution development are unclear in the current literature.

Specifically, there are two separated streams of research contributing to inter-firm and intra-firm network learning as independent processes. The marketing literature has highlighted that network learning with customers and suppliers in business networks is key to solution development (Jaakkola and Hakanen, 2013). The operations management literature has pointed out that network learning with intra-firm engineering units is the main contributor to solution efficiency, flexibility and innovation (Kotlarsky et al., 2014; Zhang et al., 2016). In this paper, we argue that network learning with

customers, suppliers and intra-firm engineering units altogether contribute to GES solution development in an integrated all-encompassing process. We will reveal the linkage between inter-firm and intra-firm network learning that contributes to engineering solution development. In brief, the main research question of our research is: **How do GES firms manage inter-firm and intra-firm network learning to develop engineering solutions in global operations**?

This paper will explore the activities and their interactions of network learning with customers, suppliers and intra-firm engineering units that contribute to GES solution development. From the perspective of learning and knowledge management, this paper will construct an integrated framework of network learning by reviewing the literature in GES solution development and network learning. This preliminary framework guides the analysis of different learning episodes from three cases. The analysis shows that GES firms manage network learning with customers, suppliers, and intra-firm engineering units within an integrated process to develop solutions. This process is facilitated by a set of knowledge boundary spanning and governance mechanisms to address knowledge boundaries between customers, suppliers, and engineering units. As the key contribution, this paper clarifies the linkage between network learning with customers, suppliers, and intra-firm engineering units to facilitate solution development in GES. This paper proposes a conceptual framework to improve our understanding of integrated network learning and offer managerial implications for facilitating solution development in GES operations.

2. The theoretical foundation

2.1 Global engineering services (GES)

Global engineering services (GES) refer to "the application of engineering knowledge (including engineering technologies, skills, and expertise) possessed by an engineering services firm in effective problem-solving for the benefit of customers in a global context" (Zhang et al., 2016, p.81). They include three interrelated stages: corporate technology planning, technology development, and product development (ISG, 2013). Corporate technology planning is a complex and valuable activity, directing the operations of the other stages. Technology and product development are more operational, involving engineering research, design and development, and manufacturing engineering. These operations can be distributed in many countries to enhance operational efficiency and effectiveness (Zhang et al., 2016).

GES are delivered in different types of projects at firm facilities or customer sites (Malhotra & Morris, 2009). Customers are integrated into projects for the purposes of customisation (Jaakkola & Hakanen, 2013). GES firms employ diverse teams of engineers with different backgrounds, skills and experiences, and integrate them into specialised engineering units for GES operations (Malhotra & Morris, 2009). Suppliers are also involved into GES projects to co-create the solutions required by customers, providing complementary knowledge for GES operations (Jaakkola & Hakanen, 2013).

2.2 Solution development in GES

GES projects generate customised solutions which are developed continuously to meet changing customer demands (Tuli et al., 2007). Engineering solutions involve product life-cycle development for the benefits of customers (Kujala et al., 2010). They include process-oriented and output-oriented solutions (Breidbach and Malgio, 2016). Process-oriented engineering solutions are created only when engineers are deeply embedded within the customer organisational context to co-create engineering solutions

through the eyes of the customers (Tuli et al., 2007). Output-oriented solutions are mostly created separately from the customer organisational context and rely on service provider specialised expertise, involving the delivery of artefacts as the mechanisms for service (Galbraith, 2014).

GES firms develop solutions either by enhancing their operational performance (Brady and Davies, 2004; Kotlarsky et al., 2014) or creating novel solutions (Galbraith, 2014; Zhang et al., 2016). An efficiency-focused solution development strategy enhances the operational abilities that help GES firms outperform their rivals through implementing their engineering tasks with fewer resources (Brady and Davies, 2004, Kotlarsky et al., 2014). An innovation-focused strategy highlights the operational abilities that help GES firms create new engineering solutions for customers (Galbraith, 2014, Zhang et al., 2016). Firms can also focus on a flexible strategy which emphasizes the operational abilities that help GES firms quickly respond and adapt to changing customer needs either for efficiency or innovation (Johnstone et al., 2009; Zhang et al., 2016).

2.3 Network learning for solution development in GES

Network learning has been increasingly recognized as a key strategy for solution development in GES (Brady and Davies, 2004, Zhang et al., 2016; Salonen et al., 2018). The concept of network learning has been studied within the field of organizational learning (Crossan et al., 1995, Knight, 2002). Knight and Pie (2002;2005) are among the influential authors who studied network learning as the fourth level of organisational learning which refers to the learning of organizations as a group. Network learning occurs when there are changes in network shared cognition and practices. Knight (2002) argues that network learning, whether inter-firm or intra-firm network learning, can only be captured within a network learning episode in which learning goals, actors and activities are specified. To understand how firms manage network learning, the context, content, and process of network learning should be clarified (Knight and Pie, 2005). The network learning context refers to various facets of the outer and inner contexts that drive and affect the network learning process and the network learning content. Network learning content refers to learning outcomes within a network learning episode. Network learning process refers to network practices and interactions through which network-level changes occur (Knight & Pie, 2005). Network learning faces challenges regarding knowledge boundaries between network learning actors that require knowledge boundary spanning mechanisms to facilitate knowledge transfer, translation and transformation (Dyer and Nobeoka, 2000; Carlile, 2004). In this view, network learning with customers, suppliers, and intra-firm engineering units for solution development in GES can be studied in aspects of network learning drivers, outcomes, processes and supporting mechanisms.

GES firms practise network learning with customers due to changing customer demands (Tuli et al., 2007). Under pressures from markets and regulators, customers are constantly changing their demands for innovative and more efficient solutions (ISG, 2016). Customers can demand a better service (Brady & Davies, 2004), a new product (Galbraith, 2014), or new technologies (Johnstone et al., 2009). Network learning with customers, on the one hand, is to create engineering solutions that customers demand. On the other hand, it is to capture solution knowledge co-created with customers for future exploitation (Brady and Davies, 2004; Salonen et al., 2018). Network learning processes with customers therefore include knowledge creation with customers (Brady and Davies, 2004; Jaakkola and Hakanen, 2013) and knowledge reuse for innovation with a group of customers to transform existing solutions into better ones (Majchrzak et

al., 2004; Galbraith, 2014). These processes are supported by boundary spanners and governance mechanisms such as boundary spanning tools, learning coordination, knowledge governance and technological mechanisms to facilitate knowledge sharing, creation and reuse (Breidbach & Maglio, 2016; Zhang et al., 2016).

GES firms collaborate with various sub-tier suppliers and technology partners to create solutions that customers require (Windahl & Lakemond, 2006; Coghlan & Coughlan, 2014). Under the contexts of changing technologies and changing demands, firms need to collaborate with various suppliers to have complementary capabilities facilitating customer-driven innovation (Meijboom et al., 2007). By integrating suppliers into solution networks and adopting network learning with suppliers, GES firms use suppliers' capabilities and are thus able to fulfil changing customer demands (Windahl & Lakemond, 2006; Jaakkola & Hakanen, 2013). Past research indicated that GES firms practised network learning with sub-tier suppliers to co-create knowledge for operations improvement (Coghlan & Coughlan, 2014) and with technological partners to reuse knowledge for innovation (Majchrzak et al., 2004; Windahl & Lakemond, 2006). Various boundary spanners and governance mechanisms are adopted to facilitate knowledge sharing and network learning (Coghlan & Coughlan, 2014; Salonen et al., 2018).

Intra-firm engineering units are involved in network learning to enhance GES efficiency, flexibility, and innovation (Kotlarsky et al., 2014; Zhang et al., 2016). Moore & Birkinshaw (1998) argue that the competitive advantage of GES firms is determined by their capability to bridge the knowledge gaps between internationally dispersed engineering units. GES network learning with engineering units enables knowledge sharing between engineering units (Hansen, 2002) and helps transfer intangible knowledge across dispersed engineering units (Malhotra & Morris, 2009; Kotlarsky et al., 2014). Research on network learning with intra-firm engineering units shows that GES firms reuse knowledge across different project teams for solution development (Brady and Davies, 2004; Kotlarsky et al., 2014) and create new solutions within autonomous research projects involving various engineering functions and research engineers (Hoegl & Schulze, 2005; Galbraith, 2014). In the adoption of network learning with intra-firm engineering units, GES firms face challenges caused by dispersed intangible engineering knowledge and complexity knowledge boundaries between different engineering units (Dyer and Nobeoka, 2000; Carlile, 2004). They must use different knowledge boundary spanners and governance mechanisms to facilitate knowledge sharing for network learning (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016).

2.4. The preliminary framework

The literature review suggests that GES firms adopt network learning with customers, suppliers, and intra-firm engineering units to develop more efficient and innovative solutions in GES (Brady and Davies, 2004; Jaakkola & Hakanen, 2013; Zhang et al., 2016). However, the connection and contribution of these processes to solution development remain unclear in existing studies. They have been developed within an either inter-firm or intra-firm network learning context. These processes are fragmented and inconsistent in the current literature. Figure 1 indicates the current relations between network learning with customers, suppliers, and intra-firm engineering units that contribute to solution development. The figure offers a preliminary framework to investigate an integrated network learning process for solution development in GES. With this integrated process, GES firms adopt network learning with customers to address the changing customer demands, with suppliers to

exploit complementary capabilities, and with intra-firm engineering units to leverage dispersed engineering units' knowledge. Network learning with customers, suppliers, and intra-firm engineering units all involve knowledge reuse and knowledge creation, supported by a set of knowledge boundary spanners and governance mechanisms.

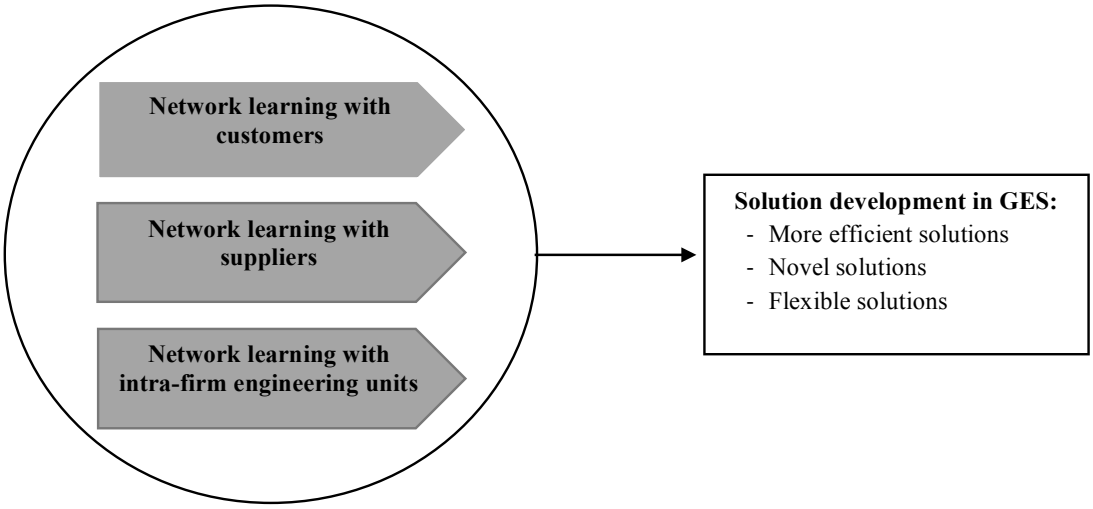

Figure 1 – The preliminary framework

3. Methodology

The inconsistency of current literature and the complexity of GES firms' operations suggested the appropriateness of using case studies for theory building of integrated network learning for solution development in GES (Ketokivi & Choi, 2014; Miller & Tsang, 2010). A multiple case study method was adopted to address the diversity of GES firms and their complex network learning practices, which enhances the external validity of our research findings (Eisenhardt, 1989; Miller & Tsang, 2010). The preliminary framework guides case selection, data collection and analysis.

Case selection- three GES firms were intentionally selected for the purpose of theoretical replication (Yin, 2018), i.e. Case A, B and C (see Table 1). Case A provides process-oriented IT solutions; Case B offers aerospace engineering solutions; and Case C produces bio-simulation solutions for drug development. They are networked engineering service firms, having relationships with numerous customers and suppliers, and being different in industries, sizes, and solution development strategies. These differences offer opportunities to enhance the emerging constructs of the theoretical framework (Eisenhardt, 1989).

Data collection- interviews were the main method used to capture empirical data. They were complemented and triangulated by documentary studies, archival records, direct and participatory observations (Yin, 2018). A semi-structured interview protocol was developed based on the preliminary framework, focusing on the key themes such as network learning drivers and outcomes, knowledge reuse and creation processes, and facilitating mechanisms for knowledge sharing. A total of 31 interviews were conducted across the three case companies in the period from September 2016 to November 2017, with the average duration of around one hour per interview. Informants were intentionally selected (Eisenhardt & Graebner, 2007) to include respondents at different management levels, and with different engineering functions and geographical locations in the UK and South East Asia. They were corporate level managers, business managers,

site managers and engineers who were engaged in network learning for solution development. There were seven informants from Case A, five from Case B and nineteen from Case C. The lead author had an opportunity to stay in the head office of Case C for one week and therefore had opportunities to reach a large number of informants. In the Case A and B, it was challenging to reach new and existing informants in terms of time and space because they were located at different sites in different countries and had tight working schedules. About one-fifth of the informants were interviewed multiple times through various communication channels such as face to face meetings, phone calls, Skype and WebEx sessions. After each interview, the data were transcribed, resulting in a total of 436 pages of text which were then input into Nvivo software for data analysis. In addition, over 20 company documents, 11 company archives, and more than 30 public company reports were used as another data source for triangulation (Yin, 2018).

Table 1 - Case companies (information updated in 2017)

Features	Case A	Case B	Case C
Services	Process-oriented IT solutions	Aerospace engineering solutions	Bio-simulation solutions
Size (employees)	1,500	11,000	400
Revenue (£ m)	10	2,000	-*
Customers	Nearly 1000 customers in diverse industries	A few large customers in aerospace, energy, medical device and automotive industries	Over 1200 commercial clients within the pharmaceutical industry
Intra-firm engineering units	A network of two engineering offshore captive centres and eight offices in the UK, Europe, the US and Asia Pacific	A network of five competence divisions with over 50 manufacturing and engineering sites located in North America, Europe, UK and Asia Pacific	A network of one engineering research centre in the UK and 19 offices worldwide
Suppliers	A few technology suppliers	Around 6000 direct suppliers	Over 250 academic and regulatory partners
Solution development strategy	More efficient solutions	Flexible solutions	Novel solutions

* Financial performance is kept confidential by the company.

Data analysis- single and cross-case analysis were conducted to explore the linkage between inter-firm and intra-firm network learning and to explain their contributions to solution development. Single case analysis was based on three network learning episodes with customers, suppliers, and intra-firm engineering units to explore their network learning drivers, processes and mechanisms, and outcomes. It allowed for the identification of the connection and contribution of these network learning episodes to each other and to solution development in GES. Interview transcriptions were coded and analysed according to predefined preliminary framework emphasizing network learning drivers, outcomes, and processes. The coding processes were assisted by NVivo – version 11 in organizing and integrating nodes into categories such as network learning drivers, outcomes, processes, and mechanisms. Pattern matching techniques were adopted for single and cross-case analysis (Yin, 2018). Network learning episodes were compared in terms of context, content and process. Such techniques enabled to clarify the connection and contribution of network learning episodes and induce an

emerging theoretical framework of integrated network learning for solution development in GES.

4. Case analysis

Single case studies showed that firms managed network learning with customers, suppliers, and intra-firm engineering units in an integrated process, rather than managing them independently, to develop solutions in GES. Firms used inter-firm network learning to capture new knowledge and information for intra-firm knowledge reuse that enhance solution operation performance and intra-firm knowledge creation and solution innovation. These integrated network learning processes were facilitated by a set of knowledge boundary spanning mechanisms that enhance knowledge sharing and network learning across internal and external boundaries. Table 2 presents key results from single case analysis.

Table 2 - Case analysis

Integrated network learning	**Case A**	**Case B**	**Case C**
Drivers	• Changing customer demands for cost-effective process-oriented IT solutions. • Knowledge gaps between dispersed and diverse project teams. • Updated supplier technologies that customers demand.	• Changing customer demands for excellent operations and new technologies. • Knowledge gaps between dispersed and diverse engineering sites. • Suppliers' capabilities and technologies.	• Changing customer needs for novel bio-simulation platforms. • Knowledge gaps between diverse research scientists. • Suppliers' research capabilities.
Processes	• Knowledge creation between project teams and technology partners to capture updated technologies for knowledge co-creation with customers. • Knowledge co-creation between projects teams and customers to capture knowledge for knowledge reuse across project teams. • Knowledge reuse across project teams for solution efficiency.	• Knowledge creation between engineering sites and sub-tier suppliers to capture best practices for knowledge reuse. • Knowledge co-creation between engineering sites and customers to capture best practices for knowledge reuse. • Knowledge reuse across engineering sites for operational excellence. • Knowledge reuse for innovation between engineering sites and customers to capture customers' problems for technology innovation. • Knowledge creation across engineering sites for new technology generation. • Knowledge reuse for innovation between engineering sites and technology partners to capture suppliers' knowledge for technology transformation.	• Knowledge reuse for innovation between research scientists and customers to capture customers' problems and data for new model creation. • Knowledge creation between research scientists for novel models that address customers' problems. • Knowledge reuse for innovation between research scientists and research institutes for new model validation and confirmation.

Integrated network learning	Case A	Case B	Case C
Knowledge boundary spanning mechanisms	• Decentralised functional teams and informal knowledge sharing mechanisms for knowledge creation with technology partners. • Centralised functional teams, global information systems, project-based coordination standards, formal human resource management (HRM) mechanisms and analytic technologies for knowledge co-creation with customers and knowledge reuse across project teams.	• Centralised functional teams, global information systems, operational standards and formal project-based coordination and HRM mechanisms, analytics and machine learning technologies for knowledge creation with customers and knowledge reuse across engineering sites. • Decentralised specialised teams, informal knowledge sharing in clusters for knowledge creation with sub-tier suppliers. • Centralised technology management board, formal, project-based knowledge sharing mechanisms for knowledge reuse for innovation with customers and technology suppliers. • Decentralised project teams and informal forums, meetings, HRM mechanisms for knowledge creation across engineering sites.	• Centralised management board, formal consortium meetings with customers and project-based coordination with research suppliers for knowledge reuse for innovation • Decentralised project teams, informal seminars, meetings and HRM mechanisms, and specialised predictive technologies for knowledge creation of research scientists.
Outcomes	• More efficient software development	• Improved global operations • New technologies	• Novel bio-simulation models

Cross case analysis indicates two patterns of integrated network learning: network learning for novel and efficient solutions (Figure 2 & 3). Case B and C developed novel solutions by re-using knowledge for innovation with external customers and suppliers to capture customers' requirements and complementary supplier knowledge for intra-firm knowledge creation. Inter-firm network learning employed centralised management teams and formal governance mechanisms to facilitate external knowledge sharing, while intra-firm network learning relied on decentralised project teams and informal coordination and governance mechanisms to facilitate knowledge creation.

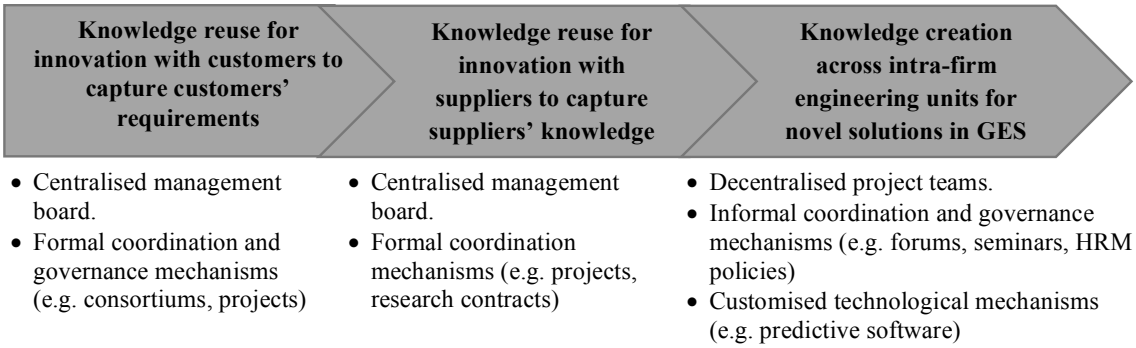

Figure 2 – Integrated network learning for novel solutions

Case A and B enhanced solution efficiency by co-creating knowledge with suppliers and customers that was reused across intra-firm engineering units. They adopted centralised functional teams and formal governance mechanisms to address knowledge boundaries across customers and engineering units. Decentralised functional teams and informal governance mechanisms were more effective to facilitate local knowledge creation with suppliers.

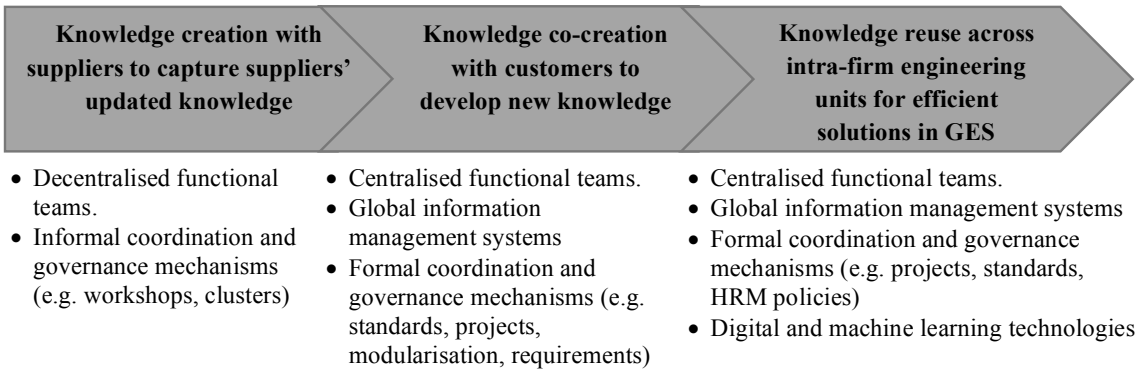

Figure 3 – Integrated network learning for efficient solutions

5. Conclusion

The paper provided a deeper insight into how firms integrate inter-firm and intra-firm network learning for solution development. It showed that firms integrated inter-firm and intra-firm network learning to develop solutions in GES through a set of interrelated knowledge capture and development processes and knowledge boundary spanning mechanisms. The analysis also indicated two patterns of integrated network learning, network learning for novel and efficient solutions.

The case study clarifies the linkage of inter-firm and intra-firm network learning processes for novel and more efficient solutions in GES which remained unclear in the operations management literature (Moore and Birkinshaw, 1998; Kotlarsky et al., 2014; Zhang et al., 2016) and the industrial marketing management literature (Jaakkola and Hakanen, 2013; Breidbach and Maglio, 2016; Salonen et al., 2018). The developed integrating frameworks also offer managerial implications for effective implementation. Managers can adopt various mechanisms to facilitate knowledge sharing, reuse and creation across internal and external boundaries that enhance solution performance. Future research is expected to further develop network learning processes through customers' and suppliers' viewpoints, validate them with large scale empirical data, and transfer them to other industrial settings.

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Dynamic Business Modelling for Sustainability: Exploring a Systemic Design Perspective

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Abstract

The design of business models for sustainability has gained increased attention recently. A common understanding of the principles and requirements for the development sustainability-oriented business model is sought. Literature has endeavoured into a profound analysis of design tools for business models. Results show methodological gaps that could be potentially addressed by further development. Within such context, the aim of this work is to contribute towards exploring how a dynamic approach to sustainability-oriented business modelling may overcome such gaps. The proposed approach uses a systemic design perspective derived from the combination between the original Business Model Canvas and System Dynamics modelling.

Keywords: business models for sustainability, dynamic business modelling, system dynamics.

Introduction

The emerging field of business models for sustainability (BMfS) have been steadily gaining attention from scholars and practitioners, with scientific conferences and journals encouraging the development of the debate on their design, use and innovation processes (Foss & Saebi, 2017). Recent studies highlighting the relevance of BMfS explored the state-of-the-art in the field, bringing out principles, criteria, and tools related to BMfS development, as well as design requirements, methodological gaps and shortcomings of the extant modelling approaches (Breuer et al., 2018; Lüdeke-Freund et al., 2019; Dentchev et al., 2018).

The research process presented in this paper begins with the review of the literature on BMfS design tools. This review is combined with an examination of existing approaches which make use of a systemic design approach to model BMfS. Thus, it offers a wide overview on the state of the art wherefrom to draw insights towards identifying methodological shortcomings and for ultimately comparing findings.

Given the multi-dimensional and complex nature of sustainability (Laasch, 2018), the process of designing business models to represent sustainable value adequate becomes a challenge (Biloslavo, Bagnoli, & Edgar, 2018). Furthermore, the extant modelling and design methods for business models are limited and rarely geared towards sustainable value (Evans et al., 2017).

As business models ultimately establish and define several of the relationships among actors across a value network in constantly changing (dynamic) setup, simulation is required in order to reveal accurate systemic decision-making (Täuscher & Abdelkafi, 2017). Drawing on these findings and with a view to overcoming the main critical issues affecting the development of BMfS, this paper aims at conceptualizing and investigating a systemic approach for designing BMfS wherein sustainable value elements (i.e., environmental, social and economic/financial) may coexist and interact forming causal feedback structures able to frame value generation processes.

Research Design

Within such context, a four-step design approach has been defined, as shown in the schematic representation of **Figure 1**. The process starts with a review of the literature on business models (BM) design tools (**step 1**). This particular review is combined with an investigation into existing approaches that makes clear use of a systemic design perspective to derive business models, with a particular emphasis on tools for sustainability-oriented modelling. This step offers a wide overview on the state of the art. From there, methodological shortcomings in the currently available tools are identified (**step 2**).

Building on this literature review, an approach named Dynamic Business Modelling for Sustainability (DBMfS) is conceptualized as a lean systemic method to model and explore the process of creating sustainable value (**step 3**). Finally, a critical analysis was performed in order to understand the main potential areas for improvement in the proposed approach, as a way to inform next steps in this research stream (**step 4**).

Figure 1 – The four-step research design

Results and Discussion

As emerged from the literature review, current design tools and approaches for developing BMfS seem to generally display three main severe limitations, namely **(i)** the main outputs (i.e., innovation ideas) originated from business modelling activities are not followed up; **(ii)** there is a persistent lack of implementation of BMfS and **(iii)** business models implemented by companies typically fail when exposed to the market (Geissdoerfer et al., 2018). This is mainly caused by the complex and dynamic nature of BMfS and its implementation (Abdelkafi & Täuscher, 2016; Demil & Lecocq, 2010; Evans et al., 2017). Namely, such a dynamic complexity characterizes BMfS as living structures, with a wealth of interactions and complementarities that can be framed through feedback loops (Abdelkafi & Täuscher, 2016; Hjorth & Bagheri, 2006; Sterman, 2000), thus capturing sustainability from a systemic perspective (Abdelkafi & Täuscher, 2016; Boons et al., 2013; Lozano, 2018).

There seems to be an underlying requirement that underpins the logic of these design tools and approaches for BMfS: innovation must be focused on producing social and/or

environmental benefits. This focus prescribes a shift of value proposition to explicitly address and encompass the society and the environment (Bocken et al., 2014; Stubbs & Cocklin, 2008). Furthermore, Breuer et al. (2018) emphasize the need to expand traditional organizational boundaries in alignment with a systemic perspective. The underlying rationale of this expansion is to integrate a multitude of stakeholders and make better use of resources, both internal and external, such as knowledge and information.

By considering a wider perspective of sustainable value creation, with multiple stakeholders, companies not only considerably reduce risks, but also mitigate the effects of potential tensions across the stakeholder network. Collaborative modelling techniques are proved to be effective for engaging multiple stakeholders into one shared and common perspective. (Rouwette, 2011). As a complement to this idea of active stakeholder engagement and management, scholars and practitioners consider the BMfS to be an extremely useful tool for examining the sustainability and viability of a business, supported by a selected set of key performance measures. More rigorous empirical approaches for collecting data and measuring performance should then reflect the potential differences between planned and actual business models, and potential unrealized activities (Dentchev et al., 2018).

The approach proposed in this paper builds upon the combination of the **(i)** modified Sustainable Business Model Canvas (Osterwalder & Pigneur, 2010) proposed by Bocken et al. (2018) and the **(ii)** System Dynamics (SD) modelling approach (Cosenz, 2017; Cosenz & Noto, 2018). **Figure 2** displays a generic schematic representation of the proposed design approach. The methodological support provided by SD has proven to be effective in modelling and analyzing business systems characterized by dynamic complexity and unpredictability, as well as in experimenting with the models to design and test strategies for performance management, sustainable development, and change (Morecroft, 2007, 2013; Torres et al., 2017; Sterman, 2000; Bianchi, 2016; Videira et al., 2010).

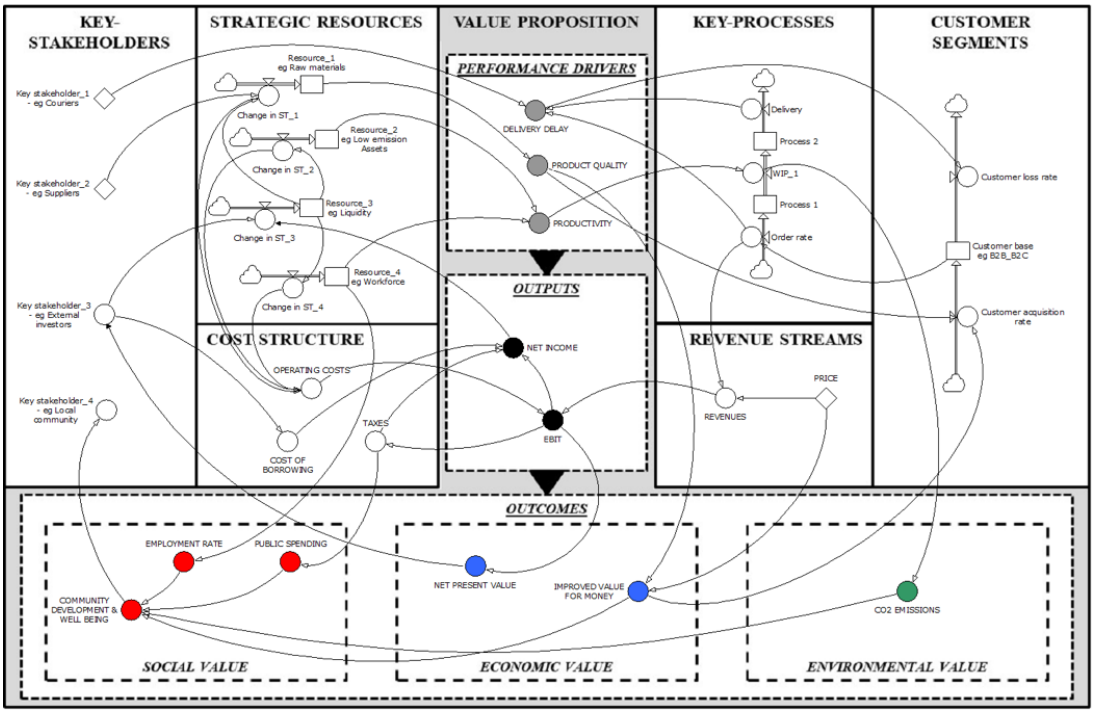

Figure 2 – Schematic representation of the Dynamic Business Modelling for Sustainability (DBMfS)

The proposed DBMfS expands the model's dimension of *key partners* by contemplating other relevant stakeholders (Bocken et al., 2015; Bocken et al., 2018). Additionally, the perspectives of customer relations, distribution channels and key activities are then unified in the *key processes* dimension. Furthermore, the core concept of value proposition is divided into sub-categories which individually addresses **(i)** *value drivers*, i.e. those critical factors influencing key processes and therefore providing mechanisms for achieving competitive edges, **(ii)** *outputs*, i.e. short-term results achieved by the company and, finally, **(iii)** *outcomes*, i.e. long-term results that displays broader impact within and beyond the reach of where the company actually operates. These outcomes are further sub-categorized into **(a)** *social value*, **(b)** *economic value* and **(c)** *environmental value* in order to frame the sustainable value dimensions better. Each sub-category in the value proposition embraces a set of indicators to measure the firm's performance according to the multidimensional perspective of sustainable value (Evans et al., 2017; Dentchev et al., 2018; Bocken, 2015; Bocken et al., 2018).

With a view to addressing design limitations and conform with the requirements for business model development (Bocken et al., 2014; Breuer et al., 2018; Dentchev et al., 2018), the methodological structure provided by System Dynamics modelling approach allows for the charting and quantification of the causal links among elements of the business model, in close alignment with a systemic and endogenous perspective. The attributes proving the effectiveness of this simulation method for the design of BMfS are also associated with the rationale geared towards understanding how results emerge from different inputs in a complex setting that is particularly full of causal loops (Davis et al., 2007; Torres et al., 2017). These elements are compliant with the pragmatic approach required by the research on design of BMfS (Bocken et al., 2014; Breuer et al., 2018; Dentchev et al., 2018). With this, the proposed DBMfS, based on a SD approach, may offer profounder understanding of how specific conditions may affect business performance.

Conclusion

This approach contributes to sustainable business model research by conceptualizing a systemic and holistic design tool which frames environmental, social and economic drivers of value generation into a unique business model causal feedback structure.

For researchers, the study offers new streams of research for simulation-based and dynamic business modelling tools to be enhanced and developed. For practitioners, the conceptualization of the DBMfS approach adds value to how a company's business model can be properly understood, adapted and changed over time in order to create sustainable value, with its three distinguished components. The study also shows how decision-makers can make use of the DBMfS to develop scenarios and "what-if" analysis.

For policy-makers, the proposed DBMfS might potentially aid the development of targeted sustainability-related policies based on the substance of value created by specific initiatives. Different industrial sectors or types of organizations might respond differently to sustainability inputs in terms of performance, thus supporting the development of context-specific policies for the development of BMfS.

Several topics for future research can be explored. In order to fully explore the potential put forth by the proposed approach, next research efforts could focus on **(i)** developing a quantitative approach based on the concept of the DBMfS in order to simulate the different scenarios for the business models; **(ii)** designing an empirical data collection protocol to test the efficacy of the DBMfS, and **(iii)** defining and structuring

the types of data that are required in order to fully develop the quantitative frame of the DBMfS.

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Modeling the enablers of sustainable new product development based on circular economy

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Abstract

In the fast changing global business, New Product Development (NPD) has emerged as an integral part of business strategy. For a firm to maintain its position in market and to gain a sustainable competitive advantage new product is an important driver to innovate. Implementation of NPD is a challenging task and is affected by numerous factors therefore choosing a right combination of variables or factors or enablers may result in a design of a unique theme for making a successful new product and also provide an opportunity to cater the needs of environmental sustainability**.**

Keywords: Determinants/Factors, Interpretive Structural Modeling, and New Product Development

Introduction

New product development basically includes all activities connected with transforming the substantial ideas into a tangible product for market affirmation. The objective of product development process is to convert the market opportunity and a set of assumptions regarding product technology into a product available for sale (Krishnan and Ulrich, 2001). In business success, New Product Development is considered as one of the most crucial areas for the competence of the firm (Guo, 2008). According to the best practices surveys conducted by Product Development & Management Association (PDMA) it is deduced that even organizations had carried out a number of new methods and techniques to improve the process of new product development, the success rates of new product remains to be steady at around 60%. The probability of increasing the success rate of new products is invariably a key motivation in carrying out research in new product development by developing the new practices.

The aim of this paper is to develop the relationships among the combined identified factors of NPD and circular economy by using interpretive structural modeling (ISM) and classify these factors depending upon their driving and dependence power. ISM is a well established methodology for identifying relationships among specific items which

define a problem or an issue (Thakkar, 2008). The opinions from group of experts are used in developing the relationship matrix, which was later used in the development of the ISM model. The factors are derived theoretically from various literature sources, and experts' discussion. Some factors are extracted from the work of those who have explored product development (PD) in general or have addressed a particular factor in detail.

Literature Review

Factors, which aid organizations to implement PD, have been identified from various authors who have researched and written directly on this issue. Studies have highlighted few critical factors influencing NPD of firms viz., product meets customer needs; company resources, launch proficiency, senior management support, cross functional integration, organizational culture and many more as discussed in the literature review.

From the results of the Cooper's and Kleinschmidt's initial work at the project level up to the end of the 1970s, concerning the NPD process the two observations can be made from the two aspects that have been had a notable positive impact on the success of new products. These are 1) the efficiency of activities performed at each stage of product development particularly in development, market observations, and launch in the market and 2) employing market information during the entire NPD process which is later confirmed by Cooper (1979a, 1980a) and Atuahene-Gima (1995). A strong market orientation, undertaking the marketing tasks in a quality fashion, doing the predevelopment activities well, and having sharp, early product definition before product development begins have all been found to be correlated with success. Aligned with this type of approach, another study to explore the practices has identified two major factors namely customers' needs, wants, and specifications for the product, customers' price sensitivity to implement product development (Mishra et al., 1996). In addition to market information and customer orientation it is observed that firm management plays a crucial role for subjective and long term performance measurement as governed by senior management support. It is essential when resistance to change is encountered (McAdam and Leonard 2004). Second, the momentum behind new product ideas is stronger if senior management is directly involved during the front end activities of NPD (Murphy and kumar, 1997; Lauto et al., 2013)

For a firm to achieve pioneering advantage (or first-mover advantage) which is defined as the capability of a firm to obtain an advantage over its competitors by the early introduction of a new product category they have to keep pace with the ever changing market (Suarez and Lanzolla, 2005). The necessary resources people, money, facilities-to achieve the stated new product objectives; R&D budgets were adequate; and the needed people-with free time-were in place. Reengineering and reorganizing new product processes and structures is an unending endeavor, as management seeks to improve new product success rates, yet reduce development cycle time.

A recent study based on 233 empirical studies done by authors Evanschitzky et al. (2012), has proposed thirty three factors, amongst them, cross-functional integration and culture have been identified as top most factors (Evanschitzky et al., 2012). According to this survey, there is no cross-functional transformation available. Merely coordinating, collaborating, or even integrating the two functions does not transfer differentiated assets between them. A creative culture encourages a firm's employees to use their innovative talent to produce and refine a steady stream of ideas (Murphy and Kumar, 1997; Kim and Wilemon, 2002). A creative culture also reinforces a firm's

market orientation by promoting consistency, efficiency, and productivity in the front end (Langerak et al., 2004).

The above factors are then compared with the factors of circular economy and their combined effect is taken in our study. The study by Sousa-Zomer et al. (2018) highlighted that for successful implementation of circular business model collaboration, involvement of different organization functions and integration between the outside factors and the business model are important. Another study by Kirchherr et al. (2018) regarding barriers of circular economy from the European Union explained the main factors as non awareness of customer, status of uncertainty of the companies, stringent laws and regulation, lack of proven technologies to adopt new processes. The behavioral study model by Singh et al. (2018) explored circular economy readiness in manufacturing MSMEs in India found environmental commitment, green economic incentives and social pressure as important components affecting other factors as well. Limitations and challenges for achieving circular economy is discussed by Ghissellini et al. (2016) in his study of the last two decades of literature review of circular economy at the micro, meso and macro level.

Based on the literature review, the authors have identified nine factors to PD initiatives in the organization based on circular economic perspective. These factors have been considered for the analysis in the paper.

Table1 - Enablers of NPD

SL. No	Determinants/Factors	Definition
1)	Product meets customer needs	Product which not only meets customer needs but also have technical maximum reusability of materials
2)	Product Price	Price of product based on non renewable energy rather than labor and renewable energies taxation
3)	Company resources	Focused commitment of company resources to a new product initiative
4)	Launch proficiency	Launch proficiency by promoting design of products for reuse, recycle, and recovery of material component parts
5)	Reduced cycle time	Technological expertise requirement in manufacturing which leads to reduced cycle time
6)	Senior management support	Senior management support and interest in new complex and costly process of manufacturing
7)	Cross functional integration	Multi department participation should be the culture of company environment promoting innovation
8)	Organizational culture	The extent to which the day-to-day decisions are governed with organization/group's shared values and norms
9)	Market potential	Demand of customers to buy innovative environment friendly products

Research Methodology

ISM is a well-established methodology for identifying relationships among specific items, which define a problem or an issue (Sage, 1977). ISM methodology is an interactive learning process whereby a set of different directly and indirectly related elements are structured into a comprehensive systematic model. The model so developed by ISM portrays the structure of a complex issue, a system of a field of study,

in a carefully designed pattern employing graphics as well as words. ISM methodology helps to impose order and direction on the complexity of relationships among elements of a system.

Steps of ISM Methodology

Structural self-interaction matrix (SSIM)
Group of experts, from industries and the academics were consulted in identifying the nature of contextual relationships among the factors. For analyzing the factors in developing SSIM, the following four symbols have been used to denote the direction of relationship between factors (i and j):

V - factor i will help to achieve factor j;
A - factor j will help to achieve factor i;
X - factors i and j will help to achieve each other; and
O - factors i and j are unrelated

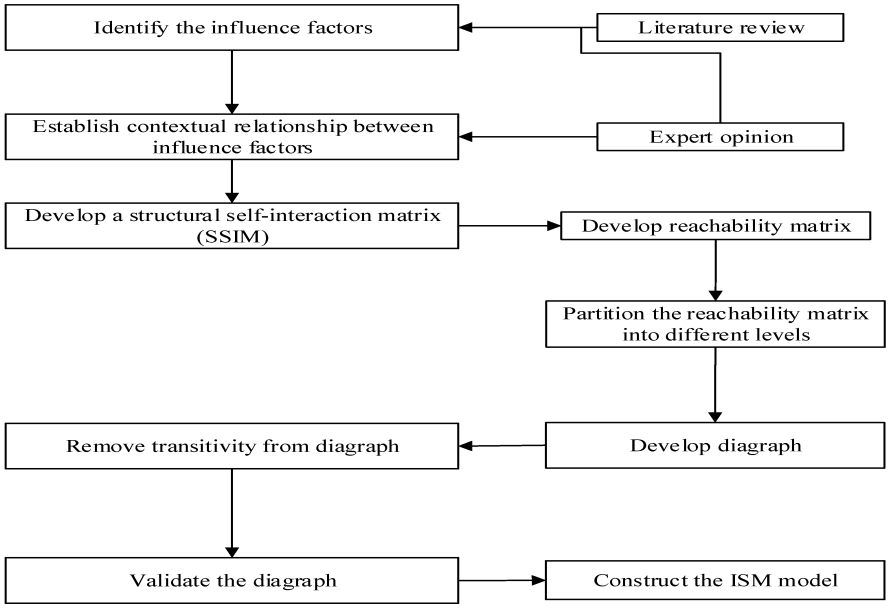

Figure 1- Flow Diagram of ISM Methodology

Table 2 - Structural Self-Interaction Matrix (SSIM)

Factor number	Factor description	Factor number							
		9	**8**	**7**	**6**	**5**	**4**	**3**	**2**
1	Product meets customer needs	V	V	V	V	V	V	V	V
2	Product Price	V	V	V	V	V	A	A	
3	Company resources	V	V	V	V	V	X		
4	Launch Proficiency	V	V	V	V	V			
5	Reduced cycle time	V	V	V	V				
6	Senior management support	V	V	V					
7	Cross functional integration	O	V						
8	Organizational culture	A							
9	Market potential								

Reachability matrix

The SSIM has been converted into a binary matrix, called the initial reachability matrix by substituting V, A, X and O by 1 and 0 as per the case. The substitution of 1s and 0s are as per the following rules:

- if the (i, j) entry in the SSIM is V, the (i, j) entry in the reachability matrix becomes

1 and the (j, i) entry becomes 0;

- if the (i, j) entry in the SSIM is A, the (i, j) entry in the reachability matrix becomes

0 and the (j, i) entry becomes 1;

- if the (i, j) entry in the SSIM is X, the (i, j) entry in the reachability matrix becomes

1 and the (j, i) entry also becomes 1; and

- if the (i, j) entry in the SSIM is 0, the (i, j) entry in the reachability matrix becomes

0 and the (j, i) entry also becomes 0.

Table 3 - Initial Reachability Matrix

Factor number	Factor description	Factor number								
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1	Product meets customer needs	1	1	1	1	1	1	1	1	1
2	Product Price	0	1	0	0	1	1	1	1	1
3	Company resources	0	1	1	1	1	1	1	1	1
4	Launch Proficiency	0	1	1	1	1	1	1	1	1
5	Reduced cycle time	0	0	0	0	1	1	1	1	1
6	Senior management support	0	0	0	0	0	1	1	1	1
7	Cross functional integration	0	0	0	0	0	0	1	1	0
8	Organizational culture	0	0	0	0	0	0	0	1	0
9	Market potential	0	0	0	0	0	0	0	1	1

Level partitions

From the final reachability matrix, the reachability and antecedent set for each factor is found. The reachability set consists of the element itself and the other elements which it may help achieve, whereas the antecedent set consists of the element itself and the other elements which may help in achieving it. Thereafter, the intersection of these sets is derived for all the factors. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level element in the hierarchy would not help achieve any other element above its own level. Once the top-level element is identified it is separated out from the other elements. Then, the same process is repeated to find out the elements in the next level. This process is continued until the level of each element is found. These levels help in building the diagraph and the final model.

Table 4 - Partition of Reachability Matrix: First Iteration

Factor number	Reachability Set	Antecedent Set	Intersection	Level
1	1,2,3,4,5,6,7,8,9	1	1	
2	2,5,6,7,8,9	1,2,3,4	2	
3	2,3,4,5,6,7,8,9	1,3,4	3,4	
4	2,3,4,5,6,7,8,9	1,3,4	3,4	
5	5,6,7,8,9	1,2,3,4,5	5	
6	6,7,8,9	1,2,3,4,5,6	6	
7	7,8	1,2,3,4,5,6,7	7	
8	8	1,2,3,4,5,6,7,8,9	8	I
9	8,9	1,2,3,4,5,6,9	9	

Table 5 - Levels of PD Factors

Factor number	Reachability Set	Antecedent Set	Intersection	Level
1	1	1	1	VII
2	2	1,2,3,4	2	V
3	3,4	1,3,4	3,4	VI
4	3,4	1,3,4	3,4	VI
5	5	1,2,3,4,5	5	IV
6	6	1,2,3,4,5,6	6	III
7	7	1,2,3,4,5,6,7	7	II
8	8	1,2,3,4,5,6,7,8,9	8	I
9	9	1,2,3,4,5,6,9	9	II

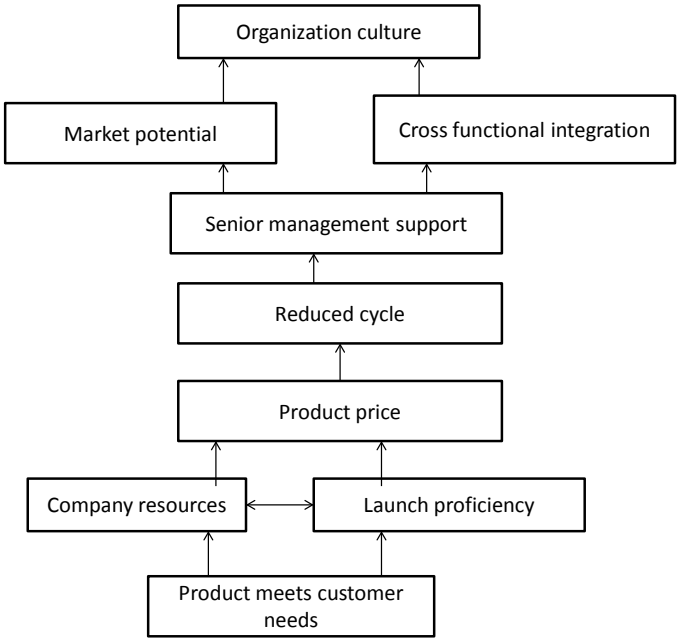

Figure 3 - ISM based model

Fuzzy MICMAC Analysis

Only binary relation is considered in the conventional MICMAC analysis. To increase the sensitivity of MICMAC analysis here we are using fuzzy set theory. There is an introduction of an additional input for the possibility of interaction among the elements

in FUZZY MICMAC. By this the strength of relationships can be improved instead of just establishing a relationship among the elements through previous method.

Binary direct relationship matrix (BDRM)
It is constructed by examining the direct relationship among the factors. The diagonal entries of the table 3 are converted to zero and hence BDRM is derived.

Development of linguistic assessment direct reachability matrix (LADRM)
The gradual assessment of the membership of elements in the set, explained with the help of membership function whose values lie in the real unit interval [0, 1]. A triangular fuzzy number "A" is presented as a triplet (l,m,r) .The membership function is defined as $'\mu_{\tilde{A}}(z)'$ can be defined as

$$\mu_{\tilde{A}}(z) = \begin{cases} 0 & x < l \\ \frac{x-l}{m-l} & l \le x \le m \\ \frac{r-x}{r-m} & m \le x \le r \\ 0 & x > r \end{cases} \quad (1)$$

Table 5 - The linguistic scale for the analysis of factors

Linguistic variable	Triangular fuzzy number
No effect	(0,0,0)
Very low effect	(0, 0.1, 0.3)
Low	(0.1, 0.3, 0.5)
Medium	(0.3, 0.5, 0.7)
High	(0.5, 0.7, 0.9)
Very high	(0.7, 0.9, 1)
Complete	(1,1,1)

The relationship among the factors is obtained by taking the opinion of the same industry experts and then superimposed on the BDRM to get the linguistic assessment direct reachability matrix LADRM. Since, the matrix operation can't be performed on fuzzy numbers therefore to obtain the crisp values we have used the equation of best non-fuzzy performance value. By this method we have obtained the fuzzy direct reachability matrix (FDRM).

Fuzzy MICMAC Stabilized Matrix
The FDRM is taken as input to obtain the Fuzzy MICMAC Stabilized Matrix. The matrix is multiplied repeatedly until the hierarchies of the driver power and dependence stabilize. Fuzzy matrix multiplication is followed by the equation.

$$P = Q, R = \max k\ [(\min(q_{ik,} r_{kj})] \text{ where } Q = [q_{ik}]\ and\ B = [r_{kj}] \quad (2)$$

Table 6 - Fuzzy Micmac-stabilised matrix

	1	2	3	4	5	6	7	8	9	Driving Power
1	0	.5	.5	.5	.7	.7	.9	.9	.9	5.6
2	0	0	0	0	.1	.1	.5	.7	.5	1.9
3	0	.7	.7	.7	.7	.7	.7	.7	.7	5.6
4	0	.3	.3	.3	.5	.5	.5	.5	.5	3.4
5	0	0	0	0	0	0	.3	.3	.3	.9
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
Dependence power	0	1.5	1.5	1.5	2	2	2.9	3.1	2.9	

Classification of factors

All factors have been classified, based on their driving power and dependence power, into four categories as autonomous factors, dependent factors, linkage factors, and independent factors.

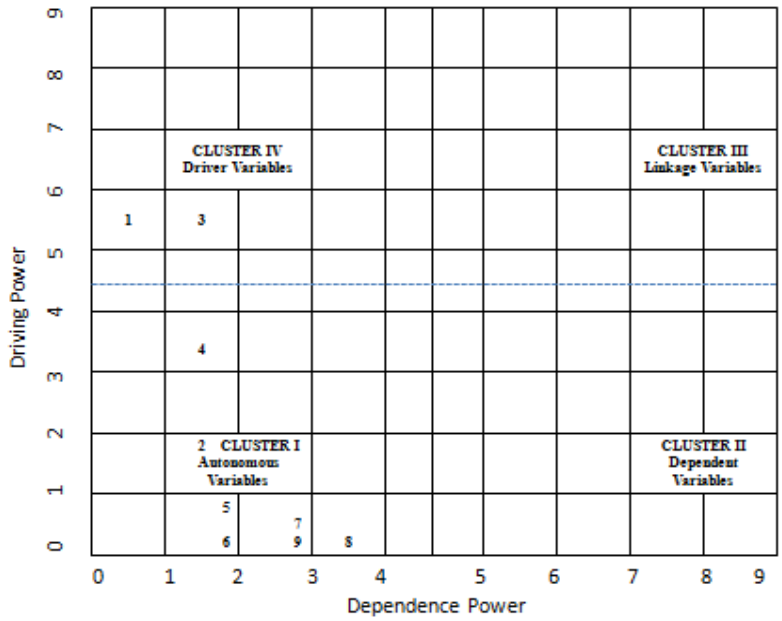

Figure 2- Cluster of PD factors

It is observed that factor 1 has a driving power of 5.6 and a dependence power of 0 and therefore, it is positioned at a place which corresponds to a driving power of 5.6 and a dependence power of 0 as shown in Fig. 2. The objective behind the classification of factors is to analyze the driving power and dependence power of the factors. In this classification of factors, the first cluster is of autonomous factors that have a weak driving power and weak dependence power.. The second cluster consists of dependent factors that have weak driving power and strong dependence power. The dependant

factors are relatively disconnected from the system. In the present case, there are no dependant factors. The third cluster consists of linkage factors that have strong driving and dependence power. Any action on these factors will have an effect on the other factors and also a feedback effect on themselves. In this case, there are no linkage factors. The fourth cluster includes independent factors that have strong driving power and weak dependence power. In this case, factors 1 and 3 are in the category of independent factors. The driving power and dependence power diagram for factors is shown in Figure 2.

Results and Discussion

The levels of factors are important in understanding of successful NP implementation. Product meeting customer needs and company resources are the most important factors due to its high driving power and low dependence among all the identified PD factors. These factors are positioned at the lowest level in the hierarchy of the ISM-based model. The factor, organization culture, is at the highest level in the ISM-based model due to its high dependence power and low driving power. Those factors which are at the fourth and third levels in the model with highest driving power are known as 'strategic factors'. These factors play a key role in product development and also creating an environment for the budding ideas. These factors require greater attention from the top management. The driving power and dependence power diagram gives some valuable insights about the relative importance and interdependencies of the factors. The driving power and dependence diagram (Fig. 2) indicates that there is no dependence factor in the process of successful product development. Dependence factors are weak drivers but high dependence. The absence of dependent and linkage factors in this study indicates that all the identified factors influence the process of successful product development. Therefore, it is suggested that management should pay serious attention to all PD factors.

The proposed approach gives managers a better understanding of the determinants/factors that have most influence on others (driving determinants/factors) and are therefore crucial. These are the ones which forms the basis for the rest of the factors and due to this should be taken into account at first. Those measures which are most influenced by others (dependent determinants/factors) and whose performances are always relative to the driving factors. This kind of information is strategic for managers who can use it to identify which performance measures they should concentrate on and how they can manage the trade-offs between measures. The relationship between new product development and the state of the economy has long been acknowledged. People are purchasing products keeping in mind about the time frame after which the product will become obsolete instead of using it to the last penny. But now the government policies in industrialized countries like Britain have sought to separate economic growth from the environmental contexts. This requires an alteration from a linear model to a circular economic model. In circular economy the focus is on minimizing the throughput of materials and energy by optimizing products longevity, reuse of products, reconditioning the products and their components and recycling.

Conclusion and Future directions

The levels of factors are important in the PD implementation process. It can also be observed from Fig. 2 that three factors, namely product meeting customer needs (factor 2), company resources (factor 3), and launch strategy (factor 4) have high driving power and less dependence power. Therefore, these factors can be treated as key PD factors.

On the basis of above discussion, we can conclude that all the nine factors are important in varying degree for the purpose of successful implementation of PD. In this research only nine PD factors have been used to develop the ISM model, but more PD factors can be included to develop the relationship among them using the ISM methodology. Further, in this research, the relationship model among the identified PD factors has not been statistically validated.

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Determinants of SOI capability in manufacturing firms

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Abstract

Although attention to sustainability-oriented innovation (SOI) continues to grow significantly, less is known about the capabilities that firms need to develop in order to advance their approach. In this study, we conducted a qualitative study of firms' approaches to SOI, the barriers they face, and the specific capabilities required to become a sustainable innovator. Our findings revealed that the majority of firms operated in an operational optimization as the basic context in the SOI approach. The specific capabilities required capture SOI idea, a proactive strategy, a process to commercialize or implement SOI, stakeholder management, governance, and continual learning.

Keywords: sustainability-oriented innovation, capability, qualitative

Introduction

In recent years, sustainability-oriented innovation (SOI) is generating considerable attention among researchers and practitioners in order to develop sustainable competitive advantage (Adams et al., 2016; Varadarajan, 2017; Watson et al., 2018). SOI is concerned with organizational innovation that is not only for profit, but also involves environmental and social sustainability benefits in their innovation (Hansen and Große-Dunker, 2013; Adams *et al.*, 2016). SOI is crucially important in practice in the era of growing discussion over global warming and climate change. For example, a study from Unilever shows that one-third of consumers prefer to buy a brand that they believe has a commitment to sustainability (Unilever, 2017). Sustainability is also being considered as a key driver for innovation (Nidumolu et al. 2009).

Despite the growing attention in this area, the debate tends to focus on the model or typologies of firms' behavior or approaches towards SOI (e.g. Aragón-Correa *et al.*, 2008; Elkington, 2012; Klewitz and Hansen, 2014; Adams *et al.*, 2016). These typologies are useful to map the level of maturity of firms in adopting and developing SOI. However, less is known about the specific capabilities required to attain the greater degree of maturity among these typologies. Francis & Bessant (2005) in the context of innovation management capabilities argued that specific capabilities are required in the course of

firm's growth. Likewise, this applies to the firm's journey to become more sustainable in their innovation. A gap in literature is observed by seminal reviews of Klewitz & Hansen (2014) and Adams et al. (2016) in terms of understanding the capabilities required to develop SOI. In the future research direction, both highlighted that the identification of capabilities required to be a sustainable innovator, will be an important contribution to literature. Similarly, Dangelico, Pujari, & Pontrandolfo (2017) suggested that the study of SOI from a capability perspective is still rare in the existing literature, and empirical research with a sound theoretical underlying is required.

To follow up on this opportunity, our study aims to understand firms' readiness to develop their SOI capabilities. The specific research questions are: (a) How do firms approach SOI? (b) What are the barriers these firms are facing to becoming a more sustainable innovator? and (c) What specific SOI capabilities are required to be a more sustainable innovator? To address these questions, we conducted an empirical qualitative investigation in context of Indonesian firms in multiple sector scenarios. The important contribution of this study to the SOI literature is the findings on specific capabilities required for developing SOI, which are outlined by previous researchers as important areas of interest (Klewitz and Hansen, 2014; Adams *et al.*, 2016; Dangelico, Pujari and Pontrandolfo, 2017).

Research context

This empirical study focuses on manufacturing firms in Indonesia. The manufacturing sector is considered for this study due to their considerable impact on the economic, natural and social environment of a country. More specifically, we emphasise on two manufacturing industries that are of top priority for Indonesia from 2015 to 2035 based on regulation No. 14 of 2015 (Government of Indonesia, 2015) namely (a) food and beverages industry, and (b) textile, leather, footwear, and multifarious industry. Also, some other top priority industries which have high entry barriers such as pharmaceuticals, cosmetics, and medical devices, automotive industry, and electronics and ICT industry are included to the research sample which in this study is referred to as (c) other industries.

Indonesia is an interesting context for SOI research. In the reviews of Klewitz & Hansen (2014), Adams et al. (2016), or Watson et al. (2018) the emerging economies context is under-represented, with none of the studies discussed Indonesia. As one of the fourth largest major economies in the world after China, India, and the US, it represents a large market size. Indonesia, with its rapid economic growth, has not yet shown good performance in innovation and sustainability. This is reflected in its Global Innovation Index ranking, 85th of 126 (Cornell University, INSEAD and WIPO, 2018) and Country Sustainability Index ranking, 48th of 65 (RobecoSAM, 2018). From the policy side, recently Indonesia has shown a great desire to be able to significantly enhance its innovation and sustainability conditions as reflected from its official document of Master Plan Indonesia 2011-2025 (Indonesia Ministry for Economic Affairs, 2011) and The National Medium-Term Development Plan (RPJMN 2015-2019) (Bappenas Indonesia, 2014).

Methodology

The nature of this research is exploratory, considering the fact that the research on SOI from a capability perspective is still lacking (Dangelico, Pujari and Pontrandolfo, 2017) and very few empirical data comes from an emerging economies context (Klewitz and Hansen, 2014; Adams *et al.*, 2016; Watson *et al.*, 2018). This nature is best approached using a qualitative approach to address the phenomena effectively. Data for this study was

collected through semi-structured interviews with key participants that are firm owners or managers, given their knowledge of innovation and sustainability in their company.

The instrument for this study uses an interview schedule which has been tested and subtly refined following the pilot study that we did in the first half of 2018. The initial part of the instrument contained questions about general information of the firm. Then they were asked their opinion about the innovation, sustainability, and capabilities that might be required for SOI with questions mainly adapted from literature, including Bansal and Roth, 2000; Tidd and Bessant, 2009; Bos-brouwers, 2010a; Adams et al., 2016.

The sampling strategy used is purposeful sampling (Patton, 1990). In constructing samples, we try to elaborate views from the sample with diverse characteristics in terms of industry and size. This strategy provides advantages in the form of a detailed description of voice from diverse characteristics of the sample. Industrial classification is based on industry grouping according to regulation No. 14 of 2015 (Government of Indonesia, 2015). Firm size refers to the Enterprise Survey (The World Bank, 2015) where a small firm is defined as a firm with 5 to 19 employees, a medium 20 to 99, and large more than 100 employees. Potential participants were identified through several means, including: (a) Business incubation centre of one of the public universities in Indonesia that partners with business sectors, (b) One of the state-owned enterprises in Indonesia that also partners with businesses across Indonesia, (c) Chain or snowballing, (d) Personal contacts, and (e) Advertisement. Samples were spread across six provinces (Banten, Jakarta, West Java, Yogyakarta, East Java, and Lampung) in Indonesia.

In total, thirty-three interviews were conducted, each for average fifty minutes duration, involving 25 different firms. These 25 firms were cross-size and cross-industry. Eight small, eight medium, and nine large firms. Ten firms from industry I (food and beverage), eleven from industry II (textile, leather, footwear and multifarious), and four from industry III (other sectors including pharmacy, cosmetics, and medical devices industry or transportation industry or electronics and ICT industry). The oldest firm was established in 1950 dan youngest was 2015. We conducted site visit to most of the firms (sixteen of twenty-five). Interviewees' position varies including CEO, VP operations, R& D manager, marketing manager, and HR & legal manager. All interviewees gave their consent for the interview to be recorded. All interviews were conducted in 2018 and early 2019. To improve the rigorousness and reliability of our data, we also talked to people outside the company, and collected archival documentation.

Collected data were subjected to thematic analysis. Thematic analysis is a logical way to search for themes or patterns across datasets, and leads to rich descriptions, explanations, and theorisation (Braun and Clarke, 2006; Saunders, Lewis and Thornhill, 2016). To ensure analytical rigor, we followed and combined approaches from Braun and Clarke (2006) and Gioia, Corley and Hamilton (2012). Braun and Clarke's approach is useful in helping with the thinking process during data analysis, which is then visually displayed in the form of a thematic map. The Gioia approach is very useful in showing links between data and themes in a systematic and transparent way. In this paper, data analysis followed five key phases: preparation and familiarization, generate initial codes, finding the themes, develop the data structure, and producing the report. The computer-aided qualitative data analysis package NVivo 12 and spreadsheet MS Excel are used to assist the analysis. We use MS Visio to help visualization.

Specific for the SOI approach, to complement the thematic analysis, we follow the technique of Watson *et al.* (2018) in which scoring was determined to identify firms' SOI approach by a certain number as a threshold. The difference is that Watson et al. applied this assessment to filter the quality of the paper in their review. In this study, SOI approach is identified from the data based on three criteria as outlined in Adams *et al.* (2016: 185)

including the innovation's relationship to the firm, innovation outcome, and innovation objective. We set a score of 5 (out of a maximum possible 9) as a threshold where companies with a lower average to average (0 to 5) categorize operating in operational optimization, and companies with a score above average (6 to 9) are categorized as a company that moves beyond operational optimization.

Findings

The SOI approach reflects a firms' approach to the innovation in their organization. Two approaches identified from participants: (1) operational optimization and (2) beyond operational optimization. We find that most of the firms (19 of 25) are in the context of operational optimization and there are some that move beyond operational optimization. A summary of the results and examples of quotes is shown in table 1.

Firms in operational optimization context basically innovate with the characteristics of incremental improvement, harm reduction, and compliance/efficiency. Incremental improvements in the food and beverage industry are manifested in the form of changes in packaging, modification of recipes, and diversification of similar products. Firm A, for example, made an innovation incrementally in packaging. Firm A succeeded at first by packaging the traditional Indonesian food "rendang." "Rendang" was voted as one of the most delicious food in the world based on a readers' choice of Cable News Network poll (Nurmufida *et al.*, 2017). Firm I introduced a number of similar new variants using fish caught by local fishermen.

Table 1 – SOI approaches

SOI approach	Example of representative quotes			Firms
	Innovation's relationship to the firm	**Innovation outcome**	**Innovation objective**	
Operational optimization	"producing in a better way than before" Firm B "improving the product means developing better, better, better products." Firm R *Characteristic: Incremental*	"I also no longer use MSG (monosodium glutamate)" Firm I "The use of skincare that containing mercury are very harmful … Finally I made a product that is safe." Firm N *Characteristic: Reduce harm*	"it completed with computerized system, more energy efficient..." Firm G "…it's part of efficiency, to reduce the environmental impact" BCPX *Characteristic: Compliance/ efficiency*	A, B, D, F, G, H, I, J, K, M, N, P, Q, R, S, T, U V, W
Beyond operational optimization	"There are 6 points… the sixth… carried out corporate social responsibility that focused on balancing social and environmental financial performance." Firm X *Characteristic: Fundamental shift in firm purpose*	"I fixed the road, people came here comfortably. The parking lot is spacious can fit 2 or 3 large buses…That's the point. From the very beginning I was an anti-mainstream. I want to be different, so it is more visible." Firm O *Characteristic: Creates shared value*	"The one who use mushrooms in their product was a restaurant outside the city and when I contacted them, they had never made it (mushroom floss)" Firm E *Characteristic: Novel product, services, or business model*	C, E, L, O, X, Y

Firms in the context of beyond operational optimization is a firm that approaching SOI beyond basic context. They have the characteristics of a shifting purpose, not just financial returns, creating shared values, and novel products, services, or business models. A fundamental shift of their purpose is seen in the strong social mission of the owner or top management in innovation. We found that the innovation carried out was more of a

process innovation. It is as carried out by firm E which aims to educate the public about the benefits of mushrooms for health and inject the spirit of entrepreneurship to students around them. Firm E is located near the university. Firm O, which operates in the leather industry, has a different method. This company is one of a few Indonesian leather companies that are able to export their products abroad. The main market is the Netherlands, Australia, Japan, and the Indonesian market, with a production capacity of 42,000 bags and 2,400 pairs of shoes per year. Despite having a global reputation, when we conducted a site visit, we were quite surprised because the location of both the workshop and the showroom were in a simple village. Their presence there is intentional because according to the owner they are anti-mainstream and believe that good products will be sought by people, wherever they are located. Especially now that there are digital maps like Google Maps or Waze. Because of its contribution to bringing local products to the world market, even though the location is in a village, this company has been visited several times by the first and second lady.

SOI barriers

Based on the analysis, the barriers to developing SOI are divided into two factors, namely internal and external. Findings related to the barriers are presented using a thematic map. Internal barriers include capital, human resources, and organizational priority. Capital is associated with a large investment need to develop sustainability elements of innovation, for example to purchase assets such as land, buildings, or machinery. This obstacle, for example, was expressed by participants from Firm A, “innovation is always limited by funds” and Firm P, “…don't have special funds that we can set aside.” The human resources barrier was emphasized by quite a lot of interviewees, for example the participant from Firm F, "I think it depends on the man". The organizational barrier is the view that SOI is not an organizational priority, as stated by participants from firm B, “It’s actually not a main priority.”

External barriers include raw materials, technological, governmental, and macroeconomic. Raw materials are related to their availability and price. This is, for example, as expressed by participants from Firm L, “the condition of resource availability at that time”. Technological, similar to raw materials, deals with availability and price. For example, as expressed by participants from Firm B, “it’s expensive and the technology may not yet exist.” Barriers from government as explained by participants from Firm H, “must be supported by the government, because it requires large area”. Macroeconomic is related to consumer purchasing power and economic conditions. This is for example as expressed by participants from Firm C, “is because of decline in purchasing power”.

SOI capabilities

The SOI specific capabilities reflect the specific capabilities needed by the firms to become a sustainable innovator. Two key groups of capabilities are observed here: (1) substantive, and (2) dynamic. We see a pattern that substantive capabilities are owned by all firms while dynamic capabilities are owned by firms that approach SOI in a more sophisticated manner. Figure 1 shows the process of developing thematic maps based on data. Figure 2 shows data structure for SOI capabilities.

Substantive capabilities reflect the firms’ fundamental ability to create their products. There are three visible elements of all companies, both those that are in operational optimization and beyond operational optimization context, namely: (1) production, (2) marketing, and (3) environmental and social. Production refers to the company's technical capabilities in producing products.

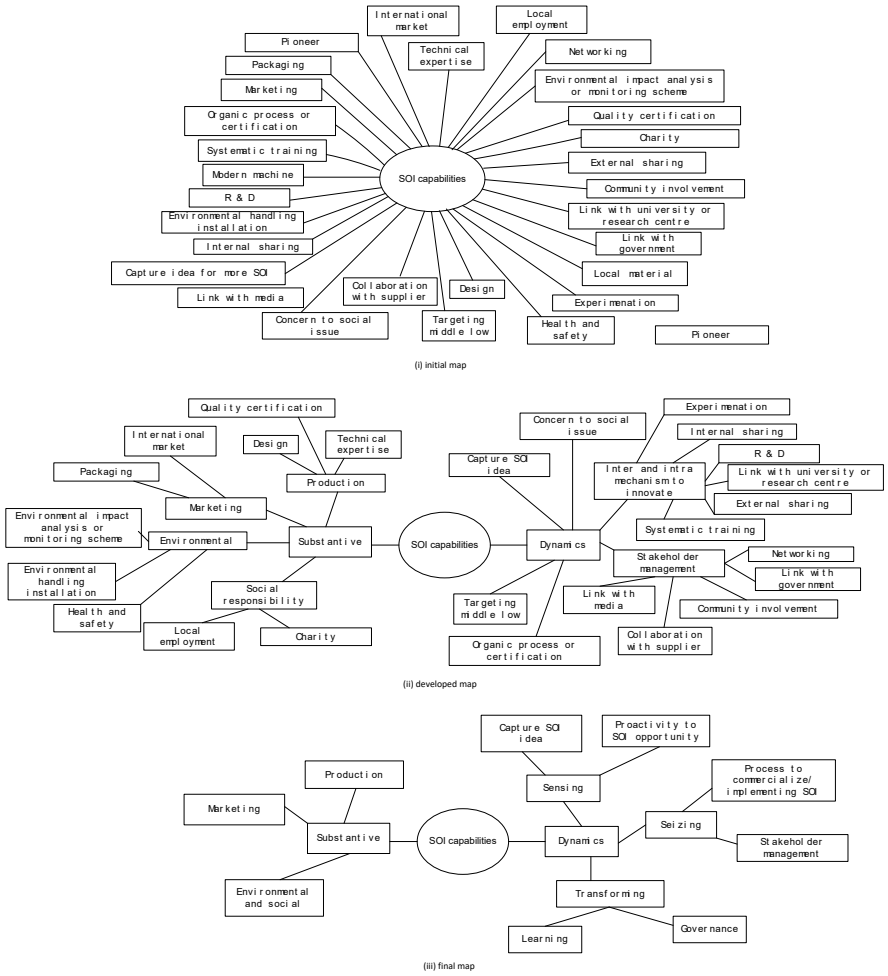

Figure 1 – Thematic map of SOI capabilities

All our interviews show that all firms have deep technical capabilities in producing their products. Marketing capabilities, which reflect the firms' abilities to market and sell their products. This was also found in all participants we interviewed. Because of the importance of this marketing ability, participants from firm H said that "no need to think hard for operating, the thing we should think more about is marketing". For the capability related to environmental and social, we found that it is included substantive capabilities, not dynamic. This is because all firms in the sample are registered firms, which when registered are required to have the ability to manage waste that has the potential to pollute the environment. As for the social aspect, in the Indonesian context there is also an unwritten rule that the company must employ workers from the immediate surrounding environment.

SOI dynamic capabilities reflect the company's ability to adapt, integrate, and reconfigure their ability to respond to contemporary sustainability challenges (Teece, 2007; Adams *et al.*, 2016). We explore this capability, especially from firms that are more mature in their SOI level. We found that there are six specific capabilities that need to be possessed, namely generating a SOI idea, creating a proactive strategy, having a process to commercialize/implement SOI, managing stakeholders, governance, and continual learning. We group them into three dimensions: sensing, seizing, and transforming (Teece, 2007).

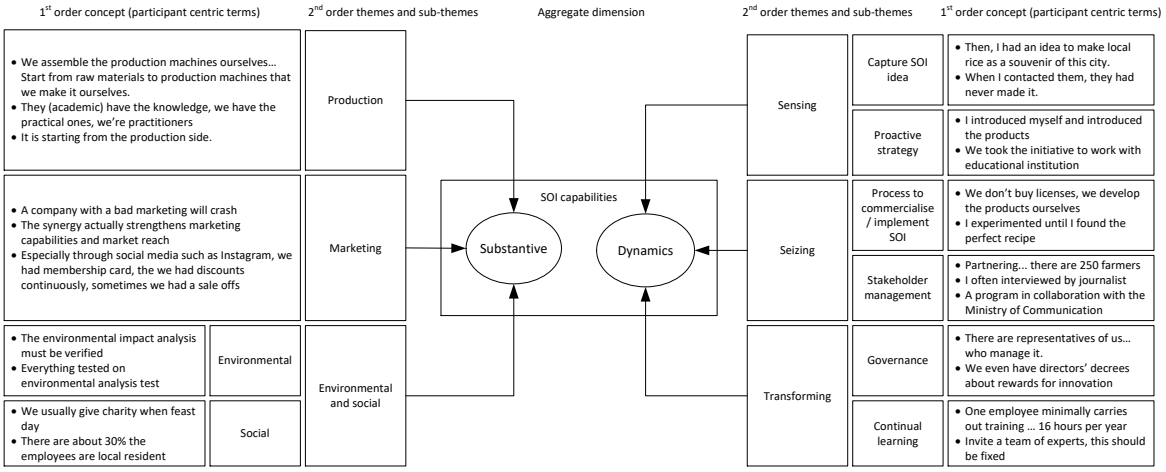

Figure 2 – Data structure of SOI capabilities

Sensing reflects the company's ability to detect opportunities for SOI. In this study we found that sensing included the generation of SOI ideas and proactive strategies to follow up. We found that the role of owner in scanning and detection is highly dominant for SMEs. Seizing reflects the firms' ability to address sensed opportunities by generating innovations that contain elements of sustainability. Transforming reflects the company's ability to maintain its SOI. Governance, for example, is practiced through the mechanism of rewards and recognition for internal stakeholders who play a role in giving ideas (as practiced by Firm L) or forming teams and mechanisms so that relationships with suppliers from the surrounding environment can be lasting (as practiced by Firm C). Continual learning in Firm C, Firm E and Firm O still emphasize the role of entrepreneurs, while company L formally facilitates learning by employees, with learning requirements for each employee of at least a certain number of hours each year.

Discussion

This study investigates firms' approaches towards SOI, the barriers to SOI, and the specific capabilities needed to become a sustainable innovator. This study contributes to the SOI literature by empirically investigating the capabilities required for developing SOI, which are outlined by previous researchers as important areas of interest (Klewitz and Hansen, 2014; Adams *et al.*, 2016).

Our findings indicate that most of the companies in our sample (19 of 25) approach SOI using operational optimization as a basic context in Adams et al.'s (2016) model. This result is not surprising considering Indonesia is considered an emerging economy, which typically has high economic growth but still experiences severe sustainability challenges (OECD, 2012). Some practices that appear in operational optimization come in slight changes in product design (Alston *et al.*, 1999), or changes in aspects of waste handling (Dangelico and Pujari, 2010). The nature of this change is incremental and focuses on the intra-organizational. Among the unique things that we found in the Indonesian context is creativity to modify production machines, as part of process innovation, so as to reduce resource use, provide higher efficiency, or produce better quality products.

Firms operating beyond operational optimization have approaches that are more inter-organizational in nature and have a wider impact. Among the practices that we found are product innovation by offering products that are healthier, consumed by the public, or raising local cultures. As a process, we have found SOI practices that have mutual partnerships with suppliers from the surrounding environment. This practice is beyond just local sourcing (Rodgers, 2010) because there are elements of training, effort to maintain quality, and work together for mutual benefit.

The fact that most firms are still limited to complying with regulations might be attributed to various barriers both internally and externally. Internally, these barriers can take the form of financial or capital factors (Skjøndal Bar, 2015) due to limited company funds to finance R&D as well purchase assets and materials for SOI. The other internal barrier that we found was the priorities of the organization, where SOI was not considered a priority because the demand was unclear (Laukkanen and Patala, 2014) while the investment was high. This can be due to a lack of understanding that current sustainability is a driver of innovation that has the strategic potential to increase profitability and competitive advantage (Porter and Kramer, 2006). Externally, creating an eco-friendly product usually requires relatively expensive raw materials that are not necessarily available in the market. To produce such a product, new machines are needed, which in general are also different from the standard product that is produced currently. From the government side, obstacles to developing SOI originated from the government because there were no clear and attractive incentives or facilities (van Hemel and Cramer, 2002).

The government is expected to be able to create incentives and support with attractive facilities and can also prioritize local products compared to imported products so as to make producers more passionate about developing SOI.

Although facing a number of barriers, firms operating at a higher level of SOI have specific capabilities above baseline substantive capabilities (production, marketing, environmental and social) that help them become more sustainable innovators. The first two specific capabilities are SOI idea creating and having a proactive strategy to follow up on the idea. In theory, these dynamic capabilities (Teece and Pisano, 1994; Teece, 2007) are categorized as SOI sensing, which refers to sensitivity and proactivity towards SOI ideas SOI sensing relies on the role of the owner or entrepreneur or the strength of the firm's R & D. The next specific capability is the process of commercializing or implementing SOI (Tidd and Bessant, 2009; Adams *et al.*, 2016), and stakeholder management (Watson *et al.*, 2018) which when referring to the theory can be categorized as SOI seizing. The process for following up on SOI ideas takes the form of intensive experimentation, sampling, and market testing. We found that larger companies maximize their relationship with research institutions at this stage and have formal procedures in developing new products or processes. The last two capabilities are governance and continual learning (Tidd and Bessant, 2009) which in the theory are categorized as transforming. Governance and continual learning in smaller companies relies on the role of entrepreneurs, while larger companies rely on formal procedures and programs.

Conclusion

The firms in Indonesian context have significant room for improvement, considering that they are still limited to complying with regulations. Our study indicates that with various advantages and disadvantages in the context, there are firms that are able to operate beyond the basic context of operational optimization. This means, for companies small, medium and large, they have the same opportunity to develop their capabilities for SOI by focusing on SOI specific capabilities. For policy makers, the desire of the Indonesian government to build an innovative and sustainable economy (Indonesia Ministry for Economic Affairs, 2011; Bappenas Indonesia, 2014) can be realized in policies that support the business community in developing SOI specific capabilities as discussed in this study.

This study certainly has several limitations. First, this study focuses on manufacturing sectors, more specifically, two priority industries in Indonesia (Government of Indonesia, 2015), namely food and beverages industry, and textile, leather, footwear, and multifarious industries, plus other priority industries (pharmacy, cosmetics, and industrial medical devices or transportation industry or electronics and ICT industry) so the results of the study apply only to these industries. Further studies can be conducted in different industries. Second, this study was conducted in the Indonesian context, so the results are limited to that context. However, the results of this study may be applied in other emerging economies, keeping in mind their similar characteristics.

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Investigating the moderating role of employee's learning intent in creation of supplier driven innovation: Multi perspective analysis capturing employee's reflections through social media

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Abstract

This study attempts to answer the question why certain buying firms tend to leverage suppliers' input better than the others in creating innovations. Using theory of planned behaviour and embeddedness, this paper seeks to shed a light on this by investigating the moderating role of buying firms' employee's intent to learn in facilitating efforts in mobilising input from the buying firm's supply network. The results suggested that the strong moderation of employee's intent to learn, meaningful work and work-life balance with the two dimensions of embeddedness such as between degree centrality and betweenness centrality on the buying firm's innovation creation.

Keywords: planned behaviour theory, innovation, supplier network, structural embeddedness, text mining.

Introduction

It is obvious that the supply network is an importance source of innovations for buying firms. There have been a number of studies investigating the link between the buying firm's reliance on suppliers for innovation creation (Narasimhan and Narayanan, 2013) and there have been a constant stream of research investigating the place of suppliers in buyers' innovation creation (Wagner 2012; Henke and Zhang, 2010; Wagner and Bode, 2014). However, there is lack of research investigating this from the perspective of a supplier network, which is characterised by interactions and different actors, resources and processes (Bellamy et al., 2014), influence on buying firms innovation performance. A innovation research from the supply network view, however, is still relatively rare. The main reason for this is the difficulty in obtaining a real-life supply network data, therefore, the majority of such studies analysed firm level ego networks (e.g., Kim et al., 2011). In addition, a study by Lawson and Potter (2012) explains how closeness with supplier can uncover protectiveness in knowledge transfer across firms. However, learning intent scale used in the study reflects only the knowledge capture but didn't say anything about employee's learning intent. Buying firms extraction of knowledge depends on employees' intention to invent. There are also studies that support the well-being of

employees and firm's innovation (Bryson et al., 2009). However, it is still not clear how employees' intention to learn within a firm helps to derive innovation from supplier.

The literature review revealed three major gaps. Firstly, there is a scarcity of studies integrating planned behaviour theory with embeddedness theory for explaining how a buying firm leverages contributions from external organizations in its supply network towards its own innovation. Secondly, "intent to learn" construct was mostly done through a survey instrument, which many not be sufficient in reflecting "collective intent to learn". It is obvious that using anonymous platforms, such as a social media review, to measure a construct of this nature would alleviate this issue, however, not widely used in academic literature. It is well established that higher levels of engagement will lead to higher profitability Thirdly, there is a contradictory argument that innovative culture will lead to lack of attention in work-life balance and causes time-based stress, depletion of resources, including psychological and physical energy (Sok et al., 2014).

Given the above background, we seek to answer the question why a certain buying firms tend to leverage suppliers' input better than the others in creating innovations by considering the firm's employees' collective intent to learn as a moderator.

Literature Review

This paper uses multiple theoretical lens (i) social network theory and (ii) planned behaviour theory the answer the above research question.

Embeddedness of a Buying Firm in its Supply Network and its Innovation Creation

The social network theory is based on the idea of embeddedness (Kim et al., 2011). Embeddedness refers to non-economic factors, motivating various economic exchanges (Moran, 2005; Barden and Mitchell, 2007; Cowan et al., 2007; Kim, 2014). One notable example of embeddedness is "a social tie" (Koufteros et al., 2007; Dong et al., 2015), since economic activities are often embedded in them (Uzzi and Lancaster, 2003). The link between a firms' performance and its embeddedness has been scrutinised by the scholars to find out how the embeddedness would explain how different levels of embeddedness are related to the variations in the firm's performance (Adler and Kwon, 2002; Kim, 2014).

Firm's embeddedness has been investigated from two distinctive perspectives, which are (i) configurations of social ties and (ii) quality of social ties, (Gulati, 1998; Uzzi and Lancaster, 2003; Moran; 2005; Autry and Griffis, 2008; Dong et al., 2015; Kim and Henderson, 2015). As such, even though there are some variations of conceptualisation of the embeddedness (Tsai and Ghoshal, 1998; Min et al., 2008; Kim, 2014), two salient forms of embeddedness are (1) relational and (2) structural (Granovetter, 1985, 1992; Uzzi, 1996, 1997; Gulati, 1998; Rowley et al., 2000). Relational embeddedness refers to the strength of dyadic ties (Granovetter, 1992; Moran, 2005; Kim, 2014) that is an extent to which a firm develops close and personal relationships with other members in its network (Barden and Mitchell; 2007; Autry and Griffis, 2008; Landoli et al., 2012; Dong et al., 2015). On the other hand, structural embeddedness, which is the main focus of the investigation of this paper, refers to configuration of linkages/relationships among actors (Nahapiet and Ghoshal, 1998; Gulati and Gargiulo, 1999; Moran, 2005; Barden and Mitchell, 2007; Dong et al., 2015).

Accumulation of knowledge assets for a firm's innovation creation has two main sources, those are (1) internal knowledge generation and (2) knowledge with an external origin (Cooper and

Edgett, 2007; Bellamy et al., 2014). For a buying firm, its supply network is an important external source for its knowledge assets (Autry and Griffis, 2008; Bellamy et al., 2014) such as knowledge and resources held by its supplier. Such resources can provide a firm with external information necessary for idea generations as well as improving its process (Tsai, 2001) as well as an opportunity to combine their knowledge for innovation creation (Ahuja, 2000). Therefore, a buying firm's structural embeddedness in its supply network indicates its ability to access the knowledge and information held by its imminent suppliers and beyond (Uzzi, 1996; Tsai, 2001; Cowan et al., 2007; Greve, 2009; Bellamy et al., 2014). The implications of different aspects of a buying firm's structural embeddedness on its innovation creation has been investigated mainly from the perspective of the buying firm's centrality in its network. The centrality of a buying firm reflects its relative importance in its supply network (Kim, 2011; Dong et al., 2015).

A company occupies in a central location, it will get access to information and knowledge more easily helping them to create knowledge assets for its innovation creation (Tsai 2001; Bell, 2005; Greve, 2009; Autry and Griffis, 2008; Bellamy et al., 2014). Moreover, the level of centrality of a buying firm would signal its reputation to its suppliers (Borgatti and Foster 2003), alleviating their fear of failing to protect their knowledge as a result of a buyer opportunism (Mayer, 2006) and would result in more information sharing activities.

Buying Firms' Employees' Intent to Learn

A theoretical aspect to exploit employee's learning intent in leveraging supplier input for its own innovation creation is the Planned Behaviour Theory, which is used to understand individual behaviour and it is a function of attitude, subjective norms and control (Ryan, 2010). Using the above analogy, in our case, employees' intent to learn depends of three dimensions such as meaningful work, subjective wellbeing and work life balance.

Meaningful work capture individual's attitude towards work using four dimensions such as developing the inner self, unity with others, expressing full potential and service to others (Lips-Wiersma et al., 2012). A study by Pradhan and Jena (2019) unfolded the lack of studies that explored the role of meaningful work on the relationship between transformational leadership and innovative work behaviour. Since meaningful work construct is relatively a new term and its usage is limited in the literature. However, subjective wellbeing is a psychological factor that is defined as individual's cognitive and affective evaluation of the experience in terms of pleasant emotions, negative mood and life satisfaction (Wang et al., 2017). An individual's subjective wellbeing depends on complex array of contextual factors including individual determinants, socio-demographic, economic, situational and institutional factors (Binder, 2013). Self-esteem or other personality traits are examples of individual determinants, likewise gender, age, education or marital status are examples of socio demographics. Similarly, income or unemployment corresponds to economic status, health and social relationship corresponds to situational factors (Binder, 2013). In addition, it is rare to find the integration of planned behavior theories within and external organization's contribution to innovation. A study by Binder (2013) states the individual's preferences are dynamic and the measurement of affective experience is very difficult in practice to capture that reflect the preference changes of individuals over time. To overcome this global corporations are relying on anonymous platforms to measure the satisfaction of employees and fixing them on a swift basis to improve engagement. The companies are keen to do this because it is well know that higher levels of engagement will lead to higher profitability and improved employee's commitment (Bonnici, 2018).

Employees are juggling with multiple commitments at work and home where the successful people are good at balancing the two. Conceptually, offering work life balance through flexible working hours will enable employees to perform better and stay in a single company for a longer duration. However, in practices employers are not ready to do so until they see a bottom line economic advantage (James, 2014). However, there are a few evidences that illustrates flexible working hours benefits all staff irrespective of caring staff. Besides this generalist view of benefits, there are several dis-benefits such as increased workloads, understaffing, heightened fear of job loss, dramatic change in labour and demands. In addition, from the organisation's perspective continuous innovation to meet consumer demand and pressure to increase work-life balance of employees to retain them and satisfy customers are the tricky challenges posing those (Malhotra et al., 2016).

Conceptual Model and Hypotheses

In this paper, we seek to investigate the impact of a buying firm's structural embeddedness in its supply network in its innovation creation and how an endogenous organisational factor "employee's intent to learn" of the employee of a buying firm would moderate this relationship.

First, we investigate the link three centrality dimensions of a buying firm's structural embeddedness and its innovation output measured in the number of patents it holds.

The first dimension, degree centrality refers to the number of direct links an organisation maintains with others in its network (Provan et al., 2007). Degree centrality can be interpreted as the amount of knowledge, resource and information coming into the buying firm (Provan et al., 2007; Borgatti and Li, 2009). The following is, therefore, hypothesised:

> H_1: Buying firm's degree centrality in its supply network is positively related to the number of patents it has

The second dimension, betweenness centrality refers to how often the node lies on the shortest path between all combinations of pairs of other nodes (Borgatti and Li, 2009; Kim, et al., 2011). An organisation with high level of betweenness can act as a gatekeeper to other members in its network (Borgatti and Everett, 2006, Provan et al., 2007; Borgatti and Li, 2009; Kim, et al., 2011). In supply network, this means a firm with high-level of betweenness centrality would act as a hub for material (Kim, et al., 2011) and information flows (Bellamy et al., 2014) enables it performance benefits such as access to novel information. The following is, therefore, hypothesised:

> H_2: Buying firm's betweenness centrality in its supply network is positively related to the number of patents it has. The following is, therefore, hypothesised:

The third dimension, closeness centrality refers to how close an organisation is to all other members in its network including those without direct connections (Provan et al., 2007; Kim, et al., 2011). A buying firm can acquire knowledge indirectly through spill-over from its tier 1 suppliers, with its origin back to its interactions with the supplier's own tier 1 suppliers (Gulati and Garguilo, 1990). Considering this, a buying firm with higher closeness centrality can access information, knowledge and resources from indirect suppliers beyond tier 1 more easily, therefore, it is related to the network effectiveness of knowledge access (Bellamy et al., 2014).

H_3: Buying firm's closeness centrality in its supply network is positively related to the number of patents it has. The following is, therefore, hypothesised:

As per planned behaviour theory, the influence of three dimensions of employees' intent to learn from suppliers is discussed in the following section. Typically, our intention is to explore to what extent the three dimensions enables employees to better exploit supplier inputs for its own innovation creation. A study by Pantea (2018), it is obvious that the relationship between supplier input and the buying firm's innovation creation would be stronger if employees' collectively perceive their works more meaningful. This is because,
Meaningful work refers to a place with autonomy, less-tension, spirituality and reduced level of absenteeism.

H_{1a}: As perception of meaningful work among employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger
H_{2a}: As perception of meaningful work among employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger
H_{3a}: As perception of meaningful work among employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger

Studies explored the rationale for the positive relationship between subjective wellbeing and better work performance, knowledge sharing and achievements (Russell, 2008; Wang et al., 2017). Previous studies have found that satisfaction degree and positive emotions helps individual to remember and boost creative problem solving (Koveshnikov et al., 2014; Hashim and Tan, 2015). Other than performance, positive emotions, such as feeling of joy and pleasure, one among the subjective wellbeing factors will enhance individuals to share tacit and explicit knowledge (Henttonen et al., 2016). The following is, therefore, hypothesised:

H_{1b}: As perceived well-being of employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger
H_{2b}: As perceived well-being of employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger
H_{3b}: As perceived well-being of employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger

Very few studies attempted to understand the relationship between work life balance and organization culture represented as innovative and supportive culture (Sok et al., 2014). There is a contradictory arguments that innovative culture values behaviours teamwork including solution-oriented, communicative and quick in terms of decision making. The overall understanding is innovative culture will lead to lack of attention in work-life balance and causes time-based stress, depletion of resources, including psychological and physical energy (Sok et al., 2014). However, this is not applicable to all contexts and needs to be investigated further. Based on the above arguments we propose the following sub hypothesis to test the moderation of three dimensions of employees learning intent. The following is, therefore, hypothesised:

H_{1c}: As perceived work life balance of employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger

H_{2c}: As perceived work life balance of employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger
H_{3c}: As perceived work life balance of employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger

Methodology

This paper investigates if of a buying firm's employees' intent to learn would moderate the relationship between the structural embeddedness of a buying firm in its supply network and its innovation output. For this, we used the data of 182 companies from the S&P 500 list by discarding non-manufacturing sectors such as financials and real estate as well as those companies with excessive amount of missing data.

Data

The data set for this study was built using following databases. For the embeddedness of a buying firm, the list of its suppliers was collected from Bloomberg SPLC database and Factset. As for a firm's innovation performance, the number of patents held by a buying firm was collected using Orbis database. For the intent to learn, employee reviews of their current and previous companies for 182 S&P 500 companies posted in Glassdoor between 2015 and 2017 were collected (475,910 sets of a positive and a negative review). Glassdoor is a social media website, where current and past employees can rate various aspects of their companies such as leadership, work environments and pays (Associate Press, 2013). Glassdoor is the oldest (founded in 2017) and the largest online resources in terms of the number of firms covered and the reviews (Ji et al., 2017).

Measures

In this study, we use social network analysis (SNA) to measure different dimensions of structural embeddedness of a buying firm. Considering a matrix A_{ij}, with a set of nodes and a set of edges, degree centrality is defined as the number of edges tied to a node. It is usually interpreted as the size of a node's direct network. Closeness centrality, in contrast, considers the node's wider network by measuring the distance of a node to all others in within the network. Moreover, betweenness centrality captures the importance of a node for the network by measuring the number of shortest path that rely on that node (for a more detailed overview on network measures, please be referred to Borgatti et al., 2018).

Variable	Measure	Normalised Measure
(In-)Degree centrality	$C_D(i) = \sum_j A_{ij}$	$C_{DN}(i) = \frac{1}{n-1} C_D(i)$
Closeness centrality	$C_C(i) = \frac{1}{\sum_j d(i,j)}$	$C_{CN}(i) = (n-1) C_C(i)$
Betweenness centrality	$C_B(i) = \sum_{s \neq t \neq i} \frac{g_{st}(i)}{g_{st}}$	$C_{BN}(i) = \frac{2}{(n-1)(n-2)} C_B(i)$

Table 1: Description of network measures.

Intents to learn

In order to measure employees' intent to learn of a buying firm, content analysis was used to code the textual reviews from the social media site, Glassdoor. Content analysis is "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use," (Krippendorff, 2013; p.24). As mentioned earlier, a user can leave

two separate textual review about a company, one for the positive and another one for the negative and these unistructural parts of the reviews were coded using content analysis. Due to the sheer volume of the textual data (475,910 sets of a positive and a negative review and around 17 million words), a computer-aided content analysis (CATA) was selected over manual coding. For this, WordStat 8 from Provalis Research was used. Due to the lack of a pre-made dictionary, a set of new dictionaries for the positive and negative were created from scratch using the dictionary building method suggested by Sodhi and Son (2010). Using these dictionaries, the percentages of positive and negative reviews containing specific words or phrases from the total reviews of a specific company were calculated and then, standardised. The difference between the positive and the negative was used to measure each dimension of employees' intent to learn. The assumption is that the greater the difference is the more positive employees' intent to learn.

Innovation Output

In order the measure the innovation performance of a buying firm, the number of patents the firm was used. Use of the number of patents to measure a firm's innovation output has been wildly used by the previous studies (for an example, see: Tsu, 2009; Bellamy et al., 2014; Isaksson et al., 2016).

Analysis and Results

We conducted hierarchical regression analyses using SPSS version 25 to test our hypotheses. Our main models examined if the level of 3 centrality dimensions of a buying firm is related to its innovation output (the number of patents). The results of the analyses provided support for H_1 (degree centrality => patents, $\beta = 0.31$, $p < 0.01$) and H_2 (betweenness centrality => patents, $\beta = 0.27$, $p < 0.01$). H_3, where the relationship between closeness and the innovation output was postulated, was not supported. In the interaction models, the results supported that wellbeing and work life balance positively moderate the relationship between two centrality dimensions (degree centrality and betweenness) and the buying firm's innovation, the number of patents.

Conclusion and Discussion

To the best of the authors' knowledge, this paper is one of the first to combine social network theory and planned behaviour theory to uncover the role of an organisational factor, employee's intent to learn, in leveraging input from its supply network for its own innovation creation.

Our results for the first set of hypotheses are in line with the findings of Bellamy et al., (2014) that the structural embeddedness a buying firm is related to its innovation creation since it determines (1) the amount of knowledge held by its direct suppliers and (2) how easily it can access it. Also, our results suggested that if a buying firm has high level of betweenness, this means the firm acts as hub (Borgatti and Everett, 2006, Provan et al., 2007; Borgatti and Li, 2009; Kim, et al., 2011) and would enable them to acquire novel information by playing a gate keeper role. On the other hand, H_3 for close centrality was not supported suggesting that the value of the indirect ties in a supply network for innovation creation may not be that significant as previously thought. Or findings on the second set of hypotheses on the moderating roles of employee's intent to learn suggested that their subjective wellbeing as well as work life balance do matter in fully utilising suppliers' contribution in its own innovation creation. However, our findings suggested that 'meaningful work' does not increase the efficacy of supplier inputs and uncovering the reasons behind this require further research.

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Innovation in performing arts organizations: drivers and performance outcomes

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Abstract

This study aims to recognize the idiosyncrasies of not-for-profit performing arts organizations (PAOs) and how they can provide products/services to improve and benefit a community and the broad public interests. We consider innovation as a strategic weapon in addressing PAOs' increasing need for improvement in their operating structures and performance outcomes.
Drawing on the theory of dynamic capabilities and based on a literature review, four major internal capabilities have been identified that can theoretically increase PAOs' level of product and service innovation, as well as their performance factors: Environmental Intelligence, Internal Integration, Core Operational Capabilities, External Partnerships and Collaborations.

Keywords: Not-for-profits, Innovation, Performance

Introduction

The not-for profit (NFP) organizations have received little attention despite the fact that they are quite different in terms of their resources, motivations, governance structures, and operating practices, as compared to for-profits (Rodríguez et al., 2016). To address this gap, this study aims to expand our field's discourse to recognize the idiosyncrasies of NFP PAOs and how they can survive and achieve their goal, i.e., providing products and services to improve and benefit a community and the broad public interests.

NFP PAOs are tax-exempt organizations with special institutionalized governance, financial and operational structures, which are undergoing a gradual process of change and restructuration (Glynn and Lounsbury, 2005), due to public resource scarcities, self-dependency and transparency urges, and diversity of stakeholders' expectations. Innovation is known to be one of the best strategic weapons for PAOs to cope with such changes in their institutional environment and to improve their effectiveness and performance (Tepavac, 2010).

Arts management literature has broadly considered innovation in NFP PAOs from a purely "artistic" perspective (DiMaggio and Stenberg, 1985; Voss, Montoya-Weiss and Voss, 2006) and only few studies have taken other aspects of innovation into account (Camarero and Garrido, 2008b; Castro-Martínez, Recasens and Jiménez-Sáez, 2013).

This study contributes to the literature by taking a holistic operational perspective and defining PAO innovation as any incremental movement towards change along two dimensions: product and service.

In addition, drawing on the theory of dynamic capabilities (Eisenhardt and Martin, 2000; Wu, Melnyk and Flynn, 2010; Hitt, Xu and Carnes, 2016) and based on a systematic review of the literatures on NFP organizations and arts management, we identify a set of PAOs' internal capabilities as the major drivers of product and service innovations and examine how the innovation enhancements affect PAOs' financial, social, and artistic performance.

Performing Arts Organizations

With the recent decrease in PAOs' governmental funding and graying of their audiences which are also shrinking in number, they have been experiencing a state of great turmoil and change over the past three decades (DiMaggio and Mukhtar, 2004).

Besides, PAOs are facing new struggles to compete with entertainment sector. At the same time, they need to absorb and retain new audiences by means of diversifying their target segments, reaching out to the public, and deepening their relationship with serious art audiences (Bakhshi and Throsby, 2009). Given these conditions, we could say that PAOs are currently operating within a moderately volatile environment in which their existing competencies are deemed as ineffective (Glynn and Lounsbury, 2005) and therefore, they are under an increasing pressure to develop new capabilities for survival (Scheff and Kotler, 1996a; Hume et al., 2006; Tepavac, 2010).

In doing so, and in order to become economically sustainable, PAOs attempt to pursue strategies that are already adapted and proved to be successful in the for-profit sectors; most importantly amongst those are effectiveness and efficiency (Weinstein and Bukovinsky, 2009). They also attempt to become more accountable to their funders and supporters by concentrating on issues like public value creation, social inclusion, and diversity. These, in turn, have heated the debate over two conflicting logics in PAOs: the art logic symbolizing the perspective of artists in commitment to producing "the works of art, for the sake of art itself" and the managerial/market logic promoted by funding bodies and supporting associations' tendency toward formalization, accountability, and effectiveness (Glynn and Lounsbury, 2005).

Innovation in PAOs

Similar to other creative businesses, innovation is a crucial and essential part of PAOs' existence from administrative and governance processes to their operations, products, and services. A concise view to innovation in cultural organizations, as part of the NFP sector, often considers it as incremental and continuous improvements either in terms of enhancing the audience experience, service delivery, and interaction methods through adoption of new technologies from for-profit sectors, or as managerial changes aimed at enlarging the customer base (Camarero and Garrido, 2008b). Empirical studies in arts management and public policy, on the other hand, have often been focused on artistic innovation in PAOs, that is the degree of novelty in the content or artform of the artistic products (Castañer and Campos, 2002).

To provide a broader and encompassing conceptualization, we integrate the arts management and operations management perspectives and define PAO innovation, in terms of what these organizations have to offer, as "any incremental or radical change, compared to the PAO's past situation, detected throughout the entire value chain of design, production, and supporting of its products and services". Given these specifics,

PAO innovation can be classified into two categories: Product and Service Innovation. It should be noted, however, that these categories are not necessarily mutually exclusive.

Product Innovation

Product innovation refers to the incremental or radical changes in either or both the content and artform aspects of PAOs' cultural products. Innovation in content refers to the degree of originality, novelty, or rarity of the presented artworks. Taking orchestra field as an example, programming more recent or less performed pieces is considered a product innovation, in terms of the content. Although cognitive boundaries of content and artform are blurred, basically due to their interactions, artform innovation could be simply defined as novel approaches to presenting known works of art, as well as incorporating new technologies, artistic techniques and mediums in the performance process (Brown, 2004).

Service Innovation

Our conceptualization of service innovation includes two types of change: delivery innovation and new service development. Delivery innovation refers to changes in (i) the peripheral services which facilitate and accommodate the delivery process of the main service/product─ the show, or (ii) the touchpoints, delivery process, and medium through which the main product is delivered (Hume, 2008; Menor, 2015). Scheduling versatility, improving accessibility and facilities, adding supplementary services (e.g., culinary and beverages, parking, accommodations, backstage meetings), and touring, as well as diversifying venues and concert locations are examples of incremental service delivery innovations. New service development, on the other hand, is attributed to development of new services, which often do not contain a show element and are basically aimed at fulfilling educational, cultural, and social needs of the society or the attenders.

Drivers of PAO Innovation

According to the theory of dynamic capabilities, to gain and retain competitive advantage, organizations need to have the capabilities required to detect and adapt to the abrupt changes in their market and environment (Teece, Pisano and Shuen, 1997). In moderately volatile environments, such as that of PAOs', organization's dynamic capabilities are mostly reflected in the operational 'best practices' they follow to generate, combine, and reconfigure their internal/external resources, so that they can innovate and provide new products and services (Eisenhardt and Martin, 2000; den Hertog, van der Aa and de Jong, 2010; Hitt, Xu and Carnes, 2016). Specifically, while few PAOs with adequate financial resources and artistic merits might take the leap to implement breakthrough innovations and implement highly ambitious projects to stay ahead of the game; many others gradually mimic the best practices and create new capabilities to stay in the game. They draw on their artistic and technical qualities and their social capital to reconfigure their operations with more recently-generated internal and external routines/resources or create incremental innovations in various aspects of their products and services.

In this study, based on a systematic review of the NFP organizations, professional services, and arts management literatures, we put forth a bundle of capabilities (Figure 1) which significantly drive innovation in PAOs, as discussed in the following sections.

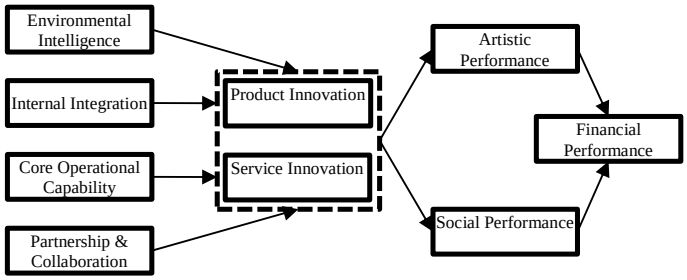

Figure 1 - Conceptual Model

Environmental Intelligence Capability

We define PAO's environmental intelligence capability along two major dimensions: accumulation and assimilation. Accumulation refers to the PAOs' routines and processes to acquire and collect information regarding every element of their broader environment. Assimilation, on the other hand, is the PAOs' ability to disseminate the information, generate a knowledge-base, and integrate it into the design, programming, production, and delivery of their products and services.

The positive relation between an inward flow of information from the environment toward the organization and innovation, new service development, and new product development has been theorized and tested in NFP sector (Camarero and Garrido, 2008b, 2008a; Weerawardena and Sullivan Mort, 2012; Sanzo-Perez, Álvarez-González and Rey-García, 2015). Particularly, innovation in PAOs is highly dependent on how their external conditions compare to their internal resources and strengths (Voss, Sirdeshmukh and Voss, 2008), which necessitates a certain level of environmental intelligence.

Nowadays, the ideas of diversity and social relevance necessitate the individual PAOs to incorporate their regional culture and local artists into their artworks. Moreover, PAOs as risk-averse organizations need to be aware of the reaction of different audience segments to the new artworks. This makes PAOs acquire and analyze both global and local data regarding the audiences' expectations and feedbacks from peer organizations and local PAOs.

- P1a: The PAO's environmental intelligence is positively related to its level of product innovation.

In addition, a thorough understanding of the local opportunities and potential partnerships aids PAOs in selecting and defining their innovative service delivery. Being aware of the challenges and necessities regarding the incorporation of services and business models similar to other NFP organizations could both eliminate waste and risks and elevate the success propensity. New service development programs also heavily depend on the in-depth knowledge of the PAOs about liabilities, needs, and characteristics of the hosting communities.

- P1b: The PAO's environmental intelligence is positively related to its level of service innovation.

Internal Integration Capability

Internal integration generally refers to both formal and informal collaborative behavior, information exchange, and joint decision-making within an organization (Gittell, 2006; Lin and Chen, 2008; Fu, 2015; Liu, Chen and Tao, 2015). The positive relationship

between internal integration and innovation and new product development in both for-profit and NFP sectors has been well established in the literature (Tatikonda and Montoya-Weiss, 2001; Agarwal, Krishna Erramilli and Dev, 2003; Hult et al., 2008; Fu, 2015).

Accordingly, in this study, we define PAOs' internal integration capability along two dimensions: design and implementation. Integration in design pertains to the inclusion of all departments and members, and their knowledge and expertise regarding the planning and programming of the products and services. Integration in implementation, on the other hand, focuses on coordinating the interactions between various processes and departments as well as allocating and integrating the resources to ensure that the planned quality, speed, and smoothness of the processes are met and the balance between the routine operations and innovative processes is maintained.

PAOs strive for creating synergies through creating organizational memory, collaboration, and coordination via a pattern of simultaneous decentralization and formalization to address their environmental complexities in design and implementation. The formation of cross-departmental committees for coordination between different constituents of the internal operations is a practical initiative for PAOs to instill internal integration. Another approach is to engage artists and other members in the decision-making processes (Tepavac, 2010).

Moreover, product and service innovations significantly add to the level of intensity and simultaneity of routines in PAOs, which, in turn, increases the multitude of logics, conflicting interests and priorities, as well as the number of experts engaged in design and implementation processes. These together lead to inefficiencies in communication, resource allocation, and conflict resolution processes both within and between teams and departments. In this vein, it could be hypothesized that higher rates of successful product and service innovation coincide with higher rates of internal integration. Thus:

- P2a,b: The PAO's internal integration is positively related to its levels of both product and service innovation.

Core Operational Capability

We define core operational capability (COC) as a differentiated set of "skills, processes, and routines for incrementally refining and reinforcing existing operations processes" (Wu, Melnyk and Flynn, 2010, pp. 727-728). This encompasses two dimensions for PAOs: (i) artistic component, which refers to the overall collective level of artistry and technical ability of the PAO as the result of its persistence and frequent experiences in performing demanding programs and pieces; and (ii) technical component, which pertains to the PAO's competencies in terms of improving their logistics for stage, rehearsals and backstage, auditorium facilitations, as well as its commitment to improve acoustic, sound, and visual systems in venue (Boyle, 2007; Tepavac, 2010).

Tepavac (2010) puts the artistic excellence as the footstone of her model of innovation in PAOs, as all five cases she had studied were high on the main technical and artistic abilities. In the same vein, we suggest that the COC acts as a driver of resource accumulation in PAOs, which in turn enables them to innovate in other aspects of their products and services by first, elevating their chances to attract other artists and partners; second, allowing them to spend their resources on experimentation and exploration on various aspects of their products and services (i.e., innovativeness); and third, by gaining legitimacy and the required financial resources (through winning peer reviewed grant applications due to perceived artistic excellence).

- P3a,b: The PAO's core operational capability is positively related to its levels of both product and service innovation.

Partnership and Collaboration Capability

The academic literature on service innovation highlights the necessity of partnerships in new service development and delivery where each partner facilitates a different component of the whole designed service (den Hertog, van der Aa and de Jong, 2010). Although taking part in coalitions of value-creation is of critical importance, the competency to coordinate and manage such interactions is also crucial since they can detract from organizational performance in the absence of coordination and cooperation capabilities or other misalignments between organizations (Eisenhardt and Martin, 2000; G. B. Voss and Voss, 2000; Teece, 2007; Tepavac, 2010; Weinstein, 2010).

In this study, we define partnership and collaboration capability (PC) as PAOs' and their members' experience and competency in absorbing for-profit or NFP, artistic or non-artistic business partners, as well as their success in leveraging frequent and long-term well-coordinated inter-organizational collaborations at low transactional costs.

There are multiple evidences of positive impact of partnership and collaboration on innovation, performance, and resource absorption in the NFP sector. (Jaskyte and Lee, 2006; Hartley, Sørensen and Torfing, 2013; Sanzo et al., 2015; Wade-Berg and Robinson-Dooley, 2015).

Presenting innovative works, either in terms of content or artform entails deployment of knowledge and capability sources which even large organizations lack in isolation, especially when it comes to interdisciplinary approaches to artform (Scheff and Kotler, 1996b). On the other hand, service innovation either necessitates knowledge, expertise, assets, and capabilities in the fields which basically fall outside the area of PAOs' business (e.g., adopting technologies, educational and other public projects) or entails combining unrelated types of service with the main products (e.g., out of venue concerts, supplementary services, accommodations, tours, tourism programs). That is why recently there has been an intense growth in the number of innovative partnerships between PAOs and for-profit technology or service providers or with other arts and culture organizations (Backer, 2002; Ostrower, 2003; Bakhshi and Throsby, 2009). In addition, the academic literature provides cases supporting a positive relationship between investment in close partnership relationships and successful innovative outcomes (Tepavac, 2010; Castro-Martínez, Recasens and Jiménez-Sáez, 2013).

- P4a,b: The PAO's partnership and collaboration capability is positively related to its levels of both product and service innovation.

PAO Performance

While, the PAOs' performance – like other NFP organizations – has been traditionally measured in terms of effectiveness rather than efficiency (Turbide and Laurin, 2009), Kaplan and Norton's Balanced Score Card (BSC) offers an effective tool for measuring the outcomes of these organizations (Weinstein and Bukovinsky, 2009). Similar to their approach, we focus on artistic (parallel to internal operations), social (parallel to customer and general public), and financial performance as the main measures of PAOs' operational outcomes.

Financial performance of a PAO is defined as its overall success in ensuing earned unearned financial resources and maintaining a feasible balance of their revenues and expenses (Herman, 1990).

In this study, we define the artistic performance of a PAO as the overall level of artistic merits and contributions that a PAO makes to the art community or the industry, as perceived by experts, peers, and artists (Glynn, 2000; Glynn and Lounsbury, 2005; Preece, 2005; Sorjonen, 2011). A high level of artistic performance or excellence is

amongst the most important factors in absorbing and retaining artistic talents and partners by PAOs (Scapolan and Montanari, 2013). It also has a significant effect on their survival, reputation, and legitimacy. Particularly, the experts' opinions directly affect the funding agencies' decisions, since fund applications are normally reviewed by peer artists. Therefore, artistic performance can play a significant role in increasing both earned and unearned revenues of PAOs (Gainer and Padanyi, 2002; Padanyi and Gainer, 2003; Preece, 2005):

- P5: Artistic performance of a PAO is positively related to its financial performance.

Social performance refers to a mix of advantages that PAOs can create for both the community they reside in as well as their audiences (Preece, 2005). In general, it can be defined as the overall success of a PAO in absorbing and retaining the continuous attendance and attention of the audiences in its public events and paid services, together with its commitment to presenting products and services to a broader and more diverse population in the society. This dimension of performance is well reflected in audience satisfaction and retention, which directly affects the PAOs' earned revenues (Gainer and Padanyi, 2002, 2005; Hume et al., 2006; Camarero and Garrido, 2008b; Hume and Sullivan Mort, 2010; Vakharia and Janardhan, 2017) as well as their public value (G. B. Voss and Voss, 2000; Z. G. Voss and Voss, 2000). The earned revenues usually account for thirty to fifty percent of the PAOs' total income (Weinstein and Bukovinsky, 2009; Orchestra Canada, 2017). Besides, although public value creation may not directly generate revenue for the PAOs, it can immensely affect their unearned revenues since the funding agencies, private donors, and corporate sponsors are increasingly concerned about this issue. Therefore,

- P6: Social performance of a PAO is positively related to its financial performance.

Innovation and Performance

Based on the dynamic capabilities theory as well as the literature on innovation in manufacturing and service sectors, innovation and new product/service development are one of the most effective approaches for organizations to gain competitive advantage and improve their operational and/or financial performance in the face of environmental uncertainties (Eisenhardt and Martin, 2000; Agarwal, Krishna Erramilli and Dev, 2003; Wu, Melnyk and Flynn, 2010; Hitt, Xu and Carnes, 2016). Particularly, the NFP organizations require innovation to deal with the uncertainties and increasing pressures to develop their products and processes in social services (Voss, Montoya-Weiss and Voss, 2006; Camarero and Garrido, 2008b; Weerawardena and Sullivan Mort, 2012; Sanzo-Perez, Álvarez-González and Rey-García, 2015).

The combination of higher levels of artistic quality and more frequent performances of modern pieces can elevate the appreciation of the artists, critics, and experts in the peer organizations, as well as the community and funding agencies. Moreover, productions that entail novel formal aspects can positively influence the artistic merits of the organization (Gainer and Padanyi, 2002). While currently only a small segment of the subscribers and general audience (i.e., arts-enthusiasts) are primarily focused on the pure artistic values of the presented works (Hume et al., 2006), research in the field has not been able to refute the general public's appreciation for the artistic merits of the artworks and PAOs are recently advised to accept the public artistic sensitivities (Gainer and Padanyi, 2002; Tepavac, 2010), as product innovations could also absorb the attention of non-expert audiences. This is, in particular, justifiable where formal sophistication and simultaneity of different streams of meaning embodied in artforms and other sources (e.g., musical, visual, and textual codes) absorb the new generations, specially the

millennials, more effectively; hence, extends the experiential aspects and appeal of the presented products (Brown, 2004; Bakhshi and Throsby, 2009). Therefore,

- P7a: Product innovation in a PAO is positively related to its artistic performance.
- P7b: Product innovation in a PAO is positively related to its social performance.

Service innovations, on the other hand, are aimed at absorbing the attention of the otherwise disconnected segments of the society by accentuating services or aspects of the service which favor the social development and public roles of the PAOs over their artistic merits. Besides, service innovations are implemented to heighten and deepen the PAOs' relationship with the general audience, particularly the entertainment-seekers, by enhancing the accessibility and experiential aspects of the artistic encounters (Hume et al., 2006; Hume, 2008). The effect of new service development on performance, effectiveness, and competitiveness in for-profit sector is established in the literature (Menor and Roth, 2008). In PAOs, the experiential aspects of the new service offerings as well as addressing the expectations of different audience segments promote the social performance; hence promote their financial performance (Andreasen and Belk, 1980; Scheff and Kotler, 1996a; Hume and Sullivan Mort, 2010; Menor, 2015).

- P8a: Service innovation in a PAO is positively related to its social performance.

In addition, service innovations are basically designed to widen the audience-base and ensure customer retention in terms of irregular audiences. Keeping higher numbers of community members in touch with art would be a contribution to the art and can result in the appreciation of arts community. Moreover, it could add to the propensity of the audiences to become serious audiences or even art practitioners. As a matter of fact, children and youth participating in public/paid educational and outreach programs are more likely to become future artists. The activities aiming to increase and retain the audience-base can also positively enhance the learning curve of the organizations in both artistic (i.e., stimulation of the appreciation of the community for art) and operational aspects, especially in the long-run.

- P8b: Service innovation in a PAO is positively related to its artistic performance.

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Innovation in the Fashion Industry: a model of development of styles and trends

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Abstract

This work aims at proposing an innovation model for the women's fashion industry, which intends to understand the behaviour of styles and trends spread by companies. The model discusses the fashion styles that remain in fashion in a continuous or discontinuous manner and the polarization of styles around feminine and androgynous concepts. The methodology adopted was hypothetical deductive. In order to verify the hypotheses, an exploratory data analysis was developed by means of descriptive statistic. The results showed there are fashion styles that remain continuously fashionable and there are polarizations periods of style grouped.

Keywords: Innovation, Fashion, Style

Introdution with a situation problem

Consumers recognize innovation in the fashion industry through the style imprinted in its products. Style is identified by the designs and colors of different clothing elements (clothes, shoes, and accessories). The combination of these elements also characterizes the formation of a style (Cappetta et al. 2006). These styles express concepts linked with cultural, social, and economic settings (Sabino, 2007).

The design of a product associated to its form limits the comprehension of its meaning. According to Kontic (2007), fashion design fits into a distinct category of knowledge, being on the edge of the productive process and product development. Therefore, design is the result of the process of developing a new product (Roper et al. 2016). However, the technological capacity of a firm determines design (Utterback and Albernathy, 1975; Tran, 2010). The consumer identifies design through shapes and colors of the products, while style is recognized by trends, meaning inclinations and repetitions through a period of time.

Since consumers identify style as the main element of innovation in fashion, understanding its behavior is fundamental for innovation processes by companies. Therefore, this research aims mainly to present a trend and style innovation model for

the women's fashion industry. The model focuses on style, which is determined and widespread by high-end *prêt-à-porter* companies.

Industrially manufactured clothing is called *prêt-à-porter*. This market segment can be divided into high-end, mid-end low-end *prêt-à-porter*. These different areas are distinguished by the consumer public and the price of the pieces. The high-end *prêt-à-porter* products are more expensive and an elite set of consumers. In the mid-to low-end ranges of *prêt-à-porter*, the pieces become cheaper and reach mass consumption (Cappetta et al., 2006). The model in this research focuses on high-end *prêt-à-porter* as these are created by the style and trendsetting companies.

The high segmentation in the fashion industry increases the companies' need to develop strategies to gain space in the consumer market. Innovation is one of these strategies. Innovation is incremental and directed to the product. Incremental innovation consists of small product modifications and improvements (Davila et al., 2008; Rogers and Schoemaker, 1971). In particular, design has an impact on the competitiveness of companies and industry standards (Utterback and Albernathy, 1975; Baldwin et al. Hippel, 2006).

This research investigates trend and current styles as an indicator of behavior by innovation in contemporary fashion. The idea is to identify which trends are permanently in fashion. Rationalizing the process systematically reduces uncertainties regarding new style releases. Moreover, some contemporary fashion styles (after 1990) show conceptual similarity, which allows grouped around the same concept.

The main motivations for this study are two aspects: there is room in the literature for more studies regarding the proposed theme, and there is a need in the fashion industry for a study about trends and style behavior. There are currently several articles in the literature referring to the subject. A bibliometric analyses was used to measure of the quantity and diversity of the topics in articles about fashion. Notwithstanding, for the specific objectives of this research, only a few of the articles are relevant and pertinent, which demonstrates that there is room for further literature in this field.

The innovation models for the fashion industry referred to in this research are from different perspectives. This gives rise to questions as to which elements are fundamental for the construction of an innovation model. The innovation model for product development, by Markevicute and Blazenaite (2011), focuses on analyzing the processes for new product production, from the generation of ideas to their dissemination. The innovation models regarding fashion trends (Jones, 2004; Caldas, 2005; Sarma et al., 2010) aim at understanding institutions and the elements that generate the styles and trends, as well as their diffusion channels. The model for fashion cycles shows fashion innovation through market behavior (Pesendorf, 1995). Lastly, innovation models for style behavior, by Cappetta et al. (2006) contribute by uniting style behavior to its period.

The main question that these models raise is: If fashion is fundamentally product, style and design changes through time, should an innovation model have these elements as variables? Only the Cappetta et al. (2006) model takes this approach. So, it is relevant and pertinent to develop a model using these attributes.

To understand their contribution, it is necessary to establish some definitions concepts about fashion, design, style and trend. Fashion is an intangible phenomenon, with trends, styles and design changes introduced at pre-determined time intervals (Lipovetsky, 1989; Caldas, 2005; Markevicute and Blazenaite, 2011). Fashion represents what is current, in evidence.

Contemporary fashion (21st century) is determined by fashion institutions, for example: (i) *prêt-à-porter*, (ii) high fashion, (iii) style bureaus, (iv) media, (v) young

subcultures/street style, (vi) social elite, wealthy people, artists, and celebrities, (vii) individuals in general (Caldas, 2005).

Design represents the form and aesthetics present in products. In fashion, design is identified by the form, volume, and silhouette of products. Design is a component of style. Style is the combination of apparel elements (clothes and accessories) that can be identified by form (design) and color. Styles express concepts recognized in cultural, social, and economic patterns. That is why styles characterize specific time periods (Sabino, 2007).

An example of style is romantic attire. At the beginning of the 19th century, more precisely between 1820 and 1840, this style of clothing was distinguishable by: a thin waist, light-colored dresses (solid print or with flowers), puffed sleeves, voluminous skirts, ruffles and bows (Laver, 2006). In other times, when clothing had similar elements to those used in the romantic period, these are classified as being of the romantic style.

In addition to styles associated with a time period, there are styles characteristic to certain companies. For example, at the house of Chanel, cardigan-style jackets (buttoned-down, long-sleeved wool coats) are present in every collection. New product versions are introduced in each collection; however, the original design characteristics are preserved. Lacoste is another example of a company that has its iconic pieces in every collection. Its polo shirts are a brand iconic piece because they were released at the creation of the company and reinforce the concept that the brand has a casual, sports style (Vincent- Ricard, 1989).

Trends are inclinations and repetitions of certain behaviors and styles. Trends are determined by fashion companies and they always looking to introduce something new. Determining trends through the components of the production chain tends to reduce the risk in developing a product collection. In the case of textile/clothing production, this is composed of threads, weaving and manufacturing, among others (Caldas, 2005).

Of the innovation models for the fashion industry, the Pesendorf (1995) use his model to define the process of the generation and obsolescence of style, and how consumer behavior influences it. The latest releases are the most desired by consumers. Products of older style and design become obsolete. Consumer behavior confirms this proposition.

For Pesendorf (1995), there are two influences on consumer behavior: the *bandwagon* and the *snob* effects. The bandwagon effect in product demand is stimulated by elite consumer behavior. Elite consumption directs other customers' consumption. The moment favored products reach mass consumption, the *snob* effect occurs. Elite consumers then discard these products and the fashion's companies releases new products.

Regarding the release and diffusion of trends and styles, Caldas's (2005) and Jones's (2004) models show that fashion trends come from opposing directions. The *trickle-down* model reinforces the idea that elite-directed consumption conditions mass consumption. The *bubble-up* model shows the opposite, where trends are defined by an "underground culture". However, in both models, trends reach the elite first and, then, are made available for mass consumption.

Cappetta et al. (2006) agree with Pesendorf (1995) independent to the process of trend appearance, elite consumption conditions mass consumption (bandwagon effect). From the moment a trend is absorbed by mass consumption, the style is rejected by the elite consumer and becomes obsolete (snob effect).

Plurality in style and trend formation and determination varies according to each period. Cappetta et al. (2006) present the hypothesis of convergence and divergence of

style. In convergence periods, styles are more similar and tend to assume the same shape and color patterns. In the divergence periods with effervescence of styles, there is the release of several styles, all different. The authors' argument is grounded in a specific fashion period – from 1984 to 2002.

The central feature of the proposed model is to evaluate whether there are fashion styles that remain in fashion in a continuous or discontinuous manner. The model also discusses the polarization of styles around feminine and androgynous concepts.

The proposed model assumes the concept that style innovation depends of the technology employed in product manufacturing, once the design is a style element. Style is determined by dominant companies in the chain production and, then, reproduced by companies of lesser importance.

Dominant companies are those that reach elite consumption first, and have brands that can be identified by the public. How companies become established in this position depends on market behavior and company strategies. A company may successfully launch a new style at one period of time, then be unsuccessful at the next.

The proposed model also assumes that the style diffusion process happens through the trickle-down model, in which the determination of trends and styles comes from chain-production dominant companies. While it is accepted that other fashion institutions may determine styles and trends, they still need dominant companies to produce and release them to the elite consumer market. As elite consumption conditions mass consumption, the bandwagon and snob effects are considered real.

The proposed model does not intend to investigate internal processes in detail; it assumes that the innovation process goes from idea generation to product dissemination in the market. In this regard, there is no contribution to the literature. The contribution of the model lies in helping to forward an understanding of contemporary style and trend behavior.

According to Jones (2004), styles can be classified as classic and ephemeral. Styles that are considered classic are those that are present in different times through fashion history. These styles are re-edited, their original version is modified but keep their basic essence. Classic styles remain in fashion for a longer time. Ephemeral styles have a short period in fashion.

A commonly accepted concept in fashion history studies is that predominant styles practiced in a time period are the opposite to those practiced in the next. For example, in the 1960s and early 1970s, there was a counter-cultural revolution where young people started to question the values imposed by society. In fashion, this was reflected in miniskirts, geometric dresses, with psychedelic colors, and the hippie style. The 1980s are culturally the opposite, reflecting the body and work cult of that time. Women's fashion clothing was more comfortable and adaptable to the job market (more ample and loose shapes) (Jones, 2004).

In contemporary fashion, there are both the coexistence of classic and ephemeral styles and the idea of the continuity of styles instead of ruptures. Fashion, from the 1990s, starts to admit a higher number of styles and trends. Furthermore, it disrupts the idea that styles and trends are specific to each decade. Styles stay in fashion for longer periods of time, with small changes to the design and colors. Conceptual aspects of each style and their cultural and socioeconomic identification patterns follow the same references.

The aim of this model is to understand trend behavior in contemporary fashion. If the coexistence of conceptually opposite and similar styles has occurred in fashion, then, it is possible that trends aggregate styles around common behavioral concepts. Trend

behavior reveals the fashion development pattern, explaining which behavioral aspects are and tend to stay current.

The research aims to investigate how contemporary fashion trends indicate aspects of current fashion behavior. The idea is to identify which trends have been constantly in fashion. Rationalizing the process a system of thought would reduce uncertainties related to launching new styles.

The first question in this research considers if styles remain in fashion in a continuous or discontinuous way. Understanding style behavior is to understand the way trends are developed. So, the first question in the research is: In contemporary fashion (from the 1990s), are there styles that remain in fashion continuously, while others do not (go out of fashion)? The hypotheses developed to help answer this question are the following:

- H1: There are styles that remain in fashion continuously, while others do not.
- H0: There are no styles that remain continuously in fashion; there is a pattern of discontinuity for all styles.

The second question in the research considers style merging. Each style has specific characteristics in terms of concept and design, although there are also similarities between styles. In this research, only women's fashion is investigated. The main differentiation in styles considered in this research is in gender identification.

Some styles, depending on their design and clothing composition, seem more feminine while others seem more androgynous. Styles that focus around gender identification may lead to an understanding of whether there are some periods where styles become polarized, and others where they do not.

Polarization means that, during a specific time period, the relative frequency of styles grouped that suggest androgyny. In other moments, the relative frequency of styles grouped suggest femininity. Depolarization means that there are no specific periods with polarization, that the relative frequency of agglutinations is constant throughout the period.

As such, the second question of the research is: Are there periods in which there is polarization of style grouped? The hypotheses to answering this question are as follows:

- H1: There are periods in which there is polarization of style combination around gender identity.
- H0: There are no periods in which there is polarization of style combination around gender identity.

The graphic representation of the proposed model, shown in Figure 1, demonstrates the beginning of the style-generating process which occurs in companies that dominate the production chain. From the moment in which the generated style starts to be disseminated, it assumes different behavioral trends (continuous and discontinued) that allow polarizations around gender identity (androgyny and femininity).

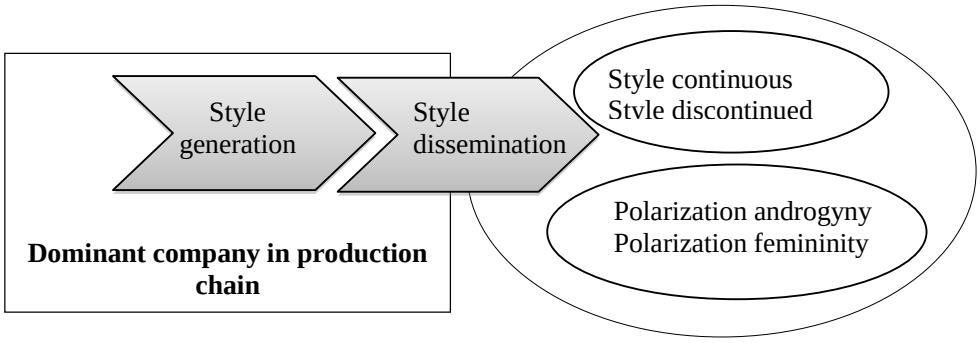


Figure 1: Proposed trend and style innovation model
Source: Prepared by the authors

Methodology

In order to test the validity of the model the empiric research was made. The research has a phenomenological, qualitative, and longitudinal approach and the methodology adopted was hypothetical and deductive. For hypothesis verification, an exploratory data analysis was used through the descriptive statistics.

The data collection sources were Vogue America issues from 1991–2013, and 230 issues were used. Vogue's View editorials were used as the analysis unit. Vogue's View editorials were chosen because Vogue America magazine addresses other topics related to fashion like: architecture, decoration, cosmetics, and behavior.

The data collection methods in phenomenological research (qualitative) are a series of interpretive techniques to describe and understand the meaning of a given phenomenon. To classify a method as phenomenological, and, therefore, adequate to qualitative research, depends of its intended use (Collis and Hussey, 2005).

Some styles are explained in the editorials, while others are only referred to. New styles are mentioned in the editorials and explained. Commonly-used fashion styles are just cited for the data collection, the editorials were read, and the photographs that referred to the cited style were analyzed.

The process of labeling each style consisted of describing its components, as collected in the explanation of the editorials. A list of the styles mentioned follows below:

- Ethnic: characterized by clothes that were inspired from Russian, Chinese, Indian, and African cultures;
- Grunge: characterized by loose T-shirts, plaid flannel and cotton shirts, ripped up jeans, wool caps and boots;
- Hippie: characterized by casual looks, long skirts, smocked tops, low waisted, straight or bell-bottom jeans;
- Casual: characterized by light fabric loose clothing (cotton and jersey), or materials appropriate for informal situations (wools, knits, and jeans). Accessories are simple and unobtrusive;
- Dandy/Edwardian: characterized by high-neck shirts, tight pants, body-hugging vests, and boots. The style implies androgyny;
- Minimalist: characterized by clothing (skirts, dresses, shirts and pants) that are straight fitted, with no volume. Clothing is a solid color (no color mixing) and accessories are simple and discreet;
- Romantic: characterized by dresses and skirts that have volume. Clothing has floral or solid patterns, with ruffles, lace and embroideries;

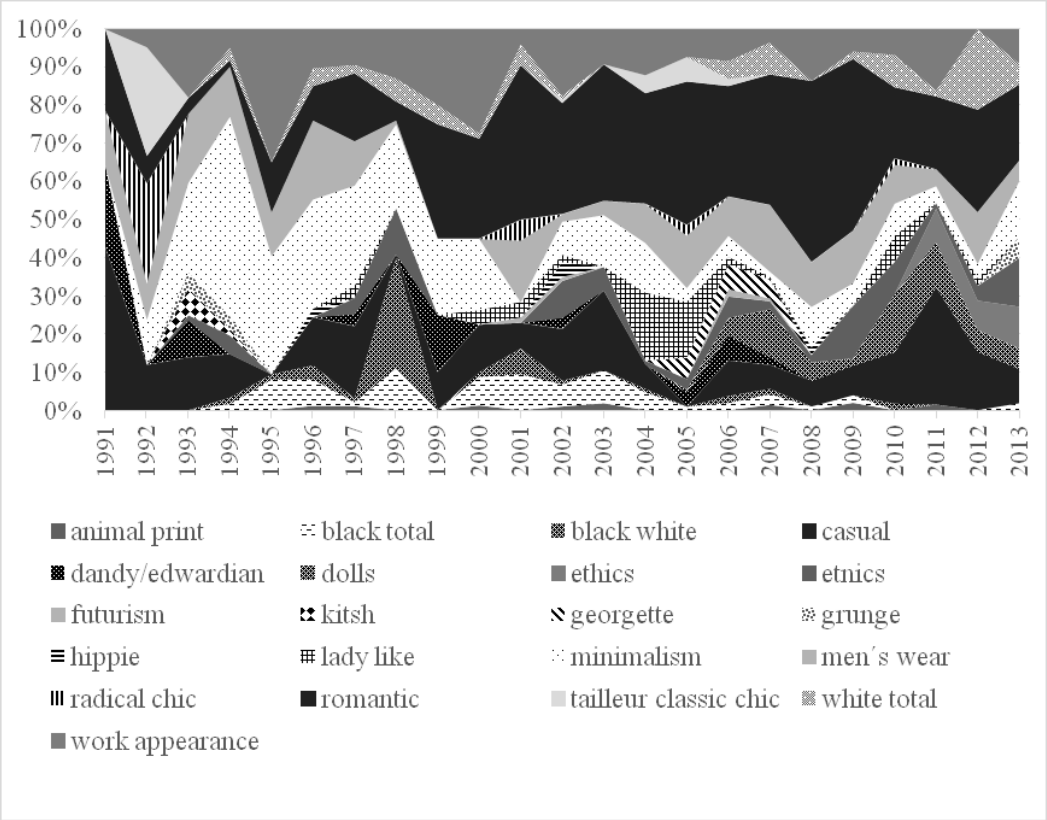
- Animal print: characterized by clothes with animal skin patterns. Suggests sensuality and femininity;
- Total black: characterized by the use of the color black in every piece of clothing;
- Total white: characterized by the use of the color white in every piece of clothing;
- Black-white: characterized by the combined use of the colors black and white. The color change is in one piece, for example, black pants and white shirt;
- Doll: characterized by clothes adequate to young women and city life romantic. Clothing features: short, tight skirts, shoulder to shoulder tops, empire waist-lines (waist comes right below the bust);
- Ethical: characterized by ecologically correct clothing;
- Futuristic: characterized by its use of plastic and synthetic fabrics, bright and bold colors;
- Kitsch: characterized as a tacky, corny style, with bright and fluorescent colors. The accessories are big and flamboyant;
- Georgette: characterized as a style of clothing inspired by 1920s' fashion. Garments are satin (fabric) dresses, with lace and low necklines. Accessories are pearl necklaces and earrings, and pointy shoes;
- Lady-like: characterized by clothing including knee-length, A-line skirts (tighter at the waist and broader at the hem), or pencil (tight, high waisted) skirts. Light fabric (chiffon, silk crepe), buttoned-down, cuffed shirts;
- Men´s wear: characterized by garments made up of: pinstriped suits (jacket and pants), shirts (buttoned-down, cuffed, with collar), trench coat (straight fit or military style) and boots;
- Radical chic: characterized by garments that are voluminous and no shoulder straps. Lace details. Metal accessories (jewelry) are large and heavy;
- Classic chic *tailleur*: characterized by composed of tailor-made suits (skirts, shirts and jackets) adorned by metallic buttons and worn with large jewelry;
- Work appearance: characterized by suits (jacket with straight pants or skirt) and normally in dark colors. Pieces are straight cut, with no volume or flamboyant details, being more suitable for the work environment.

Style combination according to gender identity can be classified in three ways: androgynous, feminine, and neutral. In fashion, androgynous styles highlight the absence of femininity. As this study is about women's fashion, it is important to briefly discuss gender differentiation in clothing. The identification of gender specific (masculine and feminine) clothing has occurred since the beginning of fashion, in the 14th century (Lipovetsky, 1989). Twentieth century fashion broke these barriers and incorporated masculine pieces into feminine clothing. When this happens, clothing is no longer essentially feminine and becomes androgynous. Androgynous styles are: dandy/Edwardian, minimalist, menswear, classic chic tailleur, work appearance.

Feminine styles, on the other hand, are the opposite, highlighting aspects such as feminine sensuality and fragility. Styles suitable for the workplace do not fall into this classification. Thus, feminine styles are: romantic, animal print, doll, georgette, lady like, and radical chic. Not all styles can be classified according to gender identity, in which case, the neutral classification was adopted. Neutral styles are those that have no elements identifiable to either femininity or androgyny. The neutral styles are: ethnic, grunge, hippie, casual, total black, total white, black-white, ethic, futuristic, and kitsch.

Result

In the research were identified twenty one different styles. The results showed there are fashion styles that remain continuously fashionable. A polygonal graph shows a stacked view of the relative frequencies of all styles. In graph 1, the horizontal axis shows the years, and the vertical axis, relative frequency. The legend indicates each of the twenty- one styles.

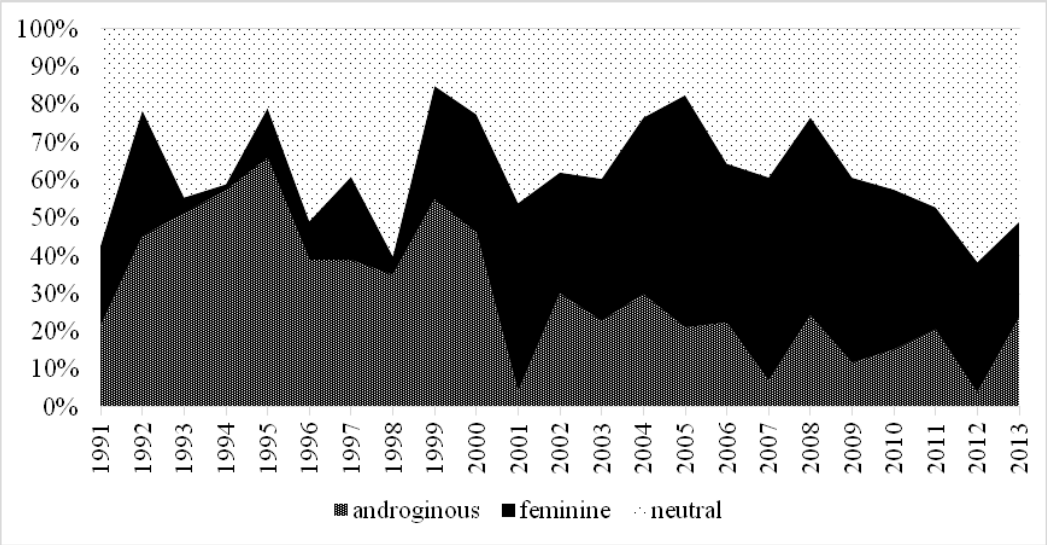


Graph 1: Stacked areas of relative frequencies
Source: Prepared by the authors

Style classification by gender identity is defined by the conceptual content of each style. Even though this research focuses on women's fashion, there are styles with greater identification to the concept of femininity, and others with greater identification to the concept of androgyny and, finally, neutral styles, which are those that do not fit into either of the above categories. The styles corresponding to each category are:

- Androgynous styles: dandy/Edwardian, minimalist, menswear, classic chic tailleur, work appearance;
- Feminine styles: romantic, animal print, doll, georgette, lady like, radical chic;
- Neutral styles: ethnic, grunge, hippie, casual, total black, total white, black-white, ethical, futuristic, kitsch.

The graphical distribution of the combination around of frequency results is presented in Graph 2. It is possible to see the polarization of the androgynous style in the period 1991–2000. The feminine gender identity predominated in the 2001–2013 period, indicating a possible polarization in this time periods.



Graph 2: Stacked areas of gender identity relative frequencies
Source: Prepared by the authors

Conclusion

The proposed model is initially grounded on fashion styles generated by the dominating chain production companies. The diffusion of generated styles leads to the formation of continuous and discontinuous behavior trends. The fact that fashion is a social phenomenon reverberates in style behavior. As fashion product consumption is an elite consumer differentiation factor, the style adhesion by the masses provokes the obsolescence of these products. Thus, style behavior is influenced by consumer receptivity to the generated products.

There are other factors that also influence product consumption in general, such as demographics, regions, and socioeconomics. However, as the model was aimed aims at high-end *prêt-à-porter* companies, which release and market their products in different parts of the world, these factors were not explored. The proposed model considered only social factors as influences to consumer behavior.

Further, when analyzed through descriptive statistical methods, the collected data was able to prove the coexistence hypotheses of continuous and discontinuous styles. The existence of polarizations around androgynous styles in the 1990s, and feminine styles in the 2000s can also be proved.

The positive aspects of the proposed model dwell in three factors. First, the presentation of a model with theoretical coverage relating the behavior of companies, innovation processes, and consumer behavior when faced with innovative product releases is original and unprecedented. Second, using statistical methods for understanding style behavior and trend generation allows clear and proper identification of the characteristics of contemporary fashion and the polarization of gender identity styles in different periods of time. Third, the research classifies and compiles existing innovation models for the fashion industry.

This model's limitations are present in the collection and classification of styles. The sole source used for the collection of styles was *Vogue America*, a magazine read throughout the world, but directed to the American market. Even though fashion is globalized and the same styles generated by high-end *prêt-à-porter* companies are diffused by world media, there are specific characteristics of the American market that foster greater preference of some styles over others. This happens in all markets.

Moreover, without any doubt, the style classification process was conceived by this author herself. While the whole classification followed pre-established criteria, still the styles went through one sole evaluation during the classification process.

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Managing digital innovation in manufacturing companies

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Abstract
The potential of digital innovations is clearly recognized. However, its implementation within manufacturing companies seems to be more difficult. Considering that digital innovation within manufacturing companies are a combination of digital and physical assets, it seems plausible that the consideration of information systems related governance mechanism may support the digital innovation management within manufacturing companies. We derive six propositions which give insights into which dimensions are relevant for digital innovation management in manufacturing companies.

Keywords: Digital Innovation Management, Digital Technologies

Introduction
The diffusion of digital technologies into the manufacturing industry creates new opportunities. These opportunities may arise from improvements in efficiency and effectiveness (i.e. smart factory) or through the offerings of new products, services or even business models. The combination of digital technologies such as sensors, actors and cloud computing with non-digital products and services provide significant opportunities but capturing the value of the digital transformation has proven to be challenging to firms in traditional industries (Henfridsson et al., 2018; Svahn and Henfridsson, 2012). Whereas the innovation potential of digital technologies is widely recognized, few studies address the management of digital innovations (Abrell et al., 2016). We aim to enhance the understanding of how to manage digital innovations in manufacturing companies. To do so, we relate to IS literature and derive insights from software development projects and compare these with the activities and challenges of eleven Industrial Internet of Things (IIoT) projects of three manufacturing companies.

Digital Transformation

Digital transformation describes how companies need to change their processes and the company's way to compete in the digital age. There exist different terms describing the changes, such as information age, industrial internet or industry 4.0. The information age started with the third industrial revolution, also known as the digital or ICT revolution, at the end of the twentieth century (e.g., Castells, 2011; Dosi and Galambos, 2013). The technologies, mainly

ICT, lay new foundations for companies, economies and societies. In addition, Musso (2013) concludes that the information age has sped up the transition from manufacturing to services, highlighting the influence of the technological changes on business models.

In industrial companies, these changes are labelled as industrial internet, industrial internet of things (IIoT) or Industry 4.0. The main approach of the industrial internet or industrial internet of things (IIoT) is to bring software and machines together (Bruner, 2013). The term stems from the US and was first introduced by General Electric. IIoT enfolds initiatives belonging to a higher degree of intelligence with the power of advanced computing, analytics, low-cost sensing, and new levels of Internet connectivity (Posada et al., 2015). Posada et al. (2015) highlight three key elements of IIoT: (1) intelligent machines, (2) advanced analytics and (3) people at work.

Industry 4.0 belongs to a similar initiative, mainly pushed from Germany. The core elements of Industry 4.0 are embedded systems, smart objects, cyber physical systems (CPS), the concept of a Smart Factory, robust networks, cloud computing, and IT-security (Bauer et al., 2014). The coexistence of the physical and virtual worlds, with the use of emerging ICT, opens possibilities such as "enhanced human-machine cooperation (including human interaction with robots and intelligent machines), connected machine networks that follow paradigms of Internet connectivity and social networks, improved human-in-the-loop interaction between the cyber and physical worlds, networked and decentralized value chain transnational scenarios, and emergence of product-service networks based in intelligent, smart products, and associated services" (Posada et al., 2015, p.27).

Whereas Industry 4.0, IoT, IIoT and digital manufacturing focus on the changes of digital technologies in industrial companies, the term digital transformation is industry independent and analysed based on the perspective of different research streams. Vial (2019) defines, based on a comprehensive literature review, digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies".

Although avoiding the term "digital technologies" in his definition, Vial (2019) highlights that that most of the digital technologies mentioned in the literature review fit with the popular SMACIT acronym, referring to technologies related to social, mobile, analytics, cloud, and the internet of things. Furthermore, it's the combination of technologies that are particularly relevant in the context of digital transformation (Bharadwaj et al., 2013). For example, the use of social media on the mobile phone may be the prerequisite for gathering and storing big data and to perform analytics.

Others, in addition, highlight the merge of the physical and digital world, enabled through IoT sensor and actuators and connectivity technologies (Fleisch et al., 2014; Yoo et al., 2010). Summarizing, the traditional processes of manufacturing companies focusing on physical products is challenged with the requirements to integrate digital aspects. How to cope with these new requirements is a challenging task for manufacturing companies. Hence, to get an understanding of the different requirements manufacturing companies are facing while developing digitally enhanced products, services or processes, we summarize the key aspects of the traditional innovation management and information systems (IS) related innovation management.

Traditional Innovation Management: Insights from Business Management

Managing innovation has traditionally focused on new product development (NPD) activities. Prerequisites for the development of products are the engagement in a bundle of activities that include the management and transformation of resources and information in order to create products that meet or create market demand (Wheelwright and Clark, 1992). Typically, in innovation management, four types of innovation exist: process, product, service and business model innovation (e.g., Teece, 2010). Considering key determinants of the traditional

innovation management, Damanpour (1991) highlights in his meta-analysis several factors that have a positive correlation with innovation: specialization, functional differentiation, professionalism, managerial attitude toward change, technical knowledge resources, administrative intensity, slack resources, and external and internal communication.

Johansson and Kullström (2018) argue that an innovation management, which has been dominated by structure and control, mirrors the circumstances where goals and objectives have been clear. Instead, innovation activities nowadays are increasingly confronted with fuzzy objectives and complex processes and traditional methods have been found lacking (Kapsali, 2013). Therefore, there is a need to find methods that suit more complex projects.

Innovation management: Insights from IS literature

Traditionally IS innovation research has focused on the adoption, diffusion, implementation, acceptance, and assimilation of IT in organizations (Fielt and Gregor, 2016). However, there is a growing interest on the paradoxes and dilemmas that digitization creates for organizations developing, deploying, and managing digital innovation (Nambisan et al., 2017). As Nambisan (2017) states: "This transition from innovation to digital innovation comes as a golden opportunity to be seized upon by information systems (IS) researchers. IS researchers have, for the last four decades, been at the forefront in observing the dawn and consecutive wakes of digitization in organizations and, broadly, in society, and explaining its repercussions." Similar to the definitions in business research, IS scholars define digital innovation as the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology. Stated differently, in digital innovation, digital technologies and associated digitizing processes form the base for new ideas. Thus, digital innovation management refers to the practices, processes, and principles that underlie the effective orchestration of digital innovation (Nambisan, 2017).

Svahn and Henfridsson (2012) conclude that product innovation and IT innovation literature provide a different outlook on innovation. While product innovation cultivates firm-centricity and exercise of formal control, IT innovation builds upon network-centricity and the creation of digital options. Network-centricity introduces uncertainty that counteracts the traditionally exercised formal control over the product innovation process. The authors conclude that more research is needed on these seemingly opposing logics (Svahn and Henfridsson, 2012).

Digital Innovation Management: Research Framework

Different researchers argue that there is a need for new theories in this age of digital innovation and digital transformation (Hinings et al., 2018; Svahn and Henfridsson, 2012; Yoo et al., 2012). More specifically, Nambisan et al. (2017) say that "[t]here is a critical need for novel theorizing on digital innovation management" that deals more adequately with the rapidly changing nature of innovation processes in a digital world. Although the innovation process itself is crucial to understand, the management is important as well.

As the proportion of software within innovations of manufacturing companies is rapidly growing, manufacturing companies can profit from understanding the requirements to successfully manage IT innovations. However, as Svahn and Henfridsson (2012) highlight, there are differences between the management of product and IT innovations and hence, there is a need to get an understanding on how to incorporate both aspects.

To do so, we rely on the concept on IT governance. As Leonhardt et al. (2018) summarizes, newer research on IT governance mainly enfolds the governance mechanisms related to structure, process and relational mechanisms.

One key aspect to IT governance is the decision-making structure, implemented to define the locus of authority for IT activities (Sambamurthy and Zmud, 1999). Choices range from centralized to decentralized or hybrid decision-making. More specifically, a central decision architecture grants all decision rights to the IT organization, a decentralized one delegates

decision-making authority to the business units (Brown and Magill, 1994). Thus, we conclude that the *locus of authority* and its role in digital innovation management needs further research attention.

Horizontal coordination mechanism enfold informal and formal designs that focus on the interaction of individuals and the coordination of activities across units (Mintzberg, 1979). The mechanism aim at facilitating interaction and problem-solving across different departments (Brown, 1999). The formal coordination mechanism refer to steering committees or cross-unit integrators. Examples of cross-unit integrators are Chief Digital Officers.

Since digital innovation requires the combination of diverse knowledge across different departments (Yoo et al., 2010), interdepartmental dynamics and the respective *horizontal coordination mechanism* may be at the core of digital innovation management.

Although Yoo et al. (2010) focus on the internal cooperation relevant to acquire knowledge, Hildebrandt et al. (2015) highlight the growing importance of cooperation with external partners. More specifically, acquiring and integrating complementary and heterogeneous external knowledge on digital technologies is an important prerequisite for digital innovation (Hildebrandt et al., 2015). Thus, we add *internal cooperation* and *external cooperation* as two further dimension as being potentially relevant to understand digital innovation management.

As it is our goal to understand digital innovation management, we focus on the analysis of the innovation process itself and the four governance mechanisms as summarized in Figure 1.

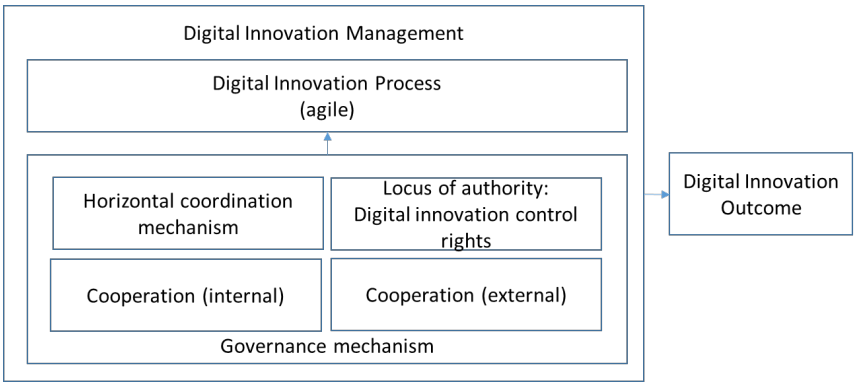

Figure 1 - Research Framework

Research methodology

We grounded our observations in data from a multi-case study with three multinational companies from the machine industry that face the diffusion of digital technologies. Each of the companies belong to a wider company network and reports to headquarters. In addition, company B acts as a national headquarter for further subsidiaries. Overall, we have analyzed eleven IIoT initiatives that are the unit of analysis for the study at hand. Because of the emergent nature of this topic, we apply an exploratory research approach. In addition, we analyze existing literature focusing on digital innovation and its management and derive a framework that guides our research (Eisenhardt, 1989). The goal is to match theory and reality in a nonlinear, path-dependent process that systematically combines empirical observations and insights from extant literature (Storbacka, 2011).

The exploratory research lasted from January 2016 to September 2017, with follow-up interviews in 2019. We accompanied the companies throughout the development process and conducted 12 to 16 meetings within each of the participating companies. The companies were part of a joint working group. Hence, there are activities that the companies conducted jointly (i.e. successful practice visits) or applied the same methods (i.e. evaluation of market trends). Other activities are company specific. The data gathering occurred through meetings within each of the three companies. During the meetings, we observed the activities and conducted

interviews. We wrote minutes for each meeting (observation and interviews), and compared them with literature.

We used Miles and Huberman's (1994) four-step approach to analyze the collected data. First, we developed a contact summary sheet in which the main themes of each interview were recorded. One researcher identified the main themes, while the other two researchers checked these themes using the interview minutes. The themes covered, for example, the content of different IIoT initiatives and the measures to implement them. Second, a complete theme list was developed based on the contact summary sheet. Third, all interviews were coded using selective coding (Strauss and Corbin, 1990) to categorize the answers into the main themes. One researcher was responsible for coding the interview minutes, while the other researcher checked the coding. In the event of disagreement, the point was discussed until agreement was reached. If no agreement was reached, the point was referred to the interviewees for clarification. This procedure ensured a high level of inter-rater reliability (Voss et al., 2002). Fourth, we wrote the case study and performed a final validity check, which was done by presenting the results to the interviewees and to the top management of the respective company.

Case study analysis

The three manufacturing companies developed nine IIoT ideas that focus on offering new services to the customers. Three initiatives focus on the digitalization of internal processes (i.e. digital working instructions, dynamic planning and production system (smart factory) and global service). Overall, the activities of the innovation process can be described according to the six generic dimensions: idea generation, idea selection (I), idea concretization, idea selection (II), development and dissemination. Table 1 and Table 2 summarize the main activities, separated into activities that each company conducted similar as well as company specific activities.

		Idea Generation		Idea Selection I		Idea Concretization	
		All companies	Specific	All companies	Specific	All companies	Specific
Case A1	**Guaranteed machine availability**	- Evaluation of market trends (general trends, customer trends) - Environmental scanning (competitors) - Generation of ideas based on creativity tools - Knowledge transfer from successful practices	- Collection of ideas from different sources within the company (meetings, informal discussions, documents)	- Visualization of ideas - Presentation of prioritised ideas (own choice) and open group discussion - Matching with strategy - Discussion based on portfolio analysis (impact and absorptive capacity) - Selection of 4 to 6 ideas	- Matching with digital transformation strategy	- Concretization based on I4.0 initiative analysis (value proposition, value chain, revenue mechanism, capabilities and technologies, connectivity) - Analysis of needed technologies and capabilities - Derivation of interdependencies between ideas	- Customer segmentation (i.e. personas) - Concretization of value offerings through service theater - Matching of value offerings with personas - Involvement of HQ
Case A2	**Pay per use**						
Case A3	**Smart Services**						
Case A4	**Smart factory of the customer**						
Case B1	**Guaranteed machine availability**		- Integration of projects from different subsidiaries (Swiss HQ perspective)		- Discussion based on functional strategies (sales, R&D, production)		- Comparison with ongoing projects and adaptation of ideas if needed
Case B2	**Digital working instructions**						
Case B3	**Smart Factory**						
Case C1	**Preventive/ predictive maintenance**		- Collection of ideas from different sources within and outside of company (e.g., meetings, informal discussions, presentations at trade shows, technical literature)		- Discussion based on functional strategies (sales, R&D, production)		- Customer segmentation (i.e. personas)
Case C2	**Global Service**						
Case C3	**Life-Cycle Management**						
Case C4	**System capability**						

Table 1: Insights from the innovation process of 11 IIoT initatives (I)

We conducted follow up interviews in 2019 to derive the level of diffusion. Whereas company A achieved to implement three pilot tests with customers (Case A1, A2 and A3), company B is also able to cooperate with pilot customers for case B1. Only company C had to stop all of its activities.

Based on the research framework derived, next to the process, we focused on the governance mechanism. Whereas in some cases, the governance mechanism have been similar for the studied company, other mechanism differed depending on the initiative. Table 3 highlights the insights of the governance mechanism.

		Idea Selection II	Development		Diffusion		Success
		Specific	All companies	Specific	All companies	Specific	
Case A1	**Guaranteed machine availability**	- Joint discussion and selection with HQ	- Setting up of roadmap and project management	- Stronger involvement of HQ and knowledge transfer with other business units and countries (A1-3) - Focus on technical requirements, data analysis and informations system (A1-3)	- Setting up roll-out activities	- cooperation with pilot customers (A1-3)	- Pilot tests
Case A2	**Pay per use**						- Pilot tests
Case A3	**Smart Services**						- Pilot tests
Case A4	**Smart factory of the customer**						- Stopped (not in the current strategic focus; 2017)
Case B1	**Guaranteed machine availability**			- Training of sales employees (selling software) (B1) - Focus on information system (incl. data and interfaces) (B1) - Joint development with external partners (all)		- Consideration of platforms and integration with complementary machine producers (B1) - Customer base: need to highlight the advantages of digitalisation (B1)	- Pilot tests
Case B2	**Digital working instructions**						- Stopped in 2018; restart in 2019
Case B3	**Smart Factory**						- Stopped in 2018; restart in 2019
Case C1	**Preventive/ predictive maintenance**	- Joint discussion and selection with HQ		- Evaluation of joint development with external partners (C2)			- Stopped from HQ (2017)
Case C2	**Global Service**						- Supplier evaluation, project ongoing
Case C3	**Life-Cycle Management**						- Stopped (not in the current strategic focus)
Case C4	**System capability**						- Stopped from HQ (2017)

Table 2: Insights from the innovation process of 11 IIoT initatives (II)

Discussion

The specific activities of company A and B at the beginning of the innovation process highlight the need to coordinate with other subsidiaries or activities conducted throughout the company. At company A, during the idea concretization phase, headquarters was involved to align the subsidiary activities with companywide initiatives. Although each of the four cases at company A was presented to headquarters, the “pay per use” initiative needed further alignment as the potential service offering influenced process steps covered from other subsidiaries and was clearly in the locus of authority of headquarters.

The interdisciplinary project team is a central part in traditional as well as digital innovation management and was present in each of the studied initiatives. Interdisciplinarity seems to be important, not only for the knowledge needed for the development of digital innovation but also for the strengthening of internal cooperation and thus the implementation of the digital innovation throughout the company. More specifically, the interdisciplinary teams helped to improve the attention throughout the company and, in addition, to integrate knowledge from other functions. In the case of company B, internal cooperation was strengthened through a mix of focused project developments and larger group meetings that involved up to forty employees from different functions and subsidiaries. Although company B’s project team consisted of internal members, there was a continuous possibility to take in additional knowledge from the network. Company A and B continuously harmonized their activities with other ongoing projects and hence, allowed to take in additional knowledge from the network. Thus, the insights suggest that besides the internal cooperation, digital innovation management is strengthened through collaboration with the company wide network.

P1: Internal cooperation through interdisciplinary project teams supports the knowledge intake from different functions and the knowledge diffusion throughout the company and hence, the digital innovation management.

P2: Cooperation throughout the company wide network supports the knowledge intake and hence, the digital innovation management.

Internal Cooperation
- Interdisciplinary project team, high attention of topic throughout the company
- Involvement of members of the company network where needed
- Interdisciplinary project team, various other initiatives on subsidiary level
- Mix between focused project teams of 4-6 members and bigger meetings (up to 40 people) to involve different functions and subsidiaries
- Interdisciplinary project team
External Cooperation
- Successful practice visits for idea generation
- Customer involvement happened late in the innovation process. Due to the strong internal competencies in the company wide network, no involvement of external cooperation partners.
- Idea concretization: collaboration with user experience specialists and software suppliers
- Continous integration of customers to understand the customer needs
- Smart Factory: supplier selection but supplier could not deliver the expected content. Own development activities but with to narrow focus. Stop of project (new start in 2019)
- External cooperation late in the innovation process and only for one initiative.
Horizontal coordination mechanism
- Assigment of a leader digital transformation, high involvement of CEO, decentralized approach (subsidiary decision authority), coordination between functions and with HQ, continous alignment between ongoing projects and digital transformation initiatives
- Digital transformation as part of the business development department (strategic projects), regular involvement of different employees of subsidiaries.
- Low involvement of Swiss COO, change of COO and stronger involvement and hence, re-start of smart factory project.
- Horizontal coordination through sounding board (CTO, COO, CEO)
- High involvement of CEO, no special assigments
Locus of authority
- In the beginning the locus of authority was within the Swiss subsidiary (decentralized approach). As one idea is within the competency of HQ, HQ involvement was needed.
- At the beginning: Authority of projects at Swiss HQ but parallel project developments at subsidiary level (hybrid solution with no clear regulations). Integration of projects into the Swiss HQ driven projects (involvement of key employees of different functions and subsidiaries).
- Development phase: global HQ started to intervene and stopped the initiatives in order to develop a global digital transformation strategy. After interdependency was achieved (buy out), re-start of projetcs with clear locus of authority at Swiss HQ (but involvement of subsidiary).
- In the beginning the locus of authority was within the Swiss subsidiary. HQ stopped further developments as it was unclear if subsidiary remained within the company.
Process
- Linear process with view iterations
- From early on application of agile development activities with a strong human centered approach (for guaranteed machine availability project), linear process activities for smart fabric project
- Linear process with view interations

Table 3: Insights from governance mechanism of 11 IIoT initiatives

With focus on external cooperation, the eleven initiatives differed. The development activities of the four initiatives of company A are conducted internally or in cooperation with the company wide network. Company C had an even stronger focus on the knowledge of internal members. Only company B did involve external partners, exemplifying the agile development philosophy through an early involvement of customers and suppliers. Based on the follow up interviews, the management of company B highlighted that the early collaboration with partners (customers and (technology) suppliers) helped for the internal and external focused innovations. The digital transformation representative of company A confirmed, as he states: “We should have integrated the customer right in the beginning”.

P3: External cooperation with partners (customer, supplier, experts) is important for digital innovation management.

The initiatives of company A have been orchestrated by a specifically assigned digital transformation leader. His role was to coordinate the different initiatives and to integrate the various activities throughout the company. In addition, the CEO had a central role, showing the

importance of the digital innovations and fostering its implementation activities. Company B assigned one initiative to the leader of strategic projects (guaranteed machine availability) and the internal focused projects to the COO. Whereas the leader of strategic projects continuously involved employees from different functions and subsidiaries and actively strengthened the informal knowledge transfer, the COO did not install similar coordination mechanisms. At company C, one initiative (Global Service) was assigned to the head of global services. Even though there was a high involvement of the CEO in company C, horizontal coordination mechanisms were missing for the other initiatives.

P4: Formal and informal coordination mechanism are important to consider for the digital innovation management.

The analysis of the locus of authority within the cases leads to different insights. In company A, the initiatives are highly linked to headquarters as the offerings of the services lies in the responsibility of headquarters. Being aware of this, the company tried to involve headquarters early and continuously. The locus of authority within company B changed during the innovation process. Whereas in the beginning, the company had the authority to decide, there was a development stop ordered from headquarters. Only after the company achieved a buy-out a re-start of the innovation processes were possible. After that, Swiss headquarters was officially assigned to be the locus of authority and, in the case of case B1, successfully continued the project. Similarly, based on headquarters orders, company C was not allowed to invest in the development of digital innovations as headquarters wanted to integrate the initiatives network. Since they were driven from the Swiss site alone, headquarters did not allow continuing with the initiatives before analyzing which other sites from the company wide network needs to be integrated into the development process.

Each of the analyzed initiatives had issues with the locus of authority. It seems that the primary prerequisite is to have it defined and second, to handle changing locus of authority and to adapt the management of digital innovation.

P5: The definition of the locus of authority is a requirement for digital innovation management. If new requirements lead to a change in the locus of authority, digital innovation management needs to be adapted.

Only one of the studied initiatives (B1) did integrate the agile development philosophy. The follow up interviews with the leader of the strategic development projects supported the importance of this philosophy, while contrasting the success of the digital innovation (B1) with the two other projects (B2 and B3). Similarly, company A highlights retrospectively that an earlier involvement of customer needs (and pains) and a more agile development process would have helped to speed up the development process.

P6: An agile innovation process with an early involvement of customers and suppliers as well as iterative phases supports digital innovation management.

Conclusion

The analysis of the management of eleven IoT initiatives exemplifies the difficulties of managing digital innovations within manufacturing companies. We add to literature as we compare the micro-level activities of the development of the IoT initiatives with the relevant dimensions derived from the IS literature on digital innovation and its management. First, we show that a linear development process, as implemented from the manufacturing companies, does not respect the complexity of digital innovations. As suggested from the IS literature on digital innovation, an iterative and agile approach helps to get a better understanding of the

underlying interdependencies. Another influencing factor is the interdisciplinary of teams, which need to be visible throughout the company and act as intermediaries between their functions and the project team (internal cooperation). Third, external cooperation is not only needed in the idea generation phase but during all the development stages. The development of digital innovations is complex and often, there is a lack of knowledge and experience which needs to be incorporated from external partners. Forth, in addition to internal and external cooperation, the cooperation within the company wide network is another important dimension for knowledge intake and diffusion. Fifth, changing locus of authority led to project stops and hence, exemplified its importance. The sixth dimension, horizontal coordination mechanism, shows the need to have defined responsibilities, which covers the interdisciplinary nature of digital innovations.

The exploratory research approach and the comparison with insights from IS literature allows to expand our understanding of digital innovation management. All derived dimensions need to be considered to successfully manage digital innovations within manufacturing companies. Limitations occurs as the development activities are still ongoing. In addition, more cases are needed in order to understand if one of the derived dimensions do have stronger impacts on digital innovation management than others.

Nevertheless, the derived proposition provide a starting point for further research. For example, the locus of authority needs further research attention as despite the clear finding of its importance, it remains open, how subsidiaries need to operate within the realm of headquarters.

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Applicability of Agile and Scrum to Product-Service Systems

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Abstract

Developing Product-Service Systems (PSS) is uniquely challenging in terms of both the offering and the development process due to the combination of product and service components. This paper investigates the applicability of agile and scrum method, having originate in the software industry, to the development of PSS to address these challenges in practice. Based on a combination of agile and servitization literature, this paper offers a conceptual framework detailing the applicability of four agile elements (application, management, technical, personnel), and nine scrum elements in three groups (events, artefacts, roles). This research contributes to the servitization literature by extending the knowledge on PSS development and deriving suitable management practices.

Keywords: Agile, Scrum, Product-Service System, Project Management

Introduction

Manufacturers are increasingly seeking to servitize their business through the provision of Product-Service Systems (PSS), compound offerings of products and services. This trend promises the provider high gains including closer customer contact, stable revenue streams, and higher profit margins (Isaksson et al., 2009). However, by far not all manufacturers experimenting with the concept of PSS are able to harvest these benefits. Indeed, the history of servitization shows many examples of PSS development projects, which fail already during the development and never even reach the market. In response, a stream emerged in the academic servitization literature, which discusses in particular the challenges of PSS development.

Core challenges for manufacturing firms in the development of PSS often arise because of the radical nature of the final offering (Baines et al., 2017), the systemic complexity of parallel development of the product and service (Trevisan and Brissaud, 2017), and the difficulty of project execution (Morelli, 2006). Here challenges can arise in the course of defining and testing intangible service elements, as many services are

produced and consumed simultaneously (Lankhorst, 2012). In addition, manufacturers often have to manage the systemic complexity of developing not only the product and the service distinctly, but as a system. Here manufacturers often lack knowledge regarding the diverse interfaces in this systemic integration (Trevisan and Brissaud, 2017). Lastly, uncertainty arising from the unpredictability of the competitors' actions, the precise customer needs, or other macro-economic changes can impede the development (Kreye, 2017). In short, the development of PSS is often characterized through high uncertainty and complexity (Ramírez Hernández et al., 2018).

While contributions in the servitization literature investigated the challenges of PSS development, no suitable solution has been identified up to date. The PSS development methodologies offered today (Dingsøyr et al., 2012; Vasantha et al., 2012a) are still strongly oriented on the traditional stage gate approach (Aurich et al., 2006; Vasantha et al., 2012b; Weber et al., 2004). Academic literature has however reflected upon uncertainty management in new product or service development. As such, Rice et al (2008) proposed the use of more "agile" methods under circumstances of high uncertainty, and more "staged" methods, under circumstances of low uncertainty. Short development cycles through testing of assumptions about uncertain conditions and incorporating these learnings into the development project to plan the next short iteration are used to navigate these uncertainty conditions. Moreover, Boehm and Turner have investigated the concept of agile further and identified the basis of agile, i.e. when agile works most successful. They distinguish four elements; Application, Management, Technical and Personnel, and discussed their variance for the optimal application in agile. These four elements of agile represent a guidance for *where* to apply agile.

Further, the concept of agile manifests itself in several methods, of which scrum is one of the most mature and widely applied (Dingsøyr et al., 2012). It is divided into three groups; events, artefacts and roles, with three elements each (Cooper and Sommer, 2016a; Schwaber and Sutherland, 2017). The events include the sprint planning and sprint, the daily scrum, and the review and retrospective meeting. The artefacts contain the product backlog, the sprint backlog, and the increment. The roles are distinguished into the product owner, the scrum master, and the scrum team. These nine elements of scrum provide guidance on *how* to apply agile.

While the body of knowledge about agile (and its manifestation in scrum) has grown substantially in the field of software, its application outside this realm is still nascent. Specifically, the applicability of agile and scrum in contexts such as PSS development is promising, yet underexplored. Accordingly, we ask the following research question to close this gap:

Which elements of agile and the scrum methodology are applicable to the development of Product-Service Systems?

Based on the analysis of existing servitization and agile literature, we offer a conceptual framework detailing the above-mentioned four elements of agile and nine elements of scrum, in terms of their applicability in PSS development. While describing these elements of agile and scrum is not in itself a new contribution to the literature, assessing their application and adaptation to the PSS development context contributes to theory building in the field of servitization and agile.

Research Design

To answer the research question, we conducted an exploratory literature review based on contributions in the field of agile and servitization. The aim of the literature review was

to create a rich understanding of the state-of-the-art literature and to comprehend the applicability of agile and scrum to the PSS development context. The literature review is based on contributions identified through a keyword search in the search databases including Scopus and Web of Science.

The review of the agile literature included search strings derived from the following keywords: "agile" (Boehm and Turner, 2003; Dingsøyr et al., 2012; Moran, 2015), "agile development" (Conforto et al., 2014; Nerur and Balijepally, 2007), "scrum" (Dybå and Dingsøyr, 2008; Schwaber and Sutherland, 2017), "agile service development" (Cocca et al., 2015; Lankhorst, 2012), "agile product development" (Cooper and Sommer, 2018; Karlström and Runeson, 2006). Similarly, the review of the servitization literature was conducted using keywords "Product-Service System" or "PSS" (Beuren et al., 2013; Mont, 2002; Tukker, 2004), "integrated solution" (Storbacka, 2011), "bundled services" (Schmenner, 2009), "servitization" (Baines et al., 2017; Díaz-Garrido et al., 2018), "PSS development" (Aurich et al., 2006; Wallin et al., 2015; Wuest and Wellsandt, 2016), and "new service development" (Papastathopoulou and Hultink, 2012; Santos and Spring, 2013). Based on the initial findings, we refined and combined the keywords further in the course of the literature review.

The literature review revealed the need to differentiate between the application of agile as a concept and its manifestation in a specific method (Boehm and Turner, 2004). Agile as a concept provides guidelines of a general setting under which agile is best applied. Boehm and Turner, (2004) summarized a framework which distinguished four elements as the general basis of agile: Application, Management, Technical and Personnel. The *Application* of agile details that it unfolds its full potential in volatile conditions through rapid value creation in small teams. The *Management* relies strongly on intense customer involvement in the project, with qualitative control mechanisms and strong utilization of tacit, interpersonal knowledge. The *Technical* element details simple designs, which are easily refactorable in short increments with test cycles, as well as prioritized requirements, which are evolving continuously. Lastly, agile relies strongly on *Personnel* who are 100% dedicated to the project, working co-located and with a culture of empowerment. These four elements of agile constitute the overall applicability of agile to a certain setting and thus form the basis for our discussion in the PSS development context.

The manifestation of agile finds its way into several methods in practice. One of the most applied and researched methods is scrum, which describes an iterative development process with incremental value delivery. Although scrum is often modified to fit the particular situation, for the purpose of the present research we will refer to the original form derived from the software development (Schwaber and Sutherland, 2017). It distinguishes events, artefacts and roles, with three elements each (Cooper and Sommer, 2016a; Schwaber and Sutherland, 2017). The events include the sprint planning and sprint, the daily scrum, and the review and retrospective meeting. The *sprint planning* is an event in which the work packages for the upcoming development are planned. The *sprint* represents the subsequent intense development period of usually 1-4 weeks duration, in which the previously defined work packages are created. The *daily scrum* represents a stand-up meeting on each day of the sprint, in which each team member reflects on the progress of the developments, as well as potential problems. After the sprint a *review and retrospective* meeting is held, in which the team reflects upon the developed work, as well as the process through which it was developed.

The artefacts are the product backlog, the sprint backlog, and the increment. The *product backlog* represents the prioritized list of requirements, which is continually updated to incorporate the learnings of each sprint. The *sprint backlog* is the amount of

work chosen by the development team to be executed in the course of one sprint. Unlike the product backlog, the sprint backlog requirements do not change during the sprint. The *increment* is the outcome of the development work in the course of one sprint. It is used in the review and retrospective meeting to test and seek feedback from customers and stakeholders. Based on this feedback, the product backlog is re-prioritized.

The roles include the product owner, the scrum master, and the scrum team. The *product owner* is the person responsible to update and manage the product backlog to achieve the desired product. The *scrum master* is the process owner and facilitates the team in the application of scrum, as well as the removal of impediments of the development project. Lastly, the *scrum team* is responsible for the actual development and consists of a cross-functional, fully dedicated team.

While the application through reduction of uncertainty promises a beneficial application of agile and scrum in PSS, it is however important to note that PSS also differ from the origin of agile in pure software development. While software is intangible, infinitely divisible, and easily refactorable, this is not true for PSS. Particularly the product element of PSS is tangible, most likely not infinitely divisible, and, once produced, only refactorable under additional costs. The service element on the other hand is intangible and often easily refactorable (or adjustable to the customer conditions), but can only fully be tested in the field as it is produced and consumed simultaneously. As such, it remains to be investigated which elements of agile and scrum can be applied to PSS development to address the strong challenges during the development.

Conceptual Framework: Applicability of Agile and Scrum in PSS Development

To answer our research question, we utilize a conceptual framework combining the four bases of agile defined by Boehm and Turner (2003) with the nine elements from the events, artefacts and roles described by (Cooper and Sommer, 2016a; Schwaber and Sutherland, 2017). We apply this framework to assess the suitability and adaptation of agile and scrum in the specific context of PSS development.

Agile Elements

(1) The Application

The first basis of agile, the *Application*, is highly similar to the original description, as regularly also in PSS development, volatile conditions have to be managed and customer needs addressed. In addition, PSS often possess systemic complexity between the product and the service part, which implies that scrum needs to be scaled to coordinate the separate developments of several components (e.g. service and product components) in parallel through e.g. “scrum-of-scrum” (Dingsøyr et al., 2018). Overall, no adaptation to the element of *Application* to PSS development is needed.

(2) The Management

For the basis of *Management*, small adaptations have to be considered in the PSS context. The development of PSS may be highly customer focused and involve a close collaboration or even co-creation with the customer (Kristensson et al., 2008; Vargo and Lusch, 2008). It also often relies strongly on communication and team collaboration (Wolfenstetter et al., 2015). However, large and traditional enterprises moving towards servitizing their business through offering PSS are likely unable to abandon their legacy plan-based and KPI-driven development and solely rely on qualitative control mechanisms and tacit, interpersonal knowledge (Boehm and Turner, 2005). This organizational resistance to agile may be overcome through change management

practices. As such, the agile basis of *Management* is generally applicable to PSS development, calls however often for additional change management practices.

(3) The Technical

The *Technical* basis of agile partly conflicts with the characteristics of PSS. Some PSS can possess a high systemic complexity, which arises from the combination of (tangible) product and (intangible, process-focused) service elements. This combination creates high interdependencies to ensure operability of the Product-Service System. As such, the service has to be tailored to the product characteristics, and the product design should consider the service-ability (Trevisan and Brissaud, 2017). Due to this strong limitation, literature proposes a more structured approach such as the application of e.g. the Scaled Agile Framework (SAFe) (Leffingwell et al., 2013), to coordinate the integrated development. In addition, the product element is not as easily refactorable as pure software code due to its tangibility (Conforto et al., 2014) and thus, limits the optimal operation of agile as suggested by the *Technical* basis. However, PSS generally complies with the struggle of volatile requirements and the need for testing the developed increments (Morelli, 2006; Wolfenstetter et al., 2015) mentioned for the *Technical* basis. Concluding, while some parts of PSS development characteristics comply this *Technical* basis, others call for strong adjustments.

(4) The Personnel

Lastly, the agile basis of *Personnel* is again partially applicable to PSS development. While PSS development thrives on cross-functional teams with high customer engagement (Wolfenstetter et al., 2015), traditional manufacturers regularly struggle with full staffing of the employees on the project. In addition, large organizations are often regionally spread out, which hampers the ability to develop with co-located team members (Conforto et al., 2014). Furthermore, traditional manufacturers may struggle with the transition from a hierarchical towards a flat and empowered culture (Paasivaara et al., 2018). As such, in principle PSS development complies with the *Personnel* basis of agile; in practice however, manufacturers may need to adapt agile to operate within the existing structures of the organization.

Scrum Elements

(1) Sprint and Sprint Planning

The first event consists of the *sprint planning and sprint*. The agile literature has already investigated the applicability of the sprint planning and sprint to new service development as well as to new product development in separation. In new service development, the service may be developed through planned, time-boxed iterations and short feedback cycles with the customer (Cocca et al., 2015; Lamberth-Cocca and Meiren, 2017; Lankhorst, 2012). In new product development however, the *sprint planning and sprint* is not as easily applied. Due to the tangibility of the product, many teams struggle to decompose the physical product into several fully-functional sub-products which are developed in sequential, periodic sprint cycles. As such, not every *sprint planning and sprint* may be able to create a functional sub-product that can be demonstrated to the customer as originally defined. Rather, several *sprint planning and sprints* may be required to deliver the concept, the CAD-model or drawing, the testable component, an integrated prototype, and finally the product (Cooper and Sommer, 2016b). In addition, the systemic complexity of integrating product and service elements calls for a more structured approach to coordinate the interrelation between them (Morelli, 2006; Wolfenstetter et al., 2015). To answer these limitations of PSS development to a pure *sprint planning and sprint*, literature proposes a more linear agile process, called the Agile-Stage-Gate hybrid (Cooper and Sommer, 2016a). Here the linear development

mode and the periodic control of the stage gate process are merged with agile sprints in between the gates.

(2) The Daily Scrum

The second event, the *daily scrum*, is intended to foster a short, intense exchange of the most critical information regarding the development project (Paasivaara et al., 2012). PSS development frequently also builds upon intense collaboration between the team members to coordinate the systemic complexity (Trevisan and Brissaud, 2017). The daily scrum is thus easily transferrable to the PSS development context and may even enhance the collaboration.

(3) The Retrospective and Review Meeting

The third event of scrum is called the *retrospective and review meeting*. Here lessons learned are implemented already in the course of the development project. In contrast, in traditional PSS development literature, the revision of the PSS developed and a reflection on the underlying process is conducted after finalizing the PSS (Aurich et al., 2006; Vasantha et al., 2012b). Thus, the lessons-learned are implemented in the subsequent development project. Given the often high degree of uncertainty in PSS development, fast learning and adaptation is not only transferrable, but also strongly recommendable.

(4) The Product Backlog

The first artefact of scrum is the *product backlog* and comprises a prioritized list of features the final offering should have. It represents the counterpart to the detailed requirement specifications in PSS development (Aurich et al., 2006). However, the product backlog of scrum is a tool which acknowledges the degree of uncertainty connected to the requirements and is thus constantly updated (Schwaber and Sutherland, 2017). Due to the uncertainty in the context of PSS development (Morelli, 2006), the application of ongoing adaptable requirements can be recommended. As the most important items of the product backlog assure the most important items for the creation of customer value (Schwaber and Sutherland, 2017), the application of the product backlog (in combination with iterations collecting customer feedback) enhances customer satisfaction (Cooper and Sommer, 2018). Since PSS often aim to create strong long-term customer relationships (Beuren et al., 2013; Visnjic et al., 2016), the application of the product backlog may not only reduce uncertainty, but also strengthen the customer relationship (and satisfaction).

(5) The Sprint Backlog

The second artefact is the *sprint backlog*. The sprint backlog is the selection of the most important requirements to be developed in one sprint and remains unchanged in the course of this sprint. At its core, the sprint backlog provides the team with the necessary structure and implies a small plan-based approach: after planning the requirements, the actual development is carried out. Traditional PSS development methodologies follow this logic (just at a larger scale) (Aurich et al., 2006; Vasantha et al., 2012b). Accordingly, if the structure of periodic sprints is to be used, the sprint backlog should be easily transferrable to PSS development.

(6) The Increment

The third artefact is the *Increment*. This is the complete, functional, testable and releasable outcome of a sprint (Schwaber and Sutherland, 2017). Although in the context of new service development, the increment could be easily applied (Cocca et al., 2015; Lamberth-Cocca and Meiren, 2017; Lankhorst, 2012), in the context of new product development the original definition of the increment is troublesome (Cooper and Sommer, 2018; Karlström and Runeson, 2006). As elaborated before, the physicality of the product hampers the development complete and functional product increment (Karlström and Runeson, 2006). Research from the use of scrum in product development

proposes here a redefinition of the increment towards "a complete and testable deliverable", which can thus also be applied in the context of PSS development (Cooper and Sommer, 2016b).

(7) The Product Owner

The first role is the *product owner*. The product owner is responsible for the prioritization of the product backlog and the stakeholder management to ensure management support (Schwaber and Sutherland, 2017). In PSS development, this role requires a strong understanding of both the product and the service elements, as the product owner must continually re-prioritize the requirements for the entire project. While the role as such is easily applicable to PSS development, in practice it may require senior experts to execute this role (Dikert et al., 2016).

(8) The Scrum Master

The second role is the *scrum master*. The scrum master is responsible for the correct execution of the scrum methodology and the removal of obstacles the development team may encounter (Schwaber and Sutherland, 2017). In the context of PSS development, organizational resistance can arise as both, the PSS offering (Visnjic et al., 2016) and the scrum process (Dikert et al., 2016), may be novel to the organization. Therefore focus should be laid on a properly trained scrum master with strong stakeholder management capabilities (Boehm and Turner, 2005). Overall, the scrum master should be easily applied to any PSS development project.

(9) The Scrum Team

The *scrum team* is defined as the last role of the scrum methodology. Here, in the original definition the team should be fully dedicated, co-located, empowered and cross-functional (Schwaber and Sutherland, 2017). As mentioned in the *Personnel* element, full dedication, co-location and empowerment can be challenging for traditional manufacturers. The scrum methodology specifies however, that the full potential of scrum can only be reached if the elements are kept as defined – specifically the fully dedicated and co-located team (Boehm and Turner, 2005). Weakening of this requirement would strongly impact the team's ability to learn and adapt fast. Accordingly, an adaptation for this challenge could be to apply scrum only to highly critical projects of PSS development with high uncertainty. In short, the application of the scrum team in its original sense poses challenges to traditional manufacturers, but should not be compromised when applied in the PSS context.

Figure 1 summarizes our conceptual framework. In sum, the concept of agile is generally applicable to the PSS development context. While some elements are fully or through smaller adaptations directly transferable to PSS development, the *Technical* element requires major adaptation in the PSS context. The same accounts for the application of agile through the method scrum. Some elements are easily transferrable to the PSS development context, while others need major adaptations.

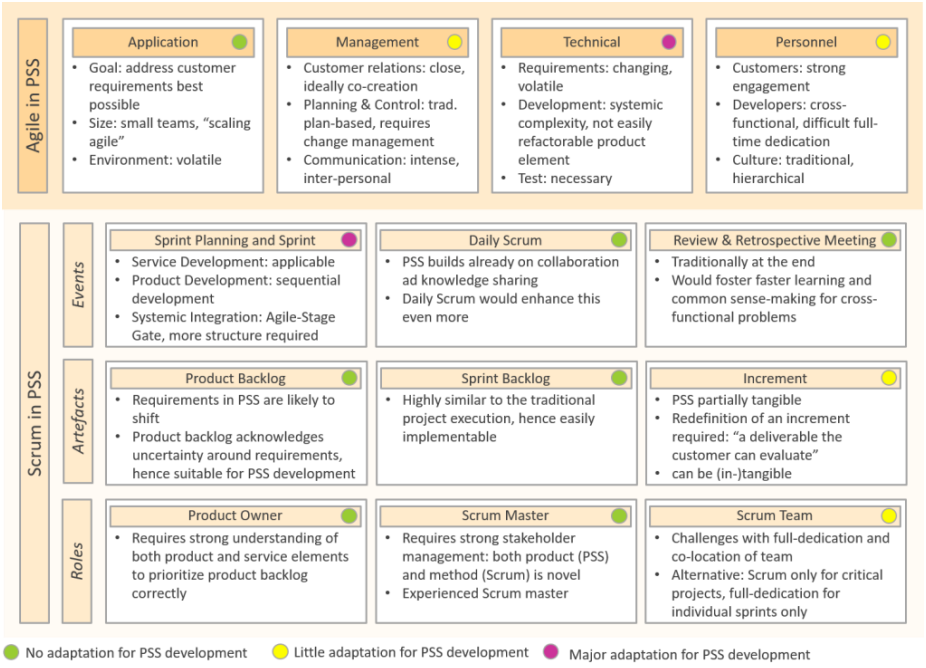

Figure 1 Framework illustrating the application of agile and scrum in PSS development

Implications and Conclusion

In this paper, we investigate the question of which elements of agile and scrum are applicable to the development of Product-Service Systems. Through an exploratory literature review, we derive a conceptual framework based on the literature streams of agile and servitization. This framework distinguishes four elements of agile, and nine elements of scrum, which are each discussed in the context of PSS development. While the concept of agile and scrum have already been discussed in depth in the software development literature, we investigate the expansion of its application areas to the context of PSS, which has not been discussed previously.

This framework contributes to the servitization literature by discussing a theoretically founded, alternative development approach of PSS through the application of agile and scrum. Through uniting the bases of agile with a method of implementation, scrum, we help solving the challenges during the development of PSS due to its often volatile and uncertain conditions.

This paper also contributes to the agile literature by expanding its areas of application. Through the theoretical discussion of the application of agile and scrum in PSS development, we test its functionality from the original realm of software. We reveal its strengths and limitations in the context of PSS, and expand the discussion through the proposition of potential adaptations needed for this application.

For managers, this research holds several implications. The proposed framework raises awareness to the distinct circumstances of PSS development. It provides managers further with a guideline on when to apply agile management methods, and how scrum can be utilized in the context of PSS development. It also gives suggestions on how to adapt scrum specifically to the PSS development setting.

This research bases on the retrospective and conceptual analysis of academic literature, which represents a major limitation for the validity of the framework. Further research is planned to advance the insights from this framework through case-study research.

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The influence of intrapreneurship on the introduction of process innovations for administrative processes in context of digitization projects

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Abstract

Industry 4.0 and the digital transformation of economy and society are currently dominant topics. Process innovations aim to optimise existing processes in the company. Administrative process innovations in particular, such as robotic process automation, represent radical organisational change. Intrapreneurship is an opportunity to promote innovations. My dissertation therefore considers the following research question: How does intrapreneurship influence the introduction of administrative process innovations in the context of digitisation projects? New insights are expected for executives and experts regarding the design of organisational structures to promote intrapreneurship.

Keywords: intrapreneurship, administrative process innovation, project management

Derivation of the research question

Industry 4.0 and the digital transformation of economy and society are currently dominant topics. Both concepts lead to fundamental changes. Under these framework conditions, process innovations, such as the digitalisation of production and the digital transformation of controlling (e.g. through the introduction of SAP S4/Hana), can enable promising solutions in international competition for industry in Germany (Gassmann/Schweitzer, 2018; Malanowski/Brandt, 2014). Administrative process innovations in particular, such as the introduction of shared service centres or robotic process automation, represent radical organisational change that can generate considerable savings potential (Svatopluk et al., 2018; Dietrich et al., 2014; Beck et al., 2008). Furthermore, competitiveness requires continuous process innovation. Process innovations pursue the goal of optimising existing processes in the company, for example to be able to produce a product more cost-effectively or with higher quality by using new raw materials. Formally, this innovation represents at least a further development of the original process and contributes to increasing entrepreneurial success from the earnings perspective. Companies must enable organisational structures that promote the introduction of process innovations (Grübner, 2007; Eversheim, 2003; Wettengl, 1999). In the following, only projects that pursue the goal of introducing process innovations are considered (Gerpott, 2005; Antoncic/Hisrich, 2001).

Intrapreneurship is often attributed the role of innovation driver within a company (Heim, 2015; Völker, et al., 2011; Haid, 2004). This term is used to describe the entrepreneurial spirit of employees in established companies or existing organisations (Hauschildt/Salomo, 2011; Hisrich, 1986). Intrapreneurship is a people-oriented

approach in which employees are seen as a decisive factor for entrepreneurial behaviour within a given organisation (Schießl, 2015; Becker, 2008; Pinchot, 1985). This means that an employee in an established organisational environment is motivated on his own initiative and perseveres despite internal resistance to implement innovative ideas within the organisation. It can be assumed that at least 16 % of the members of an organisation are intrapreneurs. According to a study by Engelen and Weinekötter, there are four different groups of employees within a company: blind activists with high entrepreneurial activity and low entrepreneurial potential, stabilisers with low activity and low potential, passive intrapreneurs with low activity but high potential, and active intrapreneurs with both high activity and high potential. Both active and passive intrapreneurs are relevant for this study (Engelen/Weinekötter, 2015). Employees act as promoters in the introduction of innovations. Promoters are people who actively promote an innovation process (Witte, 1973).

Implementation in the form of project management links the social (human) with the technical subsystem on the one hand, and the organisational structures on the other. The future management of process innovations must consider the increased requirements during the implementation; time, budget, and quality requirements are essential here (Lischka, 2011). It is still unclear what influence intrapreneurs have on the introduction of process innovations.

The following question is derived from the problem:
How does intrapreneurship influence the introduction of process innovations (with a focus on administrative processes)? To answer this question, the following sub-questions (Figure 1) must be addressed:

1. What are the characteristics of process innovations with a focus on administrative processes in the context of digitisation projects?
2. What characteristics and behaviours do intrapreneurs exhibit when introducing administrative process innovations?
3. Which essential factors (people, technology, and organisation) influence the introduction of process innovations?
4. What implications for research and practice can be derived from this?

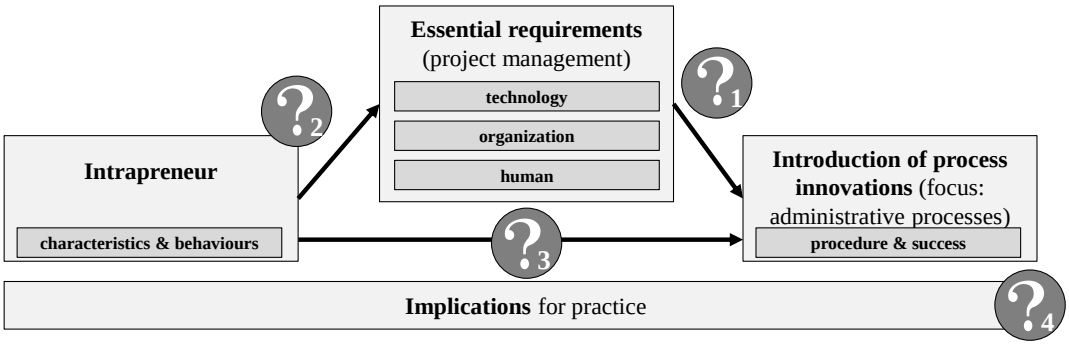

Figure 1: Context of the research question and sub-questions

The first sub-question deals with the properties and characteristics of process innovations. These are to be operationalised with regard to the different properties and characteristics.

The second sub-question serves to investigate the characteristics and behaviours of intrapreneurs in the introduction of process innovation, which also needs to be operationalised.

The third sub-question focuses on the interrelationship (moderator, mediator) between intrapreneurs and the essential factors (technology, organisation, and personnel) for the introduction of process innovations.

The fourth sub-question concerns recommendations for action for research and practice. Implications for corporate management are to be derived with regard to the identified influencing factors for increasing competitiveness.

The aim of this research project is to prove that intrapreneurship influences the introduction of process innovations.

Proof of the scientific relevance of the research question

The research question focuses on the influence of intrapreneurship on the introduction of process innovations. The following presents the current state of research on intrapreneurship and process innovations. Subsequently, the research question is justified based on the research gap identified in the literature.

Classification of intrapreneurship

To date, research in the field of intrapreneurship has focused on the framework conditions for the occurrence of intrapreneurship in companies. The characteristics, influencing factors, and prerequisites for intrapreneurship in the company have been identified. At the organisational level, intrapreneurship is often subsumed under corporate entrepreneurship (Lumpkin et al., 2009; Green et al., 2008). Intrapreneurship can be classified using a comparative classification scheme. For this purpose, a distinction is made between the employment relationship and the behaviour of the individual on the basis of two characteristics (Wennekers, 2006). First, the employment relationship may be either self-employed or salaried. Second, behaviour is divided into three dimensions: entrepreneurial behaviour, which is dedicated to the new economic focus (for example, the new business models); leading behaviour, which pursues the coordination and organisation of existing resource combinations; and non-leading behaviour. The intrapreneur shows the same behaviour as the entrepreneur; the difference is in the employment status (Wennekers/Thurik, 1999).

Classification of process innovation

The concept of innovation is not defined uniformly in the literature, but is always understood as the creation of something new (Stummer/Günther, 2013). In most cases, process innovations are described as redesigning or improving the performance of a company. Their aim is to increase productivity and efficiency, which is usually accompanied by quality improvements and cost reductions (Perl, 2007). One can refer to different business processes: material processes (for example, manufacturing a product) and informational processes (for example, exchanging and processing information). The present work exclusively considers administrative processes, in the sense of informational processes (Vahs/Brem, 2015). For this purpose, it is of fundamental importance to design the organisation in companies, which differs in terms of process and organisational structure. The process organisation structures the activities in the company, while the organisational structure bundles competencies into an organisational chart. The administrative processes (including administrative activities) are reflected in the cross-sectional functions of the organisational structure (Spath et al., 2017). Examples include the introduction of shared service centres and the integration of robotic process automation in accounting and controlling. Although process innovations have a considerable influence on the success of a company, both research and practice focus on product innovations.

Scientific approaches to the influence of intrapreneurship on process innovation

In general, the development of an innovation takes place in different phases (see Figure 2). This PhD project focuses on the realisation and usage phase. In this phase, the innovation is introduced by a project team, and adapted in the three areas of organisation, technology, and human resources. The realisation and utilisation phase extends from adaptation to actual implementation and the subsequent test run. From a formal point of view, the test run continues into the usage phase. This is indispensable for the measurability of the success of an introduction. Adaptation in particular usually takes place through the interaction of several people within a company.

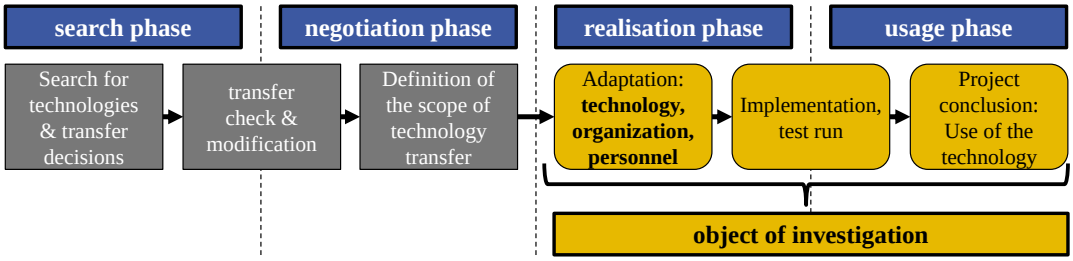

Figure 2: Phases of the innovation project (Corsten 1982)

As a rule, innovations are implemented in the company with the help of project management, which is the cross-sectional discipline of general business administration that ensures the professional handling and achievement of objectives in projects (Krings, 2012). This consists of different employees with different roles. Witte's promoter model distinguishes three basic types: the professional promoter, who brings competence and creativity into the project as resources; the process promoter, who brings in social connections; and the power promoter, who provides financial resources. Promoters are people who actively and innovatively promote an innovation process. When introducing process innovations, project management has the greatest influence on personal characteristics, leadership, and tactics. It is also possible to institutionalise cooperation between promoters within the framework of project management. The promoter model considers the different roles in the implementation of an innovation. During innovation, there are usually factual and personnel barriers that disrupt the process flow. Different promoters counteract these different barriers (Hauschildt/Salomo, 2011).

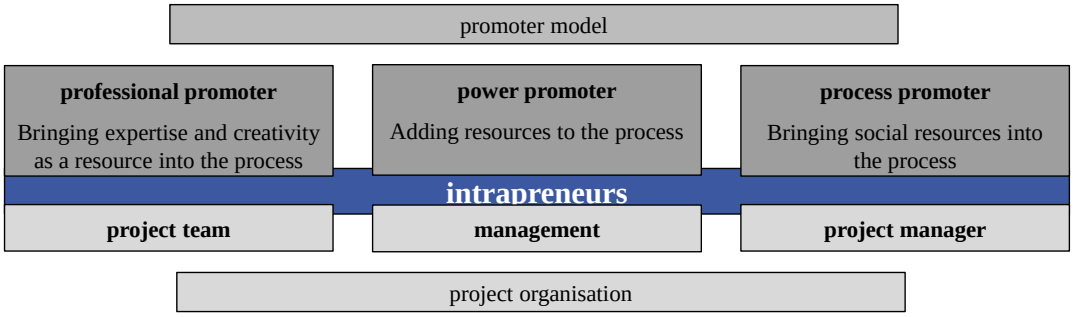

Figure 3: Intrapreneurship as an interface for innovation projects

So far, research has not investigated how intrapreneurship affects the introduction of process innovations. In this context, the question is how intrapreneurs can act as

promoters for the introduction of process innovations due to their intrinsic motivation to act entrepreneurially (see Figure 3).

Measurability of the influence of intrapreneurship on the introduction of process innovations

The interaction between people, technology, and organisation within a company (socio-technical system) is a complex entity (Preisendörfer, 2016). It can be mapped using system theory as a complexity-reducing modelling approach. A model is used to simplify the representation of a real system (see Figure 4) with the aim of identifying cause-effect relationships.

Projects can be monitored and controlled by means of project management and controlling. The methods used for this purpose 'serve the purpose of comparing the planned with reality in order to then derive project changes from it if necessary'. In the classical literature, the triangle of time, cost, and result or quality is used to measure the success of a project. In accordance with DIN EN ISO 9000:2015-11, the term 'quality' refers to the 'degree to which a set of inherent characteristics meets requirements'. The task is to achieve the project goal by a fixed date and with a certain amount of resources made available at the beginning of the project. Project controlling focuses on monitoring schedules, reviewing and planning the resources to be deployed, and controlling the degree of completion. Performance measurement is based on operational and strategic aspects (multidimensional criteria) (Bösch, 2007). The qualitative recording of introduction processes in terms of duration, dynamics, complexity, and uncertainty is problematic. The introduction of process innovations requires the control and motivation of the project team and proof of performance (Pleschak/Sabisch, 1996). The failure of an introduction is often the result of a misdirection of resources.

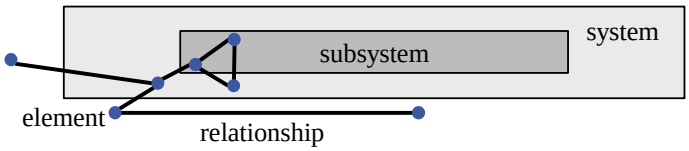

Figure 4: System theory (Haberfellner, 2015)

The research question encompasses three research fields: intrapreneurship (element for increasing company profits), process innovation (securing economic performance), and project controlling (measurability of project output). Gawke et al. and Newman et al. postulate that intrapreneurship has an effect on corporate performance and on the organisation. They provide an impetus for the research question chosen here, since to date no study has investigated project performance in the introduction of process innovations in the context of intrapreneurship research (Newman et al., 2018; Gawke et al., 2017).

Proof of the practical relevance of the research question

Innovation management plays an important role in companies. The focus is not on the actual implementation of innovations, but on their development in general. However, less importance is attached to process innovations, although they are a partial goal to achieve cost and quality leadership (Haneda/Ito, 2018). Moreover, studies show that process innovations increase competitiveness. According to a ZEW study, process innovations increase the efficiency of companies by 3.2%. This success is measured by the reduction of the average costs per unit or per process. The ZEW study further indicates that approximately 28% of companies in the manufacturing sector initiate process innovations every year. From a business perspective, companies should promote intrapreneurs by

creating structures that make intrapreneurship within the company possible in the first place (Rammer et al., 2017).

In the present feasibility study, interviews were conducted with managing directors and executives from the mechanical and plant engineering industry and the manufacturing sector. The aim of these interviews was to discuss the practical relevance of the research question. The surveyed companies expect high potential in the identification of intrapreneurs for the introduction of new processes in management accounting. However, the influence varies with the degree of the process's innovation. Companies are aware of the potential of intrapreneurship, but hesitate to promote this approach.

Proof of the degree of innovation of the research question

Although many studies have already dealt with the topic of intrapreneurship, its influence on the introduction of process innovations has not yet been explicitly addressed. There is a lack of research measuring the potential of intrapreneurs in the effective and efficient introduction of process innovations. The present study is the first to combine the introduction of process innovations with the topic of intrapreneurship. To measure project success, this study proposes a project scorecard adapted to the specifics of intrapreneurship in addition to general quantitative key figures and qualitative statements. The degree of innovation of this dissertation project can be justified from both a scientific and a practical perspective (see Table 1).

Table 1: Scientific and a practical perspective

Scientific perspective	**Practical perspective**
The study develops a theory-based model to determine the influence of intrapreneurship on the introduction of process innovations.	The study contributes to the discussion on the topic of intrapreneurship by determining whether there is a positive effect on process innovations.
The research supplements the existing intrapreneurship literature with regard to the previously unexamined influence of intrapreneurship on success in the introduction of process innovation by analysing situation-specific effects.	It derives design recommendations for management, in particular regarding action for the design of technology, organisation, and personnel management for the introduction of process innovations by means of intrapreneurs.
It extends the existing literature on process innovations with a focus on the implementation process for administrative processes.	
It expands the existing literature on intrapreneurship. This involves operationalising the influence of intrapreneurship on the introduction of process innovations.	

Research design to answer the research question

This project can be divided into three dimensions with different objectives. To answer the research question, a suitable research design is required that is empirical and application oriented. Hence, the research design consists of descriptive, model designing, and model sampling phases (Horváth, 2007).

Qualitative phase

First, the relationships under investigation (Figure 1) are operationalised (Schnell et al., 2014). To this end, the research field is defined: the theory of social networks (network theory) provides the framework for the present dissertation (Schwaiger/Meyer, 2011). Social networks are associations of concrete and abstract actors connected by relationships. At the heart of this framework is the explanation of the impact of individual action on the network. The theory has been used since the 1930s in the analysis of social networks and in organisational research. The actor network theory is an extension of the network theory (Latour, 2007). It can be used to explain the relationships between the members of the project team and their influence as a network on the project outcome. The conceptual frame of reference for the influence of intrapreneurship on the introduction of process innovations within project management is validated by a literature analysis and expert discussions. The theory-based explanatory model is based on these findings. Therefore, an extensive literature analysis is used to derive hypotheses that explain the relationship between the properties of an intrapreneur and his or her influence on the introduction of process innovations as a function of the moderators in the SEM. After deriving the hypotheses and developing the explanatory model, the research question is analysed by means of a questionnaire study (see quantitative phase).

Quantitative phase

The quantitative phase includes data collection and evaluation. First, data will be collected by means of a questionnaire and project controlling. The questionnaire will be answered by all members of the project team, including x-Intrapreneurs. The project success will be determined by data from project controlling and by an interview (using the critical incident technique) with the project manager. Since project teams consisting of different employees are critical when innovations are introduced, it is necessary to measure the relevant facts in the company at employee level (Homburg et al., 2012).

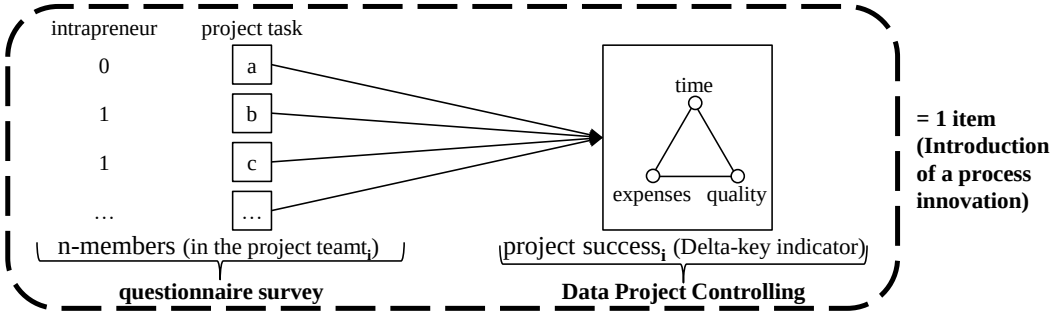

Figure 5: Data collection

Jong et al. (2015) uses a multi-item measuring instrument for the evaluation of individual entrepreneurial behaviour, which allows firm statements to be made about this behaviour. Three questions are asked on each of the three dimensions of innovation, proactivity, and risk-taking, and employees must rate these on a 7-point Likert scale. The average across all dimensions provides information about the degree of individual corporate entrepreneurship (=intrapreneur) (Jong et al., 2015). The project success is determined on the basis of the relative deviations between planned and actual values of the project planning. The 'iron triangle', which consists of budget, time, and quality key figures, serves as a key performance indicator (see Figure 5).

The data is then evaluated. In this study, a structural equation model (SEM) is expected to be used for this purpose (see Figure 6). This can explain real, complex facts (explanatory models), but the user must have a clear idea of the context of those facts.

The model serves to illustrate the relationships between intrapreneurship and the introduction of process innovations. Furthermore, the model explains the influence of the moderator variables. Subsequently, statements about correlations between different variables are possible, which can be confirmed by empirical testing (Weiber/Mühlhaus, 2014).

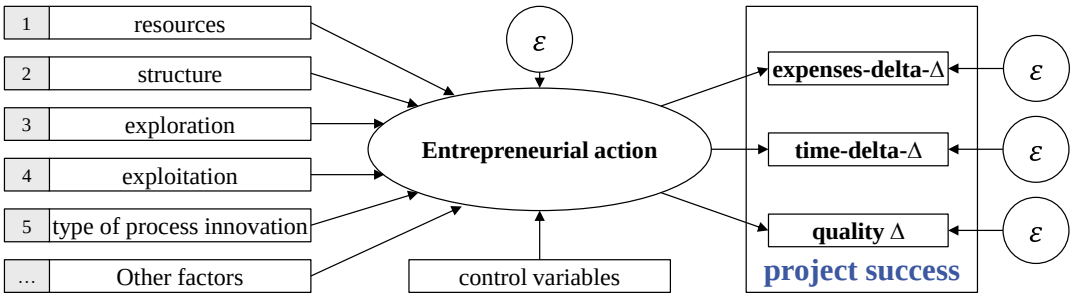

Figure 6: Provisional structural equation model

Interpretation phase

After evaluating the preceding steps, the collected results are discussed in practice and subsequently converted into recommendations for action. In practice, these should help to recognise the phenomenon of intrapreneurship in peripheral areas of innovation management and to exploit its positive effects. These recommendations are again validated in practice based on 10 interviews with representatives of three large, three small, and three medium-sized enterprises as well as one representative from the scientific community. As a result, a catalogue of recommendations is created for the design of the technology as well as for the organisation and personnel management for the introduction of process innovations by intrapreneurs.

Feasibility of the research design

As described in the previous section, the research design requires an empirical examination of hypotheses to answer the research question. For this purpose, primary data are collected by means of a questionnaire study and used as an empirical basis. To ensure the quality of research, care is taken to meet the requirements of objectivity, reliability, validity, and generalisability of the results (see Figure 7).

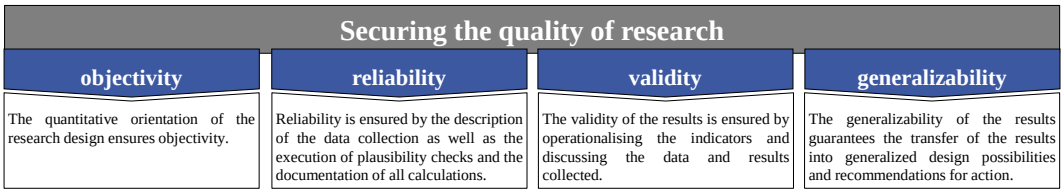

Figure 7: Ensuring the quality of research (Himme, 2009)

Conclusion

As discussed in this paper, it is relevant for companies to know whether an intrapreneur in the project team has a positive effect on the project outcome. This analysis aims at identifying practical implications for project management in order to optimize the composition of projects with regard to the characteristics of intrapreneurship.

Two major conclusions can be drawn from this paper. First, intrapreneurs influence project success in some way. The intrinsic motivation is likely to ensure that the project

will probably fulfil the KPI. All team members will be examined for their intrapreneur score by answering a questionnaire. Idea: A high score leads to a lower exceeding of the △-KPI. Second, all intrapreneurs must be identified role-specifically, i.e. the role in the project must also be clearly measured by using questionnaires. This information will later be relevant for project management, as it can be used, for example, to derive meaningful incentive systems for employee management.

As an outlook, the next steps of this research are described briefly. Based on the findings of this paper, the theoretical framework is used to derive research hypotheses. Next, data is gathered using a questionnaire design. The hypotheses are evaluated using a SEM. Finally, interviews are conducted and practical implications are derived.

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Digital process innovation and financial performance: An event study

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Abstract

Digital process innovation—defined as the use of digital technology for process innovation—has recently become a new orientation of manufacturing companies to solve operational problems; however, the actual impact of digital process innovation is still unclear. In this research, we study the actual effect of digital process innovation on organizational performance. We further examine whether the impact of digital process innovation is strengthened if manufacturing firms increase their absorptive capability and their slack resource. This research provides valuable insights into how to effectively implement the strategy of digital process innovation.

Keywords: Digital process innovation, Absorptive capacity, Slack resource

Introduction

Operational problems, such as high-volume inventory, continuously increasing operational cost, operational inefficiency, are usually the concerns of the conventional manufacturing process (e.g., Boston Consulting Group, 2014; Kearney, 2016). Recently, digital process innovation—defined as the use of digital technology for process innovation—has become a new orientation of manufacturing companies to solve such kind of operational problems and has demonstrated its effectiveness. Taking GE Company (d'Aveni, 2015) as an example, it adopted digital technology in the production mode transformation of an engine from the assembly of twenty separate cast parts into direct production of one piece. This saves 75% of the operational cost. Nevertheless, there are some other concerns towards the effect of digitized operational processes. For instance, more energy is required in three-dimensional printing than in the traditional injection molding (Chen et al., 2015). Thus, the actual impact of digital process innovation is still unclear.

In this research, we study the actual impact of digital process innovation on organizational performance. We further investigate operational factors that may exert significant bearing on digital process innovation to enhance a firm's performance. Specifically, we examine that the impact of digital process innovation is strengthened if manufacturing firms increase their knowledge absorptive capability and their slack resource.

Theoretical Background and Hypothesis Development

Digital process innovation enables firms to promptly and accurately identify customer requirements and preferences and to offer customized even new products that, in turn, better meet customer individual requirements (Armenakis and Harris, 2009; Ye et al., 2007; Judge et al., 2009). This may result in increasing firms' performance. Hence, we hypothesize that the adoption of digital process innovation can improve a firm's performance, as shown below.

Hypothesis 1: Digital process innovation enhances organizational performance.

Operational absorptive capacity is referred to the capability of an organization's operational units to obtain, assimilate and exploit knowledge from external source (Patel et al., 2012). In a company, when its operating unit has absorptive capacity, the unit is more likely to have the ability and flexibility to obtain, assimilate and exploit the information provided by external parties and required for the implementation of digital process innovation, leading to higher organizational performance. Therefore, we hypothesize:

Hypothesis 2: Absorptive capacity of a firm positively moderates the relationship between digital process innovation and organizational performance.

Slack resource is defined as the buffer resource, in excess of the minimum necessary resources for a firm's daily operation, for coping with environmental uncertainty (Nohria and Gulati 1996). Companies with slack resource are likely to have buffer resource as safeguard to present the risk imposed while implementing digital process innovation, leading to enhanced organizational performance. Thus, we have the following hypothesis.

Hypothesis 3: Slack resource of a firm positively moderates the relationship between digital process innovation and organizational performance.

Methodology

We conducted a longitudinal event study to test the effect of digital process innovation on organizational performance. We focus on manufacturing companies that are publicly listed firms in the Mainland China. Driven by the recent China's policies such as Made in China 2025 and internet plus manufacturing action (China Daily, 2016), many manufacturing companies have gradually adopted and even have fully implemented the strategy of digital process innovation. Hence, manufacturing companies in the Mainland China are the most proper setting to conduct this study.

We consider digital process innovation as a firm's official launch of digital innovation initiative for its manufacturing process. Accordingly, we collected the

announcements about the adoption of digital process innovation from Factiva and Wisenews using keywords, for example digital platform, digital channel, digital manufacturing, intelligent manufacturing, additive manufacturing, and three-dimensional or 3D printing. Return on asset is regarded as the performance outcome of the firm. R&D intensity as a proxy for absorptive capability while slack resource is based on inventory level.

Finally, we obtained the relevant announcements from a sample of 168 firms. For these sampled firms, we collected data on return on asset, absorptive capacity and slack resource from the China Stock Market and Accounting Research databases.

Data Analysis and Results

We employed the approach of longitudinal event study to test the causal relationship between digital process innovation strategy and organizational performance. The results show that digital process innovation has a long-term effect on the performance of manufacturing companies. Subsequently, we conducted the ordinary least squares regression to examine the potential moderating effects of absorptive capacity and slack resource on the association among digital process innovation strategy and firm performance. The findings demonstrate that absorptive capacity and slack resource strengthen the effect of digital process innovation on firm's performance.

Discussion and Conclusion

This research reveals the real impact of digital process innovation on organizational performance in the manufacturing domain and explores the factors to enhance such impact. Specifically, it fills up the gap how to effectively implement the strategy of digital process innovation. This research also provides useful guideline for effective implementation of digital process innovation by considering a firm's internal absorptive capacity and slack resource.

Acknowledgements

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Developing a Modular Service Architecture for Energy Flexibility Aggregators

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Abstract

Multi-sided platforms (MSPs) have to evolve over time to remain competitive and to survive on the long term. The evolvability of MSPs can be supported by a modular service architecture. The purpose of this paper is to study how MSPs evolve over time and how service modularity principles can be applied to support platform evolvability. To gain these insights, the study adopts an exploratory case-study methodology. Results highlight different forms of platform evolution and their effects on the main information processing capabilities of MSPs. Subsequently, modularity principles are proposed to support these forms of evolution.

Keywords: Multi-sided platform, Platform evolution, Modularity, Architecture

Introduction

The importance of multi-sided platform (MSP) companies has grown significantly the last 10-15 years (Parker et al., 2016). Well-known examples are Uber, Airbnb and eBay, but also credit card firms such as Visa and MasterCard can be considered as MSP companies. The services offered by these companies, denoted as MSP services, are matchmaking services that create value by linking distinct customer groups, where associates of at least one group prefer to enter into transactions with the associates of the other group (Hagiu and Wright, 2015). Essential for MSP services is the underlying *service platform*, which is the system with specific information processing capabilities operated by the MSP company that link customers and enable the transactions to be made among them.

Although MSPs services are often considered in the literature as rather static, it is increasingly recognized that MSP services need to evolve (Staykova and Damsgaard, 2017). In their early days, MSP companies generally start with establishing a primary core exchange platform between two customer groups. Then, over time, successful MSP companies tend to evolve and scale by layering new interactions on top of the initial core exchange (Parker et al., 2016). MSPs companies primarily evolve over time to safeguard their market survival when

facing internal and/or external challenges (Tiwana 2014). Adding new features, functionality and interactions to the service platform can help to increase its usefulness, attract more users and remain competitive and value adding in the long term. Hence, being able to evolve over time is an important ability for MSP companies to survive in the long term (Parker et al., 2016; Staykova and Damsgaard, 2017).

The evolvability of MSP services is impacted by the underlying service architecture, where an important design decision is whether to develop an integral or modular service architecture. An integral architecture has advantages especially when the service needs to be developed quickly and to serve a single purpose, often in the early days of a platform. However, in the long run, the literature argues that successful MSP services require a more modular architecture, especially stemming from the inherent need to evolve over time (Parker et al., 2016; Staykova and Damsgaard, 2017). Adopting a more modular architecture allows to easily adding new service components with new functionality (Baldwin and Woodard, 2009; Parker et al., 2016).

Although MSP services gained significant attention in the literature and the potential of a modular architecture is recognized, studies focussing on the implementations and the underlying service architectures are scarce. As Brax et al. (2017) argue, research on modular service architectures is scant in the context of MSP services and attention is needed due to the specific characteristics of this service type. In addition to this, although it is recognized that MSP services need to evolve, MSP evolution remains an ill-defined and rather abstract concept in the literature (Staykova and Damsgaard, 2017). This makes it unclear how MSP services evolve exactly over time. Understanding how MSP services evolve over time is important as this can help to design appropriate modular service architectures that support their evolvability.

Based on these gaps in knowledge, this paper aims to study how MSP services evolve over time and how service modularity principles can be applied to support platform evolvability. This objective is formulated in the following research questions: *How can service modularity principles be applied in the design of MSP services to support MSP evolvability?* To answer this question, the following guiding sub-questions will be answered: (1) What are the main information processing capabilities that constitute the service platform of MSP services? (2) What forms of evolution can be distinguished in MSP services that impact the service platform? (3) What modularity principles be applied in the design of the service platform of MSP services?

By answering these questions, this paper adds to the literature on MSP service evolution and architecture. Specifically, it makes the following contributions. First, the paper contributes by discussing various forms of MSP service evolution and their impact on the underlying service platform that creates the core exchange. Second, the paper contributes by proposing a modular functional framework of the main information processing capabilities that create the core exchange of MSPs to support MSP evolvability.

Theoretical background

Multi sided platform services

MSP services create value by linking two or more distinct customer groups, where the members of one customer group have a specific interest concerning the members of the other group (Stabell and Fjeldstad, 1998, Parker et al., 2016). Specifically, MSPs exist because they support or enable exchanges to be made between the customers of both sides. These exchanges are often denoted as the core exchanges of the platform (Parker et al., 2016) and would probably not occur without the MSP service. Hence, MSPs create value for both customer sides by minimizing transaction costs (Stabell and Fjeldstad, 1998). The value of MSPs for customers of one specific side often depends on the number of customers on the other side with whom

they can interact, which is referred to as 'positive network externalities' (Hagiu and Wright, 2015). Hence, it is important for MSPs to continuously attract new customers on both sides, which can be realized by adding new features (Parker et al., 2016).

Key platform elements to create core exchanges
The goal of an MSP company is to repeat and optimize the value creating core exchange enabled by the service platform. To establish/create the core exchange, MSPs generally encompasses the following basic key elements (Parker et al., 2016), which are visualized in Figure 1.

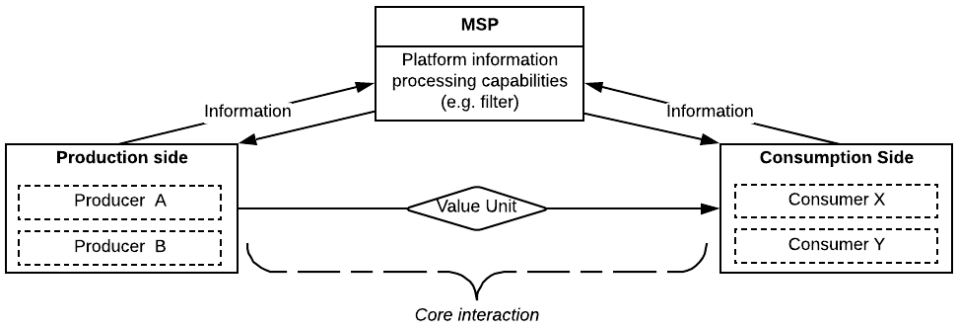

Figure 1 – Key platform elements creating the core exchange

The Value unit - The value unit is the key product or service where the core exchange is all about. Based on supplementary information interactions, the platform participants may decide to exchange the value unit. This can occur either through or outside the platform. As an example, in the case of Uber, the value unit is a taxi ride provided by a driver who is matched with the customer by the platform.

Platform participants - Core exchanges are always between participants of both sides of the platform, often denoted as the producers and the consumers on the platform. The participants can have one-to-one exchanges, but also multiple-to-one, one-to-multiple or multiple-to-multiple. In the case of Uber, the taxi drivers are the producers on the platform and the customers are the consumers on the platform.

Supplementary interactions - Every core exchange enabled by an MSP generally involves two types of supporting interactions. *(1) Information;* every core exchange starts with information interactions between the participants (both sides) and the platform, which enables the participants involved to decide whether, and how, to engage in a further exchange. Information exchanges always takes place through the platform and is therefore one of the fundamental characteristics of a platform business. Uber, as an example, continuously gathers and monitors information from their drivers (e.g. location and availability) and consumers (e.g. locations and destinations). *(2) Currency;* when goods or services are exchanged between platform participants, payment often needs to take place, which can also go through the platform or outside the platform.

The platform filter – The platform filter, often a computer algorithm, is used by the platform to determine the best exchanges of *Value units* between the involved platform participants. The platform filter has a significant impact on the 'quality' of the exchanges to be made and therewith the value created by the platform for the participants. Input for the algorithms, amongst others, can be the supplementary collected information from participants of both sides and often involves advanced data analytics. In the case of Uber, the platform filter is an algorithm that matches a customer request with a driver.

MSP evolution and evolvability

MSP evolution is a rather ill-defined concept in the literature and is studied under different labels, such as platform development (Ruutu et al. 2017), platform expansion (Hagiu, 2006) or the shift of platform boundaries (Gawer, 2015). Besides the use of different labels, there is also difference on what is seen as platform evolution. While some papers see platform evolution more as the growing size of the platform (e.g. in terms of the number of participants affiliated) (Evans and Schmalensee, 2016), other studies see platform evolution more as a change in functionalities offered, increasing an MSPs value proposition to existing and upcoming participants (Edelman 2015). Within the latter branch of literature, various functional changes are discussed. Some authors argue that just new features and functionalities can be added (Hagiu, 2006; Staykova and Damsgaard, 2017), although it is unclear/unspecified how this relates to the core exchanges provided by the MSP. Others, such as Parker et al. (2016) argue that the value unit exchanged between platform participants can change or that variants can be added. In addition, it is argued that new categories of platform participants, either producers or consumers, can join the platform (Parker et al., 2016). Some papers discuss mergers and acquisitions (also named platform envelopment) as a way to evolve or the creation of additional stand-alone platforms, such as UberEats (Staykova and Damsgaard 2017).

According to Tiwana (2014), platform evolvability means that MSPs have the capacity or ability to do things in the future that they were not necessarily originally designed to do. To enable this, the architecture, and especially the interfaces, of a platform should be stable over time (Baldwin and Woodard, 2009). This property allows an MSP to be extensible in the near term and exhibit emergent behaviour in the longer term (Parker et al., 2016; Tiwana, 2014).

Modular service system architecture

All types of human-made systems, including services, have architectures (Baldwin and Woodard, 2009; Eppinger and Browning, 2012). The concept of 'service architecture' is defined by Simon (1962) as "*the way/structure in which service system functionalities are decomposed into individual functional elements (e.g. activities and tasks) that together delivers the overall services provided by the system".* The creation of an architecture is the result of a design process and drives service attributes, functioning and overall system behaviour (Eppinger and Browning, 2012). As the service architecture has serious impact on service performance and value, both in the short and long term, a well-designed architecture can support the long-term viability of a service (Eppinger and Browning, 2012).

Integral vs modular architectures

Architectures can be characterized on a continuum as being more integral or modular. Where an integral architecture includes a complex (non one-to-one) mapping from functional elements to system components, a modular architecture follows a one-to-one mapping from functional elements to system components (Ulrich, 1995). Moreover, a modular architecture involves a decomposition logic that aims to divide the service system into delineated subsystems that each fulfil a specific function whereby the dependencies within these subsystems are relatively high and those between subsystems low (Baldwin and Clark, 2000; Salvador et al., 2002). Therewith, a system with a modular architecture is composed of modules that are designed independently but still function as an integrated whole (Staykova and Damsgaard, 2015).

Interfaces

A critical factor that makes modular architectures so effective is that when systems are cleanly partitioned into subsystems and components, they can work as a whole by connecting and communicating through well-defined interfaces. Interfaces, in general, prescribe how two or more components in a modular system mutually interact (Salvador, 2007). More specifically,

interfaces are the set of rules and guidelines governing the flexible arrangement, interconnection, and interdependence of service system components (De Blok et al., 2014, p. 30). Interfaces manage the connections and inter-dependencies across various types of components that comprise the system and are typically standardized. Therewith, interfaces enable the substitution and exchange of these components and allow that such components can be designed independently (Parker et al., 2016). As argued by Tiwana (2014), essential in the evolvability of MSP services is stable yet versatile interfaces that ensure autonomy between the different service platform modules. This makes the architecture rich in "real options", and permit its mutation into derivative service platforms.

Decomposition logic

A crucial question in system modularization is how to identify the individual parts of a system or service offering and how to determine which of these parts – alone or together – can be designed as modules (Salvador et al., 2002). This question relates to the *decomposition logic*, which is the explication of the design choices involved in decomposing a service offering/system into modules (van der Laan et al., 2016).

Methodology

This study adopts an exploratory case-study research methodology (Voss et al., 2002), which is deemed the most suitable as the theory development related to MSP evolution and modular architecture is in its early stages. In particular, the case studies methodology can support identifying key variables and their relationships (Yin, 2009) and allows one to explore unknown phenomena in their natural setting, thereby generating meaningful understanding (Voss et al., 2002). Further, this methodology is appropriate for studying emerging phenomenon in depth, such as MSP architecture and evolution.

Case selection and background

Although the research intents to cover multiple cases from different industries, this paper presents the results of a single case study. To scope the research, we focus on MSPs that provide on-demand matchmaking of the core exchange by the platform, when requested by a customer. That means, the platform participants provide the required input information, and the platform makes the actual match between platform producers and consumers to exchange the value unit (e.g. as in Uber). This is different from platforms where participants themselves make a match out of a list of candidates proposed by the platform (e.g. as in eBay or Airbnb). The unit of analysis is the set of information processing capabilities of the MSP that creates the core exchange.

The selected case for this study is an energy flexibility aggregator. Nowadays, due to the fast introduction of uncontrollable wind and solar energy, energy systems face serious challenges concerning the system balance of energy production and consumption. Energy flexibility aggregators, in general, aim to provide solutions to these problems by steering energy consumption of for example large amounts of household appliances, electrical vehicles (EVs) and industries on the request of Network operators and Energy retailers. In so doing, aggregators function as MSPs, filling an intermediary networking service between '*Flexibility suppliers'* and '*Flexibility consumers'*.

Data collection and analysis

The main form of data collection was through semi-structured interviews with case managers. A semi-structured interview protocol was developed to guide the data collection. In total, 6 semi-structured interviews were held. Each interview lasted between 35 and 90 minutes. Other sources of evidence were also gathered (Yin, 2009) for triangulation purposes. These include

company presentations, (informal) group discussions, telephone calls and company documents (e.g. PowerPoints, flyers, service contracts, websites, service applications, news items and commercials).

The data were coded and subsequently analysed following an inductive approach. The codes that emerged from the data were grouped into codes related to platform functions, architecture and evolution. All the interviews were coded by the main researcher.

Results

This section describes the results of the study. First the main information processing capabilities of MSPs are described and following the forms of evolutions found in MSPs.

MSP main information processing capabilities

The study's results show that MSPs encompass the following four essential Information Processing Capabilities (IPCs) to realize/establish a core exchange between platform producers and consumers.

1. Inbound information management - This IPC describes the activities in which all kinds of information are gathered from both the Production side and Consumption side participants. This information is necessary input for making the match between Production side and Consumption side participants to create the core exchange. Besides gathering information from the platform participants, the platforms generally also gather various kinds of data from other external sources that can be used by the platform to support the matchmaking. All the data gathered is generally transformed into useful input for the *Data analytics* and *Platform matchmaking* functions, described below.

Table 1: Information gathered in the Energy flexibility case

Production side info	**Consumption side info**	**Info External sources**
Technical specs of flex device (EVs/HPs), location in the grid, customer preferences concerning charge EV/ using HP	Access to platform, nomination of bid, activation set points (required kW, kW/h and durations), de-activation, invoice	Weather forecasts, energy market prices

2. Data analytics - The *Data analytics* main function is processing and analysing all gathered data and transforming it into relevant information and insights that can support matchmaking and establish the best possible core exchanges. For example, in the energy flexibility case, various kinds of forecasts are made related to both the production and consumption side of the platform. Concerning the production side, for example the expected heat demand for the heat pumps, the expected upcoming wind profiles, and the expected number of connected EVs per location is forecasted. Ultimately, this is input for predicting the expected available flexibility at the production side of the platform. Concerning the consumption side, forecasts are made about the expected energy market prices and the expected flexibility demand. Output of all these forecasts are input for the matchmaking function.

3. Platform matchmaking - Platform matchmaking is about making the best possible match, in terms of the *Value unit(s)* exchanged, between platform producers and consumers. Matchmaking is based on specific information from both *Production* and *Consumption side participants* and the information processed by the *Data analytics* capability.

In the case of energy flexibility, two types of matchmaking take place, i.e. *Tactical matchmaking* and *Operational matchmaking*. In 'tactical matchmaking', the aggregator offers certain aggregated amounts of flexibility (what he is able to provide in a certain time period) as bids to the flexibility requesting party. These bids are based on the forecasts on the expected

upcoming available flexibility. Then, when bids are accepted, the flexibility requesting party can send a flexibility request to the aggregator when a certain amount of flexibility is needed. At that moment, *Operational matchmaking* takes place, in which it is determined what flex devices of the production side will be used to offer the flexibility requested (e.g. the charging of which specific cars will be used to what specific extent). Not all cases use both *Tactical matchmaking* and *Operational matchmaking*. Most cases do not offer specific bids upfront, and only use *Operational matchmaking* when the service is requested.

4. Outbound information management - *Outbound information management* involves all outgoing information from the platform, such as communication of matchmaking information to the Production side and *Consumption side participants* of the platform, but also communication of information related to the matchmaking to external stakeholders. For example, requests of money transfers from banks.

In the energy flexibility case, examples of outgoing information to the production side are the actual control signals to all scheduled flexible energy devices to steer energy production or consumption, based on the outcome of the platform matchmaking function.

Forms of MSP evolution

The results show four different ways in which platforms evolve over time (Figure 2). In the analysis, the focus was on the forms of platform evolution that have an impact on the functions of the platform. Geographical spread and growth, as an example, is therefore not considered as a form of platform evolution and therefore not taken into account.

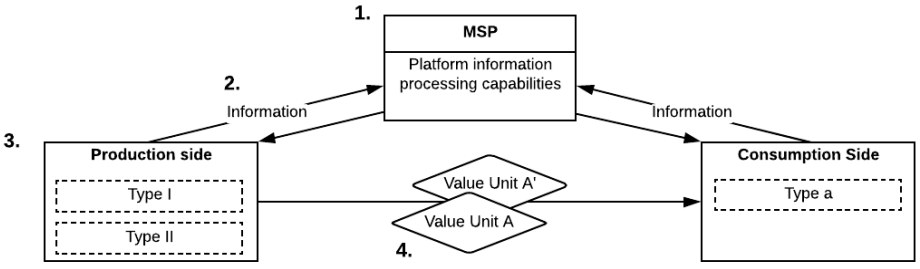

Figure 2: Forms of platform evolution and their impact

1. Technical evolution: Improved internal functioning - This form of evolution effects how the *core exchange* is created/realized by the platform. However, it has no direct functional consequences for the platform customers as it does not impact or change the *core exchange* or the *value unit* exchanged. Specific service processes, tasks, components or interfaces are updated and replaced for improved versions, but without changing functionality.

Some examples from the Energy flexibility case are the replacement of a specific matchmaking algorithm by an improved version or adding an improved forecasting sub-module in the Data analytics module.

2. Additional service features for customers on top of the core exchange - This form of evolution describes the addition of new features and functionality offered by the platform for the customers, however, without impacting or changing the *core exchange* or the *value unit* exchanged.

One example from the Energy flexibility case is the creation of an information dashboard for their flexibility suppliers (platform producers), on which all kinds of customer specific energy information is shown (e.g. info on energy productions/ consumption, provided flex, financial gains, etc.). As another example, the case also improved the manner in which EV drivers could set their charging preferences, using an app.

3. New type of participants added to the platform sides - This form of evolution involves adding new types of platform participants to the production and/or consumption sides of the platform. Therewith, it impacts the *core exchange* and the *value unit* exchanged by the MSP. Besides, this form of evolution has a significant impact on all the platforms internal information processing capabilities, as new information streams needs to be gathered and processed (i.e. incoming information, new forecasts/data analytics, changes in matchmaking algorithms and new outgoing information).

Concerning the productions side, the energy flexibility case started with EV drivers as their main producers, but over time also enabled wind turbines and households with HPs to provide flexibility. In addition, at the consumption side, the platform started supplying only to the TSO, but now also experiments with providing flexibility to the DSO (having other flexibility requirements).

4. Variance of the Value unit exchanged - This form of evolution is about enabling exchanging variances of the initial *Value unit* by the platform. Derived from the initial *Value unit*, variances that differ slightly are also exchanged between the similar platform participants. This form of evolution also has a significant impact on the platform's internal information processing capabilities, as new information streams needs to be gathered and processed (i.e. incoming information about the new value unit, changes in the matchmaking algorithms and new outgoing information about the new matches).

In the energy flexibility case, the flexibility aggregator initially only offered Frequency Restoration Reserve. However, it now also offers Frequency Containment Reserve, which is slightly different. Both are services based on flexibility, but with different time durations and technical requirements (in terms of kW, kW/h and kWh) to provide. In the end, this effects how electricity devices should be controlled at the production side of the platform.

Discussion & conclusions

Modular functional architecture of MSPs internal IPCs

This section discusses the main theoretical contribution by answering the main research question, which was formulated as follows: *How to design a modular functional architecture of MSPs that supports platform evolvability around the core exchange?*

Based on the results of this study (i.e. MSPs main IPCs and forms of evolution and their impact on the IPCs) we developed and proposed the following modular functional architecture with associated interfaces (Figure 3). The design is developed in such a way that it satisfies the 'Independence design axiom' proposed by Suh (1998). This axiom argues that all functional requirements of a design should be maintained independent of each other. More specifically, it is argued that when two or more functional requirements exist, the design solution must be such that every single functional requirement can be satisfied without disturbing another functional requirement. For this reason, all main IPCs, that needs to be present to enable the core exchange of the MSP, can be seen as independent capabilities. Moreover, both the *Inbound information management* and the *Outbound information management* IPCs are split in this design into three separate IPCs, as they all fulfil different functional requirements. Then, to support evolvability, all main IPCs can be supplemented with additional, rather independently operating modules. These modules have standardized interfaces to interact with the other IPCs of the MSP.

A clear data flow can be seen through the platforms IPCs, indicated by the arrows that also represent the interfaces. Information is gathered from multiple sides, processed internally, and then resulting in multiple outgoing information streams to the platform participants and external stakeholders. No clear logical starting point exists in the information flows, something which is characterizing for MSPs in general.

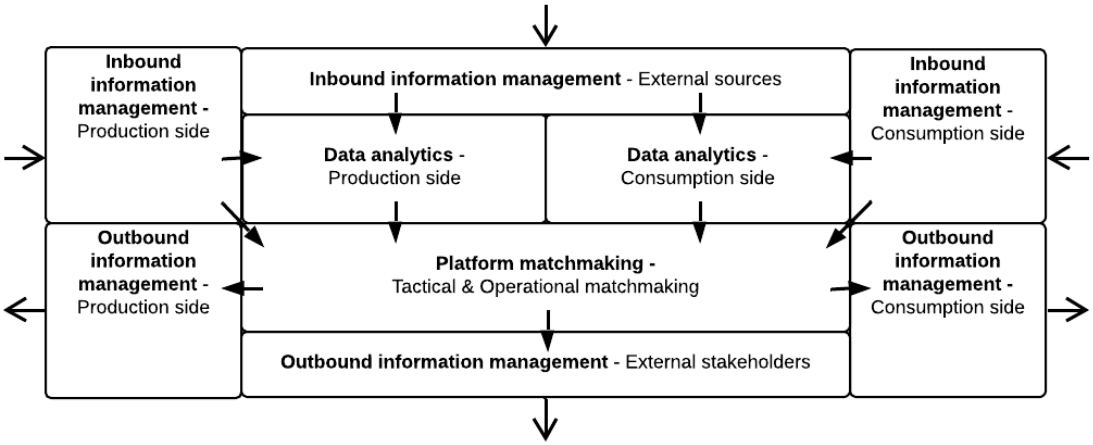

Figure 3: Modular functional design of MSPs main IPCs

Theoretical contributions

This study makes two contributions to the literature on MSP evolution and architecture. First, the paper contributes by discussing various forms of MSP evolution around the core exchange enabled by MSPs. So far, MSP evolution remained an ill-defined and rather abstract concept I the literature (Staykova and Damsgaard, 2017), making it unclear how MSPs evolve exactly over time. Understanding MSP evolution is important as this can help to design appropriate modular service architectures supporting evolvability. Second, the paper contributes by proposing a modular functional design of the main IPCs that create the core exchange of MSPs with the aim to support evolvability. So far, the literature on MSPs recognized the potential of modular architectures to support evolvability (Parker et al., 2016), however, studies focussing on their implementations and the underlying service architectures are scarce. In addition, argued by Brax et al. (2017), research on modular service architectures of MSPs is limited and requires attention due to the specific characteristics of this service type.

Managerial implications

Beyond the theoretical contributions, this study also has practical implications for MSP service development. The results of this study (i.e. the design a modular functional architecture of MSPs) can be used by both existing and starting business aiming to developing an MSP. The proposed functional architecture can be used as a generic modular blueprint of the main IPCs to be developed, for example by further specifying the specific information processes of the platform to be developed or reengineered. In the end, this can help practitioners to design modular architectures that can evolve over time supporting the long-term viability of their service.

Suggestions for future research

Our exploratory study, and its associated limitations, gives rise to several possibilities for future research. First, while this study focussed on one specific type of MSPs (i.e. on-demand automated matchmaking by the platform), it can be interesting to study other types of MSPs as well. Second, we suggest to study the long-term effects of applying service modularity principles to support platform evolvability. This can be realized by for example longitudinal case studies and a design science approach.

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Information Systems in Operations

Data Sharing in Agriculture 4.0: Applications of AI for Access Control Decisions

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Abstract
The context of Industry 4.0 has been manifested in the farming sector where the wave of Agriculture 4.0 provides multiple opportunities for the farmers, consumers and extends to the world population and nations. The major obstacle in the adoption of Agriculture 4.0 paradigm is associated with the data sharing concerns. Small and medium farms often fail to follow the evolution and applications of Industry 4.0 (nevertheless the multiple opportunities) due to concerns around the data sharing practices. Data sharing agreements and access control should build an essential path for data management among various entities/agents of the farming systems.

Keywords: Agriculture 4.0; Artificial Intelligence; Data Sharing; Argumentation Reasoning

Introduction
Following the recent advances of the information technology in a broad variety of areas and the availability of data in increased volume, in different forms and from various sources, not only digital and technological sectors have shown interest, but also more traditional sectors like agriculture try to benefit from this disruption of the industrial landscape. The wave of Industry 4.0, due to the evolution of Big Data Analytics and the associated capabilities provides opportunities but also new challenges the traditional farming has to overcome. The evolution of Industry 4.0 in the farming sector, Agriculture 4.0, has been manifested in the field as new Big Data initiatives and applications in various areas (i.e. agriculture) are becoming economically viable. The proliferation of data and the associated applications has evolved due to the lower (comparatively to previous years) costs of sensor solutions, data storage and processing in cloud infrastructures, development and expansion of mobile networks and the

transmission of data sets from fields around the world. Data can improve not only individual farms but also a large group of farms that utilise the information, technology, equipment and benefit from a wide range of services. The data evolution and the transformation of the agrarian operating models should not only focus on value creation for the consumers, but also for the individual farmer and the society through the use of Big Data.

Trying to expand the context of Industry 4.0 to the agricultural sector, as stated by CEMA (CEMA - European Agricultural Machinery, 2017a, p. 1) the *"Digital Farming is structurally similar to the concept of Industry 4.0".* In our study, we follow the definition of Industry 4.0 which *'entails a confluence of technologies ranging from a variety of digital technologies (e.g. 3D printing, Internet of Things, advanced robotics) to new materials (e.g. bio or nano-based) to new processes (e.g. data-driven production, artificial intelligence, synthetic biology) and these technologies will be available in the near future.'* (OECD, 2016, p. 3). Nonetheless, the notable distinguishing parameters in agricultural production processes are somewhat different from industrial processes, as agriculture is heavily determined by natural and biological factors (CEMA - European Agricultural Machinery, 2017a, 2017b), and therefore the 'physical' artefact should be strongly considered. The terms 'Digital Farming', 'Smart Farming', 'Farming 4.0' and 'Agriculture 4.0' are often referring to similar contexts and therefore are used interchangeably (Lamborelle, 2016; Weltzien, 2016; Yahya, 2018).

In our study, we follow the definition of 'Agriculture 4.0' (CEMA - European Agricultural Machinery, 2017a, p. 1) as the '*evolution in agriculture and agricultural engineering from Precision Farming to connected, knowledge-based farm production systems'.* Applying data-intensive practices and Internet-of-Things (IoT) technologies in the areas of agriculture and farming, due to the increasing benefits arising from the data evolution; can provide a lens for ensuring the transparency of the farming practices and sustainability of the food production processes. The focus of Agriculture 4.0 on digitalised ways of farming can generate renewed interest in transforming the traditional operating and process models to digital data-intensive ones focusing on analytics and decision-making practices. The use of data analytics and associated technologies could create value for the businesses that could harness the innovation opportunities arising from this evolution (Duan et al., 2018; Pape, 2016), but also manage the challenges that come along this change.

There is still an open discussion, and multiple challenges about Agriculture 4.0 and specifically a resistance wave from small farms due to data sharing concerns and access control policies of the data available among the multiple parties. Building on the background of data management and the data quality attributes; this paper proposes techniques from Artificial Intelligence (AI) through an argumentation reasoning approach for bridging the data sharing concerns. This approach focuses on the attributes of agricultural data and defining Data Sharing Agreements (DSAs) around specified attributes.

Theoretical Background

Data in Supply Chain Management

Nowadays, firms from multiple industries invest on data-driven decision-making and business analytics solutions, for improving their performance and operations (Akter et al., 2016; Feki et al., 2016; Wamba et al., 2015). The use of data in supply chain management as well as raw materials in production and service improvement is

presented the last decade as a solution for enterprises to create value by using their analytical skills in visualising, optimising and transforming their supply chains (Hazen et al., 2016; Waller and Fawcett, 2013). Although data can be used along with the core business focus in different industries, we can observe that the recent data evolution expanded the business scope and disrupted the operating models providing opportunities to work solely on data as the main "raw material", processing this data, creating new products and services and also reselling and exchanging data (Spanaki et al., 2017, 2016).

The analogy of the data production process to a manufacturing process is prevalent in data management studies (Karafili et al., 2018; Spanaki et al., 2017). There are some significant differences between the data production process and the manufacturing process, but also noticeable similarities between these two (Karafili et al., 2018).

- The manufacturing process involves the processing of raw materials as inputs to that process, the materials are refined, and the result of this process is the output in the form of a manufactured product.
- The data manufacturing (production process) involves the data as raw materials and the input which triggers the process, the data is refined in a data product as the output of this process.

The main difference of these two processes is around the quality of data. Data of bad quality used through the data manufacturing process should be cleaned, and tailored until the quality is improved and the data product qualifies to be sold or marketed (Hazen et al., 2014; Jones-Farmer et al., 2014; Yeganeh et al., 2014).

The data manufacturing framing presented in data management literature of the previous decades could be applied in the context of data processing and production. The major concern though, is the fact that it should be extended in a boundary-less context between firms and the target should be innovative outputs, as these are mostly the results of the data evolution (Spanaki et al., 2017). Data manufacturing analogy was based on the data artefact as a unit of analysis; however, data era requires novel techniques focusing on the processing of data but not solely on their processing mechanism, but also the quality and sharing attributes associated with them (Karafili et al., 2018). Data sharing control was not the major focus of data management in previous decades; as the data were mostly shared within the boundaries of a company or between single databases. Dealing with problems of a sole database or a single company, we imply that the trust and security issues were solved by the individual sharing entities and the associated agreements between interested parties.

The Agrifood Supply Chain

The Agri-Food Supply Chain (ASC) encompasses a set of activities that move agricultural products across the chain from production to consumption; the set of operations includes *farming, processing, packaging, warehousing, transportation, distribution, marketing* (Iakovou et al., 2014). A number of actors are involved as part of these activities such as research institutions, farmers, an agricultural cooperative, intermediaries, manufacturers, distributors, traders, wholesalers, retailers, and consumers (Jaffee et al., 2008). The sector is highly concentrated on retailers and large agricultural enterprises and small scale farms (UNCTAD, 2016). ASC farmers face many challenges due to high input costs, production inefficiencies, high levels of food waste, and low-profit margins (Anderson and Gundel, 2011). All the different ASC stakeholders are

also affected by the sector-specific challenges related to the increasing need for transparency and sustainability, world's food insecurity, future resource scarcity, limited agricultural land availability, food waste levels across the chain,and supply chain risks (Driscoll, 2012; Fearne, 1998; UN Food and Agriculture Organization, 2011).
ASC has some unique characteristics compared to other food supply chains and in general other supply chain networks (Luo et al., 2018; Tsolakis et al., 2014). Some of these unique characteristics are the following: short shelf-life, seasonality, quality and quantity variability, compliance with national and international food regulations, specific requirements for transport, handling, and storage due to perishability, need for efficiency and productivity, price variability, dependence on weather conditions (Iakovou et al., 2014). These unique characteristics of the ASC in combination with the challenges faced by the ASC stakeholders hinder the effectiveness, profitability and sustainability of the sector and therefore provide a ground for innovation in the field following the technological advances (Meola, 2016).

Data Access and Usage Control
The research focus of data sharing studies usually is around the protection of the data itself (for used and shared data), as well as the databases where they are stored (Gertz and Jajodia, 2008) or the network used for the transfer of this data (Kaufman, 2009). Due to the increasing connectivity between users, there is a parallel increase of the associated security breaches and attacks. Protecting and securing the environment where the data can transferred/stored/used or even re-used was always and is still remaining a major challenge for all the interested parties (Karafili et al., 2015). Data-centric security solutions have dominant position in the literature (Bayuk, 2009; Kim et al., 2010; Pearson and Casassa-Mont, 2011; Wang et al., 2010; Zhou et al., 2010) and specifically the data protection of the data transfers and transactions. Data-centric security solutions present two main challenges associated with the access and the usage control of the data. Both of them, have been widely studied and the research has developed multiple solutions for solving such problems (Ferraiolo et al., 1992; Lazouski et al., 2012). The existing solutions will be presented briefly at this section to distinguish the proposed approach from previous research paths.
Role-based access control according to Ferraiolo and Kuhn (Ferraiolo et al., 1992) can be presented based on specifying the user roles in the data access controls. Motivated by this direction, we expand this context with a data representation technique for specified user roles with defined usage access and policies for the data. Usage control (UCON) as defined by Park and Sandhu (Park and Sandhu, 2004) is a widely studied concept following different approaches, some of them represent the UCON for controlling the access and usage of digital information emphasizing on the problem of rights delegation (Park and Sandhu, 2002).
An additional approach for sharing and accessing data is the use of sticky policies (Pearson and Casassa-Mont, 2011). Sticky polices are machine readable policies that contain conditions and constraints attached to data that describe how the data should be treated while shared among multiple parties. The sticky policy paradigm, technologies for enterprise privacy enforcement and the exchange of customer data are represented through a privacy control language for specified privacy rights and obligations (Karjoth and Schunter, 2002). The privacy control language presents authorization management

and access control for user consents, obligations and distributed administration, with extension of the sticky policy paradigm also for the cloud environment (Trabelsi and Sendor, 2012).
Before creating, sharing and using the data, the data subject, controller and processor should agree regarding the different rules that describe how the data should be treated, that are called data sharing agreements (Swarup et al., 2006). The DSAs describe not only the agreements between the data subject, controller, and processor, but also the compliance of the different business and regulatory contexts for data sharing. A language representation of different rules for data sharing agreements (DSAs) as presented by Matteucci et al. (2010) fails to provide expressivity. This language cannot permit the representation of complex DSAs, as well as analysis for the DSAs and leaves unsolved the problem of deciding which rules to apply to the DSAs.
All the above represented approaches, from the data access and usage control, to the sticky policies and finally the DSAs representation, seem incomplete to provide a decision background for the rules that should apply to the shared data. Following this motivation, we propose a combinatory analysis of the rules with a conflict resolution technique. The proposed analysis is based on abductive (Kakas et al., 1992) and argumentation based reasoning (Bondarenko et al., 1997; Dung, 1995), as this technique can facilitate decision making mechanisms under conflicting knowledge (Bandara et al., 2009; Kakas and Moraitis, 2003).

Methodological Approach
The approach presented in this study assumes that data are processed by different entities. Data Sharing Agreements (DSAs) are established between the entities for data processing composed of various constraints and rules. An expressive policy analysis language is used in this case for representing the DSAs. Data quality is the main focus of the data processing mechanism; therefore the policy language is enriched to capture various data quality properties like accessibility, timeliness and accuracy. The used policy language permits the analysis of the various policies and the detection of the rising conflicts, redundancies or the missing cases. We follow argumentation and abductive reasoning to build our proposed method to capture and solve conflicts between context dependent rules. The introduced analysis permits the construction of precise DSAs that can be applied in various contexts during data processing phase.

General Representation Context
We introduce here the general representation context, where we put a background case of collecting, processing and sharing data. We show in the coming section how our methodology for Data Sharing Agreements is used in this scenario for naturally representing the needs of the various actors involved, and effectively deciding who can access to what part of the data.
The main actor of our scenario has a data-related activity, and decides to start collecting data around this specific activity. The collection of the data can be made in different ways: manually, through IoT devices, drones etc. The way the data is collected can influence directly the accuracy aspect. The collection of data can occur in different intervals within the day/time, e.g., every hour/day/month, always. The collection time/period influences the freshness of the data. This freshness is strictly related also to the type of data.

- The owner of the data-related activity is called the **data owner**, and in this case s/he is also the **data subject**, as part of his data are collected as well, e.g., name of the activity, his personal data, and the **data controller** as s/he determine the purpose and means of processing the data.
- The **data recipients** are all actors that want to access/use/share the data owner's data, the stakeholders involved in the activity or similar activities. Data recipients need to comply with the data controller rules.
- Sometimes the owner of the activity relies on *third parties* that provide the technical support for collecting the data. In this case owner is the **data owner/subject** but he can delegate the control of his/her activity data to a third party that is now the **data controller**.
- The **data processor** is an entity (public authority, agency, legal person) that is processing the data on behalf of the controller. In our use case, the collected/processed/shared data can be stored in the cloud. Thus the cloud provider is considered the data processor as far as it respects the instructions of the controller. The controller rules that should be respected by the processor can also have a legal nature, e.g., if the controller is in an EU country, the cloud provider should as well be in an EU country and cannot send the data to countries outside the EU and EEA.
- A **third party** is an entity (public authority, agency, legal person) that is not the data subject, data controller or processor, and that under the direct authority of the controller or processor is authorized to process the data. In our case, a company that is outside of the immediate boundaries of the data owner which is granted access can be considered a third party. Once access is obtained, the third party becomes a data controller and has to comply with the data protection principals.

The Policy Language

The proposed model is based on the policy analysis language (Craven et al., 2009) that is constructed using the Event Calculus. This language represents the required rules and constraints for accessing, using and sharing the data. The policy regulation rules are composed of predicates and domain descriptions, and represent the authorization and obligation rules. The authorization rules have in their structure a specific **subject**, as well as specified **targets**, and **actions**. A brief introduction to the language with some of the main predicate is given below.

$$req(Sub, Tar, Act, T) \qquad obl(Sub, Tar, Act, T_s, T_e, T)$$
$$permitted(Sub, Tar, Act, T) \qquad denied(Sub, Tar, Act, T)$$

The above predicate represents correspondingly: a request made from the subject Sub, at the instant of time T, to perform a certain action Act at the target Tar; the obligation for a given subject to perform an action during the period of time from T_s to T_e; that a given subject is permitted/denied at time T, to perform a certain action to the target. A domain description predicate is $holdsAt$, which means that a given property/predicate is true in a given instance of time.

The used policy language can represent the permission, denial and obligation concepts for the DSAs. In the following examples, we introduce the representation of some DSAs rules from our use case.

Example 1. For our example, we assume that the farmer is the owner of the data and wants to access the data. We use the owner property for stating that a given actor is the owner of the data.

Rule 1: The owner of the data can access his/her data with the original quality they were captured.

$$(1)\quad Access(data, O, permitted) \leftarrow Owner(O, data).$$

The conclusion of the rule is presented on the left side of the arrow (←) in this case is $Access(data, O, permitted)$, which states that subject O is permitted the access to the data. The preconditions of the rule are presented on the right side of the arrow (←). In the above case, the precondition of the conclusion is composed of just one predicate to be satisfied in order to have the conclusion, and it is $Owner(O, data)$, which means that subject O needs to be the owner of the data. In case there is more than one predicate to be satisfied, then the predicates are separated by a comma (,) in case they all need to be satisfied, in order for the conclusion to hold, or by a $(\vee)$ that represent the logical symbol for OR, in case at least one of the predicates needs to be satisfied in order for the conclusion to hold. In case the conclusion is always true, thus it does not need any precondition to hold, then the right side of the arrow is empty.

Example 2. A third party Research Institute wants to access the data and provide tailored services and information about agricultural production, advances in technology (Agri-Tech) and advice on farming practices and activities.

Rule 2: The research institute can access all the data related to a particular product, and the accuracy and timeliness of the data are high.

The research institute can access all the related data of a particular product that they are interested in, and the data are only the production-related data. In this case, as the subject is a research institute $ResearchI\ (R)$, and its main focus is to conduct a scientific research that in the future would bring benefits to the farmer, the quality of the data is not altered.

$$(2)\quad Access(data, R, permitted) \leftarrow Interest(R, data), ResearchI(R), Prod(data).$$

Representation of the Quality and Sharing Aspects

The sharing and usage of data raises issues around the description of other properties related to the quality of the collected data. When working with data quality the entities that are using, sharing, storing the data are called **data consumers**. In our case, the data consumers are considered the data collectors and the data processors. The data quality is an important factor when we are working with data consumers, where **data quality** is defined as data that fit the requirements for being used by data consumers (Wang and Strong, 1996).

Accessibility: Also another important aspect of data quality is **accessibility**. Our DSA representation together with the used policies set data accessibility permissions. The used methodology ensures the data accessibility complies to data owner's constraints, and other legal internal and external frameworks and regulations.

Accuracy: An important data quality attribute which should be met is the **accuracy** of the collected data. When data are collected by an human actor, we can put in act a deontic obligation for the actor to use a particular accuracy level when collecting and storing the data. This case can suffer from human errors. On the other hand, when a device is collecting the data, e.g., an IoT device, we can be more specific and ensure the data accuracy by checking the parameters of the various devices.

$$accuracy(Data, T) \leftarrow holdsAt(meas(Device, Data), T), \\ holdsAt(acceptP(Device), T).$$

In the above case, we state that the data collected are accurate, as the device that collected them is able to measure the data with acceptable parameters, ($acceptP$), for ensuring data accuracy.

Freshness: Another important data quality characteristic is data **freshness** which is the degree data represent reality in the required point in time. The notion of data freshness is part of the **timeliness** as a data quality aspect. For our scenario we will work only on the data freshness predicate, as it represents the data timeliness depending on the different contexts. Data freshness is a predicate that expresses the last time when a given piece of data has been updated:

$$freshness(Tar, T)$$

where Tar is the targeted data, and T is the last instant of time when the data were updated.

Conclusion

The study proposes an approach for the data sharing problem in Agriculture 4.0, where data can be accessible by different entities. Through the application of Artificial Intelligence (AI) and Logic Programming, we aim to present through case scenarios new ways to build efficient Data Sharing Agreements (DSAs), thus eliminating data sharing concerns which hinder the wider adoption of Agriculture 4.0 paradigm.

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Digitalisation stages in firms: towards a framework

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Abstract

Recent advancements in digital technologies and a growing availability of data create new opportunities for firms to increase revenues and improve operational efficiency. To date, there is a gap in research describing transition pathways to digital-intensive models of production and operation companies may choose depending on the industry context, company sizes, technology push and market pull forces. This conceptual paper develops a framework of digitalisation stages in firms: analogue, coordinated transition, digitally fragmented, and a full-fledged digital enterprise. Examples from the industry are used to illustrate the framework.

Keywords: digitalisation, technology push, market pull

Introduction

Digitalisation leads to paradigm shifts in the business sector with far-reaching effects on value chains, business models and company structures. According to Gartner (2019), digitalisation is the application of digital resources to change business models and capture new revenue opportunities. Digital transformations unravel in highly uncertain and rapidly changing technological and socio-economic environments characterised by unpredictable outcomes of investments into digital products and services. Digitalisation is largely seen as a powerful intervention into the core business of companies and associated with organisation-wide modernisation efforts (Valenduc & Vendramin, 2017). Recent advancements in digital technologies like AI and blockchain are expected to bring about major changes for how firms are organised and governed and how decision-making is executed and translated into real actions. In order to harvest opportunities and mitigate the risks of digital disruptions, companies both from traditional sectors (e.g. construction, agriculture) and technology-intensive industries (e.g. telecom) design “strategies that embrace the implications of digital transformations and drive better operational performance” (Hess et al, 2016).

A digital transformation strategy serves as an overarching and a company-wide vision steering an organisation through digitally induced changes and strengthening the ability to react proactively and timely to internal and external shocks caused by organisational, cultural and technological implications of digitalisation. Due to a relative novelty of transformational changes of digitalisation, its complexity, profound and long-lasting impacts on versatile aspects of production and operations, corporate digital transformation strategies and the mechanisms for their initiation and implementation have not been thoroughly studied by the academic community. At the same time, there is an urgent need from the side of the business sector to have conceptual frameworks to support a frictionless evolution towards a new functioning

model of a business organisation supported by an intensive use of digital technologies. This paper addresses main rationales, promises and challenges of digitalisation in firms with a view to providing a classification of different stages of digital transformations. The research findings are based on an extensive literature review of underlying technological and organisational trends and the phenomenon of digital transformation strategies.

Framework conditions that affect digital intensity of firms

Digitalisation requires the development of strategies to proactively react to external and internal shocks brought about by technological advancements. A successful market performance is associated with an ability of a firm to manage complexity of production and operations, be it management of a global network of factories or commercialisation of research findings. A current wave of changes in digital technologies unravels on a much deeper level compared to the past developments. Digitalisation contributes to blurring of lines between industries (WEF, 2016), disruptive changes in innovation cycles (Rachinger et al, 2018), new means of value creation, new types of relations and hierarchies among customers, producers and suppliers (Heinonen & Michelsson, 2010; Lee & Berente, 2012). Digital transformations exhibit a tendency for a strong reciprocity between transformed and impacted business activities (Ismail et al, 2017). That is to say that digitalisation of a product or a service will sparkle changes in a whole value chain and should be inevitably aligned and supported with digitalisation or managerial changes of all stages of production and operations. Firms need to integrate digital technologies into their business processes and operations and channel complementary investments into the reorganization of hierarchical structures, skills and business models. This 'domino effect' of digital transformations increases the complexity and the uncertainty of actions a firm needs to undertake to fully harvest a potential of technological advancements.

Conception and implementation of digital transformation strategies are affected by a combination of external and internal factors: market pull (changes in client demand, market trends), technology push (advancements in a computational power), type of industry and company size. A study of micro-data from the Statistics Canada Survey of Advanced Technologies (2015) identified that large companies use advanced digital solutions more often in comparison to small and medium enterprises (Galindo-Rueda et al, 2019). Under advanced digital solutions we understand in this context tools based on machine learning, natural language processing, deep learning, blockchain, the semantic web, advanced visualization methods and Big Data. Whereas the application of cloud computing and other infrastructure service technologies have the same levels of proliferation for all company sizes, small and medium enterprises generally have lower capabilities in integrating advanced digital technologies into organisational settings to extract a commercial value. Therefore, company size may be a path-dependent force defining frameworks for a digital transformation.

Clavino et al (2018) proposed a taxonomy of industrial sectors based on the use of digital technologies in production and operations applying a set of indicators designed atop the OECD country-specific data, e.g. investments in technological solutions, human capital required to exploit technologies, and changes in output market (online sales). According to the study findings, ICT, telecommunications, finance are leading in the digital intensity, whereas companies involved in agriculture, mining and real estate are lagging behind. A type of industry, in which companies operate, has an impact on technology intensity of firms and whether they start the adoption of digital solutions early on. Both company sizes and industry types are not decisive factors for digital intensity of firms. Some start-ups and small and medium enterprises have a high capacity in designing new products, services, business models

leveraging a potential of digital technologies ("digirati" or "digital-born"). While operating in the retail sector which generally does not exhibit high digital intensity, Walmart is gradually becoming a digitally intensive company by using big data analytics to improve customer experience and advance supply chain management. Company sizes and industry types can tilt companies to a direction of digitalisation, but cannot be a decisive force for the success of such transformations.

Changes in company operations that happen under the impact of digital technologies can be seen from the classical theory of the technology push and demand pull (von Hippel, 1976; Mowery & Rosenberg, 1979; Dosi, 1982). The concept of technology push proposes a linear process of innovation, in which research and development are ultimately translated to commercialized outputs (Bush, 1945). The concept of the demand pull, on the contrary, argues that the anticipated customer demand is the main driver of innovation activities, as it provides incentives to conduct research and development in new areas (Schmookler, 1966; Scherer, 1982). Scholars reached a consensus that there is a close interplay between technology push and demand pull which is largely defined by different industry life cycles, characteristics of the end market and broader economic conditions (Mowery & Rosenberg, 1979; Stefano et al, 2012; Balconi et al, 2010). Digitalisation brings new dynamics into this paradigm by strengthening a technological impacts on a broad array of operations in firms and market developments. A technological aspect is becoming more pervasive in defining rationales for corporate strategies and market pull dynamics. Although advancements in digital technologies and a growing availability of data have not fundamentally changed technology push and demand pull forces, the general direction goes to a more heavy-weight technological component.

Technology push

Organisations are engaged in an iterative process of exploring the potential of digital technologies for their business needs. Companies start adopting digital solutions to improve operational efficiency and effectiveness (Bilgeri et al, 2017), decrease costs (Valenduc & Vendramin, 2017), improve supply and demand matching (Groen et al, 2017), ensure strategic differentiations from competitors (Andriole, 2017), enhance skills of workers (OECD, 2016) and support strategic planning, problem-solving and decision-making (Carlsson, 2018). Digital technologies contribute to an emergence of new business models, products and services. According to the survey of the Harvard Business Review, 84% out of 783 company senior managers believe that their industries are already being disrupted or will be disrupted by digital technologies by 2020 (Harvard Business Review, 2017)[1]. The Internet of Things (IoT) enables companies to design on-demand services creating sizable efficiency gains both for customers and providers. Several examples of such solutions include lighting on demand service of Philips, Power by the Hour service of Rolls-Royce, performance-based contracts of General Electric and on-demand services of Kaeser Kompressoren. Through such services, customers may reduce their financial risks, improve planning of operational costs, pay for highly personalised products and services only when in use and benefit from automatic and constant improvements. Digitalisation enables rapid prototyping, computer modelling and simulations, reducing costs and material use and accelerating innovation cycles. Over-the-air software updates let manufacturers launch a product on the market before it is fully finalised. For

[1] The survey covered companies active in manufacturing, finances and technology. Organisations with more than 10 000 employees formed 53% of respondents, organisations with 1000-9999 employees accounted for 26% of respondents, organisations with 100-999 employees constituted to 21% of respondents. The geographical representation is as follows: North America (35%), Europe/MEA (35%), Asia/Pacific (23%) and South and Central America (35%).

instance, Tesla launched its S model in an alpha version. Through constant software updates and monitoring of the product usage behaviour, Tesla was able to further improve the functionality of the S model on the go without recalling cars for a technical maintenance.

Data-driven services let companies bypass intermediaries and build up direct relationships with their customers, thus strengthening bargaining positions in value chains. New operating models and process innovations powered by digital technologies can also disintermediate relations between suppliers and customers. With the emergence of digital services developed atop existing physical products, firms can engage in closer interactions with their customers and extract value beyond the sale date. Consequently, revenue streams can become less vulnerable to cyclical fluctuations and exhibit positive tendencies for a substantial growth.

Another factor which raises the interest of firms in digital technologies is new opportunities for revenue extraction provided by digital platforms. According to the findings of the World Economic Forum's Digital Transformation Initiative (DTI), digital platforms have a potential to generate $10 trillion of value for companies till 2025 (WEF, 2017). Platforms introduce new ways for interactions between customers and suppliers, blur boundaries between industries, enable the co-creation of new services with ecosystem partners and raise the scalability of businesses without significant follow-up investments (Tiwana, 2014; de Reuver et al 2018; Von Engelhardt et al, 2017). Technology companies like Amazon and Google leverage their capabilities in data analytics to design digital platforms for connected and autonomous vehicles and telematics. While in the future that may raise competition for car manufactures who are also interested in providing paid digital services, the collection of large volumes of user data already enables Amazon and Google to become active in the auto insurance market, thus reducing market shares of insurance companies. Digital platforms are seen as an important instrument for digital transformations of traditional industries, where they serve not only as a tool to provide valuable additions to the core business, but also as a powerful instrument to further advance key organisational competences and create new business models.

Market pull

Changes in economic conditions and in demand have impacts on the profitability of innovations, thus providing incentives for firms to work on certain solutions (Rosenberg, 1969; Freeman, 1979; Brem & Voigt, 2009; Lubik et al, 2012). Companies embark on a digitalisation path to respond to market and competition trends and remain competitive. Customers have developed a different set of expectations towards products and services: e.g. personalised customer experiences, recommendations based on previous purchases and attractive and easy-to-use digital interfaces.

At the same time, a new generation of workforce have a different set of values and motivating factors. They have different perceptions towards working conditions (e.g. flexible working hours, teleworking) and digital competences of companies (e.g. optimisation of workflows through digital tools, convenient digital working environment) (Kaufman & Horton, 2015). Firms need to adapt to changes in demands and expectations of clients and employees by increasing a digital component in their portfolios and operations.

Digitalisation might be a way to mitigate risks to core business activities either by expanding to new markets and business lines or through creating vendor lock-ins by digital extensions to core products. For example, academic publishers like Elsevier and Holtzbrinck Publishing Group face challenges posed by terminations of national paid subscriptions to their content and the emergence of alternative channels and providers of content supply. Publishers are trying to

mitigate these risks by designing digital services atop their proprietary databases and data generated by users. The share of digital content in a total revenue by format raised from 22% in 2000 up to 74% in 2017 for the RELX Group, an owner of Elsevier. For Elsevier this number is even higher: 81% in 2017 (RELX Group, 2017). As a result of such developments, Elsevier has recently changed its status of an academic publisher to a global information analytics company. Digitalisation may offer not only an opportunity to mitigate competitive pressures, but also a chance to transform the core business of a company and capture a higher value.

Digital products and services are characterized by the 'fluidity', an ability to "be reproduced, shared, manipulated instantaneously at any scale and no cost" (Paunov & Guellec, 2018). Digital technologies like AI, big data analytics and distributed ledger technology (blockchain) are general purpose technology (GPT) and can be applied across various business lines contributing to productivity gains and efficiency improvements. By leveraging opportunities provided by recent advancements in digital technologies and a growing availability of data, firms can scale up rapidly in the market without significant follow-up investments. A so-called 'scale-without-mass effect' lowers costs of a market entry and provide companies with powerful instruments for a market expansion (Brynjolfsson et al, 2008). That may ignite a rapid development of small and medium enterprises that may undermine competitive powers of market incumbents. However, depending on a combination of internal and external factors, it may also result in a reverse trend, a 'winner-takes-most' phenomenon, in which a small group of large technology companies establish a monopoly in a market. Such dominant positions are difficult to contest due to network effects of digital products and services, economies of scale and scope, vendor lock-ins and data ownership and access.

A growing availability of vast volumes of data on product delivery and user behaviours provides companies with opportunities to manage their supply chains in a faster and more flexible manner and cause new market dynamics. Amazon is working on predictive shipping model in which the pre-packaging of goods starts before a customer purchases it. The model is underpinned by analyses of customer behaviours, product usage and online searches. Digital solutions have a potential to raise transparency, authenticity, traceability and security of transactions within supply chains (Wang et al, 2019) and improve forecasting of irregular demands thus decreasing costs (Amirkolaii et al, 2017). In previous decades, the proliferation of the Internet disintermediated several industries leading to disruptions for market incumbents. For instance, in tourism industry hotels and airlines started providing their services directly to customers through websites bypassing tourism agencies. Currently, a new value for market disintermediation is seen in distributed ledger technology (blockchain). It is already used to support the implementation of smart contracts across various industries (Kim & Laskovski, 2017) and for disintermediation of energy markets by providing peer-to-peer trading solutions, e.g. owners of photovoltaic batteries have a possibility to seamlessly sell energy to their neighbours (Andoni et al, 2019; PwC, 2017).

Changes in customer needs geared towards an improved digital content, competitive pressures on existing business, changes in supply chain management and new competitive dynamics caused by digital technologies form market trends that stimulate companies to explore a potential of digital technologies for reaching their strategic objectives.

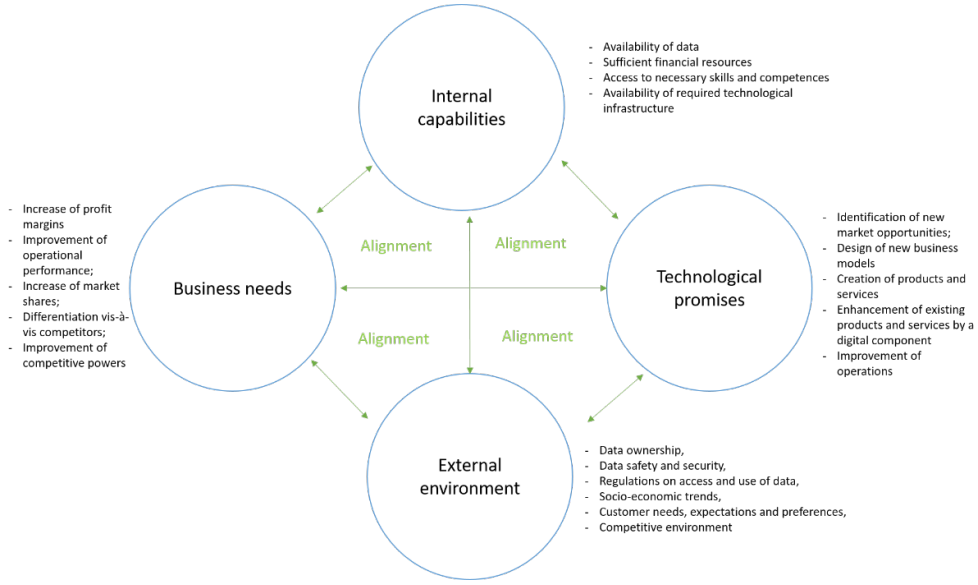
An interplay between technology push and market pull in the digitalisation context

Insights on capabilities of digital technologies coupled with information on customer needs and expectations drive the development of new products and services. That should be further

aligned with necessary changes in production and operations management (e.g. reconsideration of supplier relations, new ways of customer engagement), changes in skills (e.g. acquisition of capabilities in data analytics), the development of a new culture (e.g. strengthening of openness and transparency, data curation) and changes in organisational hierarchies (e.g. flatter organisational structures and cross-functional project teams). The most challenging task is to implement necessary reforms in decision-making arrangements: e.g. how to translate intelligence retrieved by digital technologies into a detailed sequence of actions; how to monitor areas of potential breakthroughs and accommodate promises of digital technologies to gain a competitive advantage; how to balance investments into digitalisation programmes with other strategic objectives.

In the context of digitalisation, decision-making process is organised along the alignment of business needs, internal capabilities, technological promises and the external environment (fig. 1). Whether a company will be successful in harnessing the potential of digital technologies depends on the ability to identify promising technological applications and relate them to business needs and internal capabilities with a view of possible effects from an external environment.

Figure 1. – The nodes of decision-making in the context of digitalisation



Changes in decision-making arrangements driven by new trends in client demand and the competitive landscape can be the main force behind digitalisation of a company. In situations when a technology push has a dominant role, digitalisation tend to happen in a bottom-up and fragmented manner and is focused on specific project demands. It sparkles changes in process and operations management further leading to changes in organisational structures, skills and culture, later on affecting mechanisms for decision-making. When the influence of the market pull is more significant, the whole process of digitalisation starts from changes in corporate decision-making which is further translated to other stages of production and operation. In this case, digitalisation of a company is characterised by a top-down approach and distinguished by a coordinated nature. A number of firms have launched corporate digitalisation strategies setting out objectives for digital transformations and identifying major barriers and the ways to overcome them.

Digitalisation strategies are aligned with R&D strategies, customer engagement strategies and other key documents incorporating a company's vision on its future development and measures aimed at achieving objectives. Having a corporate digitalisation strategy is instrumental for ensuring an optimal transition towards digitalised processes, business models, products and services, as it unites stakeholders over a selected list of objectives, channels required resources to priority areas and resolves duplications of efforts and information asymmetry in companies. While project-based digitalisation can bring positive results for short-term objectives, it is not well positioned to push frontiers of digital transformations, as they are constrained by existing bottlenecks of organisational settings that should have been addressed by senior management in the first place.

Figure 2. – A typology of digitalisation in firms

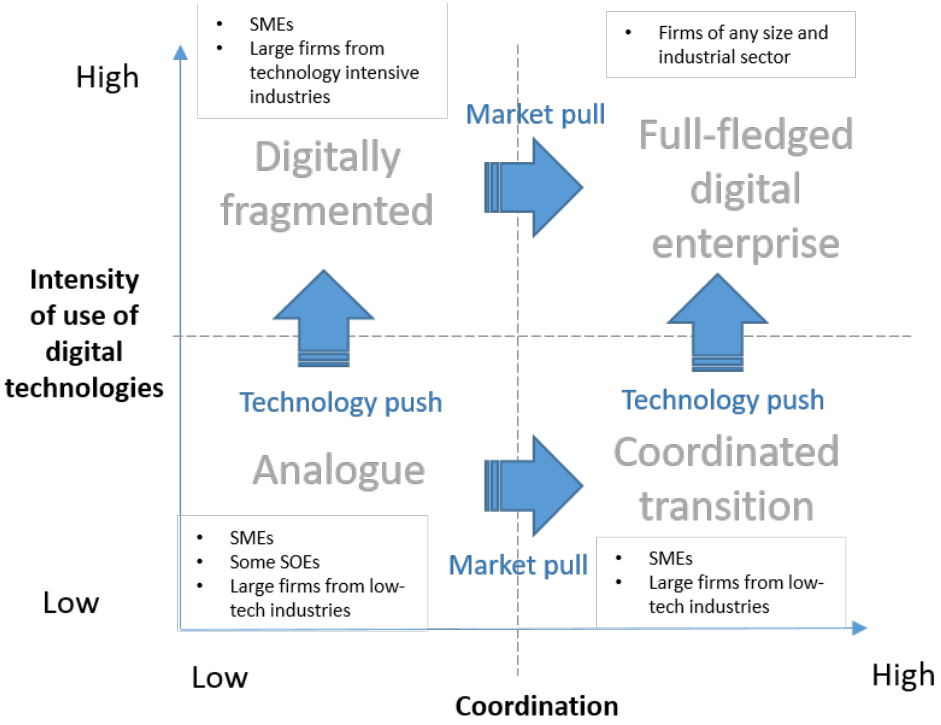


Figure 2 presents a framework for classification of digital transformations in firms based on a degree of coordination of digitalisation initiatives and the intensity of use of digital technologies. Company sizes, industry types define a starting point of digital transformations of companies, whereas the market pull and technology push can be drivers of a transition to other stages. This figure provides an analytical framework of macro-forces affecting digital transformations in firms, but it does not offer insights on transfer mechanisms to new stages (e.g. types of investments, measures aimed at organizational restructuring) that should be covered in the future research.

Analogue group: Small and medium enterprises, some state-owned enterprises (SOE) and large companies from low-tech industries form this group. Typical examples may include firms active in agriculture and real estate. Digital technologies serve as extensions for current products and operations (mainly customer engagement and streamlining of workflows) and do not contribute to creating digital products, services and new business models based on advanced technological solutions. Firms in this group are not very perceptive to technological changes due to path-dependent dynamics of their industries, infancy of their business or a low market

competition. Unlike other world largest oil and gas companies, the state-owned enterprise Rosneft does not show much progress in adopting AI and big data analytics for productivity and efficiency improvement. Dominant market positions and an access to state money stifle innovations in many Russian SOEs, result into a low labor productivity and create a hostile environment for adoption of new technologies (Abramov et al, 2017; Sanghi & Yusuf, 2018).

Coordinated transition: Some small and medium enterprises and large companies from low-tech industries start digitalisation by setting strategic objectives and formulating initiatives aimed at a coordinated transition of a whole enterprise to digitally enabled solutions and practices. Companies in this group are being disrupted or are at a risk of being disrupted by more technology-intensive market players. A growing demand from clients and employees for new ways of communications and advanced digital experience calls for subsequent changes in a capacity of firms to exploit digital technologies on a deeper level. The global healthcare company Novartis wants to digitally transform by embracing advanced analytical solutions. The corporate strategy puts digitalisation in a centre of a long-term development. Yet, applications of recent advancements in digital technologies are still in infancy and are distinguished by an experimental nature.

Digitally fragmented: small and medium enterprises and large firms from technology-intensive sectors show high levels of use of digital technologies and data-driven approaches to improve productivity and operational efficiency. There are significant changes in levels of technology absorption across industrial sectors. Industries that used to show rather low levels of technology adoption are increasingly becoming technology intensive. The financial sector is leading in adoption of advanced forms of digital tools ranging from distributed ledger technology to deep learning networks. The Swiss multinational investment bank and financial services company UBS Group launched a number of digitalisation projects aimed at among others optimisation of workflows, development of an infrastructure for smart contracts and support of credit scoring. Although digitalisation is recognized as an important vector in a corporate strategy, digitalisation efforts at UBS are rather project-based and mostly occur in a fragmented manner.

Full-fledged digital enterprise: company size or industry type do not play a major role in shaping a full-fledged digital enterprise. For successful digitalisation firms need to build strong dynamic capabilities to identify opportunities and threats, rapidly and proactively react to technological trends and effectively transform business models and resource base (Teece, 2007; Teece & Linden 2017). Organisational reforms aimed at a more efficient and effective exploitation of digital technologies are instrumental for achieving full digital maturity. Netflix can be an example of a full-fledged digital enterprise. By investing in digital skills and new technologies and improving organisational settings, Netflix was able to transition from a DVD renting business to a world leading video streaming service and an entertainment company. Expertise in data analytics and AI enabled Netflix to design an industry-leading film recommendation algorithm and gain a deep understanding on user expectations and content engagement.

Conclusion

A combination of framework conditions including company sizes, industry types, technology push and market pull set trajectories for formulation and implementation of digital strategies. A transition to more advanced stages of digitalisation is mainly driven by organisational reforms that unleash a full potential of digital technologies and align them with business needs, in-house capabilities and external environment. Examples of such initiatives include, but are

not limited to the resolution of information asymmetries, flatter organisational hierarchies, small cross-functional teams and implementation of new types of incentive sets to accelerate innovations. Further research is needed to shed light on measures companies may require to implement to achieve full digital maturity and develop strong dynamic capabilities for successful digitalisation.

Whereas other three stages of digitalisation (analogue, in-transition; digitally fragmented) are shaped by the context in which companies operate, a stage of a full-fledged digital enterprise is not a given and can be reached only by overcoming external and internal path-dependent forces and investing into capabilities to transfer technological advances into a commercial value. In this context, corporate digitalisation strategies are seen as an essential enabler of a coordinated transition to a model of a full-fledged digital enterprise. Formulation and implementation of digitalisation strategy is most likely to happen, when market pull forces have a strong influence on a company's development. When technology push is more dominant, digitalisation occurs in a project-based fashion often leading to duplications and fragmentations of efforts.

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Unbundling the W's: the interface between organisational crises, social media narratives, and image repair strategies

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Abstract

Organisations are susceptible and vulnerable to crisis situations. These organisations have been able to exert resilience, and manage reputational damage, through crisis management protocols that include stakeholder engagement. However, given the rise of social media, a new cohort of stakeholders has emerged. Organisations are therefore faced with the task of managing new stakeholder relationships. This paper applies recent advancements in social media and crisis management discourse to investigate the prevalence of new, undiscovered stakeholders in crisis communications surrounding six prominent crisis situations. The results indicate that online stakeholders are becoming more powerful, urgent and legitimacy; thus shifting dynamics.

Keywords: Crisis Communication, Social Big Data, Stakeholder Salience

Introduction

Previous studies on crisis management have sought to identify effective methods and strategies for crisis communication. Crises can be unexpected and non-routine events or activities that interfere with an organisation's normal business operations, jeopardise its public image and damage the bottom line (Faulkner, 2001). Managing crises is an important process to prevent or lessen such interference, repair images and disseminate the responding information. Therefore, 'the communication following a crisis plays an integral role in this success' (Ulmer, 2001, p592). According to Coombs (2015), crisis communication is 'the collection, processing, and dissemination of information required to address a crisis situation'.

The recent prevalence of social media platforms has created a new and low-cost channel for

communication. These platforms have also changed the way that people search, publish and share information during crises (Oh et al., 2013). The use of new types of social interactions to report real-time crisis information somehow is more influential than the mainstream news. Given this, the main organisations are no longer the only influencer, rather, there are peripheral influencers that can gain legitimacy and become important stakeholders by creating and propagating crisis information. Hence, there is a new challenge for the main organisations to identify and engage with these emerging stakeholders to communicate crisis information.

In addition, the social media platform can encompass large amount of unverified information, including lies and false rumour (Oh et al., 2013), which can then easily spread anger, threats and aversion emotions to further worsen the crises (Jin et al., 2014). Assessing and scrutinising such information is therefore important for organisations to control crises, develop responses, and repair images. Previous studies in crisis management have identified an array of strategies for crisis communication and image repairing (e.g., Benoit, 2018). This study builds on the key lessons of from these studies, and builds on stakeholder theory and image repair theory to propose new solutions for crisis communication and stakeholder engagement via social media platforms.

Given the new role of social media platforms in crisis communication, scholars have put emphasis on the complex interconnectedness and centrality of emerging stakeholders in crises (e.g., Sedereviciute and Valentini, 2011). Using the stakeholder salience model (SSM) and social network analysis (SNA), this study aims to advance our understanding of the interface between image repair strategies and stakeholder salience. As such, this study aims to unbundle the critical W's. These include: *what* is the conversation, *who* is framing the conversation, *why* do crisis-stricken organisations respond, and *when* they do.

To unbundle the W's, this study is anchored in a research agenda to address:

RQ1: How do (emerging) stakeholders shape the conversation about crises using social media platforms?
RQ2: What topics of conversation, and which stakeholder groups, encourage crisis-stricken organisations to respond?
RQ3: Is stakeholder mapping an effective tool? And, can crisis-stricken organisations use stakeholder mapping to identify salient stakeholder groups?

Literature review

Grounded on traditional stakeholder theory, dominant logic in crisis communication discourse relates to the premise that: (i) a range of stakeholders will be involved in *ex-ante* and *ex-post* crisis communication (Wagner Mainardes et al., 2012), and (ii) organisations will attempt to communicate with certain stakeholder groups to manage the situation and reduce any reputational damage (Luoma-aho & Paloviita, 2010). To effectively manage crises, and reduce reputational risk (Benn et al., 2016), it is imperative for organisations to classify stakeholders and define dyadic stakeholder-organisation relationships. Parallel to the rise of social media platforms, however, interest and participation in crisis communication has become more accessible and fluid (Valentini & Kruckeberg, 2016), with organisations facing new challenges in stakeholder mapping procedures.

Traditionally, organisations could evaluate and categorise stakeholders with a scope to identify

the most salient stakeholder with prioritised stakeholder claims. Based on this evaluation process, an organisation could then respond directly to stakeholders with priori claims. Concomitant with the rise in social media, though, the evaluation of salience is becoming less static, with frequent changes in powerful, urgent, and legitimate stakeholders. What's more, social media has also introduced a new environment in which 'undiscovered', 'new', and 'unknown' stakeholders can emerge (Himelboim et al., 2014).

The fundamental challenges for crisis-stricken organisations, therefore, are:

i. Requirements to grasp – and difficulties associated with grasping – the complex relationship between crisis situations and social media platforms;
ii. The emergence of new stakeholder groups, with Wan et al (2015) identifying new stakeholder labels, such as social media creators, social media followers, and social media inactives.

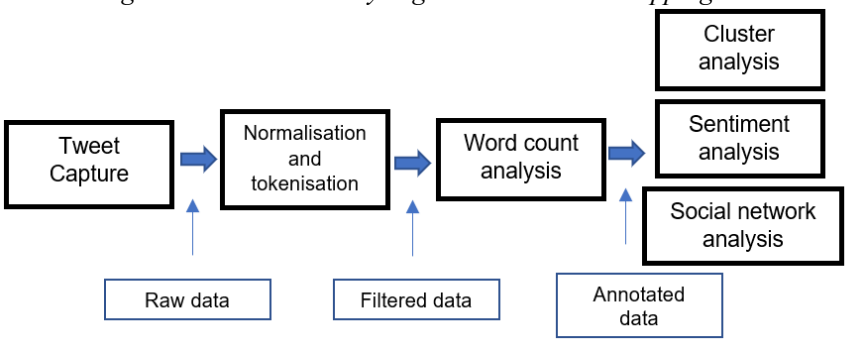
Addressing these challenges would make it possible for organisations to reconfigure their stakeholder maps, and thus recalculate salience calculations. Such possibilities could result in crisis-stricken organisations being better equipped to make optimal, rather than sub-optimal, crisis management decisions. An initial step toward providing a solution is provided by Sedereviciute and Valentini (2010). In their study, the author combined the Stakeholder Salience Model (SSM) and Social Network Analysis (SNA) to permit a mechanism to find and prioritise stakeholders on social media, with an emphasis on connectivity and content dimensions. The first dimension (i.e., connectivity), rooted in network theory, is based on connections between different online stakeholders on social media, as well as the dyadic connections between online stakeholders and the organisation. The core argument is that if an online stakeholder has a more prominent position in social media networks they will be viewed as more powerful. The second dimension (i.e., content), on the other hand, is preoccupied with the content and words propagated on social media platforms, such as Twitter, as well as the interest and relevance of this content for other online and offline stakeholders. Essentially, when an online stakeholder is seen as propagating interesting and relevant information on social media they will be deemed as urgent. When an online stakeholder is deemed both powerful (based on position) and urgent (based on content), they will be viewed as more legitimate by the crisis-stricken organisation, and thus will generally attract a response. As noted by Sedereviciute and Valentini (2010), these two dimensions will shift the traditional conceptualisation of powerful, urgent and legitimate stakeholders, and introduce new stakeholders into the mix, notably: unconcerned influencers (dormant stakeholders), concerned influencers (definitive stakeholders), unconcerned lurkers (non-stakeholder), and concerned lurkers (dependent stakeholders). This understanding will therefore be taken forward to assess *who* is important in crisis-related conversations on social media, and *how* they shape conversations on social platforms.

Methodology

Data Collection

This study develops a tweet analysing and stakeholder mapping tool to collect, extract and analyse the data from Twitter. The tool includes four analyses as illustrated in Figure 1: tweet word counts analysis (to classify trendy keywords); tweet cluster analysis (to identify dominant image repair strategies and prevalent crisis topics); tweet sentiment analysis (to identify the tweet sentiments and the pattern of information diffusion) and social network analysis (identify emerging stakeholders).

Figure 1. The tweet analysing and stakeholder mapping tool



The tweet datasets in this study are captured by a Twitter Application Programming Interface (i.e. QDA Miner and NodeXL), they contain seven recent crises and extreme events (Table 1). The software is selected based on their extensive features on exploring and analysing textual data.

Table 1. The Tweet dataset

Crises or extreme events	No. of tweets	Date
Cathay Pacific data breach	39,819	7 days (25/10/2018-31/10/2018)
Marriot International data breach	30,916	7 days (30/1132018-06/12/2018)
O2 UK day-long outage	25,243	7days (06/12/2018-12/12/2018)
United Airlines overbook incident	55,083	48 hours (09/04/2017-11/04/2017)
Mars/Snickers product recall	10,930	10 days (23/02/2016-03/03/2017)
Fiat-Chrysler dieselgate	4,303	7 days (10/01/2019-16/01/2019)

Prior to the analyses, the Twitter datasets are normalised and tokenised (Liau and Tan, 2014) in the QDA Miner software package to stem and remove stop words. Other high frequency but pointless words (e.g., HTTP, HTTPS, RT, etc.) are also removed and common misspellings are corrected.

Word Count Analysis

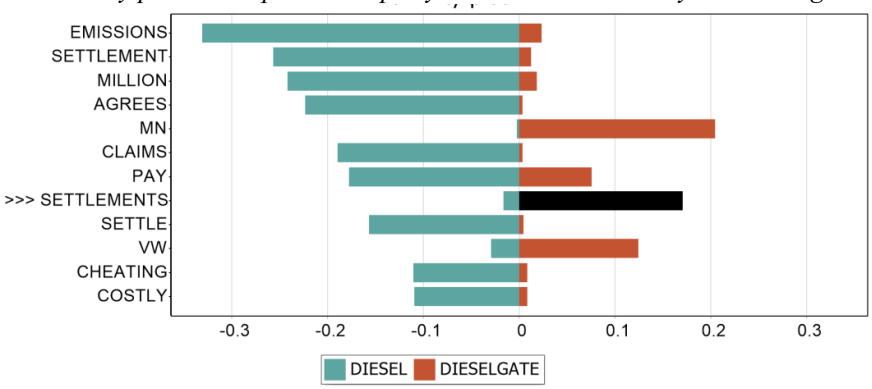
For word count analysis, the QDA Miner is used to generate word count frequency (Table 2) and predict the popular topics from the textual data. The major characteristics are also extracted in the proximity plot (Figure 2) (Mostafa, 2013).

Table 2. Word frequency table for the top 10 keywords

DATASET	KEYWORDS 1-5	FREQUENCY (CASE %)	KEYWORDS 6-10	FREQUENCY (CASE %)
Cathay Pacific Data Breach	MILLION	5383 (13.37)	INFOSEC	2833 (7.11)
	PASSENGERS	4589 (11.38)	USER	2728 (6.79)
	CYBERSECURITY	3817 (9.43)	SERVERS	2663 (3.39)
	REACH	3623 (7.43)	AIRLINE	2138 (5.18)
	RATAN	3369 (7.39)	PERSONAL	1990 (4.96)
Marriot International Data Breach	SECURITY	8634 (26.54)	GUESTS	4093 (12.98)
	MILLION	8418 (26.28)	AFTER	3604 (11.53)
	LEAK	6475 (20.69)	STARWOOD	3069 (9.56)
	GOOGLE	5368 (12.65)	CYBERSECURITY	2553 (8.07)
	HOTEL	5619 (17.76)	USERS	2363 (7.42)
O2 UK Day-long Outage	NETWORK	19828 (74.19)	OUTAGE	2378 (9.09)
	DATA	5283 (19.79)	EASILY	2294 (9.09)
	CUSTOMERS	3376 (11.88)	SIZE	2293 (9.08)
	MOBILE	3009 (10.54)	STRONGER	2293 (9.08)
	SERVICE	2431 (9.16)	JONNYGABRIEL	2288 (9.06)
United airlines Overbook Incident	PASSENGER	21111 (38.03)	PLANE	10965 (19.80)
	FLIGHT	20462 (36.42)	MAN	10269 (18.47)
	DRAGGED	16681 (30.19)	AFTER	7767 (14.04)

	CEO	12959 (22.93)	FORCIBLY	6645 (12.02)
	OVERBOOKED	11917 (21.52)	VIDEO	6511 (11.79)
Mars/Snickers Product Recall	CHOCOLATE	4264 (36.57)	ISSUES	1142 (10.39)
	BARS	3894 (33.91)	GERMAN	974 (8.90)
	COUNTRIES	3222 (28.59)	MASS	926 (8.48)
	PLASTIC	3275 (29.64)	PRODUCTS	868 (7.77)
	CANDY	1773 (15.89)	WIDENED	806 (6.58)
Fiat-Chrysler Dieselgate	EMISSIONS	2010 (44.95)	CHEATING	773 (17.78)
	MISSION	1478 (32.93)	VEHICLES	671 (15.22)
	PAY	1261 (27.31)	CASE	607 (13.06)
	DIESEL	1097 (23.36)	SETTLE	563 (12.74)
	SETTLEMENT	852 (19.36)	RECALLS	486 (10.13)

Figure 2. Proximity plot to compare the top keywords in the Fiat-Chrysler Dieselgate dataset



Cluster Analysis

The popular topics are developed based on the keywords and their co-occurrence by using Multi-Dimensional Scaling (MDS). A matrix of distances between the popular topics are calculated to generate key topic groups (Table 4).

Table 3. Key topics of the datasets

DATASET	Key Topics
Cathay Pacific Data Breach	*'**MILLIONS** of **PASSENGERSHIT** in **WORST** ever **AIRLINE** data hack link'*
	*'**AIRLINE** hack exposes 10 **MILLION** people's most personal information'*
	*'Cathay Pacific HIT by data leak affecting 9.4 **MILLIONPASSENGER** link'*
	*'Hong Kong carrier #CathayPacific is under pressure to explain why it took five **MONTHS** to admit it had been hacked and **COMPROMISED** the data of 9.4 million customers, including passport numbers and credit card details'*
	*'Just checked my email and yes, it turns out I am one of the 9.4 million Cathay Pacific passengers whose personal data has been **COMPROMISED**. Why wait 7 **MONTHS** to disclose this to the public? Link via @SCMPNews'*
	*'Post-breach, Cathay Pacific hit by **GROUPACTION** by UK **LAW** firm link via gcluley'*
Marriot International Data Breach	*'The world's biggest **HOTELCHAIN** Marriott **INTERNATIONAL** disclosed that unknown #hackers **COMPROMISEDGUESTRESERVATIONDATABASE** its subsidiary **STARWOOD** hotels and walked away with **PERSONALDETAILS** of about 500 **MILLIONGUESTS**. #CyberCrime link'*
	*'**FACEBOOK** exposed the **PRIVATEPHOTOS** of 6.8 million users back in September, but is only now admitting to the data breach'*
	*'Thanks to a second data leak, Google+ will shut down sooner than anticipated. Read more: https://t.co/9gyJ4GVmyt #technology #**GOOGLEPLUS** Link'*
	*'Google will **SHUT** down **GOOGLEPLUS** four MONTHS EARLY AFTER second data **LEAK** #gafe Link'*
	*'**DATABREACH**: Marriott, between 2014-2018?? #security #databreach Marriott HIT By Massive Data Breach, One Of **BIGGEST**?'*
	*'Marriott's breach **RESPONSE** is so **BAD**, security **EXPERTS** are **FILLING** in the **GAPS** ? at their own **EXPENSE**'*
O2 UK Day-long Outage	*'DATA **PROBLEMS** HIT O2 **MOBILE NETWORK** LINK'*
	*'**BREAKING** O2 down **ACROSSUK** as **CUSTOMERS** HIT by **NETWORK** and 4G **PROBLEMS** LINK'*
	*'@O2 I can't make voice calls. It says I have no **NETWORK**. Why are o2 saying this is Only a **DATA** issue? Myself and my partner cannot make calls'*

	*'O2, **BRITAIN**'s second **BIGGEST** network, reported network outages, leaving many customers unable to access internet services. h?'*
	*'Customers on one of **BRITAIN**'s **BIGGEST** mobile **NETWORKS** have found themselves with no service. O2 says it's **INVESTIGATINGISSUES** with its 4G network. Customers on Tesco Mobile and GiffGaff have also been hit by the outage.'*
	*'thank you for doing your best in restoring your network Appreciate the effort your teams put into it! Too many people rely on their mobile phones nowadays...it's not the **END** of the **WORLD**'*
	*'@O2 so I went a day without 4G, lost a days work, missed **IMPORTANT** emails and then I receive this today. Are you actually having me on? #o2outage'*
	*'Avengers 4: We're very sorry for Thursday's network issues. We **UNDERSTAND** how **IMPORTANT** it is to stay **CONNECTED**, especially this time of year. You'll receive a credit for two days of your monthly airtime subscription charges by the end of January.'*
	'*O2 blames network borkage on **SOFTWARE** glitch affecting third-**PARTY** supplier'*
	*'O2 network down: O2 blames **'GLOBALSOFTWARE** issue**'** for O2 data **OUTAGE** that prevents people from using 3G or 4G across the UK | City A.M.'*
	*'@O2 Whatcompensationcanweexpectfrom yesterday's outrageous network blackout? Have a **BUSEINSS** to **RUN** here!'*
	*'@O2I**RUN**my**BUSEINSS**onyournetwork, I assume you'll put out a link for compensation?'*
	*'We survived the war we can survive a no deal **BREXIT**!.... though admittedly we'll struggle if the O2 network goes down for a few hours...'*
	*'Fights when there's no chicken, People losing their **SHIT** without the O2 network. No **DEAL BREXIT** is going to be carnage.'*
United airlines Overbook Incident	'*United **DRAGGING** a **PASSENGER** from **OVERBOOKEDFLIGHT** was lesson in stupidity - LA Times'*
	'*That **PASSENGERDRAGGED** Off That **FLIGHT'***
	*'MAN gets **DRAGGED** off of United Airlines just bc FLIGHT was **OVERBOOKED**& no one voluntarily got off so they picked a guy and **DRAGGED** him out'*
	*'@united CEO OSCAR MUNOZ issued a **LETTER** defending his **EMPLOYEES**, saying the passenger was being ???DISRUPTIVE and **BELLIGERENT**. Seriously?'*
	*'@Mikel_Jollett @united **CEOMUNOZ** CALLS him **"DISRUPTIVE** AND **BELLIGERENT"** in EMAIL TO EMPLOYEES #LIAR RESIGN NOW! #united3411 #wtf #cnn'*
	*'MUNOZ is a moron United **CEODEFENDSACTIONS** of STAFF in VIRAL video, as lawmakers CALL for investigation'*
	*'**#NEWUNITEDAIRLINESMOTTOS** FLY **United** - Now with a free, priority **DRAG** off **SERVICE** randomly available to all **PAYINGPASSENGERS'***
	*'Non-PAYING #United Airlines employees more important than PAYING CUSTOMERS. FLY with #United and get ASSAULTED. The not so **FRIENDLYSKIES**.'*
	*'FLY the **FRIENDLYSKIES**...on Some Other **AIRLINE**. **#NEWUNITEDAIRLINESMOTTOS'***
	*'I'm absolutely disgusted, @united! I HOPE that POOR man will SUE the **HXXL** out of the **COMPANY**. #unitedAIRLINES #disgusting'*
	*'@united HOPE you get the **SXXT** sued out of your COMPANY, FXXKING disrespectful degenerates. **FXXK** you and your employees #neverflyunited'*
	*'I HOPE HE SUES THE HXXL OUT OF THIS **FXXK** AXS **AIRLINE'***
	*'Unbelievable. "Reaccommodate?" WATCH: **JIMMYKIMMEL** created a brutally honest COMMERCIAL for United Airline'*
	*'I had to share this. Too funny last night! United Airlines **COMMERCIAL** (**JIMMYKIMMEL** LIVE)'*
Mars/Snickers Product Recall	*This is the focal group which has the highest frequency words - "**CHOCOLATE**", "**BARS**", "**PLASTIC**", "**RECALL**", "**GERMAN**" – 'chocolate recall: Mars and Snickers bars in Germany contain plastic.'*
	*"**BIGGEST**", "**FOOD**", "**DRINK**", "**HISTORY**" – 'Mars recall spans 55 countries: is this the biggest food and drink recall in history?'*
	*"**CHOCCY**", "**HORROR**", "**CONFECTIONER**" – '**CHOCCYHORROR**, the recall of chocolates by confectioner Mars makes several front pages'*
	*"**ANNOUNCED**", "**MASSIVE**", "**BITS**" - 'Mars has issued a massive recall of chocolate bars after bits of plastic were found.' and 'Mars and Snickers just announced a massive recall in 55 countries.'*
	*"**NETHERLANDS**", "**PRODUCTS**" "**MANUFACTURED**" – 'AVA issues recall of Mars chocolate products manufactured in the Netherlands.'*
	*"**FUN**", "**SIZED**", "**WORSE**" – 'the mars candy bar recall is anything but fun-sized...and it just got worse.'*
	*"**MILKY**", "**SINGAPORE**" – 'AVAsg issues recall of Dutch-made Mars, Snickers and Milky Way chocolates in Singapore.'*
	*"**WIDENS**", "**SUPERMARKET**", "**MULTIPACKS**", "**UK**"– 'Mars chocolate recall widens to supermarket multipacks.' and 'Mars widens recall of chocolate to include UK after plastic found in bars.'*
	*"**CONTACT**", "**CARE**", "**HAPPY**", "**TEAM**", "**GOOD**" - 'Please check your product if it is labeled with Mars Netherlands, if it is, please contact your local consumer care team.' and 'Hi Ami, that's no good! Give our UK chocolate team a call at 800-862-6293. We'd be happy to help you out.'*

	*"**REMOVE**", "**SHELVES**", "**DFS**" – '**DFS** in Singapore removes Mars products from shelves following global recall.' and 'Mars, Snickers Milk Way and Celebrations pulled from shelves after plastic found in chocolate.'*
	*"**COST**", "**FIRM**", **MILLIONS**" - 'Mars, Snickers and Celebrations recall could cost firm millions.'*
	*"**CHILD**", "**FINDS**", "**FREE**" – 'Mars, don't recall your Mars Bars, simply offer any child who finds a plastic ticket a free Wonka-style tour of your chocolate factory.'*
	*This is the focal group which has the highest frequency words - "**CHOCOLATE**", "**BARS**", "**PLASTIC**", "**RECALL**", "**GERMAN**" – 'chocolate recall: Mars and Snickers bars in Germany contain plastic.'*
	*"**BIGGEST**", "**FOOD**", "**DRINK**", "**HISTORY**" – 'Mars recall spans 55 countries: is this the biggest food and drink recall in history?'*
	*"**CHOCCY**", "**HORROR**", "**CONFECTIONER**" – '**CHOCCYHORROR**, the recall of chocolates by confectioner Mars makes several front pages'*
	*"**ANNOUNCED**", "**MASSIVE**", "**BITS**" - 'Mars has issued a massive recall of chocolate bars after bits of plastic were found.' and 'Mars and Snickers just announced a massive recall in 55 countries.'*
	*"**NETHERLANDS**", "**PRODUCTS**" "**MANUFACTURED**" – 'AVA issues recall of Mars chocolate products manufactured in the Netherlands.'*
Fiat-Chrysler Dieselgate	*'FinancialReview .fiat Chrysler will PAY about $US800 **MILLION** in fines and costs to **SETTLE** US **LAWSUITS** that said the **COMPANY**'s cars violated clean-air rules.'*
	*'Fiat Chrysler **AGREES** to **EMISSIONSSETTLEMENT** WORTH $800M'*
	*'Fiat Chrysler to pay $515 MN in US '**DIESELGATE**' **SETTLEMENTS** Link'*
	*'Fiat Chrysler agreed to pay **HUNDREDS** of **MILLIONS** of **DOLLARS** to settle lawsuits accusing it of it rigging certain diesel-powered pickup trucks and Jeeps with illegal software to pass emissions tests. '*
	*'**EPS** for Fiat Chrysler AUTOMOBILES N.V. (**FCAU**) Expected At $1.01'*
	*'Fiat Chrysler AUTOMOBILES N.V. $**FCAU** Analysts See $1.01 **EPS'***
	*'It's hard to give credit to this administration for this settlement when @EPAAWheeler's EPA is still working to roll back emissions and fuel economy standards that will harm our **PUBLICHEALTH**, especially our children. #MomsDisapprove'*
	*'Fiat Chrysler to pay around $650M in emissions cheating case $FIATY #FIATY **#POLLUTION** #Environmentalconcerns **#ENVIRONMENT**https://t.co/BUvgfNID8c'*
	*'38,000 people a year die early because of diesel emissions testing failures | **ENVIRONMENT** | The Guardian #vw #dieselgate **#POLLUTION** #diesel #volkswagen #Germanauto #dasauto #citypollution'*
	*'FCA Will Pay Nearly $800 Million to Settle Diesel Emissions Claims **VOLKSWAGEN**'s emissions-cheating SCANDAL may have **GARNERED** the most **HEADLINES**, but it's not the only **AUTOMAKER** that's gotten into TROUBLE with its diesel ENGINES. In a STATEMENT, Fiat CHR?'*
	*'Dieselgate is back? **VOLKSWAGEN** again suspected manipulation of diesel'*
	*'Fiat Chrysler **RECALLS** 1.6M **VEHICLES** to **FIX** TAKATA AIR BAGS $TM #TM #Automobilerecalls #Automobilesafety #Productsafety'*

Sentiment Analysis

The sentiment analysis is applied to understand the motive behind the tweets. This study uses the lexicon-based method to the tweets to measure the semantic orientation, adopts the SentiStrength classifier (Thelwall et al., 2010) to analyse the sentiment expressed in the tweets.

Table 4. the overall sentiments of the datasets

Crises or extreme events	Overall sentiments
Cathay Pacific data breach	-0.570
Marriot International data breach	-0.704
O2 UK day-long outage	-0.502
United Airlines overbook incident	-0.413
Mars/Snickers product recall	-0.262
Fiat-Chrysler dieselgate	-0.581

Social Network Analysis

The social network analysis (SNA) (Coombs, 2002) is performed to identify the key stakeholders who are accounted for the information distribution. NodeXL is employed to calculate the in-degree (the total mentions of a twitter account), eigenvector centrality (the total connections to other influential accounts) and betweenness centrality (the numbers of shortest connections with other non-neighbouring accounts) of each account in the network.

Figure3. The O2 UK Day-long Outage dataset network based on Mention (@)

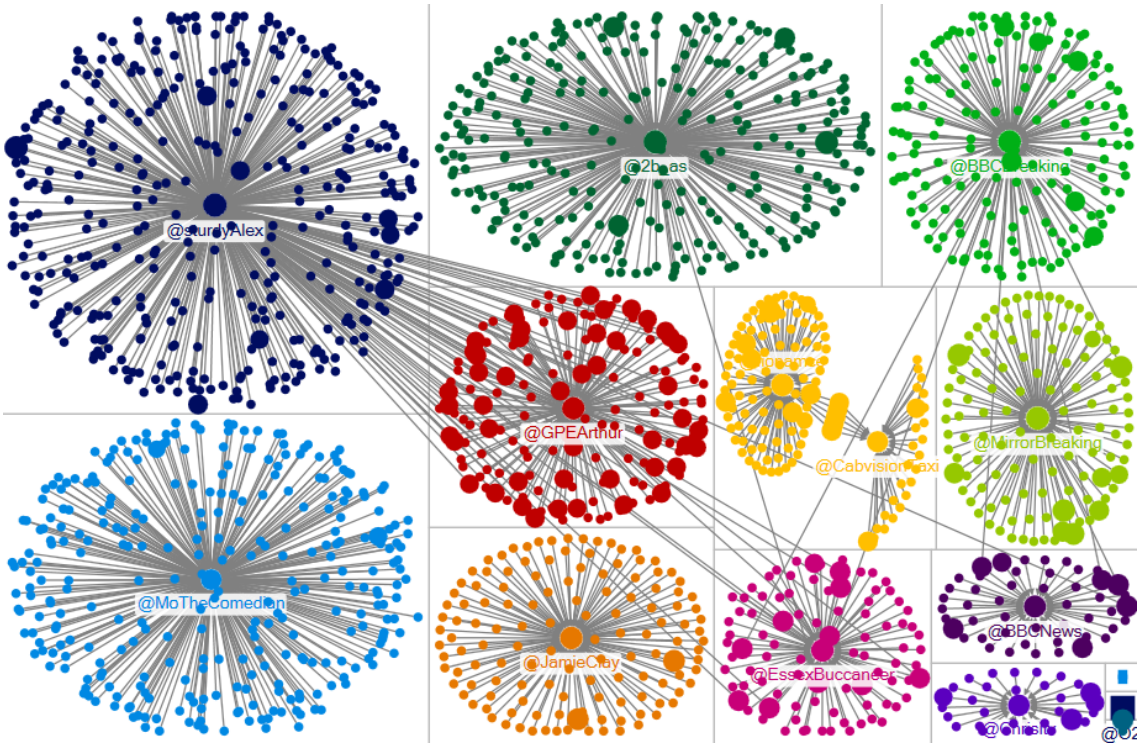


Table 5. the top 10 stakeholders based on in-degree, eigenvector centrality and betweenness centrality for the O2 UK Day-long Outage dataset

In-degree	Eigenvector Centrality	Betweenness centrality
@sturdyAlex(425)	**@sturdyAlex** (0.00252)	@tomthemac (2828340)
@MoTheComedian (299)	@Un1v3rs4L (0.00067)	@chriswb (1673679)
@2b_as (271)	@AshleyW12945493 (0.00067)	@ioniqman (1193729)
@BBCBreaking (159)	@kerrybroughton (0.00067)	@xa329 (995606)
@GPEArthur (147)	@HammerForLife (0.00067)	**@sturdyAlex** (838681)
@JamieClay (130)	@squired (0.00067)	@Shomer1Steve (838460)
@MirrorBreaking (114)	@A_Munn (0.00067)	@shellwinfrey (838460)
@fionamce (95)	@dentin_dentin (0.00067)	**@EssexBuccaneer** (618772)
@EssexBuccaneer (89)	@ruskin147 (0.00067)	**@2b_as** (572130)
@BBCNews (48)	@Jojobkk17 (0.00067)	@paracord_pete (555424)

Results and implications

The word count frequency presented in Table 2 provides the basic tweet information on each dataset, the results help to construct key topics, identify main stakeholders, compare relationships between incidents and lay down the foundations for later sentiment analysis. In Table 2, the top keywords from each dataset are those mainly used to describe the crisis

situations, the cause of the crisis and the public expectations. They form the main topics during the crises which link to the main stakeholders. For instance, the keywords used in the Fiat-Chrysler Dieselgate dataset are related to the RECALL due to the VEHICLES EMISSIONS CHEATING, and expecting SETTLEMET PAY. In Figure 2, these keywords are compared against 'DIESEL' problem and the 'DIESELGATE' crisis. It can be noted that stakeholders have mentioned more about whether or not AGREES have been given to SETTLE the DIESEL problem, compare the stakeholder in the DIESELGATE who are more concerned with the cost in MN (millions) to SETTLE.

Table 3 highlights the important and related keywords and how they form popular topics. For instance, tweets to describe the crisis incidents, provide information about the impacts are affected areas, products are focal topic groups in every datasets. However, there are also tweets, although less, that form topics to offer suggestions and give feedback (to reduce the crisis impacts), asking questions (to fix the problem). In addition, there are also tweets represent groups to express jokes (schadenfreude) and sending disappointed messages (blame).

From the results of the SentiStrength classifier illustrated in Table 4, the overall average sentiment of all between the band distribution of circa -1/+1, which may indicate that some tweets are not very affective (Mostafa, 2013) and suggest a more detailed analysis to look into the sentiment score of each topic group/stakeholder groupand at different timeframe for more meaningful explanations (Cao et al., 2018).

The results of the SNA to the O2 UK Day-long Outage dataset is illustrated in Figure 3 and explained in Table 10. Each of the three metrics used in this study indicate the influence of the tweeter users, such as a high in-degree indicates a high fluence of the account, a high eigenvector centrality represents a large number of connections with other influential accounts, and a high betweenness centrality shows an account with the most numbers of shortest connections with other non-neighbouring accounts. In this study, the key influential stakeholders are listed in Table 10. In particular, **@sturdyAlex** is the most influential stakeholder, as this account has the highest in-degree and eigenvector centrality, and a high betweenness centrality within the top 10 range. **@2b_as** and **@EssexBuccaneer** are two other important influential stakeholders.

Conclusion and recommendations

By adhering to Sedereviciute and Valentini's (2010) holistic approach to stakeholder mapping, within the context of several novel and important crises, this research has uncovered a few important research notes. These are:

i. Concerned and definitive stakeholders have the capacity to shape crisis-related conversations based on their position within social media networks. For example, **@sturdyAlex** was seen to influence the narrative through a central position.
ii. Once categorised as non-powerful, non-urgent, and illegitimate, these undiscovered online stakeholders require responses from crisis-stricken organisations in order to control and mitigate reputational damage, as was seen in the O2 outage case.
iii. The combination of SSM and SNA facilitates the identification of new, undiscovered online stakeholders, which are integral in the narrative, tone, and longevity of crisis situations and their manageability.

To advance this research effort, and to generate managerial implications, the authors call for

further research on online stakeholders, especially those on Twitter, to identify the timeframe in which they are *powerful, urgent, and legitimate.* This can then be mapped against company response. Scholarship could also compare online stakeholders with offline counterparts to review salience across channels.

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Understanding Value of Social Media in Supply Chain Management

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Abstract

The purpose of the paper is to extend the social media analytics frameworks reported in the existing literature to create value from the data captured from heterogenous social media and IoT sources in a global supply-chain. The paper will aid the practitioners to understand the importance of focussed analysis and the key requirements for this analysis by offering a guide to organisational needs. The framework and requirements proposed in the paper will aid managers to capture value from the data (i.e. gain key insights) and augment human decision-making.

Keywords: Social Media, Analytics framework, Value creation

Introduction

Social media has become a major phenomenon for different organisations globally, and the field of supply chain management has slowly recognised its value for organisations (Chae, 2015). Companies are creating their own online platforms to interact with customers (Correia Loureiro, Serra, & Guerreiro, 2019) or collecting information to use it to enhance customer loyalty (Gamboa & Gonçalves, 2014) and to improve the products offered to consumers. The purpose is to "win with data" (Hopkins & Lavalle, 2010). This perspective is very appealing because technological advances and the increase use of social media by customers.

How to properly harness the benefits of social media in supply chain management, however, it is still a growing area. Information from a multitude of sources is collected and analysed to take advantage of it, but that can become a complex and time-consuming task because of the large volume, variety and velocity of the data, along with its unstructured state (Singh, Shukla, & Mishra, 2018). This is an important consideration because poor quality of data can render the data useless (Hazen, Boone, Ezell, & Jones-Farmer, 2014). This paper states that a different approach is required. Instead of only looking at the volume and the quality of the data, it is important to start looking at the question that the data is trying to answer.

Current analytics frameworks assume that value is created at the final stages, once analytics are applied to the information to find some trends/insights. This article presents a review of two case studies in supply chain management to identify the important elements that create value from the use of social media and redefine current analytics framework. From a more practical perspective, this paper is looking at the most beneficial approach to create value for decision-makers. The objective is to offer a conceptual framework that can be used by stakeholders to take advantage of social media for value creation.

The contribution of this paper is to change the current paradigm from a more "exploratory" analysis of social media data to a focused process introducing "value creation" as a stage defining and guiding the analysis. This shift can become beneficial to address several of the shortcomings identified in the literature about the use of social media in organisations. The paper is also providing a guide with the value creation requirements and organisational needs to exploit the benefits of social media.

Cases

Currently, the role adopted by the social media is increasing world-wide with the advances of cross-platform Web 2.0 applications and services (Palen, Starbird, Vieweg, & Hughes, 2010). To analyse the impact of social media in the supply chain and to identify the needs to exploit its potential impact, this research is looking at two different supply chains: retail and humanitarian. Both supply chains have similar components, but the objectives and strategy of each one of them exhibit significant differences, allowing the authors to identify the common elements to exploit social media in supply chain management.

Case study: Zara

Zara has been a very interesting case in operations for a long time because of the fast response and flexibility stemming from their practices (Kasra Ferdows, Machuca, & Lewis, 2015). The concept of fast fashion and the high level of vertical integration applied by this company has shown the value of staying at the forefront of operations and its impact on performance. Zara is part of the Inditex group, with more than 650 stores over 50 countries (K. Ferdows, Lewis, & Machuca, 2004) which has led them to achieve nearly 75% of sales of the whole group (Kasra Ferdows et al., 2015).

Speed is an essential quality in the fashion industry. Responsiveness is one of the goals of different companies, but Zara is able to claim achieving responsiveness because of the agility embedded in its supply chain (Kasra Ferdows et al., 2015; Martínez, Errasti, & Rudberg, 2015) as a result of the high level of control rom the supply of materials until the customer purchases the garments (K. Ferdows et al., 2004). For instance, Zara has

been able to introduce new items of clothing to its different stores in around two weeks, from design until delivery (Kasra Ferdows et al., 2015).

Zara has been able to thrive by leveraging new technologies to support its fast fashion approach. The high degree of control over the different links of the supply chain has allowed Zara to have better information sharing as part of their supply chain. Knowledge from the links directly in contact with the customer in the supply chain have allowed the company to be more responsive, using private systems to reduce delays, and enhance the quality and attractiveness of the garments.

With the development of Web 2.0, e-commerce has become a valuable channel to sell products and services. Zara has taken advantage of that opportunity to make their products available to consumers (Fondevila Gascón, Del Olmo Arriaga, & Bravo Nieto, 2012; Gamboa & Gonçalves, 2014) and leveraging from brand enhancement from electronic word of mouth (Correia Loureiro et al., 2019). Similarly, consumers are taking a more prominent role through new communication channels opened by Web 2.0. The introduction communication channels supporting many-to-many interactions have allowed consumers to participate and even collaborate with companies (Gamboa & Gonçalves, 2014). Therefore, several companies are using online platforms in which customers can take part to become closer to the company (Correia Loureiro et al., 2019)

Social media has become a new battlefield for fashion companies because it has become essential to shape the reputation of the brand and achieve customer loyalty (Fondevila Gascón et al., 2012). Zara is the example of an organisation that has embraced social media, as it is one of the fashion companies with the highest number of fans on Facebook (Gamboa & Gonçalves, 2014), which allows them to enhance the engagement with consumers (Fondevila Gascón et al., 2012) and advertise new products and relevant updates about the brand (Correia Loureiro et al., 2019).

Zara's engagement in social media involve constant interaction with customers and posting photos and videos with relevant content (Correia Loureiro et al., 2019), which has paid-off with an increased level of customer loyalty (Gamboa & Gonçalves, 2014) and improved advertising strategies, but it has also carried some challenges. For multinational organisations it is important to consider decentralisation, language, culture and campaign coordination across markets (Fondevila Gascón et al., 2012). The evolution of the content provided and aligning social media to the strategy of Zara is essential to continue enjoying the benefits of social media.

Occupy Sandy: Social media for disaster relief

U.S. Congresswoman Susan Brooks stated in 2013 the importance of social media and technology in disaster management, as well as the value of digital volunteers to enhance the potential of social media and increase situational awareness (Kirac & Milburn, 2018).

A good example of the potential of social media in disaster management is the situation occurred after Hurricane Sandy hit the US. Hurricane Sandy has been one of the costliest disasters that have affected the United States of America. The disaster had devastating impact in several states of the country after growing into a category 3 Hurricane (Yoo, Rand, Eftekhar, & Rabinovich, 2016), striking the East coast in October 2012. It was challenging for FEMA to cope with the situation because of the scale of the disaster, which allowed a small group stemming from the Occupy movement to show the potential of social media to support disaster management with their activities in Brooklyn (Feuer, 2012). In fact, disaster response from the Occupy movement was quicker than larger and more established organisations such as FEMA and Red Cross (Kavner, 2012).

Social media has been heavily linked to disseminating information in disaster situations and to target search and rescue activities (Panagiotopoulos, Barnett, Bigdeli, & Sams, 2016), but the potential of these tools go beyond that. FEMA has recognised the value of social media have a two-way conversation with people and to look at them as resources (Tobias, 2011). This was experienced after Hurricane Sandy hit the US, because the occupy movement was able to set-up communication hubs to re-establish communication and use it to create an emergent supply chain.

Procurement was performed appealing at donations from citizens in two ways. Financial donations using Webpay (Webpay, 2012) were collected to finance response activities and projects, with a total tally of $1,361,337.19 (Occupy, 2013). On the other hand, in-kind donations were also encouraged through the use of Amazon's wedding registry (Occupy, 2012) . In this alternative, an updated list of the most needed items in ravaged areas was posted online for donors to but the items directly and use Amazon retail services to deliver the items to one of the outposts from the movement (Feuer, 2012). The collection of in-kind relief was successful as well, as shown by the delivery of over 35,000 items in few weeks after the storm hit (Islam, Vate, Heggestuen, Nordenson, & Dolan, 2013). They used Sahara Eden to request assistance, to print waybills with items and delivery areas, and to track requests (Homeland_Security, 2013)

Exploiting both supply channels represented operational challenges to manage the relief. The relief was delivered to Occupy Sandy distribution sites split between two churches in Brooklyn, which were the facilities used to deploy relief end volunteers to affected areas (Kavner, 2012). Coordination of these volunteers and relief can become problematic task, especially with numbers between 5,000 and 10,000 volunteers (Homeland_Security, 2013). The Occupy movement used communication systems to enable collaboration by matching human resources with the required activities (Kavner, 2012; Occupy, 2012). That way, a set of borrowed cars and trucks were used to move items and people from the distribution hubs to the affected areas (Feuer, 2012) with the purpose of providing further support to the victims and distribute the relief available.

The size of the occupy movement, however, was not enough to supply all the affected areas. The integration of different organisations and initiatives quickly became a priority to manage operations. That is the reason a link between formal and informal response efforts was essential. Geeks without Bounds became that link for Occupy Sandy, allowing them to coordinate with FEMA and other formal organisations to make operations more efficient (Homeland_Security, 2013). Additionally, they provided situational awareness through crowd mapping. They worked with Hurricane Hackers NYC to provide a map of the affected areas (Homeland_Security, 2013). Therefore, the Occupy movement was able to use public social media as an enabler to create an emergent organisation to provide support online and on the ground (Kavner, 2012). Overall, Occupy Sandy was able to leverage social media across different parts of the supply chain to support disaster affected areas. The collaboration among different links of the supply chain, the constant monitoring of physical and financial aid, the ability to match supply and demand to coordinate different stakeholders, and the use of crowdsourcing to enhance information during the event are some of the examples of the potential of social media in these situations.

Framework

In this section, we extend the existing social media analytics framework (Figure 1) to include a value creation stage, which will aid the decision-makers and relevant supply-

chain entities to understand the purpose of using the analytics for processing the big data captured from social media sources. The key challenge with the voluminous and heterogenous data collected from different sources are lack of focussed analysis (i.e. what do we want from the data) and trying to find a pattern (generate insights without knowing what exactly we are exploring). Thus, the proposed framework extends the existing social media analytics frameworks reported in the extant literature (Lee, 2018; Stieglitz et al., 2018; Holsapple et al., 2018; Chae, 2015)

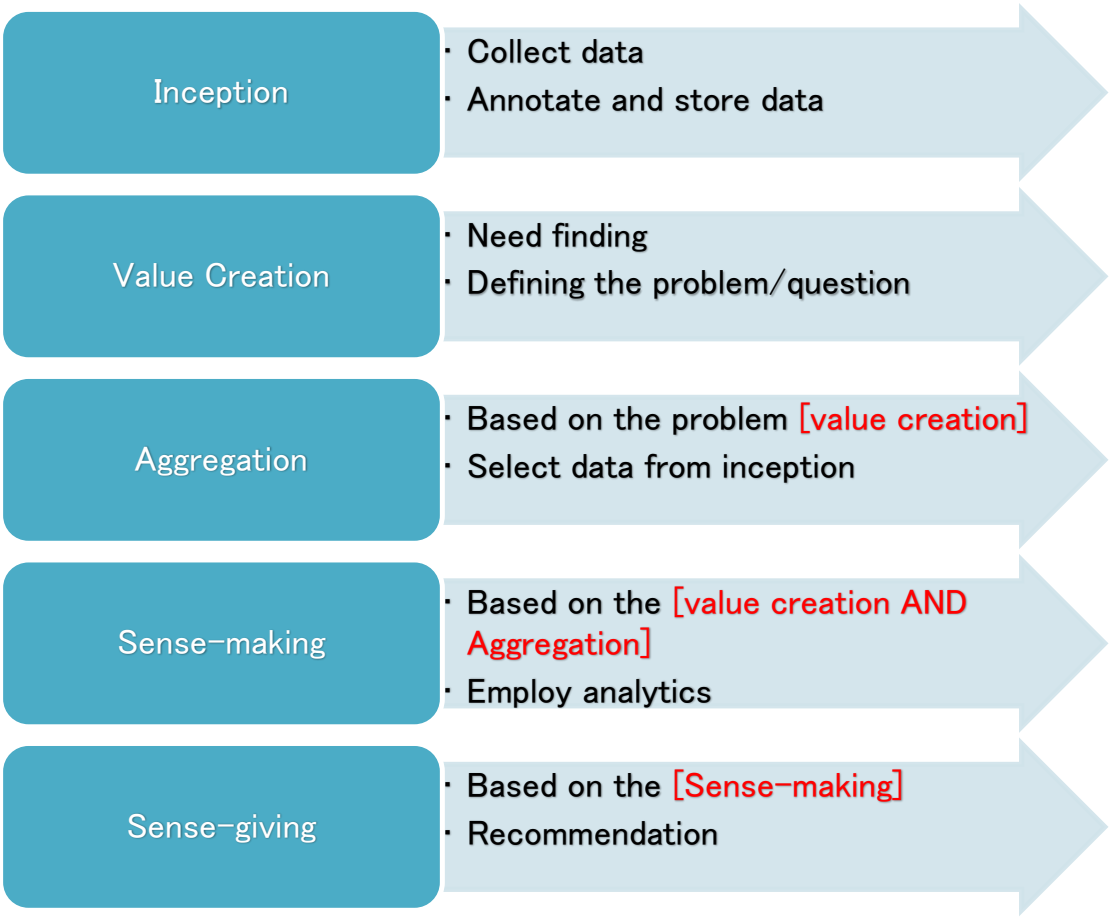

Figure 1: Analytics process to create and capture value from social media data

- ***Inception:*** The primary activities in this stage are collecting the data, followed by cleaning it (i.e. formatting with suitable annotations), then storing it in a structured-way for future use. The primary deliverable is not only a data repository but a report that can guide the next stage, where managers will identify the value of the stored data for purposeful use.
- ***Value Creation:*** This stage is essential to the outcome of the analytics and a component that has seldom been considered in the existing analytics frameworks. The main idea is for managers to use the inception report to understand what data is available from various social media sources and define the questions that they would like to pose to make the analysis focussed. The focussed analysis will aid in capturing value from the process and aid human-decision making.

- ***Aggregation:*** The relevant data from the inception stage will need to be integrated into a consistent format suitable for analysis (basic analytics and advanced analytics). The data selection will depend upon the problem (questions posed by the decision-makers), thus making the both the analysis and outcome focussed and purposeful (Govindan et al, 2018).
- ***Sense-making***: The sense-making stage will employ algorithmic procedures depending upon the questions posed by the managers (in the value creation stage). This stage will include two deliverables: (1) a summarised snap-shot of the data which will help to gather suitable information from the data (which is likely to be voluminous and gathered from heterogeneous sources); (2) output of the analytics employed (such as predictive, prescriptive) using machine learning techniques (Fan and Gordon, 2014). The summary and output will help the managers to capture value from the data, i.e. gain suitable insights for the problem/question identified in the value creation stage, which in-turn will aid in formulating recommendations thus reducing the information and cognitive overload.
- ***Sense-giving:*** This final stage will present the information (summary and output of the analytics) in a visual form, which is intuitive and easy to understand using suitable pictorial representation (such as linked-graphs, trees, filters). The visual representation will help the mangers to have a high-level understanding of the output and offer further drill—down to understand the rationale behind the recommendations (for a recommender system), which ought to depend upon historical information (data bias), heuristics used in the analysed (factor weighing) and source as well as type of data (textual, numerical values, audio and videos).

Overall, the proposed framework demonstrates the importance of value creation stage, which drives all the other stages in the analytics framework towards a focussed analysis. The outcome of the analysis will aid managers to understand the value of the data and have the potential to optimise business processes.

Organisation Needs

This section will discuss the key needs for an organisation to use the proposed framework for creating value and eventually capturing it through the analytics process. The key elements comprise of resources and activities that will aid organisations to build capabilities (such as technology, tools, skills) for successful deployment of the initiatives. The key elements (Figure 2) for consideration are as follows.

- ***Organisation culture:*** This represents the willingness and attitude of the business organisation (managers and team) to invest in contemporary initiatives (data-driven vale creation), appreciate the associated long-term and short-term risks, and evolve the process over time (i.e. remain agile to the advent of technology and novel data contribution platforms). The mindset of the organisation will determine the keenness to take risks, make changes and evolve to create and capture value using data-driven initiatives.

- ***Skills requirements:*** This element pertains to the ability of the organisation, decision-makers, and key employees to understand, manage and align the value creation process to deliver the business needs of the organisation. Additionally, ability to create strategies that will co-ordinate and streamline business and

technical capabilities is pivotal for value creation and capture. It also requires managers to interpret and recognise the information presented in the sense-giving stage to make decisions.

- ***Identifying relevant data sources:*** This relates to identifying, capturing and storing real-time data obtained from social and physical sensors that will aid the organisation in creating value, which requires understanding of the data and business needs of the organisation. This element will require domain expertise (i.e. understanding the business needs to identify relevant sources) and knowledge about the analytics framework (not necessarily technical but conceptual).
- ***Relevant Tools:*** This represents the technological needs of the organisation to harvest relevant insights from the data, i.e. transform data into knowledge using suitable analytic tools, and infrastructure to support such techniques. It requires making decisions for purpose of the analytics to capture value, a strategy to identify and invest in the resources.

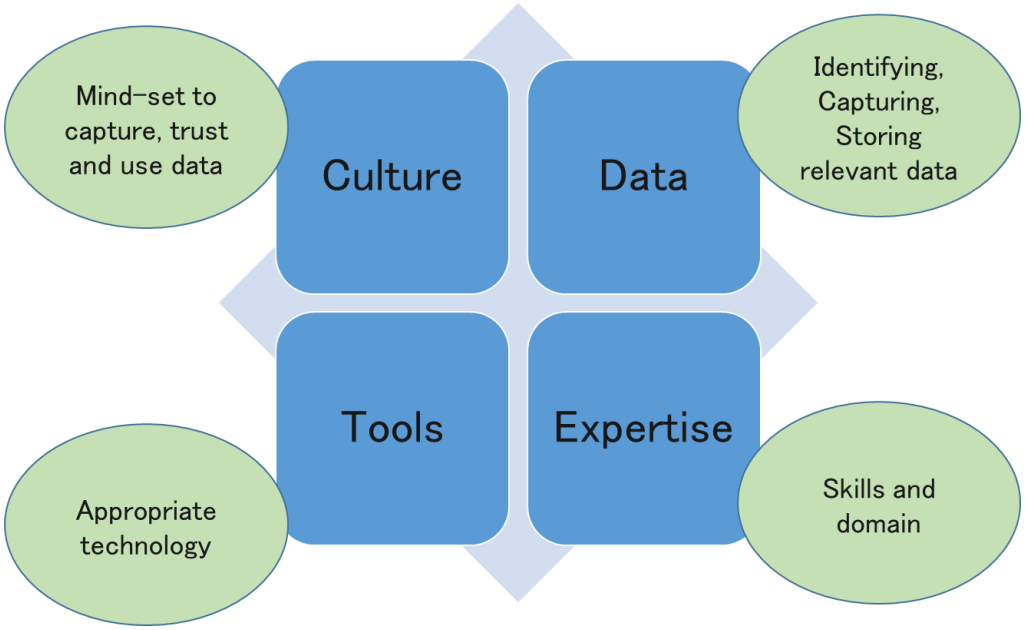

Figure 2: Needs of the organisation to employ the proposed analytics framework

Value creation process

Business organisations in a supply-chain need to understand the key elements involved in the value creation stage, to formulate suitable questions that will be posed to the analytics process. The quality of the output derived from the automated analytics process will depend upon the quality of the question (or the problem formulated by the managers). This section provides and overview of the key elements *(Figure 3)* that managers will need to consider in the value creation stage of the proposed framework taking into account an array of factors preceding this stage.

- ***Purpose:*** It is necessary for the organisations (key decision-makers) to use their domain knowledge, understanding of the business needs, and knowledge of the data sources to outline the purpose of the analytics, i.e. what is the question the automated process will aid in answering. This will streamline and eventually co-ordinate the business needs, data availability, analytics process and value creation (Sanders, 2016). The purpose will also determine which social media streams should be used depending on the nature of the query, quality and type of data available from the stream, and organisational trust in the data stream.

- ***Question:*** The question (i.e. definition of the problem) is a critical element to guide the aggregation and sense-making stages of the analytics framework (Shah et al., 2012). The relevance of the question should be critically assessed considering four key factors: (1) whether the question can be answered, or key insights can be gained by employing analytics; (2) whether the organisation has relevant access to the data streams that will aid in answering the question; (3) how answering the question/ gaining insights will add value to the business needs of the organisation; (4) whether the question is relevant to the contemporary needs of the organisation, i.e. relevance and alignment to business needs, objectives and existing strategy.

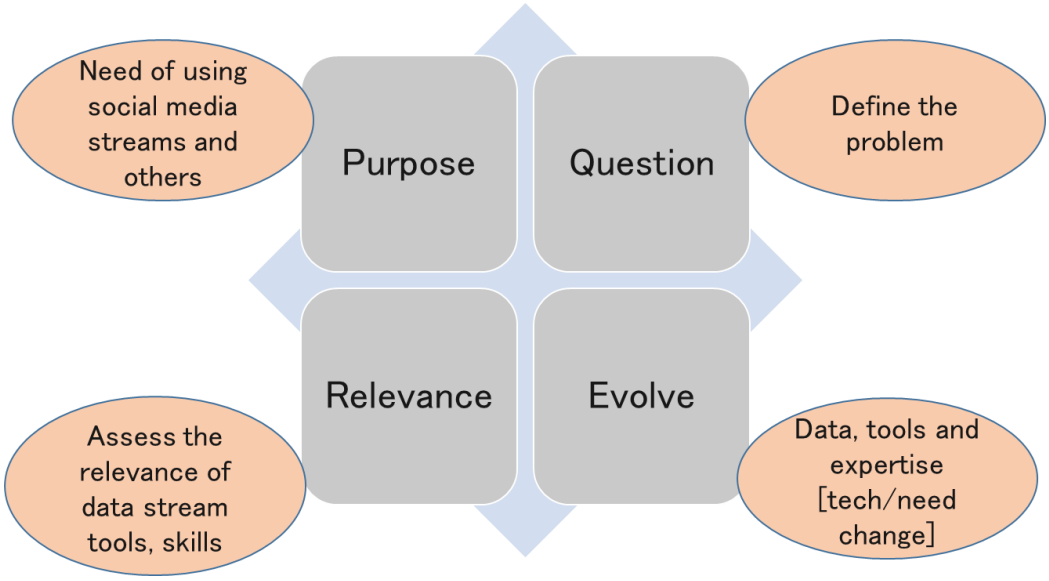

Figure 3: Key elements to consider in the value creation process

- ***Relevance:*** It is key for the organisation to assess the relevance of data stream, i.e. how much the data source can be trusted after the pre-processing, given the veracity involved in the data collected from social sensors. It is critical to assess the key features of the data which will include capturing platform, times-stamp, location, author, motivation to create the data and event associated with the data. Additionally, relevance of technology, expertise to use the technology, and suitable tools need to be considered as well, which should again streamline with the purpose of the analytics and potential intended benefits.

- ***Evolve:*** This is a critical consideration for the organisation to the evolving needs pertaining to technology turbulence and the supply-chain (at all levels – both upstream and downstream). The whole analytics process is evolutionary both in terms of value creation requirements and needs of the organisations. Organisations need to be agile to manage and respond to market movements and make changes dynamically, which will involve taking risks and strategically tackle the uncertainty. Therefore, organisations will be required to revisit their strategy and reflect on it, instead of sticking to a one-stop solution, which is unlikely to reap benefit over a period of time.

Conclusion

This paper demonstrates the need to include a value creation stage in the existing social media analytics framework, so that organisations can streamline the technological and business needs in a suitable manner, which will aid in reaping the benefits from social media data. In this context, organisation will need to adopt an agile strategy that will respond to changes in market as well as the technological turbulence in this digital era. The conceptual framework reported in this paper is yet to be validated in a practical business setting through a longitudinal study. In the future, we aim to conduct multiple case-studies with organisations (both small and large businesses) to validate the framework and identify the barriers stemming from the adoption of this framework. Nonetheless, the value-creation stage in social media framework is non-trivial because in a real-life business setting, organisations often delve into analytics (both social media and IoT data), without having substantial knowledge of the process and randomly searching for patterns in the hope of capturing some insights (which eventually becomes a barrier due to uncertainties stemming from an non-focussed analysis).

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IS capabilities, service quality and environmental dynamism

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Abstract

Research on customer integration and Information Systems (IS) capabilities has mainly focused on manufacturing settings. Although some of the theoretical implications are likely to be similar in service contexts, the fragmented process induced by customer involvement during service delivery, requires a more process-specific focus. We, therefore, aim to explore the relationships between IS capabilities, customer connection, and service quality. The analysis indicates that for service firms, the integration of customer connection should be taken into account for its mediation effect in linking IS capabilities and service quality. We also investigate the impact of firm's stable and dynamic environments.

Keywords: IS Capabilities, Customer Connection, Service Quality, Environmental Dynamism

Introduction

The application of Information Systems (IS) has become a significant effect on contemporary service operations. Firms invest in IS with the presumption that they will facilitate operations processes so that their performance will improve. Yet, IS resources by themselves are not sufficiently "unique" and thus it would be more useful and theoretically relevant to focus on the processes they affect (e.g., Bharadwaj, 2000; Santhanam and Hartono, 2003). One such organisational process, which has attracted a lot of research attention by supply chain management scholars, is the integration of customer connection, where IS-enabled customer connection enhances communication and contact processes, and with such customer resources integration comes greater success for the firm in its abilities to develop a good understanding of customer needs and set accurate customer profiles (Mithas, Tafti, Bardhan, & Mein Goh, 2012). Nevertheless, prior studies on IS capabilities have focused on either one specific type of technology or operationalised it as a highly aggregated concept. Moreover, although conceptual

frameworks have been identified to show customer integration is valuable in service provision (e.g., Moeller, 2008; Jaakkola and Alexander, 2014), there is much to learn about the practices of integrating customer resources (Kleinaltenkamp *et al*., 2012).

In this research, we break down IS capabilities into three dimensions based on the framework of Wade and Hulland (2004): IT for supply chain activities (outside-in), flexible IT infrastructure (inside-out), and IT operations shared knowledge (spanning); and focus on their impact on operational performance of firms in services. With this background, this paper addresses the following questions:

- How do IS capabilities affect the integration of customer connection, and service quality?
- What is the relationship between environmental dynamism and the relationship of customer connection and service quality?

Theory and Hypotheses

In this study, customer connection refers to the communicating and contacting activities in which the firm is involved with its customers. Specifically, these include the process of acquiring and assimilating customer requirements information, and related knowledge. These types of connection are important in the process of integrating with customers, as they help the firm to better understand customers' preferences, and to build relationships with customers (Swink, Narasimhan, & Wang, 2007).

IS capabilities and their impact on customer connection

IT for supply chain activities (ITSCA) refers to the extent to which a firm has adopted IT for processing transactions, co-ordinating activities, and facilitating collaboration with suppliers and customers through information sharing. Previous research has highlighted the use of IT in improving customer connection processes by providing easier access to information, and developing more flexibility to respond to customer information requests (e.g., Lederer, Mirchandani, & Sims, 2001; Rai, Patnayakuni, & Seth, 2006). A firm's use of ITSCA promotes its customer connection by digitally enabling the process of acquiring and assimilating customer requirements information and related knowledge. Specifically, ITSCA enables the firm to electronically communicate with customers, and to manage relationships with them (Bharadwaj, 2000; Feeny & Willcocks, 1998). For example, web-enabled customer interaction technologies provide the firm with an integrated set of functionalities at the customer interface to gather and store customer information and knowledge (Mithas, Krishnan, & Fornell, 2005). Therefore,

Hypothesis 1a: The use of ITSCA has a positive influence on the degree of customer connection.

Flexible IT infrastructure (ITINF) refers to a firm's ability to deploy a shareable platform that supports a foundation for data management, communications network, and application portfolio. A flexible IT infrastructure provides an integrated platform that enforces standardisation of data and processes, making possible timely and accurate information gathering and sharing across business functional areas (Lu & Ramamurthy, 2011). ITINF provides a sharable platform for data warehousing, data mining, and reporting, thereby supporting the processes involved in connecting with customers

(Suresh, 2004). Supported by the shareable and firm-wide databases, flexible IT infrastructure also facilitates an integrated communication presence, which enables online customer communication for after-sales services such as support for products bought or services delivered in physical stores as well as real-time live chat that provides online customers with access to customer service assistants (Jana, 2007; Oh, Teo, & Sambamurthy, 2012). Therefore, the discussion leads to the following hypothesis:

Hypothesis 1b: ITINF has a positive influence on the degree of customer connection.

IT operations shared knowledge (ITOSK) refers to the knowledge that the operations manager possesses regarding how IT can be used to improve operations processes. Previous research has emphasised the significance of business managers' familiarity with information technologies and their potential business impacts (e.g., Bassellier, Benbasat, & Reich, 2003; Sambamurthy & Zmud, 1999). To promote IT in their business processes, business managers have to work closely with the department responsible for developing IT. Therefore, a business manager's intention to further develop partnerships with the IT departments is considered to play a critical role in successfully implementing IT in business processes (Bassellier et al., 2003). Indeed, it is believed that the stronger the relationship between business and IT, the more effectively IT can be deployed in support of business goals (e.g., Chan & Reich, 2007) Placed within an operations context, IT knowledge shared by operations managers should promote and support IT utilisation in the firm's communications with customers, hence facilitating customer connection processes. IT-knowledgeable operations managers are more likely to be involved in IT planning for customer connection processes. Furthermore, ITOSK should also ensure that the firm is able to respond swiftly, effectively, and efficiently to changes in customer connection processes, and this entails supporting technological innovation to facilitate those processes. To this end, ITOSK is expected to facilitate the firm's customer connection. Therefore,

Hypothesis 1c: ITOSK has a positive influence on the degree of customer connection.

The mediating effect of customer connection on service quality

ITSCA can enhance and accomplish connection processes between a service firm and its customers in terms of acquiring customer requirements information, and related knowledge. Customer connection processes that are ITSCA-enabled allow a service firm to develop a good understanding of its customer needs and to focus efforts on meeting those needs, thereby precipitating improved service quality (Ellram, Tate, & Billington, 2004; Valarie A Zeithaml, Bitner, & Gremler, 2006). Customer knowledge that has been captured across service encounters can then be made available for all future transactions, enabling the firm to improve the accuracy of its customer profiles and to respond to any customer need in a contextual manner (Tsikriktsis, Lanzolla, & Frohlich, 2004). With accurate customer profiles, the service provider is able to enhance service quality by being responsive to customer requirements, and this in turn, increases the perception among customers that the services they are receiving are performed accurately and dependably, and can thus, be relied upon. Consequently,

Hypothesis 2a: Customer connection is positively related to quality performance and mediates the ITSCA–quality relationship.

Flexible IT infrastructure (ITINF) enhances customer connection processes by facilitating the accessibility of customer information and data across the firm. With such accessibility, a firm can leverage its stock of accumulated knowledge and experience for the purposes of effective customer relationship management (Lu & Ramamurthy, 2011). ITINF-enabled customer connection empowers the firm such that it becomes more familiar with the customer data management issues involved in initiating, maintaining, and terminating a customer relationship. This familiarity enables the firm to leverage its collection of customer data to customise offerings and respond to customer needs (Mithas et al., 2005). A firm's ability to satisfy the needs of current customers will lead to improved service quality (Connor, 2007).

Hypothesis 2b: Customer connection is positively related to quality performance and mediates the ITINF–quality relationship.

ITOSK has the potential to promote and support IT utilisation in customer communication processes, and to facilitate customer connection. ITOSK-enabled technologies utilisation in customer connection contributes to improved quality performance of the service provider. For example, the use of online customer service processes enables the firm to respond to customer requirements in a quick, accurate and dependable way, increasing service reliability (Valarie A. Zeithaml, Parasuraman, & Malhotra, 2002). Using web-enabled customer interaction, the firm can help its customers to better understand their own needs, and can simultaneously facilitate the firm's ability to customise service content and procedures according to individual requirements (Tan, Benbasat, & Cenfetelli, 2013). Customised offerings enhance the perceived quality of services from a customer's point of view (Mithas et al., 2005). Therefore,

Hypothesis 2c: Customer connection is positively related to quality performance and mediates the ITOSK–quality relationship.

Figure 1 shows the hypothesised research framework of the proposed indirect effects of each dimension of IS capabilities (ITSCA, ITINF and ITOSK) on service quality through their positive effects on customer transactions.

Environmental dynamism refers to the 'amount and unpredictability of change in customer tastes, production or service technologies, and the modes of competition in the firm's principal industries' (Miller and Friesen, 1983: 233). With increasing competition and advances in technology, firms are facing environments that are extremely dynamic (Yu et al., 2018). From dynamic capabilities view, firms with the capabilities that can extend, modify, change, and create business capabilities in response to environmental dynamism plays a fundamental role in changing operational routines and in ensuring that the firm can change its overall operations and have new sets of decision options (e.g., Winter, 2003). The fit between the firm's customer connection capability and the competitive environment demands will positively affect the firm's competitive position (Drnevich and Kriauciunas, 2010).

Hypothesis 3: The greater the degree of environmental dynamism, the stronger the positive impact of customer connection on service quality.

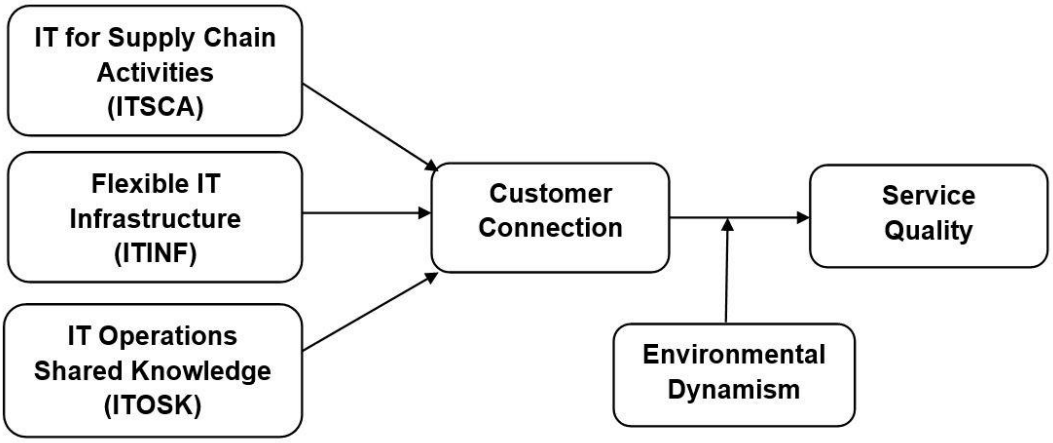

Figure 1 – Hypothesised Framework

Data and methods

We collected data via online survey from service establishments in the UK, with operations directors as the key informants. A total of 156 usable surveys were received. No statistically significant differences among variables were found, suggesting that the non-response bias is minimal.

Measures

The survey scales were either established scales or developed from the extant literature. *IT for supply chain activates* are represented in our survey by measuring the extent of implementation of 19 different types of process-level IT applications that used in service industry. Consistent with prior IS and OM research (e.g., Saldanha, Melville, Ramirez, & Richardson, 2013), we measure the extent of implementation (adoption) of each type of IT applications. *Flexible IT infrastructure* was measured using a two-item scale on a 1-7 Likert scale (from "Strongly Disagree" to "Strongly Agree"), assessing the degree to which the firm has established corporate rules and standards for hardware and operating systems to ensure platform compatibility; and has identified and standardized data to be shared across systems and operations department (Chen, Daugherty, & Landry, 2009; Lu & Ramamurthy, 2011; Ray, Muhanna, & Barney, 2005). *IT operations shared knowledge* was measured using a three-item scale on a 1-7 Likert scale (from "Strongly Disagree" to "Strongly Agree"), indicating the degree to which they agree with there is a common understanding between IT and operations managers regarding how to use IT to improve operational performance (Bassellier et al., 2003; Ray et al., 2005). *Customer connection* was assessed using a three-item scale on a 1-7 Likert scale (from 'Not at all' to 'Extensive'), indicating the extent of integration or information sharing between their firms and customers on connection processes (Baltacioglu, Ada, Kaplan, Yurt, & Kaplan, 2007; Kulp, Lee, & Ofek, 2004). *Service Quality* was measured using a seven-item scale

on a 1-7 Likert scale (from "Much Worse than Competition" to "Much Better than Competition"), rating the external service quality (Parasuraman, Zeithaml, & Malhotra, 2005; Safizadeh, Field, & Ritzman, 2003).

Data analysis

Confirmatory factor analysis (CFA) was used to check convergent validity, following the two-step procedure suggested by Andersone and Gerbing (1988). CFA was conducted by corelating the constructs (ITINF, ITOSK, customer connection, and service quality). The measurement model shows a good model fit: CMIN/df is less than 4 (1.173), CFI = 0.937, RMSEA is less than 0.08 (0.033). GFI = 0.937, AGFI = 0.901, and IFI = 0.994 further confirm that the measurement model is acceptable. Moreover, the standardised coefficients, which range from 0.844 to 0.981; AVE values range from 0.76 to 0.84. The Cronbach's alphas ranged from .801 to .956, consistent with the suggestion that alpha levels above .80 are very good (Hair, Black, Babin, & Anderson, 2009).

Findings

Figure 2 shows the overall results for the structural model (Numbers show above the arrow represent the standardised regression weight.). There is a good model fit, with acceptable values - CMIN/df = 1.657; CFI = 0.978; RMSEA = 0.065; GFI = 0.988; IFI = 0.979; NNFI = 0.925. Moderating effect of environmental dynamism on the relationship of customer connection and service quality is showed in Figure 3.

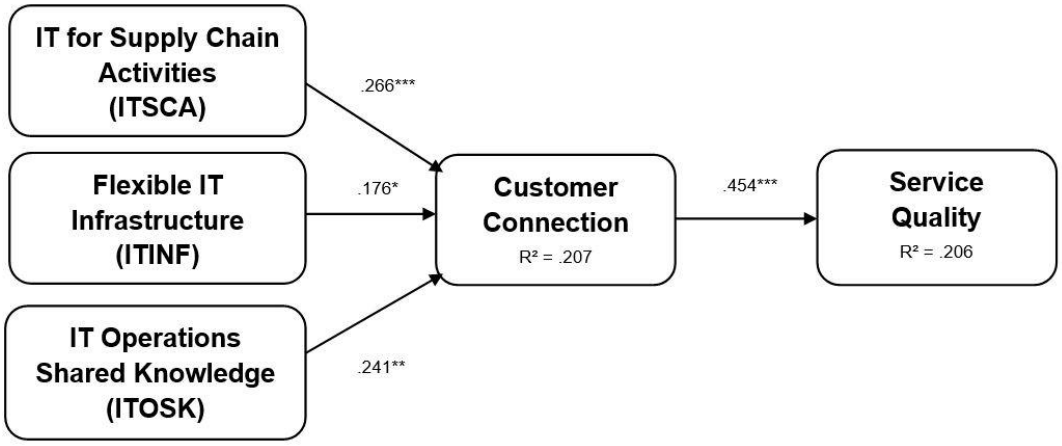

Figure 2 – Structure Model Results

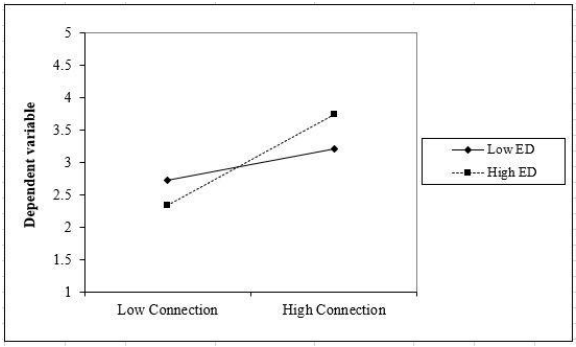

Figure 2 – Moderating effect of environmental dynamism on the relationship of customer connection and service quality

Our results show that ITSCA, ITINF and ITOSK have a positive influence on the degree of the integration of customer connection. In addition, customer connection positively related to service quality; this relationship is further emphasised when firms work in a dynamic environment. Our results provide robust evidence for customer connection as a mechanism through which IS capabilities influence the quality performance of service firms. Put differently, customer connection, involving information sharing and operational co-ordination in respect of customer communication and contact processes, is the means by which the intrinsic value of ITSCA, ITINF, and ITOSK is translated into improved quality performance. The results suggest that manager in service firms should also consider the indirect role of IS capabilities in their firm performance, and the strength of the mediating role of integrated customer connection. Indeed, service firms that decide to develop and leverage their IS capabilities should also implement processes that encourage customer connection processes integration. More specifically, a higher degree of customer connection enables a service firm to collect the appropriate customer information, develop accurate customer profiles, and provide better customer support, all of which can enhance a firm's ability to retain, improve, and extend its relationships with customers. When it engages in a long-term relationship with customers, the firm can at the same time improve the response to customer needs, and reducing demand uncertainty.

Contribution

We make the following contributions. Firstly, we contribute to a scarce but increasing body of research on customer and supply chain integration in service contexts. Specifically, we provide and validate a process-specific approach to empirically investigate customer integration (e.g., Moeller, 2008; Vargo & Lusch, 2008). We therefore respond to recent calls to better understand the practices of integrating customer resources (Kleinaltenkamp et al., 2012). Secondly, we explore the relationship between customer integration and operational performance in service contexts. We find that in service contexts IS capabilities lead to improved performance when they help develop processes for the integration of customer connection first. The practical implication of our finding is that service firms that embark on the development of IS capabilities should at the same time implement processes that encourage customer connection. This

development approach is even more significant for operations working in dynamic environments. Finally, we respond to calls from supply chain management literature to explore a comprehensive range of IT in SCM by developing and validating the measurement scale of IS capabilities in managing service supply chains (e.g., Ostrom et al., 2015; Zhang, van Donk, & van der Vaart, 2011).

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Blockchain and the Digital Supply Chain- a critical review

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Abstract

The literature on Blockchain suggests that the technology will enhance efficiency and trust in the supply chain due to its incorruptible and verifiable properties. This could also help in increasing sustainability due to the reduction of waste. This paper focuses on Blockchain technology and considers the feasibility of this technology within the domain of digital supply chains. The study utilises a systematic literature review process to review the literature in this domain. The topic of Blockchain is a new area of research and hence the academic literature is scarce. The study strives to identify current research gaps in this area.

Keywords: Blockchain, digital supply chains, literature review

Introduction

Satoshi Nakamoto proposed Bitcoin as a decentralised and non-refutable cryptocurrency (Nakamoto, 2008). As illustrated by Satoshi Nakamoto, blockchain is an accessible, distributed ledger that can record transactions between two parties without the authorisation of any intermediary (Nakamoto, 2008). Industry currently is investing huge sums of money in Blockchain-based solutions that bear the potential of revolutionising supply chains. This growing industry focus has inspired academic researchers to investigate the Blockchain technology from varying theoretical standpoints.

The distributed ledger characteristic of the Blockchain helps in working as a decentralised financial transaction. This also enables to provide a clear overview of supply chains. In order to scrutinise Blockchain technology and its potential implication on supply chain management, this paper provides a systematic literature review. The review strives to close a current research gap through exploring existing barriers, challenges and potential benefits, along with accessing the feasibility of Blockchain application for digital supply chains.

The shift from traditional supply chains to the digital supply chain requires to embrace a new way of linking physical and digital assets (Mussomeli et al., 2016). There are a great number of technologies available to significantly change the current SCM, such as

Cloud computing, IOT, 3D-printing, Blockchain and mobile technology. However, this paper concentrates on the feasibility assessment of using Blockchain for supply chain management. Due to the scarcity of knowledge and limited understanding of the new technology, there remains a considerable research gap between theory and practice. Based on a systematic literature review, this paper identifies current barriers and challenges of Blockchain applications that are pertaining to SCM. It also analysed benefits the Blockchain technology will bring to digital supply chains.

The research aims to answer the following research question: **How will blockchain technology influence digital supply chains?**

Blockchain characteristics and application

The five key characteristics of Blockchain technology are tamper-resistant, anti-counterfeit, immutable, time-stamped and accessible (Iansiti & Lakhani, 2017; Nakamoto,2008). Blockchain provides irrefutability through a chain of blocks, each cryptographically linked to the previous, using a hash digest. The Blockchain is a sequence of records, each hashed and linked to the previous block with a unique timestamp. Hence, once a transaction is entered in the database and verification completed, the records cannot be tampered since they are permanent and chronologically ordered (Iansiti & Lakhani, 2018). The design and operation rules of Blockchain are based on computational logic. Various computational algorithms and approaches are deployed in the protocol. With complicated algorithms and encryption, the database could achieve cybersecurity theoretically, to resist malicious hack. Every transaction is visible to participants within the chain. However, access is not public to every user in a private Blockchain or consortium Blockchain, which requires permission for privacy protection. Without a central authority, any transaction or communication occurs directly between peers. Each involved party has access to track transmission in any time node. A single party will not control the database in terms of personal interests.

The current applications of blockchain technology are concentrated on cryptocurrencies and to an extent smart contract. Apart from Bitcoin (BTC), a considerable amount of cryptocurrency successively appears in the financial market after 2008. Litecoin (LTC), Ethereum (ETH), EOS, Peercoin and so on are multiple types of cryptocurrencies underlying the same distributed ledger technology but with a different encryption algorithm. The main advantage of such encrypted transactions is economic efficiency and cost-saving by trust-based peer-to-peer interaction (Swan, 2015). Smart contracts enable transfer of assets that are wider than simple cash transactions such as stocks, bonds, futures, loans, mortgages, titles, property etc. it is similar to standard contracts but without the need of trust between parties (Swan, 2015). A firm could signal via blockchain that a particular good has been received or obtain the update of location, in turn, triggered a payment (Iansiti & Lakhani, 2018).

Some leading global organisations, with a high level of supply chain digitalisation maturity, are already moving ahead in terms of Blockchain pilot test or empirical conceptual model for a potential reward. Alibaba, AusPost, Blackmores, and PwC has teamed together to explore the use of Blockchain technology to combat food fraud. Developing a "Food Trust Framework" is the major assignment of this cooperation. This framework is invented to fight against counterfeit ingredients and improve the integrity and traceability of worldwide supply chains (Bindi, 2017).

Methodology

For the consideration of clearly identifying what is known and not known about a given topic (Briner & Denyer, 2012), an explicit systematic literature review suggested by

Denyer, Tranfied, and Smart (2003) are adopted in this paper as a research methodology to select and synthesise data collected from databases. Distinct from traditional narrative reviews, an SLR follows a strict set of process which requires reviewers to analyse all existing information about the topic in a thorough and unbiased manner (Denyer & Tranfield, 2009). The structured Literature review approach provides a systematic, replicable, transparent, process that is based on an evidence-informed knowledge investigation. As a consequence, for creating new knowledge through rigour in the standards for selection and evaluation, this study conducting five distinctive processes as shown in Figure 2: (a) formulating research questions and establish focus, (b) locating studies, (c) selecting relevant information by rigour criteria, (d) analysing and synthesising findings, (d) summarize and report results.

The primary step of the systematic literature review is to framing research questions, as well as establish a research focus. The application of blockchain technology in an increasingly digitalised supply chain status quo is sought by analysing the existing literature to provide a comprehensive framework from barriers and potential advantage perspectives. For the consideration of building discussion based on exhaustive literature resources and high-quality evidence, this research acquired academic papers through Emeraldinsight, Science Direct, EBSCO (Academic Search Complete and Business Source Complete), ABI (ProQuest) and Scopus. The research string used for the search was “Blockchain” AND “supply chain. The time horizon of locating the review is from 2008 to 2019, since the blockchain technology has been prominent from 2008 with the emergence of bitcoin. The search on ABI and Science Direct provided a return between 165-185 papers. This number is low as the visibility of Blockchain technology within the supply chain domain is relatively new with the majority of papers being published in the first four months of 2019. The filtering process was focused on Operations Management and Supply chain journals and hence it was decided to use the journals rated as 2, 3 or 4 under the Operations management category in the Chartered Association of Business Schools journal guide. The filtering process provided 18 unique papers for further analysis.

Thematic Analysis

The 18 papers were analysed for two criteria: barriers and challenges, future opportunities. The focus for this has been the implementation of the Blockchain technology within the supply chain domain.

Barriers and challenges

1. Throughput and scalability

Throughput and scalability are considered as vital elements for implementing Blockchain. Swan (2017) and Vermeulen (2017) made a meaningful comparison between Blockchain technology transaction speed and traditional payment technology. The paper suggested that current bitcoin Blockchain network only processes about 7 transactions per second, which is lower than Ethereum that has an estimated speed limit of around 20 transactions per second. Nevertheless, VISANet can process nearly 2000 transactions per second. In comparison, the throughput of Twitter is as high as 5000 transactions per second. Vermeulen (2017) also pointed out that bitcoin uses a push method of paying while VISA uses both push and pull methods. Based on the data presented by Swan (2015), Reyna et al. (2018) and Li et al. (2018) proposed an argument that limited transaction throughput is a substantial challenge of Blockchain technology for wide implementation.

2. Security (Double-spend attack):
Swan (2015) stated that by combing peer to peer file-sharing network with public-key cryptocurrency, Blockchain technology created a new digital currency and solved a double-spending problem without a central intermediary. Double-spend is the particular situation that spends the same money more than once. However, during the transaction process, the risk of double-spend still exist. In order to prevent this issue, each transaction has to be verified before added to the chain. Since there is no central intermediary, Blockchain applications users should have tolerance with few minutes of verification time to ensure the security of transactions.

3. 51-per cent attack
The Blockchain technology was designed on the assumption that honest nodes will control the network (Nakamoto, 2008). However, a 51-per cent attack might occur when malicious users get together and manage to do more "virtual work" than the "good people" (Prashar, 2013). The entire network will be controlled by malicious users in such a situation. The probability of this attack happening will increase with the fast evolution of mining pools which compromise the integrity of Blockchain. Beikverdi et al. (2015) also argued that market-based centralisation of mining power is against the nature of a decentralised network. Further research is required to limit these challenges if supply chains need to consider adopting Blockchain applications.

4. Transparency vs privacy dilemma
There is an increasing amount of attention towards the anticounterfeiting ability, immutability, and reliability nature of Blockchain. However, without a central authority every involved user has access to make transactions. Since each transaction will be recorded chronologically and cannot be tampered; each member in the private supply chain network can trace and track goods, information, cash flow in time and geographic manner. The advantage of transparency discloses every single fraud and fault. Hence, it is important to maintain the integrity of private Blockchain networks. The concern that decision-makers have about business secrets, such as pricing strategy, product innovation and customer information will influence the adoption of Blockchain (Wang & Kogan, 2018). The private Blockchain protocol should normally face a comparatively lower risk of information leakage since users cannot have access without permission. However, Wang & Kogan (2018) have suggested a more serious situation, if the key-enabler department was controlled by a malicious party, the risk of privacy disclosure is still uncontrollable. Even worse, the entire private chain will be manipulated according to personal will.

5. Regulation absence
When applying the Blockchain technology in a domestic supply chain network, there is lack of exclusive governing laws and clauses to clarify rights and obligations of each involved company which courts can take charge if a dispute occurs (Mckinlay et al., 2016). A dedicated regulatory framework is necessary for building network architecture and further judging ownership issue like jurisdiction. In EU, the European Parliament voted to adopt a smart regulatory hands-off approach; it allows the regulator to develop sufficient capacity in such dynamic innovative environments, as well as regulating the application of Blockchain network (European Parliament, 2014). In the US, the Federal Reserve, the Securities Exchange Commission, the Treasury Department and relevant state regulators are taking charge to form and shape regulatory thinking towards Blockchain.

6. Wasted resource

Mining bitcoin requires a large quantity of energy for computing and verifying transactions (Swan, 2015). In the bitcoin system, the first internal factor causes the waste is the computation race game between miners. Clarified by Wang and Liu (2015), with the quantity of miners increasing, the difficulty level to maintain safety has increased. The growing time of verification reduces the bitcoin mining rate. Apart from the competitive mining situation and time-consuming encrypted mechanism; some scholars still see the potential in saving costs in a Blockchain-based supply chain network.

Strengths and Opportunities

1. Cybersecurity

Skwarek (2017), Kshetri (2017) have suggested that Blockchain in terms of decentralisation, autonomy and trustworthy, is likely to address key security challenges associated with cloud and IOT-system. The three main requirements for information security are: confidentiality, integrity and availability. Described by Li et al. (2018), **confidentiality** refers a set of rules to ensure all users were authorised which could be guaranteed by symmetric encryption. **Integrity** rules ensure that the sent data should be the same as received data. The hash mechanism of a block is designed for anti-tampering and to prevent any change through information transmission. **Availability** requires all authorised users to possess reliable access to information. Skwarek (2017) believed that the distributed ledger mechanism is able to withstand manipulation and errors. Kshetri (2017) proposed that the Blockchain could play a possible role in strengthening security and protecting the privacy of customers' information in the healthcare industry.

2. Traceability

From a conceptual perspective, Blockchain technology which provides real-time information about operations matches the pre-requisite of asynchronous supply chain. Blockchain can be used to track raw material into the supply chain both internally and externally. In the healthcare industry, Glover & Hermans (2017) outlined the benefits of using Blockchain technology to improve the traceability of medications from active pharmaceutical ingredient (API) to a patient, while facilitating the gathering of patient-level data in a HIPAA-compliant manner. Some researchers have also advocated the traceability capabilities of Blockchain technology to maintain safety in the food industry.

3. Trustworthy and Anti-counterfeit

Notheisen et al. (2017) & Scott et al. (2017) both analysed Blockchain technology and suggested that the trust-free transaction system allows companies to move value and manage ownership transformation even with divergent interest, and without a central institution. Nodes establish reliable communication between one another by generating transparent, cyber secure and immutable record of transactions.

4. Accessibility and Network facilitating

With today's digital supply chain, every strategic decision made is supported by sufficient data analysis. The Blockchain technology addresses the risky problem by ensuring users with permission add and access a permanent and time-verified record. Inter-organisational relationships will be influenced by the transparency and non-immutability of the data through the peer to peer transactions. The Blockchain technology therefore, has a significant potential to reduce communication costs among disconnected parties and promote information transaction efficiency in the supply chain.

5. Monitoring and value creation
Nowiński & Kozma (2017) summarised the Blockchain potential implication on business from three dimensions: strategic components, customer & market components and value creation components. Tapscott and Tapscott (2017) pointed out that Blockchain allows companies to eliminate transaction costs and create value both from internal and external. Vertical integration and central controlling may still make sense and maintain high efficiency in interior governing. Lanko et al. (2018) revealed an advantage of combining existing tracking technology with Blockchain. According to their research, the combination of RFID, GPS and Blockchain will significantly reduce losses caused by human error and intentionally fraudulent information, eliminate turnover problem caused by insufficient credit between participants.

6. Optimise SCM performance
Kshetri (2018) concluded that supply chain performance measurement is often conducted in terms of objectives such as cost-efficiency, dependability, speed, flexibility and risk control. Based on multiple-cases studies, Kshetri (2018) researched the Blockchain's potential in optimising supply chain performance. Cost however plays a major role in adoption of the technology. With constant tracing and tracking, defective products can be easily identified and removed early on thus reducing high cost of loss and reputation risk. Secondly, in the consortium protocol, every transmission could be validated by digitally signed documents. Paper records will gradually be discarded while developing digitalising SCs. Thirdly, regulatory compliance costs decrease since inter-organisational conflicts will be solved by technical code or commercial rules rather than intermediaries. Smart contracts will help in increasing procurement effectiveness and efficiency.

Future of Digital SCs with Blockchain application
Following a thorough review of Blockchain' implication on digital supply chains, several trends that are developing can be identified.

Industry 4.0.
Blockchain was highlighted as the critical technology for facilitating Industry 4.0. The proof-of-work mechanism enables cyber secure guarantee for current Internet-facing organisations. The Blockchain is an important technology to establish a reliable protocol that ensuring cyber security and reliability by technical codes rather than central authority. Moreover, Blockchain can operate as a distributed ledger to develop a trusted and flexible relationship between upstream suppliers, downstream retailers or even end customers. For instance, applying smart contract that allows credible transactions without third parties, in managing supplier relationship, Blockchain technology could make it possible that digital signature replaces of signed documentary records; Which meet automation requirement of Industry 4.0.

Disintermediation
Disintermediation is the reduction in the use of intermediaries between various parties. Blockchain technology provides significant opportunities for disintermediation. The Blockchain-based protocol is recognised as trustworthy, reliable and decentralised.. According to Joshi (2017), Blockchain is facilitating disintermediation from following three perspectives. Firstly, Blockchain supports trading products and services across a web of partner network, which allows trading whether tangible or intangible that is of value. This means here comes a trend of assets digitalisation. Secondly, a validity and

reputation system will be established by fairness and accessibility. Thirdly, Blockchain eliminates conflicts by supporting ownership clarification.

Incentivisation

The Blockchain concept provided Bitcoin as the incentive for processing the transactions and deriving the hash. The aspect of providing the incentive is an important element of the irrefutable and traceable network. However, this incentive until now has been provided on public networks due to the processing power required for deriving the hash. Private networks or supply chain platforms currently do not emulate the Bitcoin approach as-is but provides a very good possibility of providing incentivissation in other forms (not Bitcoin). Smart contracts and Block chain based supply chains could create some novel forms of incentives for members to participate.

Conclusion

Since the introduction of Bitcoin, Blockchain technology has been identified in various applications among different industry sectors. However, academic research on Blockchain relevant to supply chain management is mostly focussed after 2016 ad has increased in 2019. This study conducted a systematic literature review, extracted and analysed 18 academic papers from a operations management perspective. The paper has identified barriers from selected papers and outlined the potential opportunities brought by Blockchain technology in supply chain management. Blockchain can serve in different forms such as cryptocurrency, private platform, consortium protocol or public Blockchain. Blockchain could facilitate achievement of SCM objectives- Visibility and transparency, which are regarded as key challenges for shifting from traditional supply chain to a digital network. Based on the above study, four recommendations on future research directions of Blockchain technology application in SCM are identified:

1) Conduct more studies on balancing the transparency and privacy need. Provide solutions supported by practical experience to resolve the dilemma.
2) Continue to identify practical barriers for applying the technology. Propose solutions to narrow gaps between theory and varying operations.
3) Investigate technologies that have the potential to facilitate Blockchain application.
4) Propose new business models and incentivisation mechanisms.

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Demystifying supply chain visibility: A systematic literature review

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Abstract

Supply chain visibility (SCV) has been in trend after the millennium and raised interest of both academics and practitioners. However, there is still an ambiguity on the topic, which hinders a proper SCV application. This study aims to clarify the fuzziness of the area by conducting a systematic literature review. By reviewing 67 articles, we have identified a conceptual model that covers three main roles of information sharing for SCV and their impacts on the positive and negative constructs of SCV. This framework illuminates the inter-construct interactions and, also provides diagnostic insights for the implementation of SCV in the firms.

Keywords: Supply chain visibility, information sharing, systematic literature review

Introduction

SC concept relies on the movement of materials from suppliers to customers and finance and information in the opposite direction (Baihaqi & Beaumont 2006). However, these flows generally go further beyond the horizon that the focal firms see. This situation sometimes creates problems because there is no capability of the focal companies to interfere with the issues beyond their visible boundaries (Carter et al. 2015). Moreover, this has become to be a bigger issue as once unimportant factors that are of no need to trace gain importance with the new requirements of dynamic market conditions (McKinney et al. 2015)**.** For example, some problems related to social governance strategies that mega companies experienced are a result of not being aware of after boundaries. Similarly, being unaware of the processes within the boundary has been turning out as extra costs and problematic relationships. Therefore, as a result of the need to see, supply chain visibility (SCV) has become essential for supply chains, to mitigate the risks and maintain the confidence of supply chains (Fan et al. 2013). Various authors highlighted the importance of SCV (see (Barratt & Oke 2007; Dubey et al. 2017; Sarker et al. 2016; Nooraie & Parast 2015; Musa et al. 2014). Therewithal, practitioners have

also realised that importance (Bartlett et al. 2007). Enslow (2006)'s survey shows that 79% of the respondent companies mention that lack of SCV is one of their top concerns. Another study conducted by Sarker et al. (2016) affirms that results and demonstrate the importance of SCV among practitioners. However, the very same studies and some others also refer to SCV as one of the points that firms are incapable of achieving. Although there are various, contingent reasons for the issue, a dominant school of thought in the field believes that the gap between the targeted and achieved visibility levels can be a result of the ambiguity around the term of SCV (see Williams et al. 2013; Gunasekaran et al. 2017; Barratt & Oke 2007; Basole & Bellamy 2014; Zhang et al. 2011; Wang & Wei 2007) The vagueness starts with the definition of SCV. Since there is no consensus even in the definition, a misunderstanding dominates the topic (Francis 2008). Moving from Dubey et al. (2017)'s study, we suggest that the roots of the problem may be searched in delineating visibility from 'information sharing' term, which is a significant component of visibility and supply chain management (Baihaqi & Beaumont 2006).

Information sharing and SCV has been often used to state the same concept in supply chains: the state of the information prevalence among SC partners. In fact, moving from the previous studies, we can make a basic differentiation between these two terms with a resource-based view. As the visibility is basically accepted as the 'capability of accessing and sharing information', we can see the information as the main resource behind this capability and 'information sharing' as a single activity unit of that resource (Holcomb et al. 2011). However, the interaction between these two terms is not limited to only this. As there are authors that see information as a means of implementing visibility, some others regard it as a consequence of having information. Although all propositions are correct in theory, that situation blurs the field and hinders to constitute an SCV implementation roadmap for practitioners. Lack of a holistic study that will aggregate different schools and organise them into an applicable form motivates this study to construct a conceptual model of for the interactions between information sharing activity and the SCV dynamics.

Thus, this paper targets to investigate different interaction models between information and SCV dynamics and consequently produce a conceptual model. By that framework, the gap between theory and the practice will be narrowed down and the organisations with better SCV understanding will increase their SCV and overall SC performance. In order to achieve these aims, this paper utilises systematic literature review (SLR) methodology. Remainder of the paper will inform about the SLR methodology and the specific process of this paper and then demonstrate the descriptive and thematic findings of the study.

Methodology

A systematic review (or systematic literature review (SLR)) is defined as a review of a clearly formulated question conducted via a set of systematic and clear methods which identify, scope, and evaluate the relevant research in a critical way and then collect and analyse data of included studies (Siddaway 2014**).** It is adopted by researchers to identify, justify or refine the processes (Mulrow 1994). SLR, being a fundamental scientific activity in its nature, has various reasons to be preferable against traditional literature reviews. Characteristics of SLR compose some of the differences, such as replicability, positivity and transparency (Tranfield et al. 2003). Information overload is another reason to select SLR over traditional review. (Petticrew & Roberts 2006). In order to achieve the aims of this study, it was critical to conduct a holistic research and not to miss any perspective, so systematic literature review (SLR) has been adopted as the research methodology. Figure 1 demonstrates the phases of this SLR:

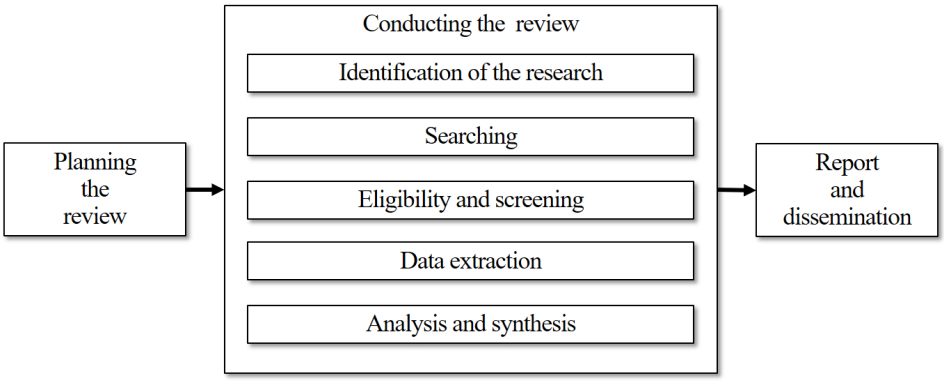

Figure 1 – Phases of SLR process (Adapted from Transfield et al. (2003))

Denyer & Tranfield (2009) propose that less experienced researchers should tap into a scoping study in the field just ahead of the SLR. It is suggested in order to provide an introductory understanding of the constructs, so that they can conduct a better review with an increased awareness. In the planning step, this process has been achieved by the complete review of 28 papers, which deliver a good amount of background details about the variables. Together with scoping the research area, a review panel and an SLR protocol have been structured. Review panel helps the study increase objectivity by bringing distinct and expert perspectives, while protocol document formally captures the steps of the review and fulfil the transparency and replicability requirements (Tranfield et al. 2003).

Scoping the field and discussions in the review panel help the study to create specific review question or questions. They clearly put forth the variables of the study, which compose the keywords and search terms, and ultimately search strings (Tranfield et al. 2003). In light of this, the following main review question and sub-questions were identified to form the main framework of this research:

- How do supply chain visibility and information sharing interact to improve supply chain performance?
  - What are the enabling and inhibiting factors for SC visibility?
  - What are the benefits (improvements in SC performance) of improved SC visibility?
  - What are the challenges (vulnerabilities) ensued by improved SC visibility?
  - What are the core constructs of information sharing in its interaction with SC visibility?
  - What are the relationship models between information sharing and SC visibility?

In order to be able to find successful and complete answers for these questions, following keywords and search terms were used (Table 1) to the final search string.

Table 1 – Keywords for variables and related search terms

Keywords	Search Terms
Supply	(suppl* OR demand OR value OR logistics)
Chain	(chain OR network OR web OR distribution)
Visibility and Information Sharing	(visib* OR transparen* OR “information shar*” OR “information exchange” OR “information disseminat*”)

For searching, three major databases for management and organisations studies have been selected, namely Scopus, EBSCOHost, and Web of Science. Search ended up with 45,296 papers in the aggregate, which then are filtered and evaluated with three sets of results: eligibility filters, focus and relevancy criteria and quality evaluation. Eligibility filters included publication type and quality (only 3-4* journal articles in order to focus only on quality data and to avoid drowning in the excessive and repetitive data), research field (operations research and management, business, management and supply chain management), publication year (all included), and language (English). Filtered papers, then, were checked for their relevancy and focus by a title and abstract review. Next, remainder papers were evaluated according to four criteria: theory, contribution, methodology and results. In total, 54 journal articles were selected for the SLR. Lastly, they were supported with two main cross-referencing techniques (namely, snowballing and citation-tracking) in order to avoid missing essential information that is initially dismissed by the eligibility screening (Greenhalgh et al. 2005). It has brought 13 additional papers and, the study has been constructed on the review of 67 papers in total.

Along the review process, data have been extracted from papers in a systematic way. First, review sub-questions were considered as the main categories. Then, in order to create the granular codes within each category, a repetitive review process has been conducted. The findings of the review were analysed descriptively and thematically. Descriptive analysis demonstrates the trends in the field, in terms of publication year, resource, adopted methodology and theoretical approach. Thematic analysis, on the other hand, presents the context-based findings like state-of-the-art in the field, taxonomy of the constructs and related interrelationship.

Descriptive Analysis

In order to understand the main characteristics of the field, papers have been first analysed descriptively, in terms of their publication year, research methodology, and theory utilisations.

In the eligibility criteria, there was not any limitation for the publication year. However, descriptive analysis shows 2000 as the earliest publication year of 67 paper reviewed. Considering the non-existence of any restriction, we may infer that SCV is a rather new area. Moreover, we have identified that the last decade has an average of 5.7 publication on SCV. It indicates the importance of the area in academia and its need and fruitfulness to be illuminated.

In terms of paper type, we have observed that 15% of the papers (11) provide either conceptual or theoretical contribution to the field. These type of studies help researchers keep up-to-date with the state-of-the-field, and suggest promising directions for further research. On the other hand, the remained 85% (58) utilise empirical research methods, either in order to explain previously asserted conceptual phenomenon or to explore the area further. We suggest that the ratio of 15% to 85% is a good balance for the steady and continuous improvement of the SCV area. Among these 58 papers, 49 use three major research methods: case study (21), survey (17), and modelling (11). These figures tell that academics of SCV 1) are in a search of furthering the area with majorly doing exploratory case studies; 2) are interested in the correlations (of internal SCV constructs or with other SC constructs) related to SCV; 3) and look for creating a universal quantitative measurement for SCV. While these research methods dominate the field, there is a rarity in methodologies like field and laboratory experiments and action studies. These methodologies, comparing the others, give more control to researchers and help them investigate causal relationships. Hence, adopting them more will bring a holistic sharpness to SCV, and lead it to be a well-understood and applicable field.

Another descriptive area we assessed in this study is the theoretical approach of the reviewed papers. Utilising a theory in the research is essential because it defines the boundaries of the study and provides study to stay in that limits, not less or more. Therefore, the research field grows within robust blocks. Lack of theoretical base, on the other hand, ends up with suspending ideas and a fuzzy research field. SCV field also experiences this problem, where only 26 out of 58 papers adopt a theoretical approach. Considering that ambiguity is SCV field's biggest problem, we can assert that this may be one of the reasons. Resource-based view is the most adopted theory, which accepts visibility as a capability for SCs. However, authors look at the phenomena from 18 other perspectives as well (Table 2).

Table 2 – Distribution of theories in SCV field

# of frequencies	Theories
5	Resource-based View (RBV)
2	Contingency Theory, Dynamic Capabilities View, Network Analysis, Organisational Information Processing Theory
1	Transaction Cost Economics, Social Exchange Theory, Systems Theory, Systems Dynamics Approach, Bounded Rationality Theory, IDEF0, Contingent RBV, Social Capital Theory, Process Oriented Approach, Design Theory, Set Theory, Dependency Theory, Technology-Organisation-Economy

Thematic Analysis

Roles of information sharing in SCV

Information sharing is accepted as a vital tool for many supply chain constructs like coordination, integration and flexibility (Baihaqi & Beaumont 2006; Williams et al. 2013). When it comes to visibility, the degree of that importance scales up, as information sharing constructs the core of SCV. This relationship, however, brings some problems as well: interchangeable usage of SCV and information sharing (Swaminathan & Tayur 2003). We believe that this interchangeability underlies the ambiguity of SCV context. Here, we define two main interactions between information sharing and SCV.

The first school of thought accepts information sharing as a source, which results in having visibility capability along the supply chain (Brandon-Jones et al. 2014; Holcomb et al. 2011; Barratt & Oke 2007). This relationship is obvious as the majority of SCV definitions rely on information sharing/accessing capability and information quality attributes. In this concept, we can tap into the resource-based perspective. We can infer that information sharing is only the activity that provides discrete benefits when the resource is used. On the other hand, a continuous information sharing powered by a completely visible supply chain will lead to a holistic set of benefits along the supply chain. The second group of authors, on the other hand, assert that when there is a viable visibility in supply chains, it can ease sharing information and getting benefit from that activity (Yu & Goh 2014; Caridi et al. 2010; Pfahl & Moxham 2014; Brandon-Jones et al. 2015). This relationship may be explained by the facilitating role of visibility, in terms of providing requisite technical and technological infrastructure. When the conditions are

more suitable to share and access information, it will be more possible to have more flow of information among supply chain partners. Other than technical assist, SCV can help construct the right environment for information sharing. The visibility-led higher level of trust between partners will make them more volunteer to share information (Baihaqi & Beaumont 2006).

Therefore, we can see that there is a cycling relationship between information sharing and SCV. While this brings the ambiguity and interchangeability for the field, it also complicates the practical implication of SCV. Since both concepts trigger each other, organisations may be confused about the starting point of visibility process. Somapa et al. (2018) bring an original set of ideas for information sharing and visibility interactions, which can be a solution to the issue. Authors look SCV from a process theory perspective and create three main categories for SCV characteristics. Then, they match the categories with suitable attributes of information: accessibility of information, quality of information and usefulness of information. These categories fit our findings and develop them by highlighting the difference between accessing information and the quality attributes of accessed information like completeness, accuracy, timeliness, usability, and format. Since quality-related information attributes are independent than the state of reaching information, we can accept it as another information sharing-SCV interaction model. Conclusively, we can classify these interaction modes as follows: information as-enabler-of-SCV, information as-means-of SCV, and information as-result-of-SCV. Investigating SCV contributes amongst these interaction modes will increase the robustness of the field and ease the applicability of both concepts.

Positive SCV constructs

Review of 67 papers has provided us to have a comprehensive analysis of SCV constructs with 49 concepts that affect SCV in a positive way. However, without analysing and synthesising them, they were not suitable to use. They were dispersed, in some cases repeating or covering others, in other words, far from creating a systematic tool. After repetitive analysis of the reviews, we have identified two main taxonomies for positive constructs of SCV, namely antecedents, and enablers.

Antecedents represent the prerequisites, of which existence is required for a better or easier setting of an activity. In this context, their impact can be considered as a moderating variable. Literature has provided one tangible and five intangible groups of antecedents. The first antecedent is the *connectivity*, which is the only tangible one (Scholten & Schilder 2015; Hardgrave et al. 2013; Kyu Kim et al. 2011; Chew et al. 2013; Caridi et al. 2014; Pfahl & Moxham 2014; Brusset 2016) It refers to the technological infrastructure readiness for an end-to-end SCV. Many authors consider connectivity as an essential prerequisite, as it provides the technical background for the collection and dissemination of information along supply chains. Hence, we can accept connectivity as a starting point for SCV implementation in the cycling interactions of information sharing and SCV. Other antecedents are related to intangible concepts. The first one is *culture.* It involves the interorganisational culture elements like shared language and narrative (Johnson et al. 2013) or country culture (Dubey et al. 2017) and intraorganisational culture elements like organisational culture (Dubey et al. 2017), knowledge management culture (Busse et al. 2017), joint learning culture (Scholten & Schilder 2015) and risk management culture (Rajagopal 2017). Second intangible concept, *trust* is accepted of a great essence, as it supports SCV and at the same time is supported by SCV (Johnson et al. 2013; Klueber & O'Keefe 2013). *Relationship management* is another antecedent for SCV. It can be assessed as two groups: strategic relationship management, including internal and external SC integration and collaboration (Williams et al. 2013; Rajagopal

2017; Scholten & Schilder 2015; Steinfield et al. 2011), and operational relationship management covering length of relationship, power distribution, enthusiasm, network ties and configurations (Akkermans et al. 2004; Klueber & O'Keefe 2013; Johnson et al. 2013; Scholten & Schilder 2015). Last antecedent group is related to external environment, which is *demand uncertainty* (Yang et al. 2018). It is suggested that visibility is best utilised in a problematic demand profile. It should be remembered that these factors have moderating impacts. In other words, they do not result with a better SCV implementation on their own, instead, their existence plays a supportive role for the initiation of SCV.

Second group of positive constructs of SCV is composed of enablers. Enablers play a role of initiating and driving visibility. Literature provides three main enablers. First and the most important one is *information sharing* and quality of information shared. Since previous section has elaborated this concept, we do not repeat the details here. Second enabler is about *regulatory and contract requirements* (Johnson et al. 2013; Yang et al. 2018). This enabler does not have an incentive role but instead has a directive function. Organisations may need to be more visible according to their industry-specific requirements (e.g. pharmaceuticals, cold-chain food industry). In the other aspect, an SME may be demanded to become more visible in a collaboration with a multinational corporate. The last enabler is about *behavioural norms* (Johnson et al. 2013). Behavioural preferences of managers or operators trigger the implementation of visibility. However, it should be kept in mind that this behavioural propensity can work as an inhibitor as well.

Negative SCV constructs

Similar to the positive constructs, there are negative factors that inhibit a prosper SCV implementation. The review of the literature has demonstrated that these negative factors can be classified into two main groups in order to comprehend them in the best manner: extant challenges, and inhibitors before SCV initiation.

Two main existing challenges hinder companies to consider adopting SCV in strategic perspective. The first one is related to the management of SCs. Lack of alignment among SC partners aggregates the integration. Hence, it turns into an obstacle before companies, and even inhibits them to consider being visible to their partners, which are mentally far to collaborate (Maghsoudi & Pazirandeh 2016; Busse et al. 2017). Second problem arouses from technological reasons. Since the technology plays an important role of reaching data and then disseminating it, adopting the right and integrated technology along SC is regarded as essential for SCV (Maghsoudi & Pazirandeh 2016). However, the short life-time of communication technologies and their increasing infrastructure costs make an end-to-end SCV implementation difficult, especially for SEMs (Steinfield et al. 2011). These two problems are the obstacles that should be solved before creating strategies for implementing a holistic SCV.

Second set of negative constructs appears when firms decide to become visible. The main problem is the ambiguity around the visibility field (Basole & Bellamy 2014; Dubey et al. 2017; Francis 2008). Its interchangeability with information sharing, its deficiency of not having a single definition prevent organisations to have a standard road map for the implementation process. Another setback is about the management of information. The difficulty of data standardisation, having low quality information and the discrepancies in the information sharing process lead firms to unsuccessful SCV initiatives from the beginning (Maghsoudi & Pazirandeh 2016; Steinfield et al. 2011; Williams et al. 2013).

Lastly, behavioural reasons play an important role before SCV applications in negative direction. Biases of managers against the dependability of information, their

underweighting manners against its importance cause reluctance in information sharing (Caridi et al. 2014; Williams et al. 2013). Besides, partners having trust issues have the fear of opportunistic behaviour from opposite side of relationship, when they give access to them for their information (Dubey et al. 2017). These hesitations hinder the relationship and prevent having the full benefit of SCV.

Conceptual Model

Concluding, this study has investigated the different impacts of information sharing roles on SCV. In order to elaborate their interactions, following conceptual model can be a base for future studies in the SCV area (Figure 2).

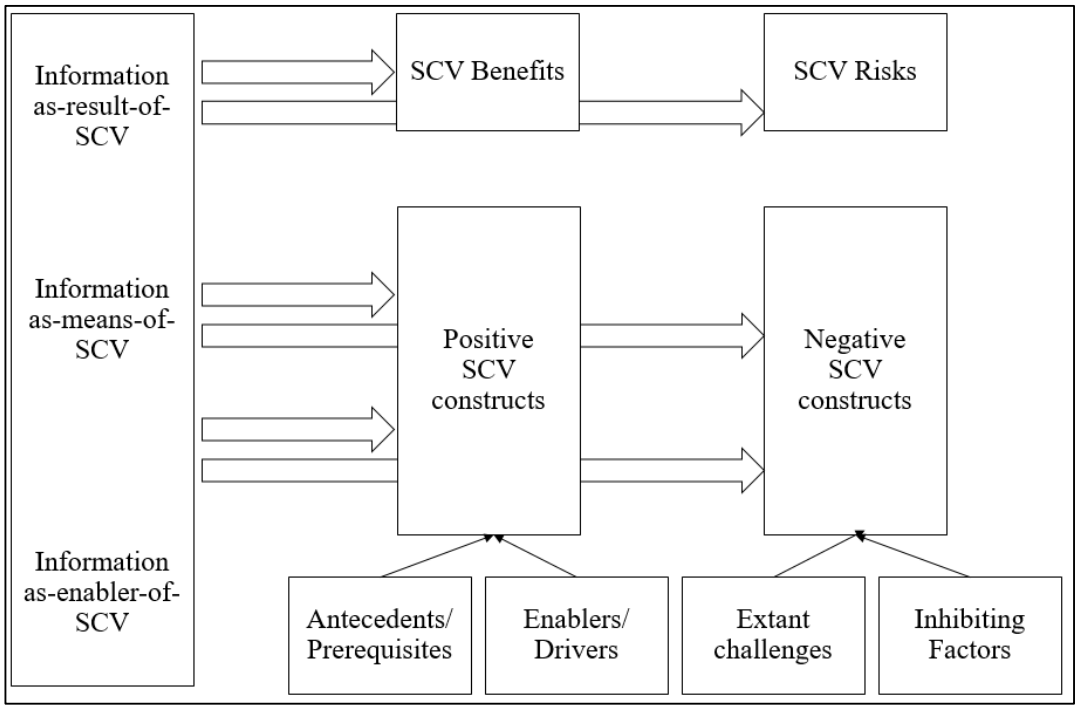

Figure 2 – Conceptual Model

Conclusion

This paper aims to clarify the fuzziness in the supply chain visibility by investigating its interactions with information sharing activity. In order to achieve the aims of the study, SLR methodology has been adopted in this research. Analysing 67 papers, three main roles of information have been found and their impacts have been observed in their interactions with SCV constructs. Two main contributions have been gathered from the study: interaction between information sharing and supply chain visibility has been illuminated in order to abolish the fuzzy nature of the research field. Secondly, positive and negative constructs of SCV have been classified in relations to each other. This helps researchers and practitioners to detect the interactions between constructs and draw their own roadmaps for and end-to-end SCV. We recommend future studies to test the conceptual findings of this study in empirical settings.

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Inventory Management

Optimal screening policies in an Economic Production Quantity model

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Abstract

A manufacturing process with two stages of quality control is considered. Initial screening is performed following some critical operations that generate a high proportion of defections. This allows us to discard the defective items at an early production stage and increases the productivity downstream in the production line. The initial screening cost, as well as the defect detection rate, depend on the screening speed. A mathematical model is developed and the optimal production parameters are analytically determined. We provide numerical examples and sensitivity analysis to illustrate the results and to derive managerial insights and implications.

Keywords: Optimal lot sizing, Screening time, Imperfect quality

Introduction

For many companies – e.g. those in electronics and semiconductor industries – it is reasonable to have an initial screening after some initial processing, especially, critical operations such as chemical or mechanical handling like chemical etching, drilling, etc. The reason for this is that the proportion of defections at that particular stage of the process is relatively high, and the remaining production steps are time-consuming and costly. Discarding the defective items at an early production stage increases the productivity downstream in production line and improves the overall performance measures of the system. Therefore, companies sometimes have even more stages of quality checking than one. Cao et al. (2012) provide methods for optimal allocation of inspection stations. Bouslah (2018) provide a model with two stages and joint control of production, inspection and maintenance. The reason for the two stages is the existence of two machine lines. Even though, adding initial inspection to the system might be reasonable for a company because they want to check the parts or input materials from their suppliers. Of course, the extra effort of initial screening has its own costs, and we aim to optimize the time spent with this activity in order to minimize overall costs. The optimization is carried out in the framework of the classical models of inventory analysis.

Cárdenas-Barrón et al. (2014) stated that Harris (1913) published the first inventory model. A special issue of the International Journal of Production Economics celebrated the hundred years' anniversary of this seminal paper. Among the papers published in this issue, Cárdenas-Barrón et al. (2014) contains a broad overview of the extensions of the original model as well as an extensive bibliography. Andriolo et al. (2014) provide a comprehensive summary on papers in the field, followed by Glock et al. (2014) with a survey on literature reviews in the area of lot sizing. We restrict our attention here on the papers closely related to our topic.

Our model belongs to the extensions of the Economic Production Quantity (EPQ) model, originally developed by Taft (1918) which assumes that the production rate is finite. The other research field we would like to join is focusing on imperfect quality items. A related Economic Order Quantity (EOQ) model is proposed in Salameh and Jaber (2000). It assumes that every single finished item is screened, and the imperfect ones leave the system at the end of the screening period in a batch. The authors draw up the explicit formula to calculate the economic lot size quantity and found that it is increasing with the growth of the average proportion of imperfect quality items. Khan et al. (2011) reviewed the extensions of this model where none of them considers the speed of the screening as a decision variable. Additionally, our paper is adding another stage of quality control to the EPQ version of the model.

Al-Salamah (2016) states that inventory models with imperfect quality can be classified in two categories: predictable and unpredictable identification, the former one being more often found in literature. The author considers imperfect inspection, destructive and non-destructive acceptance sampling. Reviewing most cited papers in the stream of imperfect quality, we found that perfectly reliable quality control is more often assumed which is more or less equivalent to the assumption that every single item is checked at the end of the production process. Alamri et al. (2016) argue that exhaustive inspection may eliminate the return service cost caused by defections, and the impact of letting through defective items could be severe. Instead of sampling techniques, exhaustive screening is more commonly applied in the industries we would like to analyse in this paper. Based on Sahling and Hahn (2019), the biopharmaceutical manufacturing does also belong to the stream of the possible examples with their flexible flow and very strict quality check requirements.

Moussawi-Haidar et al. (2016) were the first who integrated screening time into their production model with rework. Previous literature assumed either that all items are perfect or that screening is carried out continuously, making it possible to rework imperfect items immediately after detection. The authors provide closed form expressions for the optimal production lot size in a framework where inspection is finished later than production, and all defections are repaired. Chiu et al. (2007) consider a proportion of defections to be repairable and the remaining ones to be scrapped, and investigate the joint effects of stochastic machine breakdowns, scrap, and rework on the optimal production run time.

The speed of screening was first considered as a decision variable in Hauck and Vörös (2015). The authors built EOQ models to find the optimal lot size, screening speed, and level of investments to increase the speed of quality control. In this paper, we rather focus on the initial screening time. We assume that the defect detection rate depends on this time, i.e. the more time is spent on the screening, the higher proportion of initial defections are found. The detected defective items are discarded at this stage, saving energy and cost in the subsequent production steps.

Jaber et al. (2008) extended the model of Salameh and Jaber (2000) with the assumption that the proportion of defective items is lowering from cycle to cycle due to learning. Konstantaras et al. (2012) have further developed this model with the possible

occurrence of shortages, and managerial insights helping companies to choose suppliers. The ideas of both papers are applicable as possible extensions to our model.

Model description

A production process with two stages of screening is considered as illustrated by Figure 1. We face a deterministic, known and constant demand of rate d. At the beginning of each cycle, we lunch the production of a lot of size Q (decision variable).The production rate is P and on average, a proportion a $(0 < a < 1)$ of the production is defective after an initial processing step. Since this proportion is typically relatively high, a screening stage is added right after, to the process. We decide on the amount of time $(0 \leq \sigma \leq \bar{\sigma})$ is spent on the screening of each unit. Both the screening cost and the defect detection rate depend on σ. To avoid creating a bottleneck at this stage, the screening rate must be higher than the production rate and consequently the maximum time that could be devoted to the screening is $\bar{\sigma} = 1/P$ (unit of time per item). We assume that a proportion $p_1(\sigma)$ of the defections $(0 \leq p_1(\sigma) \leq 1)$ can be detected at this stage, and we get rid of the defect items at the end of the processing period. Initial screening cost is $c_1(\sigma)$ per unit. It is natural to assume that if no time is spent on the screening $(\sigma = 0)$ than $p_1(0) = 0$ (no defects are detected) and $c_1(0) = 0$ (no costs are incurred). We assume that $p_1(\sigma)$ and $c_1(\sigma)$ are continuous functions of σ and at least twice differentiable.

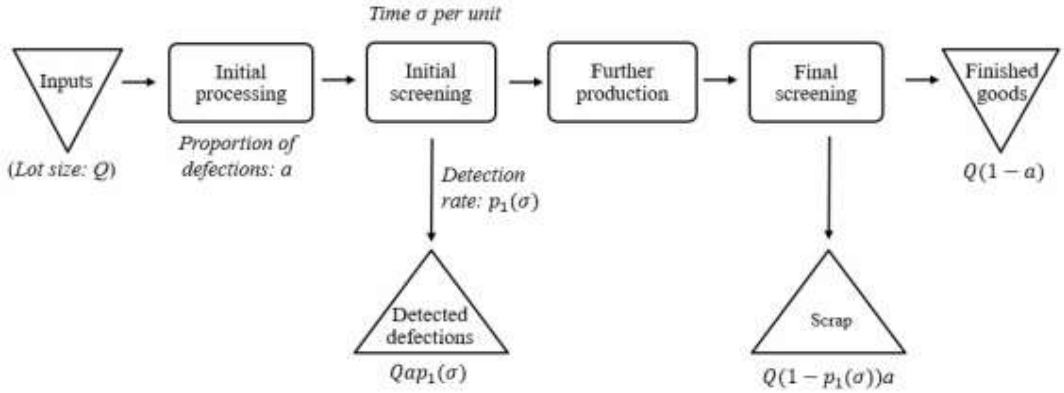

Figure 1. The production process with two stages of screening

After having separated the defects detected during the initial screening, the production continues with more expensive but reliable operations, followed by the final screening stage. At this stage, all kinds of defects are detected so only the good output is shipped. The defective items found at this step are removed from the inventory at the end of the cycle, without rework. The time spent on final screening is fixed and its cost is c_2 per unit. We assume that no backlog arises, and there is no excess inventory at the end of the cycle. In order to satisfy the demand, the defection rate has to be accounted for. The defect compensated demand rate is $d/(1-a)$ which must remain lower than the production rate (if not, the demand cannot be fully satisfied). We denote by $S = \frac{1-a}{d} - \frac{1}{P}$ (it can be interpreted as the idle production time per unit).

Notations used in this paper are listed in Table 1, and the inventory build-up diagram of the deterministic EPQ model is shown in Figure 2. During the production period, the inventory raises at rate $(P-d)$, i.e., the production rate minus the demand rate. At the end of the production cycle $R_1 = Q/P$, the company gets rid of the initially detected defections, i.e. $Qap_1(\sigma)$ items. The defective items detected later at the final screening

stage ($Qa(1-p_1(\sigma))$ items) leave the system at the end of the cycle. The total cycle length is $R = Q(1-a)/d$. The average inventory level is $I_1 = \frac{1}{2}(P-d)R_1$, during the screening period and $I_2 = \frac{1}{2}[(P-d)R_1 - 2Qap_1(\sigma) + Qa]$ during the remaining time of the cycle.

Table 1. List of notations

d	demand rate
P	production rate $(P > d/(1-a))$
a	proportion of defective items in the production, $0 < a < 1$
S	average idle production time per unit.
Q	production lot size, decision variable
R_1	production cycle length
R	cycle length
σ	time of initial screening per unit, decision variable
$p_1(\sigma)$	proportion of defective input detected at the initial screening
K	setup cost (arising every cycle)
k_1	initial processing cost per unit
$c_1(\sigma)$	initial screening cost per unit, depending on speed
k_2	second stage production cost (per unit)
c_2	final screening cost per unit
h	holding cost, per unit of product and per unit of time

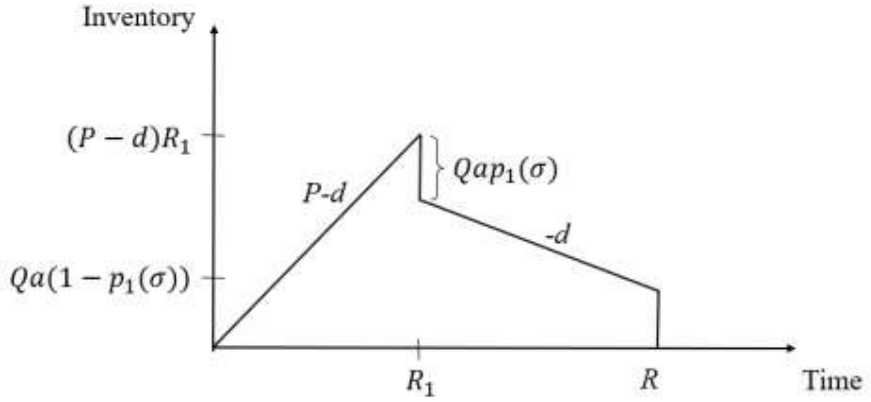

Figure 2. Inventory diagram of an EPQ model with two stages of screening

Processing, screening and holding costs are considered at both stages as listed in Table 2. The initial processing cost contains the cost of initial production for every item, whereas final stage processing cost does only consist of production costs of the items that passed the first screening (good and undetected defective items). Speeding up initial screening (spending less time with this process) saves some cost. However, it does also result in a lower proportion of defective items detected. The undetected defective items go through the second stage of production as well as the final screening, which results in higher processing and screening costs in the second-stage.

Table 2. Variable costs in a cycle

Costs	processing	screening	holding
initial stage	$k_1 Q$	$c_1(\sigma)Q$	$hR_1 I_1 = h\frac{Q^2}{2}\frac{P-d}{P^2}$
final stage	$k_2 Q\big(1-ap_1(\sigma)\big)$	$c_2 Q\big(1-ap_1(\sigma)\big)$	$h(R-R_1)I_2 = h\frac{Q^2}{2}S\left(\frac{P-d}{P}+a-2ap_1(\sigma)\right)$

Additionally, a fixed setup cost K is incurred once in every cycle. Thus, the total cycle cost writes:

$$TC(Q,\sigma) = K + k_1 Q + c_1(\sigma)Q + k_2 Q\big(1-ap_1(\sigma)\big) + c_2 Q\big(1-ap_1(\sigma)\big) + hR_1 I_1 + h(R-R_1)I_2 \quad (1)$$

Dividing the total cost in (1) by the cycle length, we obtain the average cost $C(Q,\sigma) = \frac{TC(Q,\sigma)}{R}$. After some reduction we obtain the following formula:

$$C(Q,\sigma) = \frac{d}{(1-a)}\left[\frac{K}{Q} + k_1 + c_1(\sigma) + k_2\big(1-ap_1(\sigma)\big) + c_2\big(1-ap_1(\sigma)\big) + \frac{1}{2}hQ\frac{P-d}{P^2} + \frac{1}{2}h\,QS\left(\frac{P-d}{P}+a-2ap_1(\sigma)\right)\right] \quad (2)$$

and hence, the optimization problem can be formulated as:

$$\min_{Q,\sigma} C(Q,\sigma) \qquad \text{s.t. } 0 \le \sigma \le \tfrac{1}{P}. \quad (3)$$

The average cost has to be minimized under the constraint that the initial screening should not be the bottleneck in the process, i.e., the screening rate must be higher than the production rate.

Convexity of the cost function

Let us suppose now that one of the two functions p_1 and c_1 is nonlinear but satisfy the assumptions A0-A1 and B0-B1:

Assumption A0: $c_1(0) = 0$ and $c_1'(\sigma) \ge 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption A1: $c_1''(\sigma) \ge 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption B0: $p_1(0) = 0$ and $p_1'(\sigma) > 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption B1: $p_1''(\sigma) \le 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

The convexity of the cost function ensures that a stationary point is a global minimum which is also unique if the objective function is strictly convex.

Calculating the Hessian matrix:

$$H = \begin{bmatrix} \frac{\partial^2 C(Q,\sigma)}{\partial Q^2} & \frac{\partial^2 C(Q,\sigma)}{\partial Q \partial \sigma} \\ \frac{\partial^2 C(Q,\sigma)}{\partial Q \partial \sigma} & \frac{\partial^2 C(Q,\sigma)}{\partial \sigma^2} \end{bmatrix}$$

$$\mathrm{H} = \frac{d}{(1-a)}\begin{bmatrix} \frac{2K}{Q^3} & -hSap_1'(\sigma) \\ -hSap_1'(\sigma) & c_1''(\sigma) + (-k_2 - c_2 - hQS)ap_1''(\sigma) \end{bmatrix} \quad (4)$$

The Hessian is positive definite if and only if the Hessian determinant is positive (see, e.g. Chiang, 1984), and $\frac{2K}{Q^3}$ is positive as well. The latter condition is true. Thus, the condition (H1) must be satisfied.

$$\frac{2K}{Q^3}[c_1''(\sigma) - (k_2 + c_2 + hQS)ap_1''(\sigma)] - [hSap_1'(\sigma)]^2 > 0. \quad \text{(H1)}$$

A more explicit form of Condition (H1) could be obtained for particular c_1 and p_1 functions under few assumptions.

Optimal parameters

We solve the above optimization problem under condition (H1) that guarantees the convexity of the objective function.

The Lagrangian writes

$$L(Q, \sigma, \mu_1, \mu_2) = C(Q, \sigma) + \mu_1\left(\sigma - \frac{1}{P}\right) - \mu_2\sigma, \qquad \mu_1, \mu_2 \geq 0.$$

The Karush-Kuhn-Tucker points (KKT) are obtained from the following conditions:

$$\frac{\partial L(Q,\sigma,\mu_1,\mu_2)}{\partial Q} = \frac{\partial C(Q,\sigma)}{\partial Q} = 0 \quad \text{(L1)}$$

$$\frac{\partial L(Q,\sigma,\mu_1,\mu_2)}{\partial \sigma} = \frac{\partial C(Q,\sigma)}{\partial \sigma} + \mu_1 - \mu_2 = 0 \quad \text{(L2)}$$

$$\mu_1\left(\sigma - \tfrac{1}{P}\right) = 0 \quad \text{(C1)}$$

$$\mu_2\sigma = 0 \quad \text{(C2)}$$

$$\mu_1, \mu_2 \geq 0. \quad \text{(P1)}$$

Condition (L1) implies

$$-\frac{K}{Q^2} + \frac{1}{2}h\frac{(P-d)}{P^2} + \frac{1}{2}hS\left(\frac{(P-d)}{P} - 2ap_1(\sigma) + a\right) = 0$$

$$Q^* = \sqrt{\frac{2K}{h}\left[\frac{(P-d)}{P^2} + \mathrm{S}\left(\frac{(P-d)}{P} - 2ap_1(\sigma^*) + a\right)\right]^{-1}}. \quad (5)$$

From the formula (5) we can see that higher detection rate $\left(p_1(\sigma^*)\right)$ makes the optimal lot size increase.

Now, according to complementarity conditions (C1) and (C2), we have ($\sigma - \frac{1}{P} = 0$ or $\mu_1 = 0$) and ($\sigma = 0$ or $\mu_2 = 0$). These define four cases, from which $\sigma - \frac{1}{P} = 0$ and $\sigma = 0$ cannot be true at the same time. Hence, three possible solutions remain:

(a) $\sigma - \frac{1}{P} = 0$ which gives $\sigma^* = \frac{1}{P}$ and $\mu_2 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}\left[c_1'\left(\frac{1}{P}\right) - k_2 a p_1'\left(\frac{1}{P}\right) - c_2 a p_1'\left(\frac{1}{P}\right) - a p_1'\left(\frac{1}{P}\right) hQ^* S\right] + \mu_1 = 0$$

from which

$$\mu_1 = \frac{-d}{(1-a)}\left[c_1'\left(\frac{1}{P}\right) - k_2 a p_1'\left(\frac{1}{P}\right) - c_2 a p_1'\left(\frac{1}{P}\right) - a p_1'\left(\frac{1}{P}\right) hQ^* S\right] \quad (6)$$

which must be positive in order for this solution to be feasible.

(b) $\sigma^* = 0$ therefore $\mu_1 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}[c_1'(0) - k_2 a p_1'(0) - c_2 a p_1'(0) - a p_1'(0) hQ^* \mathrm{S}] - \mu_2.$$

Hence

$$\mu_2 = \frac{d}{(1-a)}[c_1'(0) - k_2 a p_1'(0) - c_2 a p_1'(0) - a p_1'(0) hQ^* S] \quad (7)$$

which must be positive in order for this solution to be feasible.

(c) $\mu_1 = 0$ and $\mu_2 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}[c_1'(\sigma) - k_2 a p_1'(\sigma) - c_2 a p_1'(\sigma) - a p_1'(\sigma) hQ^* S] = 0.$$

Hence, σ^* is obtained from the solution of the following equation

$$c_1'(\sigma) - k_2 a p_1'(\sigma) - c_2 a p_1'(\sigma) - a p_1'(\sigma) hQ^* \mathrm{S} = 0 \quad (8)$$

which must satisfy feasibility conditions.

Note that if the initial screening cost is small and increases moderately with respect to the screening time, then we have case (a), which means that the maximum possible time should be spent on the initial screening. On the other hand, sharp increase in the initial screening cost makes zero initial screening time (case b) optimal. If initial screening cost is neither very high nor very small compared to second-stage screening, processing and holding costs, then the optimal screening time comes from equation (8) in case (c) which balances all the costs.

The condition (H1) is sufficient to guarantee the optimality of any feasible KKT point among the above.

Numerical examples and sensitivity analysis

In this section, we provide numerical examples to illustrate the computation procedure and to derive managerial insights from various scenarios regarding the shape of the underlying functions and the values of the different parameters of the model.

Assuming 40 working hours per week, the number of working minutes per year is $T = 125000$. Based on the production constraint, the maximum time that can be devoted to initial screening is 1 minute per unit. All the time related parameters are converted to minutes.

Table 3. General parameters to be used in the numerical examples

d	demand rate	80,000	units/year
P	production rate ($P > d/(1-a)$)	125,000	units/year
a	proportion of defective items in the production, $0 < a < 1$	0.04	
K	setup cost (arising every cycle)	1000	\$/setup
k_1	initial processing cost per unit	10	\$/unit
k_2	second stage production cost (per unit)	20	\$/unit
c_2	final screening cost per unit	10	\$/unit
h	holding cost, per unit of product and per unit of time	30	\$/unit/year

Additionally, to the parameters above (Table 3), we define multiple scenarios in which we consider various levels of the screening cost and/or detection rate. Furthermore, we vary the proportion of the defective items in the production (a) and observe the effect on the optimal parameters and total cost of the system.

We consider the parameters of the nonlinear detection function to be unchanged while calculating the optimal level of initial screening for cheap, moderate, and expensive parameters of the linear screening cost function. If the proportion of defective items is 4%, then parameter values that are lower than $\beta = 0.3$, the optimal initial screening time is 1, and for values higher than $\beta = 2.5$, screening is not reasonable, i.e. $\sigma^* = 0$.

Table 4. Optimal values of initial screening for various cost levels and defection rates

	Parameters, Variables	Values #1	Values #2	Values #3
Nonlinear detection function: $p_1(\sigma) = \alpha(1 - \exp(-\xi\sigma)),\ \alpha, \xi > 0$	α	1	1	1
	ξ	2	2	2
Linear cost function: $c_1(\sigma) = \beta\sigma,\ \beta > 0$	β	0.3	0.9	2.5
Level of the initial screening cost		low	medium	high
Proportion of the defective items in the production $a = 0.04$				
Optimal initial screening time	σ^*	1	0.5	0
Optimal lot size (units)	Q^*	3982	3948	3858
Optimal total cost (\$/year)	$C^* \times T$	3,313,716	3,349,839	3,376,538
Proportion of the defective items in the production $a = 0.11$				
Optimal initial screening time	σ^*	1	1	0.49
Optimal lot size (units)	Q^*	4214	4214	3915
Optimal total cost (\$/year)	$C^* \times T$	3,408,649	3,462,581	3,641,421

As to be seen in Table 4, the cheaper the screening, the more time should be spent with it. For rather low proportion of defective items in the production ($a = 0.04$), we have shown the two extremes when initial screening is so cheap that the optimal value is the possible maximum ($\sigma^* = 1$, see #1), and when it is so expensive that no time should be spent with it at all (see #3). The optimal lot size increases with the higher optimal values of σ. The minimum of the total cost decreases as the optimal initial screening time gets higher. The minimum of the total cost is higher if the proportion of defective items increases, and the differences are also bigger.

Let us also note that an increased proportion of defections, i.e. higher value of a makes initial screening more crucial. In the example above, it is optimal to do spend time with initial screening even if the costs are high and the maximal value is the optimum for a

moderate cost level already. As illustrated by Figure 3, the minimum of the total cost is increasing with both the initial screening cost and the defection rate.

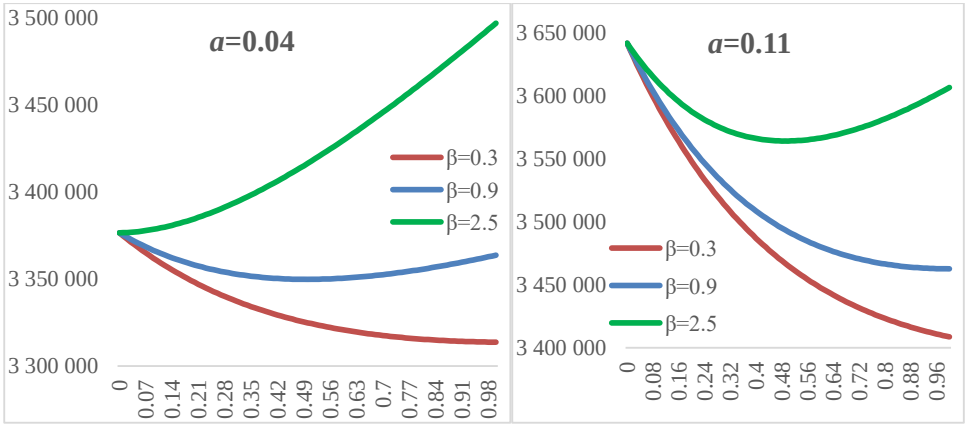

Figure 3. The total cost function with respect to σ, with low, medium and high initial screening costs, and higher defection rate in the second case

Conclusion

This paper presents an inventory model with two stages of quality screening. Jointly with the production lot size, the time allocated to the initial screening is a decision variable as well. This problem is relevant for many companies that have complex operations and many defections in the first stage of the production process.

The time of initial screening determines the related costs but also the proportion of detected defections in linear or nonlinear form. With the objective of minimizing the total production cost, we proposed a procedure to calculate the optimal lot size jointly with the optimal time of initial screening.

There are several results with high relevance for managerial implications. Firstly, the decision regarding the screening time affects the total cost of the system and modifies the optimal lot size. We found out that if the cost of screening in the first stage is too high then it is more reasonable to avoid it and bear the second-stage holding, processing and screening costs. Vice versa, if first stage screening costs are small enough compared to the other types of costs, then the maximal time should be spent on initial screening to allow the detection of a maximum number of defective items. In many other cases, the optimal screening time allows us to balance the various cost components. Other parameters that can influence the decision regarding the screening time include the proportion of the defections in the production (reliability of the production process in the first stage). The findings show that doing quality control in the optimal manner and in the right time reduces the overall system cost while ensuring the desired quality level.

The model in this paper can be extended in several directions. Possible extensions include additional defections in the second production stage, backlogging or rework, random defections, errors in screening and learning effect.

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Collaborative mechanism design for container sharing and pricing at ports

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Abstract

In this project, a collaboration mechanism in a centralized model will be designed and applied for empty container sharing between two firms. The developed model is based on two firms on two terminals. Both the firms accept the cargoes from consignee so both of them have the demands for the empty container. The two operators charge their customers separately once they accept the cargoes from consignee, which can affect the demand of empty container. Additionally, empty containers can be exchanged between two firms when the containers the operator has is insufficient whereas the other has surplus containers.

Keywords: Collaboration mechanism, Empty container, Centralized model

1. Introduction

With rapidly global trade and economic development of the world in the last few decades, port is playing more and more important and indispensable role for international trading. How to manage and re-allocate empty container takes a huge challenge to port managers. Typically, a reasonable solution is to divide whole huge port area into several terminals as individual operation entity and rent them to private port company to operate separately. Indeed, it is a right way to solve the problem, but it also takes a new question to port management, i.e. how to establish a mechanism system to collaborate and coordinate each individual terminal to maximize profit for whole port. *Xie et al. (2017)* solved the problem of empty container inventory sharing and coordination by using centralized model. According to these researches, therefore, in this research, firstly, several elements are included in the model, which are (1) office of firm 1 and 2 are responsible for operation

of product collection, dispatch, receive and transport in terminal A and B respectively, (2) a railway connect two terminals for exchanging empty container and (3) a central planner for operating two firms in the centralized model. Moreover, firm 1 and 2 own empty container at Container Yard (CY) in terminal A and B respectively *(Xie et al. 2017)*. Secondly, in this research, we have two goals. We build a centralized model between two terminal firms to develop an optimal delivery policy for repositioning empty container, which means there is a central planner operate the whole system. In addition, two variables of initial inventory of empty container and charging price 'p' to empty container are considered simultaneously when deciding optimal delivery quantities in centralized model. Therefore, this research is based on this model.

2. Literature review

In this part, we are going to review the literature in terms of empty container repositioning problem and inventory sharing game to support this research.

There are many valuable previous researches about empty container repositioning problem in empty container supply chain management *(Florez, 1986; Crainic, Gendreau and Dejax, 1993; Shintani et al., 2007; Song and Zhang, 2010, Zhang, Ng and Cheng, 2014)*. Some of the results have an important value this research. For example, in the research of *Xie., et al (2017)*, they claimed that linear programming is a most commonly way to formulate empty container repositioning problem and they investigated the sharing and coordination problem for empty container inventory in an intermodal transport. In this system, there are one liner firm in a seaport and one rail firm in a dry port operating the whole port simultaneously. By using integer program, *Choong, Cole and Kutanoglu (2002)* solved the planning horizon problem of minimizing container repositioning cost in container-on-barge intermodal transportation network. They pointed out that planning horizon need to be carefully considered for slow speed of barge transportation and they think that the transportation way of container-on-barge could be a viable alternative to rail and truck if a long planning horizon is used. *(Choong, Cole and Kutanoglu, 2002)*. In 2014, *Pérez-Rodríguez and Holguín-Veras (2009)* explored a stochastic model to formulate empty container accumulation process in urban areas over a time expanded network to investigate the influence of profit margins, acquisition costs and storage costs for accumulation of containers at areas which can be used for urban planning and policy making. They final confirm and quantify that demand uncertainty is a key factor which can affect port terminal's costs significantly. By literature review discussion and industrial practice observation, *Song and Carter (2009)* developed a research that they identified the critical factors which could affect empty container movement significantly. They adopted three main routes which are Trans-Pacific, Trans-Atlantic, Europe–Asia as an example to quantify the scale of empty container repositioning. They also use this example to contrast and evaluate different strategies of shipping lines and container operators which may reduce the cost of their empty container repositioning behaviour. Moreover, to minimize the expected total costs which includes inventory-holding costs, transportation costs and repositioning costs etc., *Dong and Song (2009)* investigated empty container repositioning problem in multi-vessel, multi-port and multi-voyage shipping systems considering joint container fleet sizing with circumstance of uncertain and imbalanced customer demand. They also developed a simulation-based evolutionary algorithm to solve the optimization problem which has been approved for its effectiveness by using a case study. They finally conducted a numerical example by using several repositioning policies which involves a heuristics repositioning policy (HRP), an evolutionary algorithm-based policy (EAP) and a non-repositioning policy (NRP) for comparison facilitation

On the other hand, there is a very long history of the research of inventory sharing game. The most classical model of inventory sharing game is 'Newsvendor model' which is a basic model well known in operations research and applied economics, then the newsvendor model has been developed in many disciplines. The word of 'newsboy' is firstly used by *Morse and Kimball (1951)* in their research *(Chen et al., 2016). Morse and Kimball (1951)* originally explained it as *"Let us consider the case of a newsboy who is required to buy his papers at 2 cents and sell them at 3 cents and is not allowed to return his unsold papers. He has found by experience that he has on the average 10 customers a day, and that customers appear at random. How many papers should he buy?"* Normally, there are two players including supplier and retailer in newsvendor model, but these two names may vary in different meanings in different research. In inventory sharing game, which is included in the discipline of supply chain management, for instances, *Rudi, Kapur and Pyke, (2001)* studied inventory transshipment problem between two firms as two players in a newsvendor model. They realized that each local decision makers usually prefer to make their own performance rather than a central planner to collaborate overall performance.

It is now necessary to discuss the knowledge gap between this research and the others to show why this paper is valuable for operational research. To the best of author's knowledge of relative literature, in centralized model, there is no evidence clearly shown that there existed researches about empty container repositioning problem in the circumstance of uncertain demand for empty container caused by empty container leasing price. (i.e. the demand of empty container is stochastic, and demand is also affected by price charging to empty container). This is the knowledge gap between this paper and previous research. Therefore, we will add the variable of "p" with the meaning of "Basic price charged for leasing empty container" to the centralized model to show demand of empty container is dependent with "p" and it is stochastic. Furthermore, based on this assumption, we will develop the centralized model with a central planner to develop an optimal policy for empty repositioning problem.

3. Model information

In this section, we fully introduce the model we design in this research with more details. For clarity and convenience reading, we will divide this section into 2 parts which are "basic model design" and "centralized model design".

Basic model design

The model includes two firms (firm 1 and firm 2) operate two terminals named A and B respectively in one port area. They can both transport and ship cargoes on land or between oversea ports individually and both firms own inventory of empty container in their terminals Container Yard (CY) *(Xie et al. 2017)*. Generally, the empty container of one of the firms can be borrowed by the other firm in some circumstances (e.g. empty container is not enough to satisfy the demand) if it is necessary and we assume that there will be a railway to connect both terminals to deliver empty container. The demand functions (X_1 and X_2) for terminal A and terminal B are denoted as below:

$$X_1 = D_1(p) + \xi_1 = a_1 - b_1 p + \xi_1, b_1 > 0 \quad (1)$$
$$X_2 = D_2(p) + \xi_2 = a_2 - b_2 p + \xi_2, b_2 > 0 \quad (2)$$

Where $D_1(p)$ and $D_2(p)$ are the demand function for firm 1 and 2, a_1, a_2, b_1 and b_2 are parameters. p is the basic payment to firm for leasing empty container. ξ_1 and ξ_2 are

error term and they are denoted with probability density function (pdf) is $f_i(x)$ and cumulative distribution function (cdf) is $F_i(x)$, i=1,2. Furthermore, we assume that there is no demand for the firm 1 at terminal 2 which means that there is no empty container accumulations and inventory at terminal 2 for firm 1 and vice versa.

On the one hand, from the perspective of firms, one firm can deliver their empty container to the other firm as long as they have extra empty container after its self-optimization. Now, it is clear to show that a transhipment game between two firms is what we are going to investigate in this paper. Now, we can show an example to clearly explain the whole process. For firm 1, the empty container inventory in terminal 1 should be firstly used for satisfying its own demand and they should unload all containers from overseas. The unloaded container of firm 1 should be added to terminal 1's inventory. The unloaded containers of firm 2 should satisfy firm 1's extra demand in terminal 1 if it is necessary, finally, if there are still some firm 2's extra empty containers in terminal 1 after demand satisfaction, these empty containers should be delivered to terminal 2 immediately. Vice versa.

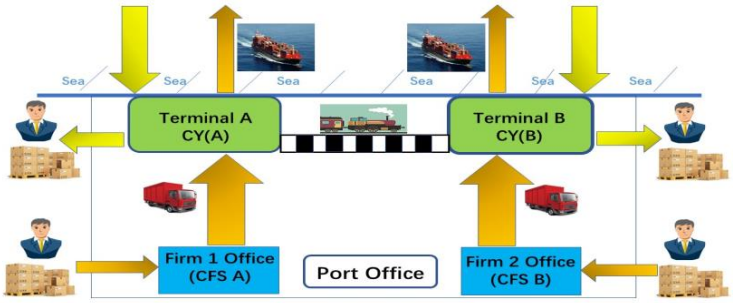

Figure 1 Model description

On the other hand, for consignors who want to transport their cargoes to overseas, they can choose the firm what they want to export their product to overseas. Firstly, the cargoes should be delivered by corresponding consignor to container freight station (CFS) in firm 1 or firm 2. Secondly, consignor should pay firm 1 or firm 2 a basic fee for leasing empty container and ocean freight cost. Lastly, the cargoes should be transported to the corresponding terminal from firm's CFS. If the inventory of empty container in any of two firms cannot be satisfied with their own demand, then the basic price for empty container leasing will be changed to fulfill the demand in both terminals and rebalance the demand in whole system. However, there could still exist unsatisfied demands in one of the firms even if port office changing the basic price to affect demand. Therefore, at the same time, under this circumstance, the other firm should transport their extra empty containers to the firm which its own demands are not fully satisfied. In addition, for considering of simplify calculation, it is assumed that the basic price (p) for leasing empty container charged by firm 1 and firm 2 is same. Moreover, for the cargoes imported from overseas, we assume that any arriving container ship can be accepted in both terminals and unloaded regardless the ownership of the container belongs to which firm. Then, the unloaded container should be added to its corresponding terminal's inventory. However, for example, if firm 1's container arrive at terminal B and firm 2 has an extra demand for empty container, so this container can be borrowed by firm 2. Otherwise this container should be returned to terminal 1 immediately and vice versa. The whole process can be found in figure 1.

Now, it is better to show the notations for this model below. It has already denoted that X_1 and X_2 represent the random demands of empty container for firm 1 and firm 2 in the CFS, respectively. Denote Y_1 and Y_2 are the empty container's random arrivals in the container freight station of terminal 1 and 2, respectively. We let n_1 and n_2 are inventory of empty containers at CY of terminal 1 and 2, respectively. Let r_1 and r_2 are revenue from shipping out per loaded container at terminal 1 and 2. At the same time, we denote r_l is revenue from leasing per empty container for both firms. We also consider a holding cost per empty container at terminal 1 and 2 are h_1 and h_2, respectively. Denote goodwill penalty per empty container at terminal 1 and 2 are g_1 and g_2. c_t is transportation cost per empty container between two terminals.

Centralized model design

The number of empty containers delivered between two terminals (q) and basic price for leasing empty container (p) are the decision variable. Basically, there is a central planner operating the whole port including firm 1 and firm 2 in centralized model. The central planner decides the basic price for leasing empty container and quantity of delivered empty container between two firms. For example, given the inventory of empty container in both terminals, the decision variable of q and p can be calculated by the central planner. In opposite, given the delivery quantity and basic price, the inventory in both terminals (n_1 and n_2) also can be fixed. It is necessary to define that the value is positive (+q) when empty container delivered from terminal 2 to terminal 1 and is negative (-q) for the opposite. Figure 2 show the whole process for centralized system.

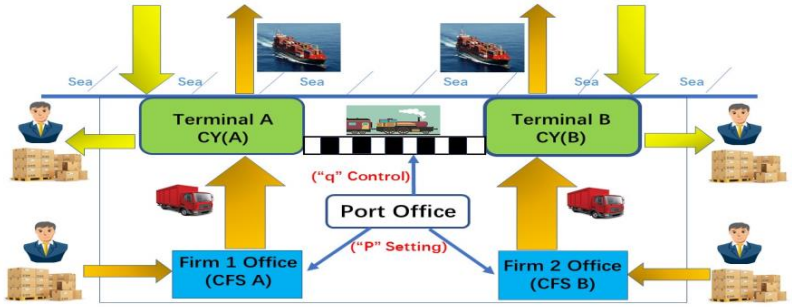

Figure 2 Centralized model description

4. Centralized Model

In section 4, a centralized model will be developed which means there is a central planner operate two firms. According to this assumption, we are going to develop the optimal empty container delivery policy.

4.1 Profit function

For terminal 1 and terminal 2:

Let $Q_1(q, n_1, p_1)$ denote the satisfied demand for empty containers at terminal 1.

$$Q_1(q, n_1, p) = Emin\{X_1, n_1 - q + Y_1\}$$
$$= EminD_1(p) + \xi_1, n_1 - q + Y_1 = Emina_1 - b_1 p + \xi_1, n_1 - q + Y_1$$

Let $I_1(q, n_1, p_1)$ denote the leftover inventory at terminal 1.

$$I_1(q, n_1, p) = (n_1 - q + Y_1 - X_1)^+$$
$$= [n_1 - q + Y_1 - D_1(p) - \xi_1]^+ = (n_1 - q + Y_1 - a_1 + b_1 p - \xi_1)^+$$

Let $L_1(q, n_1, p_1)$ denote the unsatisfied demand at the terminal 1.

$$L_1(q, n_1, p) = (X_1 + n_1 - q + Y_1)^+ \\ = [D_1(p) + \xi_1 + n_1 - q + Y_1]^+ = (a_1 - b_1 p + \xi_1 - n_1 + q - Y_1)^+$$

Let $Q_2(q, n_2, p)$ denote the satisfied demand for empty containers at terminal 2.

$$Q_2(q, n_2, p) = Emin\{X_2, n_2 + q + Y_2\} \\ = Emin\{D_2(p) + \xi_2, n_2 + q + Y_2\} = Emin\{a_2 - b_2 p + \xi_2, n_2 + q + Y_2\}$$

Let $I_2(q, n_2, p_2)$ denote the leftover inventory at terminal 2.

$$I_2(q, n_2, p) = (n_2 + q + Y_2 - X_2)^+ \\ = [n_2 + q + Y_2 - D_2(p) - \xi_2]^+ = (n_2 + q + Y_2 - a_2 + b_2 p - \xi_2)^+$$

Let $L_2(q, n_2, p_2)$ denote the unsatisfied demand at the terminal 2.

$$L_2(q, n_2, p) = (X_2 + n_2 + q + Y_2)^+ \\ = [D_2(p) + \xi_2 + n_2 + q + Y_2]^+ = (a_2 - b_2 p + \xi_2 - n_2 - q - Y_2)^+$$

Furthermore, the transportation cost for the empty containers is $c_t|q|$ between terminal 1 and terminal 2. Then, the expected profit function $\prod(q, n_1, n_2, p)$ can be written as follows:

$$\prod(q, n_1, n_2, p) = (r_1 + r_l)EQ_1(q, n_1, p) + (r_1 + r_l + r_2)EQ_2(q, n_2, p) - h_1 EI_1(q, n_1, p) \\ - h_2 EI_2(q, n_2, p) - g_1 EL_1(q, n_1, p) - g_2 EL_2(q, n_2, p) - c_t|q| \tag{3}$$

Finally, similar to that on page 9 in *Cachon (2003)*, we can rewrite the profit function. Then, the final profit function can be stated below:

$$\prod(q, n_1, n_2, p) = K[M - n(M)] + L[N - n(N)] - h_1 M - h_2 N - g_1 E(\xi_1 - Y_1) \\ - g_2 E(\xi_2 - Y_2) + (r_1 + r_l)E(Y_1 + a_1 - b_1 p) + (r_1 + r_l + r_2)E(Y_2 + a_2 \\ - b_2 p) - c_t|q| \tag{4}$$

Where $\overline{n}()$ is the complementary loss function and $K = r_1 + r_l + h_1 + g_1$, $L = r_1 + r_l + r_2 + h_2 + g_2$, $M = n_1 - q - a_1 + b_1 p$ and $N = n_2 + q - a_2 + b_2 p$. Moreover, from equation above, it is clear that $\prod(q, n_1, n_2, p)$ is not differentiable at q = 0.

4.2 Optimal delivery policy

In this part, a basic analysis for centralized model will be provided. In order to explain clearly for the steps of calculation and its outcome, we adopt step-wise analysis. Firstly, we will give the proof for special case where n_1 and n_2 are given and p and q are given respectively. Then, a simultaneous decision-making process where, n_1, n_2, p and q are jointly affected will be stated.

We denote $z_1()$ is the probability density function (pdf) for $\xi_1 - Y_1$ and $Z_1()$ is the cumulative distribution function (cdf) for $\xi_1 - Y_1$. Denote $z_2()$ is the probability density function (pdf) for $\xi_2 - Y_2$ and $Z_2()$ is the cumulative distribution function (cdf) for $\xi_2 - Y_2$. Now, we are going to prove $\prod(q, n_1, n_2, p)$ is jointly concave in q and p where n_1 and n_2 are given. Then, based on this calculation of first order condition for the model, the optimal number of delivers between two ports and price charging level from two firms will also be developed further.

Lemma 1 *Given n_1 and n_2, $\prod(q, n_1, n_2, p)$ is jointly concave in p and q, the unique optimal q^* and p^*can be determined*

To prove $\prod(q, n_1, n_2, p)$ is jointly concave in q and p is equivalent to prove that the determinants of Hessian matrix which is constituted with second-order partial derivatives of $\prod(q, n_1, n_2, p)$ in terms of p and q is negative semidefinite. In this case:

$$\begin{vmatrix} \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial p^2} & \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial p\, \partial q} \\ \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial q\, \partial p} & \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial q^2} \end{vmatrix}$$

Therefore, the result of determinant for the Hessian matrix is:

$$\begin{aligned} &\frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial p^2} \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial q^2} - \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial p\, \partial q} \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial q\, \partial p} \\ &\quad = 2(r_1 + r_l + h_1 + g_1)(r_1 + r_l + r_2 + h_2 + g_2) b_1 b_2 z_1 (n_1 - q - a_1 \\ &\quad + b_1 p) z_2 (n_2 + q - a_2 + b_2 p) \geq 0 \end{aligned} \tag{5}$$

Hence, $\prod(q, n_1, n_2, p)$ is jointly concave in q and p, which means that there exists the unique optimal solution. Therefore, an unique optimal result for p and q in the model can be developed. We denote that they are p^* and q^* respectively, given n_1 and n_2. According to the first-order condition of the model, i.e. $\frac{\partial \prod(q, n_1, n_2, p)}{\partial p}$ and $\frac{\partial \prod(q, n_1, n_2, p)}{\partial p}$, we can further obtain the unique value of optimal charging price and unique optimal number of empty containers delivered between two terminals by uniting two first-order conditions.

For q>0:

$$\begin{cases} \boldsymbol{p}^* = \dfrac{Z_1^{-1}(A) + Z_2^{-1}(B) + a_1 + a_2 - n_1 - n_2}{b_1 + b_2} \\ \boldsymbol{q}^* = \dfrac{Z_2^{-1}(B) - Z_1^{-1}(A) + b_2(n_1 - a_1) - b_1(n_2 - a_2)}{b_1 + b_2} \end{cases} \tag{6}$$

For q<0:

$$\begin{cases} \boldsymbol{p}^* = \dfrac{Z_1^{-1}(A') + Z_2^{-1}(B') + a_1 + a_2 - n_1 - n_2}{b_1 + b_2} \\ \boldsymbol{q}^* = \dfrac{Z_2^{-1}(B') - Z_1^{-1}(A') + b_2(n_1 - a_1) - b_1(n_2 - a_2)}{b_1 + b_2} \end{cases} \tag{7}$$

where,

$K = r_1 + r_l + h_1 + g_1 \neq 0,\ L = r_1 + r_l + r_2 + h_2 + g_2 \neq 0, M = n_1 - q - a_1 + b_1 p,\ N = n_2 + q - a_2 + b_2 p, A = \frac{(b_1+b_2)(K-h_1)-(r_1+r_2+r_l)b_2+b_2 c_t}{(b_1+b_2)K}$

$B = \frac{(b_1+b_2)(L-h_2)-(r_1+r_2+r_l)b_2-b_1 c_t}{(b_1+b_2)L}, A' = \frac{(b_1+b_2)(K-h_1)-(r_1+r_2+r_l)b_2-b_2 c_t}{(b_1+b_2)K}$

$B' = \frac{(b_1+b_2)(L-h_2)-(r_1+r_2+r_l)b_2+b_1 c_t}{(b_1+b_2)L}$

Lemma 1 describes the connection between basic price p^* for empty container and number of deliveries q^* when both inventory level in two terminals are given. It also reveals that there exists an unique optimal solution for the joint number of deliveries between two firms and charging price setting given both firms' inventory level. From **Lemma 1** and satisfied demand function $Q_1(q, n_1, p)$ and $Q_2(q, n_2, p)$, it is very easy to obtain the optimal satisfied demands number for empty containers in whole system as follows:

$$Q^*(q, p, n_1, n_2) = n_1 + n_2 + E(Y_1 + Y_2) - \overline{n}(n_1 - q^* - a_1 + b_1 p^*) - \overline{n}(n_2 + q^* - a_2 + b_2 p^*) \tag{8}$$

Lemma 2 *Given p and q, $\prod(q, n_1, n_2, p)$ is jointly concave in n_1 and n_2, the unique optimal n_1^* and n_2^* can be determined*

We drive the similar steps with **Lemma 1**, firstly, to prove $\prod(q, n_1, n_2, p)$ is jointly concave in n_1 and n_2 is equivalent to prove that the determinants of Hessian matrix which is constituted with second-order partial derivatives of $\prod(q, n_1, n_2, p)$ in terms of n_1 and n_2 is negative semidefinite. In this case:

$$\begin{vmatrix} \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_1^2} & \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_1 \, \partial n_2} \\ \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_2 \, \partial n_1} & \dfrac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_2^2} \end{vmatrix}$$

Therefore, the result of determinant for the Hessian matrix is:

$$\frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_1^2} \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_2^2} - \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_1 \, \partial n_2} \frac{\partial^2 \prod(q, n_1, n_2, p)}{\partial n_2 \, \partial n_1}$$
$$= (r_1 + r_l + h_1 + g_1)(r_1 + r_l + h_2 + g_2 + r_2) z_1(n_1 - q - a_1 + b_1 p) z_2(n_2 + q - a_2 + b_2 p) - 0 > 0 \tag{9}$$

Hence, $\prod(q, n_1, n_2, p)$ is jointly concave in n_1 and n_2, which means that there exists the unique optimal solution. Then, we can easily obtain the optimal value of n_1 and n_2 by solving two first-order derivation. Therefore, an unique optimal result for n_1 and n_2 in the model can be developed. We denote that they are n_1^* and n_2^* respectively, given p and q. According to the first-order condition of the model, i.e. $\frac{\partial \prod(q, n_1, n_2, p)}{\partial n_1}$ and $\frac{\partial \prod(q, n_1, n_2, p)}{\partial n_2}$, we can further obtain the unique value of initial inventory of empty container in terminal 1 and terminal 2.

$$\begin{aligned} \boldsymbol{n_1^*} &= Z_1^{-1}\left(\frac{K - h_1}{K}\right) + q + a_1 - b_1 p \\ \boldsymbol{n_2^*} &= Z_2^{-1}\left(\frac{L - h_2}{L}\right) - q + a_2 - b_2 p \end{aligned} \tag{10}$$

where, $K = r_1 + r_l + h_1 + g_1 \neq 0$, $L = r_1 + r_l + r_2 + h_2 + g_2 \neq 0$, $M = n_1 - q - a_1 + b_1 p$, $N = n_2 + q - a_2 + b_2 p$

Now, we can easily recognize that Lemma 2 is a newsvendor problem solution. According to Lemma 2, it can be determined the optimal inventory level for each firm when the price charging for empty container and exchanging quantity are given. But there are still some differences between the problem that Lemma 2 solved and classical newsvendor problem solution. For instance, *Bell and Zhang (2006)* provided a classical newsvendor problem solution for maximizing systems profit by choosing a price when firms' inventory level are fixed. Moreover, *Zhang et al., (2010)* found that it is relative independent for inventory level in each market segments when prices are given. However, Lemma 2 gives a result for a new newsvendor model that inventory level can be determined for each firm to maximize system's profit when both charging price and the exchanging quantity of empty container between two firms are given simultaneously. Compared with Proposition 1 in *Zhang., et al (2010)*, it is very clearly to notice that it is the value of q in Lemma 2 which is a key factor that cause this difference. Furthermore, the inventory level in each firm are also not relatively independent because of q existence (but the core reason is that the model of *Zhang., et al (2010)* was based on pricing competition), which is also different with *Zhang., et al (2010).* In general, although there exist some differences between these solutions for newsvendor problem, it is still an unanimous results that Lemma 2 reveals with the others, e.g. Zhang., et al (2010) and *Bell and Zhang (2006).*

Corollary 2 Assume $Z_i(\xi_i - Y_i), i = 1,2$ increase in $\xi_i - Y_i$, customer order quantity in terminal 1 increases in r_1, r_l and g_1, but decreases in h_1 and customer order quantity in terminal 2 increases in r_1, r_l, r_2 and g_2, but decreases in h_2. The result is opposite when assuming $Z_i(\xi_i - Y_i), i = 1,2$ decrease in $\xi_i - Y_i$.

In this case, it is necessary to discuss in different situation because we cannot determine the monotonicity of the function $Z_i(\xi_i - Y_i), i = 1,2$. Firstly, We assume $Z_i(\xi_i - Y_i), i = 1,2$ increase in $\xi_i - Y_i$, Corollary 2 reveals that inventory level increases in r_1, r_l and g_1, but decreases in h_1 for firm 1. Inventory level in firm 2 increases r_1, r_l, r_2 and g_2, but decreases in h_2. Similarly, in the opposite situation, inventory level decreases in r_1, r_l and g_1, but increases in h_1 for firm 1. Inventory level in firm 2 decreases in r_1, r_l, r_2 and g_2, but increases in h_2. It should be clearly stated that the inventory level in one of the firms is not independent from the price because of q existence, which means the inventory level is related to the value of q when price is given.

Lemma 1 and Lemma 2 provide a method to transform a four-decision variable problem into a two-dimensional research because of computational complexity *(Zhang., et al, 2010).* Next, we are going to show a unique solution in a general condition.

Lemma 3 *$\prod(q, n_1, n_2, p)$ is jointly concave with respect to q, p, n_1 and n_2.*

Lemma 3 provides a solution to find an optimal solution among inventory level, delivery quantity and price charging. It shows that $\prod(q, n_1, n_2, p)$ is concave in q, p, n_1 *and* n_2 and it also reveals that there exists a optimal group of q, p, n_1 and n_2 to satisfy a maximum $\prod$. Therefore, the optimal transhipments and optimal price charge can be determined. However, due to the computational complexity, we will show the optimal value of each variable in the future research.

Conclusion

In this research, we consider a system including two firms operating two terminals in a port area simultaneously. At the same time, we build a centralized model which means

there is a central planner to control the whole system. In this model, two variables considered are 1) the quantity of empty containers that need to be transferred between two terminals and 2) the price charged by each operator. In this centralized model, the two operators will be treated as a single company, which will lead to perfect collaboration to find an optimal policy for delivery of empty container. Finally, we provide three results which are: (1). Given n_1 and n_2, $\prod(q, n_1, n_2, p)$ is jointly concave in p and q and the unique optimal q^* and p^* are determined; (2). Given p and q, $\prod(q, n_1, n_2, p)$ is jointly concave in n_1 and n_2 and the unique optimal n_1^* and n_2^* are determined. (3). It has been proofed that $\prod(q, n_1, n_2, p)$ is jointly concave with respect to q, p, n_1 and n_2 and there exists optimal group of q, p, n_1 and n_2 to satisfy a maximum $\prod$. Overall, in a centralized model, we find a policy to determine the quantity of transhipment of empty container between two terminals and constrained with leasing price 'p' for empty container. However, in this paper, we just focus on solving empty container repositioning problem by using centralized model. It is necessary to keep on research to solve this problem by using decentralized, which means there is no central planner to operate two terminals but using a contract to determine the empty container transhipment.

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Lean and Agile Operations

‘Lean 4.0’: How can digital technologies support lean practices?

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Abstract

The digitalisation of business offers great possibilities to create new products and processes, as well as improve existing ones. In this paper we seek to understand how digital technologies can support process improvement in a manufacturing context. Several studies have proposed synergies among digitalization and lean at a conceptual level, yet so far we lack any empirical proof. To this effect, we present exploratory quantitative research aimed at explaining how digital technologies can support lean practices, improving our understanding how to harness the potential of digitalisation in operational improvement. We conclude with areas for further research.

Keywords: Lean, process improvement, digitalization, manufacturing.

Introduction

Digital technologies are powerful innovations that have rightfully captured the imagination of manufacturing managers. It has been frequently stated that digital technologies can support or enhance lean practices. Here, technologies often associated with ‘Industry 4.0’ are cited, and we will refer to such digital enhancements of lean practices as ‘Lean 4.0’. For example, according to Wagner et al. (2017), digitalization will not only support lean practices, but it will also enlarge their scope. Even on the

performance point of view, researchers reached the consensus on the operational improvements lean practices yield thanks to digitalization (i.e. Davies et al., 2017; Kolberg and Zühlke, 2015; Tortorella et al., 2018). However, beyond these early studies, to the best of authors' knowledge, conclusive proof of this claim is still outstanding.
It is easy to conceive areas where they directly support lean practices, yet so far much of this discourse is based on conjecture. With the underlying study we seek to provide a rigorous identification of the mechanisms explaining how digital technologies can support lean practices, and thus contribute to our theoretical understanding of the true impact of 'Industry 4.0' technologies, and to support managerial decision in making the business case for their adoption.

In this paper, we present a structured literature review of lean practices as well as digital technologies of relevance to operations management. We show findings of an initial survey that demonstrated the lack of maturity of digital technology adoption in practice and highlighted the needs for further qualitative research. We conclude with comments on preliminary results and presenting our next steps.

Theoretical background

Lean: wastes and practices

The concept of 'lean production' has been widely researched and discussed in the operations management literature (c.f. Holweg, 2007, Fujimoto, 1999, and many others). At the very heart of lean stands the concept of waste reduction, namely to improve a process by reducing non-value activities herein. Taiichi Ohno coined the original seven wastes (or 'muda') in manufacturing (often abbreviated as TIMWOOD – Transportation, (excess) Inventory, Motion, Waiting, Overproduction, Overprocessing and Defects), which later have been expanded to also include 'Skills', or wasted human talent and ideas. Muda, together with 'mura' (unevenness) and 'muri' (overburden), provides the original, and still the most succinct, way how to conceptualise lean (Bicheno and Holweg, 2016).

It is for that reason that we adopt the seven (eight) wastes for our study, coupled with the lean practices that have been built upon them to form an integrated management system (Shah and Ward, 2003; Womack, Jones and Roos, 1990). These practices work synergistically to achieve the main goals of lean production, which are related to the creation of a streamlined, high quality system that produces finished products at the pace of customer demand with little or no waste (Shah and Ward, 2003). For their nature, lean practices are applicable to the entire company (Ruiz-Benítez, López and Real, 2018). However, in the scientific community, there is no a unique classification of practices or consensus on which is the complete set of lean practices. Different authors, in fact, refers to them providing their own classification or list of practices. For this reason, and for the scope of this study, a systematic literature review has carried out, with the aim to define a comprehensive list of lean practices.

We adopted an ad-hoc keywords strategy to article title/abstract and keywords on Scopus database. Keywords selected are based on the term "lean" combined with the Boolean operator AND to terms referring to "practice" or "bundle". Moreover, we

adopted five inclusion criteria. Firstly, we reviewed only contributions in English. Secondly, we considered only journal paper belonging to high-ranked journal (Q1 according to Scimago ranking), discarding conference contributions, books chapter or journal paper published in a medium-to-low ranked journal (according to Scimago ranking). Thirdly, we included only contributions with a proper and specified review/classification of practices. Fourthly, we restricted our focus to manufacturing industry, discarding then all contributions clearly referred to service industries. Eventually, we considered contributions from 2000 on.

The review process identified 528 eligible studies from all the keywords. We filtered the studies by scanning their titles and abstracts, removing duplicates and selecting those consistent with the aforementioned inclusion criteria, resulting in 179 articles. Full-texts were assessed with the same criteria, to discard out-of-scope documents, resulting in 81 articles. 140 practices have been identified, with more than 75% of them cited less than 10 times, highlighting the lack of structured and comprehensive list of practices. Following the final selected sample of practises considered, having each a number of citations at least equal to 10.

Table 1 - Lean practices

Lean practice	Number of citations
JIT(Just in Time/ Continuous flow production)	66
Pull system (Kanban)	56
Quick changeover techniques and reduction of setup time (SMED)	53
TPM (Total productive maintenance)	47
Continuous improvement programs (Kaizen)	39
TQM (Total quality management/Zero defects)	37
Supplier involvement and developement (feedback and partnership)	34
Production smoothing (bottleneck removal, Heijunka)	31
Cross-functional work force	31
Cellular manufacturing	30
VSM (Value Stream Mapping)	28
5S	27
Work standardization (SOPs stand. operating procedures)	26
Error proofing (Poka-Yoke)	26
Lot size reductions	23
VLPM (Visual Performance Measures/Visual control)	23
Customer involvement and partnership (feedback)	22
Statistical Process Control (SPC)	17
Employees' involvement (suggestion schemes)	16
Autonomation (Jidoka)	16
Information sharing	15
Lean Management Training	15
Elimination of waste	14
Shop floor organization and safety	14
Small group problem solving	14
Preventive maintenance	13
Low inventory	13
HRM (Human Resources Management)	12
Top management leadership for quality	11
Reduced number of suppliers	10
Takt time definition	10

The resulted panel is made by 31 lean practices, with various degree of frequency. JIT and Pull systems are referred to most frequently, while Smaller number of suppliers and Takt time definition are of less interest in the reviewed literature.

As mentioned before, according to its definition, lean strives to minimize general understanding of waste (Womack, Jones and Roos, 1990). It is essential hence to

understand the role played by lean practices on the 8 wastes. Here following a table summarizing which lean practice acts on specific waste. As result of reviewing literature, some practices result to have a more horizontal impact on wastes compared to others. As example, Kaizen events affect positively all 8 wastes, while the takt time definition results to impact only on waiting and inventories.

Table 2 - Lean practices and 8 wastes

Lean practice	Transportation	Inventories	Motion	Waiting	Overproduction	Overoprocessing	Defects	Skills
JIT(Just in Time/ Continuous flow production)	x	x		x	x			
Pull system (Kanban)	x	x			x			
Quick changeover techniques and reduction of setup time (SMED)				x	x		x	
TPM (Total productive maintenance)		x		x				
Continuous improvement programs (Kaizen)	x	x	x	x	x	x	x	x
TQM (Total quality management/Zero defects)		x				x	x	
Supplier involvement and developement (feedback and partnership)	x	x						
Production smoothing (bottleneck removal, Heijunka)		x		x				
Cross-functional work force			x					x
Cellular manufacturing		x	x					
VSM (Value Stream Mapping)	x	x			x			
5S			x				x	
Work standardization (SOPs stand. operating procedures)			x	x			x	
Error proofing (Poka-Yoke)			x				x	
Lot size reductions		x		x				
VLPM (Visual Performance Measures/Visual control)		x			x	x	x	
Customer involvement and partnership (feedback)					x	x	x	
Statistical Process Control (SPC)		x			x	x	x	
Employees' involvement (suggestion schemes)	x	x	x	x	x	x	x	x
Autonomation (Jidoka)			x	x			x	
Information sharing	x	x	x	x	x	x	x	x
Lean Management Training	x	x	x	x	x	x	x	x
Elimination of waste	x	x	x	x	x	x	x	x
Shop floor organization and safety		x	x					
Small group problem solving								x
Preventive maintenance		x		x				
Low inventory		x			x			
HRM (Human Resources Management)				x				x
Top management leadership for quality	x	x	x		x	x	x	x
Reduced number of suppliers	x	x						
Takt time definition		x		x				

Digital technologies

The availability of low-cost sensors, increases of computing power and high-speed internet connectivity are some of the enablers of massive advances in technologies for operations and supply chain management. Companies have always used new technologies to advance their process. The shipping container is probably the most successful example of a technical revolution that not only significantly improved supply chain processes but also shaped global trade flows in the long term (Cooper and Levinson, 2010).

On the other hand, there are also technologies like Radio Frequency Identification (RFID) that have triggered high expectations for process improvement in retailing operations, but have so far only been able to partially fulfil (Gaukler and Seifert, 2007). Ultimately, new technologies can provide benefits in two fundamentally different ways, i.e. either by increasing efficiency or by increasing revenues – many technologies aim to achieve both. As we are interested in the technology benefits that aim at waste reduction, we carefully screened for relevant technologies in this context. Since new technology developments are currently observed every day, we focused our literature analysis on practitioner articles as well as white papers and reports issued by large technology firms

and big consultancies. While the mentioned technologies differ slightly and the terminology is also varying a comprehensive picture emerged that put six technology clusters in the focus of our interests. Table 3 provides a summary of the technologies that we identified as potentially most relevant for process improvement.

Table 3 - Summary of technologies

Technology	Description	Examples
IoT solutions	Sensors, cameras and smart devices that process and share gathered data using internet connectivity.	Process control sensors, environmental monitoring cameras, smart replenishment solutions.
Virtual and augmented reality	Interactive experience where real world objects are either represented completely "virtual" or "augmented" by computer-generated perceptual information.	Smart glass, holo-lens, virtual twins.
Advances analytics	Data science tools for improved decision making, e.g., by gaining deeper insights, making predictions, or generating recommendations.	Predictive Analytics, Machine Learning, Deep Learning, Support Vector Machines.
Autonomous vehicles	Solutions allowing semi- and fully autonomous transportation, ranging from long-distance to short-distance deliveries.	Platooning trucks, autonomous trucks, drones, self driving delivery vehicles.
Robotics	Physical robotic systems used across all supply chain processes within enclosed environments.	Robotic mobile fulfillment systems, picking robots, industrial robots, cobots.
Digital manufacturing	Integrated, computer-based system manufacturing comprised of simulation, 3D visualization, analytics and collaboration tools to create product and manufacturing process.	Digital printing, 3D printing, CNC milling, Stereolithography.

'Lean 4.0'

The integration between lean and Industry 4.0 (Lean 4.0) is currently highly discussed in literature (Buer, Strandhagen and Chan, 2018). Even if academia seems to agree on the potentials of the aforementioned integration, there are different points of view depending on the author explaining the subject. Two main perspectives can be drafted in the academia. Some authors describe lean as a basis for the implementation of Industry 4.0 (Hambach, Kümmel and Metternich, 2017). Indeed, since lean practices are aimed at wastes reduction along the process (Womack and Jones, 2003), having a streamlined and under control process represents the prerequisite for any process digitalization (Buer, Strandhagen and Chan, 2018). Other studies have significantly confirmed that companies

with a higher associated level of lean implementation benefit the most in embracing Industry 4.0 and in grasping its potentials (Hoellthaler, Braunreuther and Reinhart, 2018).

Other researchers refer instead to Industry 4.0 as a completion of lean (Kolberg and Zühlke, 2015), that was declared as limited by some studies. Market requirements are nowadays more complex and customers demand for highly personalized products may hinder lean to be still effective. Lean could not only be able to keep up with the pace of personalization using the same tools used since the second half of the 20th century with no technological advancements supporting those tools (Sanders, Elangeswaran and Wulfsberg, 2016). In this sense, Industry 4.0 represents the mean lean can exploit to face new trends in the manufacturing world, preserving its process' robustness.

The strong interest for the topic from the academia is evident, however due to the infancy of the Industry 4.0 topic, it is still difficult to assess the effect of Lean 4.0. To the best of authors' knowledge, available scientific studies are mostly focused on theoretical research, and hence conclusive proof for Lean 4.0 potentials is still outstanding.

This research is an attempt to study the mechanisms explaining how digital technologies can enhance lean, and to assess the impact of 'Lean 4.0' on operational performance. The scope is limited to industrial operations management, including manufacturing, logistics and supply chain operations, since it is the traditional application space for lean.

Exploratory survey

In this section we will we will present our exploratory survey carried out in the European manufacturing sector aimed at deepen the relationship between Lean and digital technologies adoption, as well as the effects on operational performance. Firstly, we will describe the design of the survey and its instrument, as well as its implementation. Secondly, we will present first preliminary results of our quantitative study.

Design

A survey methodology has been selected as the most suitable one among quantitative methodologies.

The questionnaire is made by 19 questions, grouped into six main clusters: (i) companies' profile; (ii) contextual factors; (iii) lean practice implementation; (iv) digital technology implementation; (v) the effect of 'Lean 4.0'; (vi) operational performance.

The constructs related to lean practices and digital technologies used in the questionnaire are based on the reviewed literature both on lean practices and on technologies. For what regards operational performance, both questions and response interval come from the study of Shah and Ward (2003). Moreover, set-up time and inventories have been included as additional items due to their relevance for the lean approach. The response interval for these items is built following the same structure suggested by Shah and Ward (2003).

The sample selected for this exploratory survey is limited to the European manufacturing sector, with plants as unit of analysis. Respondents are required to be

experienced in lean, therefore green belt and black belt experts have been targeted. These criteria led to a non-random choice of companies for the survey, a strategy used also in the study of Shah and Ward (2003). In order to define the size of the sample, it was considered that 15% is the average rate in management surveys and 100 is the minimum threshold of responses to perform a significant statistical analysis (Hair *et al.*, 2007). On the base of these numbers, sample considered valid consisted in about 1200 experts.

Implementation

The questionnaire instrument has been tested with a sample of 56 lean experts to verify and to validate the constructs and the questions. Testing phase started in May 2018 and lasted 5 months. The final and improved online survey, through Google Module, has been submitted from November 2018 to February 2019 to more than 1200 lean experts. Questionnaire submission exploited three different waves: first wave addressed 700 people, second wave 300 people, and third wave about 200 people. Non-response bias has been managed through two actions: first, while sending the survey it was specified that the questionnaire lasts at least 10 minutes; secondly, the questionnaire was sent three times with a time window of about one week.

The final number of completed surveys was 162 corresponding to a response rate of approximately 13,32%. The validity of answers was verified excluding answers coming from experts involved in service sector (56 answers) and cleaning the dataset from clearly random responses (1 answer). The final dataset is composed by 105 responses, referring to 88 different companies. In addition to all the answers provided, final dataset comprehends two additional values for each expert/plant: lean level (LL) and digital level (DL). According to the model developed by Soriano-Meier and Forrester (2002), LL can be defined starting from a self-evaluation on the implementation of several lean practices. The final LL comes from the computation of the average value of self-evaluation values. The same reasoning of LL has been used for computing DL, exploiting the six digital tools considered in the survey.

Results

In terms of production technology, responses are equally distributed among process and discrete manufacturing. Moreover, several industrial sectors are represented in the sample. Most of the respondents report their plant age as higher than 20 years while only about 7% of the plants have been built in the last decade (Figure 1 - A). About the plant size, according to the European classification, the sample is representative of medium-large plants (Figure 1 - B). Only about the 6,7% of the respondents is indeed in small plants (i.e. less than 50 employees).

Eventually, it is interesting to understand how respondents are spread out on different departments. It is indeed necessary to stress that all the respondents are lean experts, endowed with green or black belt certification, and are working in different departments within companies. 31,4% of the respondents are involved in the Production and Maintenance departments. A remarkable percentage of experts, 27,6%, belongs instead

to the so-called Kaizen Promotion Office, that is usually a support-function in charge of continuous improvement activities of the company. Quality and Supply chain functions are also represented in the sample.

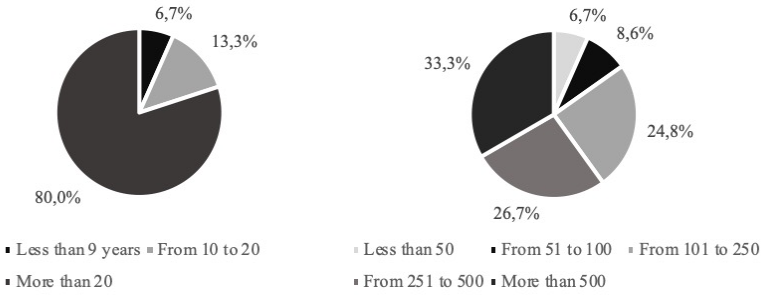

Figure 1 - Age plants (A) and Size plants (B)

Data gathered from the online survey have been using SPSS, a software of data mining and data statistical analysis.

In order to study the dependence of DL on LL, a box plot analysis was carried out to better understand how the data are distributed. As displayed in Figure 2 - A, not only data are not normally distributed but also DL shows a lower variability than LL. It is interesting to note that there are three outliners at the top of the graph: these three plants are classified as "old" and "large" and are associated with a very high LL. Same data of DL and LL are plotted in a scatter plot to have a graphical representation of the relation between the two variables (Figure 2 - B).

The second quadrant of the matrix presents a high concentration of observation, meaning that most of the plants having a low DL report a high LL. Moreover, not only the fourth quadrant is empty - there are no plants with high DL and low LL, but also DL is never higher than LL. This may confirm what is stated in the literature: highly digitalized plants are also strongly implementing lean, making lean the prerequisite for digital transformation (e.g. Buer, Strandhagen and Chan, 2018).

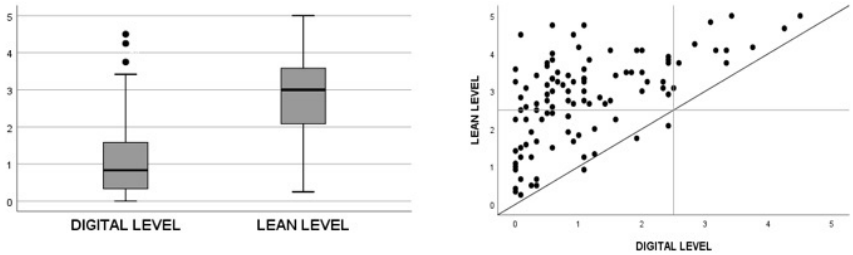

Figure 2 - DL and LL: Box plot (A) and scatter plot (B)

Despite this, too few plants registered an above average DL. Only about 10% of plants are belonging to the first quadrant, registering high DL and high LL. This prevented us to make meaningful statements on the possible digital mechanisms that affect lean.

Moreover, looking at operational performance results, the majority of plants is not at the moment affected by any significant operational performance increase. A cluster analysis of plants on operational performance highlights an interesting fact. Applying K-means methods, we ended with 3 different clusters (k=3 defined by Ward distance criterion) with plants not equally distributed among them. About 60% of plants indeed belongs to cluster 3. If cluster 1 and cluster 2 registered remarkable improvement in one or more operational performance, cluster 3 includes companies where Lean 4.0 did not affect operational performance. As shown in Figure 3, it is interesting to note that plants associated with high LL and high DL register a positive impact on operational performance. This represents an initial preliminary result on the performance improvement yielded by Lean 4.0. Unfortunately, further considerations cannot be draft due to the low numbers of observations available with high LL and high DL.

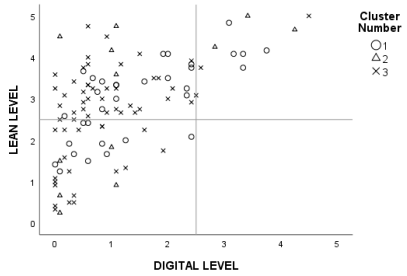

Figure 3 - Clustering analysis on operational performance

Conclusion and next steps

Preliminary results coming from our exploratory survey showed a positive relationship between the combined lean and digital adoption on operational performance. Low digital maturity levels however prevent us from fully disentangling the effects as the majority of plants still feature a low digital level. Thus, we will expand our research design to include qualitative research to identify the potential mechanisms how digital can support lean that practitioners foresee. Using a focus group-based study design (currently underway) we seek to identify both potential variation of impact, as well as level of importance, of the main digital technologies, as well as clustered mechanisms that vary across supply chain activities. In other words, we want to understand which digital technologies have the greatest impact on lean process improvement, and secondly, what the general mechanisms are how digital technologies support lean. Based on our combined survey and focus group findings we will provide a discourse on the how mechanisms identified link to the wide theoretical landscape of lean improvements, and how this can inform managerial practice to harness the potential that digital technologies offer to operations management more generally.

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Lean Value Streams: how to integrate their design into Industry 4.0

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Abstract

This paper proposes guidelines for designing lean value streams considering their integration with Industry 4.0 (I4.0) technologies. We gathered experts' opinions regarding the relationship between eight traditional guidelines for designing a lean value stream and ten I4.0 technologies utilised in previous studies. The identification of the most important relationships then provided arguments for the proposition of enhanced guidelines for designing lean value streams within the Fourth Industrial Revolution context. The integration of I4.0 into the guidelines for designing a lean value stream raises a distinct approach that benefits from the simplicity of Lean Production with the agility of these technologies.

Keywords: Value stream mapping, Industry 4.0, Lean production.

Introduction

Lean Production (LP) is widely acknowledged as a systematic approach to reduce waste and improve flow through extensive employee involvement and continuous improvement (Womack et al., 1990; Womack, 2011). Despite its pervasiveness, generalizable implementation steps have not yet emerged (Marodin and Saurin, 2013). Nevertheless, an LP practice that seems to have a more extensive and accepted adoption is Value Stream Mapping (VSM). A value stream is the sum of all activities (value-added or not) needed to take value from its beginning through to the customer.

VSM is an LP practice for analysing the current state of a value stream and designing a future (desired) state for the series of activities, hence indicating systemic improvement opportunities (Rother and Shook, 2003). Furthermore, VSM consolidates the flows of information and material, showing how they interact with each other throughout the value stream. VSM's versatility is also represented by its extensive integration with different methodological approaches, such as discrete events simulation (Helleno et al., 2015), six-sigma (Salah et al., 2010), Monte Carlo simulation (Souza et al., 2018) and analytic hierarchy process (Tortorella et al., 2018).

With the acknowledgement of the Fourth Industrial Revolution, characterized by the integration of novel information and communication technologies (ICT) (e.g. Internet of Things, big data and cloud computing) into manufacturing processes, products and services, interconnectivity and real-data collection/analysis are potentially enhanced

favouring more assertive managerial decisions (Zezulka et al., 2016; Yang et al., 2017). Such integration has also obtained the title of Industry 4.0 (I4.0), and it has been claimed that the ICT may lead manufacturers to a superior performance level (Züehlke, 2010; Liao et al., 2017). However, much still needs to be investigated to deeply comprehend the procedure to include I4.0 technologies into existing management systems. Thus, despite the envisioned interrelations (e.g. Meudt et al., 2017), the way I4.0 technologies can influence the design and implementation of lean value streams is still unknown, and there is still a lack of empirical evidence within the literature (Martinez, et al., 2016).

Therefore, this article aims at proposing guidelines integrated with I4.0 technologies for designing lean value streams. For that, based upon experts' opinion, we verify the relationship of the main I4.0 technologies with each guideline for a lean value stream design, discussing how they may impact the currently existing approach. Our proposal entails a shift on traditional guidelines for lean value stream design, providing an approach aligned with the ICT/i4.0 that is expected to revolutionise operations management.

Literature review

Value stream mapping

VSM development usually encompasses four main steps: (*i*) identify products/services families, (*ii*) draw current state map, (*iii*) design future (lean) state value stream, and (*iv*) consolidate a plan and implement improvement opportunities. Step (*i*), identify products/services families, aims at determining families of products/services whose items present similar processing needs, simplifying subsequent mapping activities. Generally, a product-process matrix, in which processes are in the columns and products are listed in the rows, is established allowing a simple visualisation of similarities (Duggan, 2012) or incorporating more complex mathematical models to identify them (De Lit et al., 2000; Eppinger and Browning, 2012).

The second step comprises drawing the current state map for the selected product/service family. Literature (e.g. Zahraee et al., 2014; Morlock and Meier, 2015; Tortorella et al., 2017) suggests that different methods can be simultaneously applied for this addressing this activity, such as oriented visits (*Gemba* walks), participatory observation, semi-structured interviews, system-data collection and focused groups with the improvement team. Based on these methods, information such as cycle times, inventory levels, machine downtimes, etc., is collected and inputted into the map. Moreover, the usual recommendation to draw a current state value streams is from downstream to upstream processes, which is supposed to facilitate the comprehension of value from customers' (internal or external) perspective.

Step (*iii*) concerns the design of the future state of the selected value stream. This future state is supposed to be an improved version (lean) of the current state map since it aims at addressing the opportunities previously identified using the variable of time (Womack and Jones, 2011). The recommendation for this step is to draw the current state map with the same team-based approach. According to Hines and Rich (1997) and Rother and Shook (2003), a lean value stream is focused on increasing system's flexibility to allow rapid adaptation to changes in demand, waste elimination, minimising inventory levels and enhancing the efficiency of materials and information flows.

Finally, step (*iv*) seeks to consolidate all necessary improvement initiatives and organise them into a strategic interdepartmental plan that is supposed to be followed-up in a regular basis (Edtmayr et al., 2016). Therefore, the recommendation is the establishment of specific working groups that, according to members' backgrounds and roles within the organisation, can address improvements with similar characteristics or

inter-related to each other. However, the existence of a value stream leader or coordinator is highly suggested to ensure the convergence of all initiatives and facilitate overcoming eventual barriers for change implementation (Bicheno and Holweg, 2000; Azizi, 2015).

Industry 4.0

Coined in the Hannover Fair in 2011, I4.0 has been referred to as the new paradigm in operations management (Hermann et al., 2016). In this ICT driven industrial context, prominent technological frameworks for manufacturing processes, products and services have been developed, entailing an array of solutions to the growing customised needs of informatisation (Kagermann et al., 2013). The novelty of this paradigm and its potential benefits envisioned have motivated a growing demand for research mainly related to its challenges, design solutions, implementation and management systems (Xu et al., 2018).

However, managers and practitioners still struggle to grasp I4.0 concepts. One of the reasons for such difficulty may be derived from the low readiness level of ICT infrastructures, undermining the adoption and understanding of I4.0 (Liao et al. 2017). Moreover, extensive incorporation of I4.0 technologies is also likely to influence other critical aspects of an organisational structure, such as customer/supplier relationship management (Schumacher et al., 2016) and human resources development (Dworschak and Zaiser, 2014). In this sense, while the adoption of cutting-edge technologies can facilitate the achievement of significant operational performance enhancement, at the same time it can also entail unknown structural shifts in organisations. Therefore, I4.0 essential features and impacts still deserve further investigation to provide a clearer comprehension for both managers and academicians (Yin et al., 2018).

Method

The proposed method comprises three main steps: (*i*) experts' selection, (*ii*) interviews, (*iii*) consolidation and analysis of relationships. For experts' selection, step (*i*), a few criteria were determined in terms of knowledge and experience level so that the gathered information was legitim and minimally reliable. First, the minimum professional experience of ten years was required. Second, experts should have deep theoretical and practical knowledge of LP practices, with particular emphasis on VSM. A third criterion consisted of a minimum familiarity level with I4.0 technologies, either employing practice or theory. Finally, to allow a diversified composition of perspectives, we looked for experts whose backgrounds were from academia, industry or both.

Initially, we identified twenty-two experts that met the criteria as mentioned earlier with easy access or with partnership relation from previous research. The first electronic message explains the research purposes and verifies their willingness to participate. Fifteen of them positively responded to the email, although only ten indicated their agenda availability. In the end, due to agenda availability mismatches, six experts had their interviews scheduled and registered, indicating a final response rate of 27.3%.

For step (*ii*), each expert holds an interview in meetings for about 45 to 80 minutes. To mitigate researcher bias, we verified issues of internal and external validity together with reliability and objectivity of information (Yin, 1994). Thus, two researchers (one associate professor and one PhD candidate) simultaneously participated in the interviews to enhance the ability of handling data and confidence in research findings (Dubé and Paré, 2003). Although the involved experts supposedly had a significant level of knowledge on the topics, we provided a brief explanation of I4.0 technologies and lean value stream guidelines to ensure a uniform understanding.

Regarding questions formulation, we adopted the eight lean value stream guidelines proposed by Rother and Shook (2003) and denoted here by g_i (i = 1,…, 8). Evidence of

their utilisation is vast (e.g. Abdulmalek and Rajgopal, 2007; Sa'udah et al., 2015) and they reasonably provide advice on how to design future state maps (Tortorella et al., 2018). In terms of I4.0, the research contains eleven technologies t_j (j = 1,…,11) due to their remarkable utilisation and citation. Therefore, during interviews experts were asked the following: "what is the intensity of the relationship r_{ij} between the development of lean value stream guideline g_i and the I4.0 technology t_j?". Responses follow an ordinal scale of nine points, where 0 indicated 'no relationship' and 9 indicated 'maximum intensity' of the relationship between g_i and t_j.

Finally, step (*iii*) consisted of consolidating and analysing results obtained from the interviews with experts. Despite their large experience, due to differences in experts' backgrounds, there might be some variability among their responses for r_{ij}. Hence, to consider such variability, the consolidated values for the relationship between the eight guidelines for lean value stream design and the eleven I4.0 technologies were weighted by the relative experts' experience w_k (k = 1,…, 6).

Then, the study inserts values of r_{ij} in the intersections of matrix **M**, whose rows contain the eight guidelines g_i for designing a lean value stream and columns present the eleven I4.0 technologies t_j. This matrix represents the overall scores for the relationship intensities. The sum of the scores of each row and column of **M** denoted the overall potential for integration of each guideline and technology, respectively. In other words, higher total values for a determined g_i represented a guideline that can be more sensitive to the introduction of I4.0 technologies. In turn, higher total values for t_j represent the overall pervasiveness that such technology may have when designing lean value streams.

The differentiation index zij determines the most important relationships between the guidelines for a lean value stream design and the I4.0 technologies. This index represents the number of standard deviations of each individual value of r_{ij} in relation to the average values of the corresponding g_i. Positive values of z_{ij} larger than 1.0 were used to indicate the most important relationships and, hence, prioritised for the proposed guidelines lean value stream design integrated with I4.0 technologies.

Results

Table 1 displays the consolidated results for **M** obtained from the six interviews. Regarding the I4.0 technologies, the one with the highest pervasiveness level across all lean value stream guidelines (total score = 55.0) appeared to be t_{10} (Big Data). As a value stream is composed of several steps and activities in both material and information flows, the simultaneous generation of large quantities of data is potentially considerable. Traditional lean value stream guidelines may present difficulty or even neglect handling such data, impairing more certain managerial decisions. Therefore, according to experts' opinion, the integration of Big Data into Rother and Shook (2003)'s guidelines can be highly beneficial for a lean value stream design. More specifically, this technology presented a unique relationship (differentiation index > 1.0) with five guidelines; they are: g_1 (define takt time), g_2 (select finish goods strategy), g_5 (determine supermarket), g_6 (create one-point scheduling) and g_7 (define interval).

These results converge in some way to indications from Meudt et al. (2017), which suggest that the main contribution of integrating I4.0 technologies into VSM would be related to recording, handling, processing, analysing and optimising information processes and data gathering. This contribution appears to be especially relevant when considering the management of customers' demand (guidelines g_1 and g_2) and production planning and scheduling (guidelines g_6 and g_7). Furthermore, it is worth to mention that a few technologies, such as t_4 (augmented reality), t_5 (cloud computing system) and t_8 (integrated engineering systems), did not present a relatively high relationship (> 1.0)

with any of the eight guidelines. Nevertheless, these technologies may also influence the design of lean value streams, although not at the same extent as the remaining ones.

Table 1 – Relationships between guidelines for lean value stream design and I4.0 technologies

Guidelines for lean values stream design	I4.0 technologies											Total score
	t_1- Collaborative robots	t_2- RFID-tag at working units	t_3- Machines with digital interfaces and sensors	t_4- Augmented reality	t_5- Cloud computing system	t_6- Artificial intelligent and machine learning algorithms	t_7- Remote production processes management	t_8- Integrated engineering systems	t_9- Additive manufacturing, rapid prototyping or 3D printing	t_{10}- Big Data	t_{11}- Internet of Things (IoT)	
g_1- Define *takt* time	1.5	3.4	2.1	4.2	5.1	3.8	2.1	2.8	8.2	7.5	2.8	43.5
	-1.1	-0.3	-0.8	0.1	0.5	-0.1	-0.8	-0.5	**1.9**	**1.6**	-0.5	
g_2- Select finish goods strategy	1.4	4.8	1.7	3.7	4.6	4,.1	1.9	2.4	8.5	6.4	3.3	42.8
	-1.2	0.4	-1.0	-0.1	0.3	0.1	-0.9	-0.7	**2.1**	**1.2**	-0.3	
g_3- Implement continuous flow	7.8	6.8	6.5	5.5	5.8	3.8	6.4	5.1	7.9	6.9	5.7	68.2
	1.3	0.5	0.3	-0.6	-0.3	-2.0	0.2	-0.9	**1.4**	0.6	-0.4	
g_4- Establish first-in, first-out	6.9	7.2	6.4	4.7	4.7	4.3	5.7	4.4	7.0	6.8	5.6	63.7
	1.0	**1.3**	0.5	-1.0	-1.0	-1.3	-0.1	-1.2	**1.1**	0.9	-0.2	
g_5- Determine supermarket	4.1	7.5	6.9	4.1	5.3	3.4	5.9	4.3	6.7	7.1	5.8	61.1
	-1.0	**1.4**	**1.0**	-1.0	-0.2	-1.5	0.2	-0.9	0.8	**1.1**	0.2	
g_6- Create one-point scheduling	5.2	7.4	7.5	3.8	6.8	7.4	6.4	3.7	4.7	7.9	6.2	67.0
	-0.6	0.9	0.9	-1.5	0.5	0.9	0.2	-1.6	-0.9	**1.2**	0.1	
g_7- Define interval	2.2	3.4	5.7	2.7	7.1	8.1	7.8	5.2	5.9	8.1	4.2	60.4
	-1.5	-1.0	0.1	-1.3	0.7	**1.2**	**1.1**	-0.1	0.2	**1.2**	-0.6	
g_8- Determine pitch	2.5	4.8	3.2	5.9	4.4	4.9	8.3	3.3	3.8	4.5	4.7	50.3
	-1.3	0.1	-0.9	0.9	-0.1	0.2	**2.4**	-0.8	-0.5	0.0	0.1	
Total score	31.6	45.3	40.0	34.6	43.8	39.8	44.5	31.2	52.7	55.0	38.3	

Note$_1$: Numbers in white cells represent the average weighted values r_{ij} of relationships for each guideline.
Note$_2$: Numbers in grey cells represent the standardised values z_{ij} of relationships for each guideline (differentiation index).
Note$_3$: Bold numbers refer to the most important relationships (>1.0) between I4.0 technologies and guidelines for lean value stream design.

In terms of lean value stream design, the guideline with the highest potential for integration with I4.0 technologies was g_3 (implement continuous flow), with a total score

of 68.2 and important relationships with t_1 (collaborative robots) and t_9 (additive manufacturing, rapid prototyping or 3D printing). 'Continuous flow' is also known as one-piece flow, single-piece flow, or make-one, move-one (Womack and Jones, 2011). It refers to producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step (Rother and Shook, 2003). It can be achieved in many ways, ranging from moving assembly lines to manual cells. As it entails a minimum inventory level between workstations, material and information flow become much more sensitive to any variation or disruption in their processes (Braglia et al., 2009). Since the adoption of 'collaborative robots' and 'additive manufacturing' might provide a more flexible and agile productive flow (Brettel et al., 2014; Karre et al., 2017), it is reasonable to expect that these I4.0 technologies can positively favour the implementation of continuous flow.

It is noteworthy that although guidelines g_4 (establish first-in, first-out), g_5 (determine supermarket) and g_7 (define interval) had lower total scores than g_3, each one presented three important relationships with I4.0 technologies, instead of the only two ones for g_3. These findings indicate the overall potential of incorporating specific I4.0 technologies into a lean value stream design, which has been somewhat envisioned by Tamás et al. (2016) and Mrugalska and Wyrwicka (2017). Our results show that all lean value stream guidelines proposed by Rother and Shook (2003) can be influenced by at least one I4.0 technology. However, the practical changes implied by such relationships are not yet evident and deserve further attention from researchers and practitioners.

Conclusion

This study proposes integrated guidelines for designing lean value streams with I4.0 technologies. For that, we used experts' opinion cross reference with relevant literature on the topic. The contribution of this research is relevant from both practical and theoretical perspectives.

First, in theoretical terms, our study raises arguments on the future of lean value stream design since it envisions the incorporation of novel I4.0 technologies into each of the traditional guidelines. Literature evidence on this subject is still scarce, and the existing studies lack further conceptual details. Thus, this research not only specifies how I4.0 technologies could benefit a lean value stream design, but it also suggests how these existing and widely accepted guidelines may change, so they became more robust and aligned with the Fourth Industrial Revolution era.

From a practical perspective, the proposed guidelines advise organisations under LP implementation about the potential changes that lean value stream design might face with the introduction of I4.0 technologies. Hence, our proposal entails a shift on traditional guidelines for lean value stream design, emphasising how novel ICT could support a distinguished and technology-integrated lean value stream management that benefits from the simplicity and efficiency of LP with the ease and agility of the technologies typical of the Fourth Industrial Revolution. Such technology-integrated guidelines may allow overcoming existing barriers while leading companies to superior performance results.

Certain limitations of this study are worth to be mentioned. Although the proposed guidelines have emerged from experts' opinion, more extensive empirical validation is still required. The development of case studies and field applications based upon the proposed guidelines for a technology-integrated lean value stream design would add evidence that could potentially entail further changes and propositions. However, as the

adoption of I4.0 technologies is still incipient in most industries, such practical verifications would deserve particular attention to mitigate biased outcomes.

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Organizational culture and Lean practices: analysis through a real case study

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Abstract

Nowadays, lean researchers are focused on the role of organizational culture and contingencies factors in the success and sustainability of lean management. This research aims at contributing to the academia debate by analysing through a deep case study whether organizational culture based on lean management can enable companies in overcoming differences related to the national culture. Moreover, the study wants to provide evidences that companies can leverage on lean practice in order to spread organizational culture among different country-based plants.

Keywords: Lean practices, organizational culture, case study.

Introduction and research context

People, practices and culture are strongly interrelated in lean mindset: extant literature shows that the large majority of companies that fail in implementing lean lacks in understanding the required relationship among these concepts (Netland, 2016). Toyota, with its Toyota Production System, represents indeed an outstanding example of how acting on the people, their mindset and company's culture will lead to success (Womack, Jones and Roos, 1990).

Companies have tried to reproduce this model but very few have been able to achieve the same performance levels (Spear, 2004): about two out of three organizational change projects fails (Netland, 2016) . The reason may lay on the fact that Toyota model has been specifically deployed to fit perfectly to the Japanese culture. National culture plays indeed an essential role while companies start lean journey. There are many contingencies that can prevent companies to a successful implementation of lean practices, and national culture is with no doubts one of the strongest (Pagell, Katz and Sheu, 2005). For a multinational company, that has to deal with different national cultures, understanding

how integrating plants located all over the world and which role is played by the underlying context and by different national cultures represents a key issue (e.g. Van Oudenhoven, 2001; Testa, 2009). Considering cultural differences for companies that are keen to grow at an international level is not an option. Cross-cultural communication is imperative: it involves a comprehensive understanding of how people from different cultures speak, communicate, and perceive the world around them (Wang, 2008).
A good leverage to act on in order to reduce existing differences in national cultures is represented by organizational culture. It conceives membership in the organization and not in a country (Bortolotti, Boscari and Danese, 2015). In 1996, Schein defines organizational culture as: "the basic tacit assumptions, on how the world is and should be, that a group of people share and that determine their perceptions, thoughts, sensations and, their evident behavior" (Schein and Graduate, 1996). According to this definition, organizational culture can be seen as a set of shared assumptions that guide what happens in organizations by defining appropriate behavior for various situations (Ravasi and Schultz, 2006). Organizational culture affects not only the way people and groups interact with each other, but also how much employees identify themselves with the organization (Schrodt, 2002). It is possible to point out a parallel between Schein model and lean philosophy: lean practices can be seen as the visible part of the organizational culture. The interaction of appropriate attitudes and group norms with lean principles contribute to nurturing commitment and engagement inside employees (Angelis *et al.*, 2011). Lean embraces the ability to constantly change as a keystone of organizational culture. However, change does not just happen, it must be managed, and the establishment of a lean culture need to be pushed by the top management, whose strong commitment is a must. According to Shook (2010), companies should consider that a change in organizational culture must be managed properly: “trying to directly change the culture” will lead companies to fail in their scope. A deep organizational shift will happen indeed only if the company acts on its behaviours, the way they do things. In this sense, lean practices and their implementation will easier the adoption of a new culture within a company. Even Schein (1996) theorized that the only way to change organizational culture is to change the artefacts, as the observable data of an organization, the way people do thinks and how they behave. Even if it seems that the academia reached the consensus on the positive role of lean practices on organizational culture, it still remains unclear how national culture can affect them. In recent years Netland (2016) declares that belonging to specific national culture does not negatively impact on the lean success or on the implementation of its practices. Unfortunately, there are still few contributions in this sense.

This research aims at contributing to the academia debate by analysing through a real case study whether organizational culture based on lean can enable companies in overcoming differences related to the national culture. Moreover, the study wants to provide evidence that companies can leverage on lean in order to spread organizational culture among different country-based plants.

Case study

A deep case study has been carried out in an Italian automotive company characterized by a strong organizational culture based on lean management. Data have been gathered through secondary data, survey and direct observations.

Company’s profile

The firm selected to conduct the study is the Italian “Prometeon Srl” (Prometeon), the former Pirelli Industrial, that operates in the automotive industry. It mainly produces and

commercializes Pirelli branded Industrial tyres for trucks, bus, agro and OTR under license. Prometeon's plants are spread all over the world, being two in South America, one in North Africa, one in Middle East and the headquarter in Europe.
Prometeon started its journey towards lean management in 2008 and adapted lean practices to its own production management system, formalizing it in the so-called Prometeon manufacturing system (PMS). Prometeon needed at that time to create a strategic model to assure standardized performance, culture and results of their operations located all over the world.

PMS is built upon a panel of selected lean practices and tools aimed at improving production performance in all the plants owned by Prometeon around the world.
All business units, and every single department (quality, R&D, processes, HR, logistics and production) are subjected to PMS. All functions are called to work together to optimize the whole process of value creation. PMS is shaped on people: every single employee highlights the difficulties, suggests improvements, feeling fully involved in the entire production process. Every plant is indeed embracing PMS and the related practices. When a plant outperforms in specific project, it becomes a model for the others. PMS brings together the experts of outperforming plants to other facilities to standardize processes, to share common practices and to spread culture.

Exactly in this direction, PMS comprehends a multi-plant improvement program, based on a full-immersion session on Gemba called Full Speed Day (FSD). FSD is aimed at improving a specific operational performance of a plant, supported by an internal and international benchmarking process. For its nature, FSD involves different functional teams belonging to different countries, that share knowledge among each other to reach the common goal of efficiency. Even though it is implemented in plants with very different national culture, being part of the same organization assures that all of them are oriented towards the common goal of improving the production process. Due to the stable structure and good results of the FSD, Prometeon considers it a strategic method for pursuing continuous improvement in the long term.
As PMS in general, FSD is based on lean approach and some practices are shared between the two. Among others, Kaizen event is of a strong importance for FSD, aimed at creating value for the company while addressing efficiency and productivity performances in a defined period, involving inter-functional teams. In this view, the precise definition of both agenda and working team emphasizes the engagement of people, feeling them part of the project, keeping in mind the path that should be followed for reaching the best performance. These short and intense projects not only bring together small teams from different departments in order to find ways to work more efficiently, but also foster the learning cycle. Sometimes teams from different countries work together on a similar problem to share best practices. This enables more cross-enrichment among employees and benchmarking among plants, bringing outstanding results.

Survey
In order to understand whether the success of FSD and its perception by experts is somehow dependent by the national culture of plants where it is implemented, a survey design was been selected as the most suitable method. The survey is addressed to all the 19 managers involved in FSD having a strong lean expertise, from October 2017 to February 2018. Experts are from Brazil, China, Egypt, Italy and Turkey. All experts are managers of several departments as quality, R&D, maintenance, engineering and industrial engineering. Surely, the sample is not representative of the whole company, but it reflects the overall opinion of experts involved in FSD. The response rate has been 100%. Following a brief descriptive analysis of the sample.

Table 1 - Roles of the respondents

Department	Role	Number
Industrial Engineering (IE)	IE & PMS Coordinator	3
	IE	5
	IE Manager	1
Production	Production Manager	4
R&D	R&D Manager	1
Maintenance	Maintenance Manager	3
Quality	Quality Manager	2
		19

The questionnaire designed is composed by 19 questions, grouped into two main clusters: (i) expert's profile; (ii) human-related and lean-related perception. Both human-related aspects and the set of lean practices were defined according to the literature and to the intrinsic characteristics of FSD.
A list is provided in the table below.

Table 2 - Human-related aspects and Lean practices

Human-related aspects	Lean practices
Involvement of people	5S
Teamwork	Problem-solving tools
Communication	Visual management
Mutual respect	Gemba walk
Leadership	TPM
Management Commitment	SOP
Rewarding	
Training, coaching and mentoring	

For the second cluster of questions (ii), respondents were asked to provide to provide us with their perception on how human-related aspects impact on the effectiveness of lean practices on a 7-points Likert scale.

Results are studied according to Hofstede's model of national culture, recognized as a good framework to verify whether differences in perception of each country-based plant can be imputable to national culture. In the analysis, the dimensions related to the five countries in which the company has plants (Brazil, China, Egypt, Italy and Turkey) have been used.

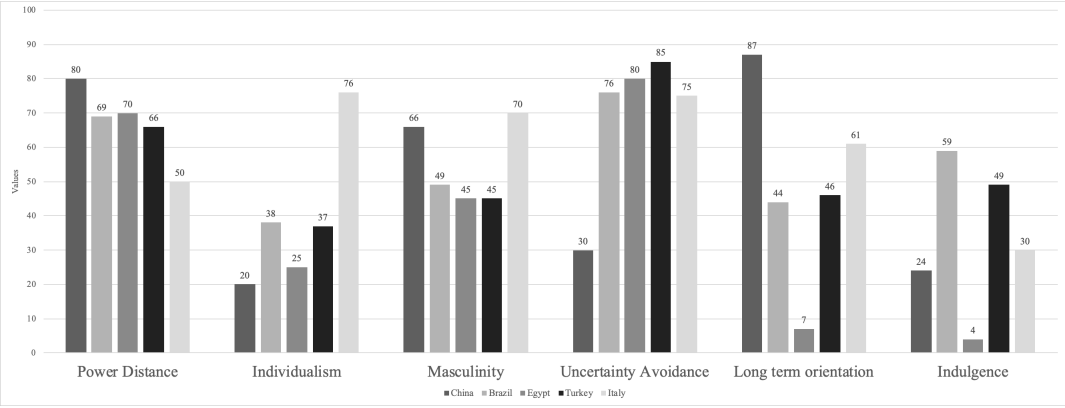

Figure 1 - Hoftsede's variables

Direct observation

In 2017, Prometeon started to support the management team of four Chinese plants (owned by Aeolus) spreading PMS. Aeolus is not sharing the same organizational culture as the one of Prometeon due to the recent integration between the two firms occurred in 2016. However, Aeolus was subjected to PMS.

With the aim to understand whether a company can act on internal lean practices to spread the organizational culture, data have been gathered through direct observation and interviews carried out during a specific PMS practice in one Chinese Aeolus's plant.

The PMS event under discussion is the already discussed FSD, as one of the most important lean initiatives developed within the company. Prometeon decided to export its FSD to Chinese Aeolus's plant as first initiative to spread its organizational culture based upon PMS. However, due to the low level of lean implementation, some changes in FSD have been put in practice for the Aeolus plant.

One issue was represented by the selection of which experts' team should practically export FSD. Egyptian team was selected as considered the Best in Class among Prometeon's plants all over the world. It was composed by experts coming from several departments: R&D, quality, production, IE and maintenance. Moreover, Industrial Engineering team of the headquarter attended the Egyptian one during the entire project in order to guarantee the alignment among different people and scopes. Thanks to their previous experience gained of both Egyptian and Headquarter teams, potential problems of Aeolus plant were hypothesized in advance in order to overcome difficulties related to different languages and different organizational culture. Language problem was totally addressed thanks to the presence of three translators, one for each identified functional working area.

FSD in Aeolus plant followed a *learning-by-doing* approach in order firstly to make Chinese team able to gain the maximum advantage in a limited time span and secondly to foster the Prometeon's culture transmission. The reason behind this choice relies on two models available in literature provided by Schein (1996) and Shook (2010). Both authors stress that in order to change organizational culture, it is fundamental to change "what we do". Starting from changing behaviors, culture will change as result. Therefore, Aeolus plant experience was based on leveraging on lean practices, more specifically on FSD, in order to shape Chinese organizational culture and the way Chinese plant was working.

We spent two consequent weeks in the Aeolus plant together with the Egyptian and Headquarter Prometeon's teams. In the first week, data collection and KPIs analysis has been performed for 2 days, followed by three days of workshop benchmarking with a series of Gemba walk sessions. Due to specific characteristic of Aeolus Chinese plant, this preparation phase lasted only 5 days compared to the 3 months of the typical FSD method. As already explained, this was due to foster the learning cycle. In the second week, an action plan was defined and then implemented during the first two days with the application of quick-wins improvement actions. It was followed by a session of 12 consecutively hours in the shop floor aimed at evaluating the improvement actions and developing a new action plan for the successive months. Even though FSD has been changed in terms of timing, the results were impressive. Quick-wins improvement actions allows the plant to succeed and gain around 8% of the capacity lost for the introduction of a new product in the production line.

Results

The case stresses the difference among experts already sharing Prometeon culture and Aeolus Chinese ones. More in detail, even though all Prometeon experts involved in the study are not sharing the same national culture, no significant differences in perceptions of both human-related aspects and lean practice exists. This is likely to be the result of a strong and already embraced organizational culture based on lean practices, which have enabled plants to overcome any existing difference due to national culture.

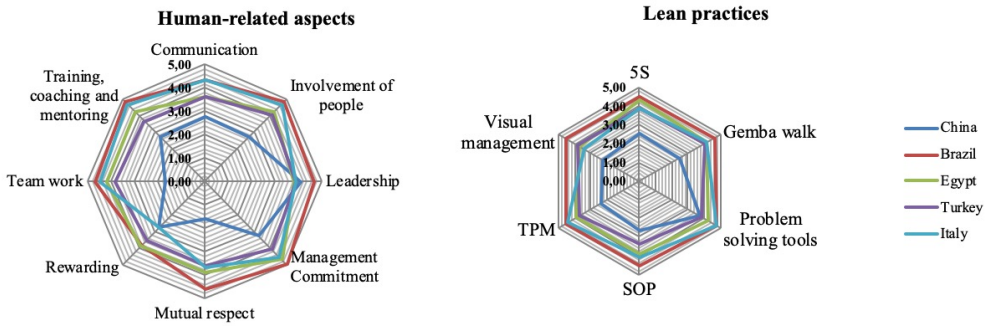

Figure 2 - Radar chart human-related aspects and lean practices

It is even interesting to notice the alignment on most of human-related aspects among the four plants of Prometeon: the first three positions of the ranking are covered by Management Commitment, Involvement of People and Training, Coaching and Mentoring. This is related to the organizational culture deeply rooted in these plants based on lean practices. Moreover, these results completely reflect the lean attitude founded on the proactive participation of people. Companies need to prioritize the sharing of knowledge and a training path which enable the personal growth (Fullerton and McWatters, 2001). The lean culture is indeed based on well trained employees to foster improvement and knowledge sharing (Alkhoraif, 2016). Teamwork enables the lean and continuous improvement attitude with the constant and recurring sharing of knowledge and information.

For what regards lean practices, all Prometeon experts agree on the high relevance of Problem solving tools and Gemba walks. For what regards Problem solving tools, the high ranking can be connected to the importance that each employee gives to the quick resolution of problems, that fosters the learning cycle. On the other hand, about Gemba Walk, all countries gave it strong relevance due to its effectiveness when implemented with inter-functional teams that, in a benchmarking context, can proceed in the best way thanks to their knowledge and capabilities. It is noteworthy to underline how in China it covers instead the fourth place. The alignment in experts' perceptions may be related the well-established organizational culture based on lean.

In the Aeolus Chinese plant, instead, experts are still in their changing process and characteristics related to national culture result to be predominant. Here, for example, the most important human-related aspects are Leadership and Management Commitment. On the other hand, for what regards lean practices, they are Problem solving tools and standardized procedures. It is interesting to stress the different ranking obtained by standard procedures: this tool has got the most significant variance between countries. In Prometeon plants, it holds a position of less importance, while in Aeolus Chinese plant it is perceived as a critical one. The reason why may rely on the need of applying standard procedures under which each operator is subjected. According to Hofstede, Chinese

national culture is indeed characterized by willingness to receive practical and direct feedbacks oriented towards the standardization of operations and methods.

Consistently with the findings of Netland (2016), the case study performed in Prometeon suggest that the success of lean practice is not depending on national culture. A strong presence of organizational culture based on lean allows indeed companies to limit the existing cultural differences among countries. Moreover, lean can be exploited to manage change and to spread organizational culture among different firms.

What it is possible to conclude looking at different Prometeon plants is that the strong presence of an organization culture based on lean practices since 2008 makes the company succeeding in limiting the existing cultural differences between the countries. The Aeolus plant instead presents different results, in terms of both human-related activities and lean practices, and they are mainly imputable to national culture. In fact, it is worthy to stress that Aeolus did not share at that time the same organizational culture with Prometeon. The goal of Prometeon of spreading its organizational culture to Aeolus plant was the reason why FSD has been implemented in the first place: according to the literature, the most effective way to change a company culture is to change its way to behave. With this in mind, strong lean activities have been deployed by Prometeon in order to set the new culture in Aeolus, based on lean practices, considering together tools and techniques while involving people in their growth. Prometeon main challenge relies in sustaining its organizational culture while its organizational structure is characterized by strong differences, both in terms of anthropological and work culture point of view. According to the data collected, no significant differences among countries have been discovered, either in terms of human-related aspects or in terms of lean practices. This results in the strong power of organizational culture based on lean practices, that hence is able to overcome any difference existing in plants due to national culture. In the Chinese plant, although different organizational culture, experts team succeeded in significantly involving the local one, which showed willingness and openness to learning new techniques. Adjusting initiatives to better integrate the knowledge and capabilities of each country, keeping in mind the critical function played by the national culture and leveraging on well-known and universal lean practices are keystone for companies that want to spread organizational culture among different countries.

Conclusion

Prometeon, with its PMS implementation, is an interesting case to highlight that national culture does not play a significant role in the success of lean practices. Within Prometeon's plants, according to data collected, no significant differences among countries have been discovered, either in terms of human-related or lean practice perception. This results in the strong power of lean practices: companies with organizational culture based upon lean are able to overcome differences related to national culture. Aeolus's plant, instead, which at that time did not share the same organizational culture of Prometeon, presents different perception compared to Prometeon's results, in terms of both human-related or lean practice. These differences are mainly imputable to national culture.

Therefore, case under discussion provides initial evidence on how a company should leverage on lean practice in order to limit the existing cultural differences among countries. Exploiting well-known and universal lean practices is the keystone for companies that are willing to spread their organizational culture among different countries. It is likely that more case studies will be collected in order to populate the database and to validate this initial evidence in the upcoming future.

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The role of organizational context and top-down decision making on continuous improvement and performance

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Abstract

Many firms often struggle to link continuous improvement (CI) to operational performance because they fail to develop a people-centric organizational context that enhances employees' engagement. Past literature has scarcely investigated the extent to which people-centric context and CI should be interrelated to improve performance. Based on a database of 330 firms across nine countries, a structural equation model is used to demonstrate that a closer fit in the relative magnitude of CI and people-centric context is associated with superior performance. Our results contribute to CI literature and contingency theory by providing evidence on the organizational circumstances that sustain effective CI.

Keywords: Continuous improvement, Organizational context, Operational performance.

Introduction

Lean firms aim at continuously improve their processes and products in order to gain a competitive advantage over their competitors and enhance operational performance. Continuous improvement (CI) triggers the evolution of a firm's lean management system through stepwise adjustments and modifications in the process of solving problems and creating value-added activities (Anand et al., 2009; Furlan et al., 2019). Many firms often struggle to link CI to operational performance because they fail to develop an organizational context that provides the backbone to relentless initiatives of incremental improvements (Anand et al., 2009; Galeazzo et al., 2017). An organizational context deploys practices that facilitate an active, involved participation of employees.

Employees play a central role in CI, implying an organizational context is deemed to support them. Without an employee's problem-solving behaviour that systematically searches for the root causes of problems, a firm would be hindered in detecting issues that prevent improvements (Tucker et al., 2002, 2007). Without an employee's

interaction with her peers and supervisors, organizational learning is difficult to develop to expand the knowledge base of a firm and adopt improvement activities (Furlan et al., 2019). Without an employee's involvement in CI objectives, it would be difficult for a firm to reduce waste and, thus, improve over time (Linderman et al., 2006). This results in the need of people-centric organizational contexts that deploy human-related practices to train employees in identifying and solving problems, support knowledge sharing and motivate them to pursue improvement goals.

Past literature has never questioned the central role of employees in explaining a firm's ability to implement CI that enhances operational performance. A people-centric context seems a necessary condition to gain an understanding of how CI effectively works. However, these findings do not explicitly examine the interrelationship between people-centric context and CI with respect to firm performance. Some studies argue that the implementation of human-related practices are preconditions for effective CI (Anand et al., 2009; Zeng et al., 2017; Ma et al., 2019) whereas others argue that they strengthen the relationship between CI and performance (Sila, 2007; Uhrin et al., 2017), thus implicitly assuming they may not be adopted by a firm. Therefore, it is unclear the extent to which people-centric context and CI should be interrelated and the resulting effects on performance.

In this paper, we seek to explain whether the match between people-centric context and CI is relevant to improve operational performance by using contingency theory and the concept of organizational fit. As literature suggests that the implementation of people-centric organizational contexts is an antecedent of CI or is a moderator in the relationship between CI and operational performance, an organizational misfit should not affect performance. Based on a database of 330 firms across nine countries, we used a structural equation model to test whether the organizational fit between people-centric context and CI positively affects operational performance. We find that a closer fit in the relative magnitude of CI and people-centric context is associated with superior performance. Our results provide both theoretical and managerial insights. We explain the contingency relationship between the organizational context and CI, thus providing empirical evidence on the organizational circumstances that sustain successful implementation of CI (Anand et al., 2009; Galeazzo et al., 2017). By showing that the organizational fit leads to superior performance, our research also identifies for managers the timing for developing CI practices and organizational context oriented to employees' involvement.

Theoretical background and hypothesis development

Organizational fit

Contingency theory argues that firms develop initiatives that more or less effectively improve performance under different organizational factors. Organizational fit is defined as the degree of coherence among activities within a firm (Siggelkow, 2001) that directly affects firm performance. In this study, organizational fit refers to the alignment between the magnitude of implementation of people-centric organizational context and CI. Instead, misfit implies that firms may either have consistently adopted CI practices with low employees' involvement or have extensively adopted human-related practices while lagging behind in CI initiatives.

Only few studies in operations management empirically explore the role of organizational fit in improving performance. For example, Zhang et al. (2012) proposed that quality improvement initiatives, i.e., quality exploration and quality exploitation, differently benefit from mechanistic and organic structure. They found that quality

exploration is associated with higher performance when firms adopt organic structures with few hierarchical levels and decentralized decision-making systems whereas quality exploitation fits better with mechanistic structures characterized by narrow span of control and centralized decision-making. Most literature, however, investigates the effect of the internal fit between organizational factors and improvement initiatives to performance using different methods (Sila, 2007; Camuffo and Wilhelm, 2016; Zeng et al., 2017). Zeng et al. (2017) showed that centralization of authority negatively impacts human-related quality improvement initiatives and positively impacts process-related quality improvement initiatives that, in turn, improve performance. Moreover, inter-functional integration positively impacts human-related initiatives but negatively impacts process-related initiatives that, in turn, improve performance. Their conclusion indicates that improvement initiatives have different organizational antecedents but it does not investigate how these organizational characteristics should be combined with improvement initiatives in order to positively influence performance. Sila (2007) found that quality improvement initiatives are not depend on contextual factors, implying no need of adjustments across firms. He employed a subgroup analysis to test difference among groups of firms having different organizational characteristics. In this case a moderating effect of the organizational factors is assumed to affect the relationship between improvement and performance. Our study differs from Sila (2007) because it emphasizes the importance to find a balance between organizational context and improvement.

The effect of organizational fit between CI and people-centric organization on performance

Past literature suggests CI is a dynamic capability. "A dynamic capability is a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness" (Zollo and Winter, 2002, p. 340). As suggested by Winter (2003), dynamic capabilities are high-order routines (or collection of routines) whose main objective is to change existing products and processes. Peng et al. (2008) operationalized CI as the combination of the three organizational routines of process management (PM), leadership involvement (LI) and improvement orientation (IO). PM includes activities that pursue process control and standardization by using techniques and charts that help reducing process variation, increasing efficiency, detecting incongruences, thus preventing problems occur and fostering improvement (Rondeau et al., 2000). LI refers to a set of practices that encourage top management and major department heads to support CI by triggering the participation of CI activities. Finally, IO refers to the development of an organizational culture oriented toward the continuous research of improvement in processes and products (Roth, 1996; Linderman et al., 2010).

A supportive organizational context enables CI to positively affect operational performance (Anand et al., 2009). Workforce plays a pivotal role in support of CI and, thus, a people-centric context is likely to be conducive to effective improvement activities. As firms aim at searching for the root causes of problems and implementing the most adequate solutions, employees' knowledge and skills are paramount (Letmathe et al., 2012). Thus, a people-centric context should implement training programs that enable employees to acquire new skills and knowledge to detect problems and, in turn, increase performance. Moreover, a people-centric context emphasizes the need to form teams that foster knowledge articulation and knowledge codification (Furlan et al., 2019) with the objective of developing organizational learning (Choo et al., 2007) and performance. Finally, a people-centric context should support employees' motivation

and encourage engagement in CI activities through goals management systems. For this reason, we operationalize a people-centric organizational context as the combination of the three human-related practices of training for quality, teamwork for problem solving and goal-based incentives.

We argue that a closer organizational fit between people-centric context and CI contributes to operational performance through a more balanced distribution of resources and a more synchronized modification of human-related and improvement activities. Conversely, a misfit between context and CI poses threats to performance through an increased risk of resource waste and poor adjustments of different activities. More specifically, when an organizational context is unable to involve employees, a firm striving for complex CI initiatives is susceptible to the risk of failure, thus wasting time. A synchronized adjustment of human-related practices and CI allows, instead, to develop reciprocal interdependencies (Thompson, 1967) that may, in turn, give rise to complementarities. In summary, the magnitude of people centrality in an organizational context should evolve at the same pace of CI maturity.

Hypothesis: The organizational fit between people-centric context and CI positively affects operational performance

Methods

Data collection and analysis

We use the fourth round of the High Performance Manufacturing (HPM) database to test our theoretical model. The HPM database is the result of an international project that involves researchers from nine countries: Brazil, mainland China, Finland, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Taiwan, the United Kingdom, and Vietnam. Following a stratified sample procedure, all the participating researchers contacted plant managers of standalone manufacturing firms or subsidiaries with more than 250 employees from three industries: electronic, machinery, and transportation. A total of 330 firms accepted to participate to the project. These firms are both traditional firms as well as world-class manufacturers (randomly selected from a list of winners of one or more awards such as the Shingo Prize or industry leaders recognized by the literature, trade magazines, or newspapers). Data was based on questions from twelve different survey questionnaires that focus on various areas such as human resources, quality management, lean management and technology. More than one informant answered most questions. They were given the hard copy of the questionnaires, translated in their native language following recommendations of Brislin (1980). The use of multiple questionnaires responded by multiple informants helps mitigating common method bias. As the unit of analysis is the firm, data from multiple respondents answering the same questions were aggregated to the firm level and questions from different questionnaires were merged together to compile a comprehensive database.

Measures

All items are measured on a 5-point Likert scale if not differently specified. They are all based on prior literature, thus content validity is assumed. Following other studies using the HPM dataset (Peng et al., 2008; Galeazzo et al., 2017), items were standardized per country and industry.

Operational performance is the dependent variable of our model. Based on Zhang et al. (2012), it was measured as a weighted index of four performance dimensions: cost, quality, delivery and flexibility. As shown in Appendix A, all the performance dimensions have Cronbach's alpha coefficients and composite reliability (CR) above their recommended cutoff values (0.7 and 0.6, respectively), thus showing construct reliability. They also load on their respective factors with values that exceed the recommended 0.5 cutoff value, thus showing construct validity. We weighted each dimension based on the extent to which a firm emphasizes it as a strategic goal. For example, a firm with a leadership cost strategy will have a high weight on the cost dimension. The formula is given in Appendix A.

CI was measured as a second-order latent variable based on Peng et al. (2008). A confirmatory factor analysis (CFA) was used to test whether manifest items loaded on the three first-order factors of process management (PM), improvement orientation (IO) and leadership involvement (LI), and, in turn, whether they loaded onto a super-ordinate factor of continuous improvement. Since the model provides a good fit (χ^2/df=1.82, CFI=0.958, TLI=0.950, RMSEA=0.051) with all manifest variables and first-order variables loading significantly above the 0.5 standard on the respective constructs, these estimates demonstrate convergent validity (Bagozzi, 1994) (see Table 1). We assessed discriminant validity comparing the unconstrained three-factor CFA model with the constrained two- and single-factor CFA models. In each case, the three-factor model provided a significantly better fit than the constrained models. We also used the average variance extracted (AVE) to further validate our second-order latent variable. Table 1 shows that all the AVE are higher than the recommended threshold value of 0.5 (Fornell and Larcker, 1981). LI has an AVE equal to 0.48 that is only slightly below the 0.5 cutoff value. Overall, CI is found to be a reliable and valid construct, and it is computed by combining the factor score weights from CFA with the standardized items.

Table 1 – Measurement and CFA results of continuous improvement

Constructs and items	**Factor loadings**	**Alpha**	**AVE**	**CR**
First-order construct: Process management (PM)		0.879	0.598	0.880
Pm01. Processes in our plant are designed to be "foolproof."	.648			
Pm02. A large percent of the processes on the shop floor are currently under statistical quality control.	.814			
Pm03. We make extensive use of statistical techniques to reduce variance in processes	.841			
Pm04. We use charts to determine whether our manufacturing processes are in control	.747			
Pm05. We monitor our processes using statistical process control	.800			
First-order construct: Leadership involvement (LI)		0.847	0.484	0.848
Li01. All major department heads within the plant accept their responsibility for quality	.646			
Li02. Plant management provides personal leadership for quality products and quality improvement	.788			
Li03. The top priority in evaluating plant management is quality performance	.561			
Li04. Our top management strongly encourages employee involvement in the production process.	.681			

Li05. Our plant management creates and communicates a vision focused on quality improvement.	.731			
Li06. Our plant management is personally involved in quality improvement projects	.745			
First-order construct: Improvement orientation (IO)		0.780	0.510	0.806
Io01. We strive to continually improve all aspects of products and processes, rather than taking a static approach.	.690			
Io02. If we aren't constantly improving and learning, our performance will suffer in the long term.	.680			
Io03. We believe that improvement of a process is never complete; there is always room for more incremental improvement	.715			
Io04. Our organization is not a static entity, but engages in dynamically changing itself to better serve its customers	.767			
Second-order measures				
Process management (PM)	.775			
Leadership involvement (LI)	.510			
Improvement orientation (IO)	.670			

People-centric context was measured as a second-order latent variable based on Anand et al. (2009). It consisted of teamwork for problem solving, training for quality and goal-based incentives as first-order latent factors. Teamwork for problem solving deals with activities enabling employees to interact and exchange knowledge for solving problems and strive for improvement. Training for quality focuses on employees' involvement in learning new tasks such as problem-solving and basic statistical techniques and improve their skills to detect quality issues. Goal-based incentives factor assesses the extent to which a firm defines rewards and salary levels to support the professional development of employees. Reliability is checked using Cronbach's alpha and CR (see Table 2). A second-order CFA model was conducted to test convergent and discriminant validity. The measurement model shows a good fit (χ^2/df=2.897, CFI=0.935, TLI=0.916, RMSEA=0.077). Convergent validity is supported because all factor loadings exceed the threshold of 0.5. Discriminant validity was assessed using a χ^2 different test for all the possible models combining the three first-order variables. Compared to the other models, the three-factor model presented better fit, thus supporting discriminant validity. Overall, people-centric context is a reliable and valid construct, and it is computed by combining the factor score weights from CFA with the standardized items.

Table 2 – Measurement and CFA results of people-centric context

Scale and items	**Factor loadings**	**Alpha**	**AVE**	**CR**
First-order measure: Teamwork for problem solving		0.750	0.504	0.801
Tp01. During problem solving sessions, we make an effort to get all team members' opinions and ideas before making a decision.	0.733			
Tp02. Our plant forms teams to solve problems.	0.614			

Tp03. In the past three years, many problems have been solved through small group sessions.	0.672			
Tp04. Problem solving teams have helped improve manufacturing processes at this plant.	0.806			
First-order measure: Training for quality		0.928	0.536	0.852
Tq01. Specific work-skills training (technical and vocational) is given to hourly employees throughout the organization.	0.711			
Tq02. Quality-related training is given to hourly employees throughout the organization.	0.793			
Tq03. Quality-related training is given to managers and supervisors throughout the organization.	0.666			
Tq04. Training in basic statistical techniques is given to employees.	0.773			
Tq05. Training in problem-solving techniques is given to employees.	0.712			
First-order measure: Goal-based incentives		0.963	0.695	0.872
Gi01. Our incentive system encourages us to vigorously pursue plant objectives.	0.817			
Gi02. The incentive system at this plant encourages us to reach plant goals.	0.886			
Gi03. Our incentive system is consistent with our plant goals.	0.795			
Second-order measures				
Teamwork for problem solving	0.508			
Training for quality	0.794			
Goal-based incentives	0.582			

Organizational fit between CI and people-centric context variable is operationalized as the absolute difference between CI and people-centric context in line with previous studies (e.g., Cao et al., 2009). High values imply a misalignment between CI and people-centric context with firms being mature on CI but having an organizational context that does not support employees' involvement and *vice versa*. Low values imply a strong correlation between CI maturity and the level of a firm's implementation of people-centric context.

We included size and age as control variables following previous literature (Zhang et al., 2012; Ma et al., 2019). Size was measured as the natural logarithm of the number of employees at plants. Age was measured as the number of years since the plant was established.

Analysis and results

Table 3 reports the descriptive statistics and correlations of the main variables.

Table 3 – Descriptive statistics and correlations

	Mean	S.D.	1	2	3	4	5	6
1. Operational performance	3.8	0.560	1					

2. Absolute difference CI-PCC	0.389	0.291	-0.102*	1				
3. People-centric context (PCC)	0.016	5.400	0.289*	-0.008	1			
4. CI	0.006	9.582	0.265*	-0.066*	0.384*	1		
5. Size	6.005	1.164	-0.005	-0.064*	0.211*	0.208*	1	
6. Age	47.396	68.301	-0.093*	-0.081*	0.027	0.034	-0.015	1

To test our hypothesis, we conducted a structural equation model (SEM). The measurement model fits well the data ($\chi 2/df=1.695$, CFI=0.918, TLI=0.903, RMSEA=0.071). Figure 1 shows the results of our model. It emerges that a greater distance between CI and people-centric context is negatively associated with operational performance, thus suggesting that organizational misfit between people-centric context and CI might explain poor operational results.

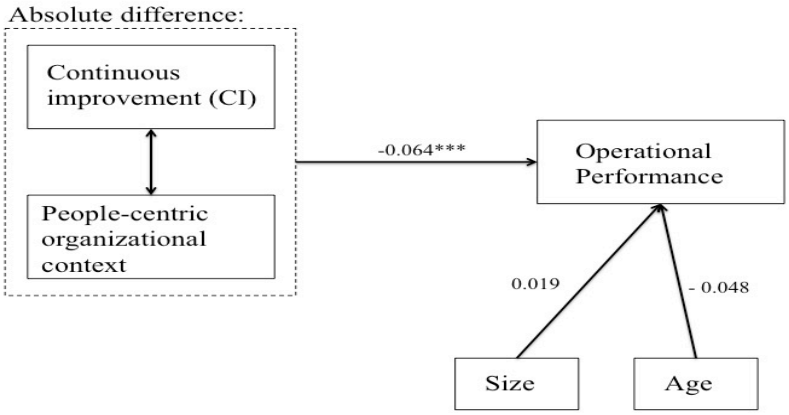

Figure 1 –SEM results

Conclusion

Our research contributes to the CI literature by highlighting the importance of matching the development of people-centric organizations and CI capability. Most previous studies that examine the relationship between the organizational context and CI do not give consideration to the extent to which they should simultaneously evolve in order to pursue improved operational performance. In particular, past research has focused on the organizational context as a CI antecedent or as a moderator in the relationship between CI and performance (Sila, 2007; Galeazzo et al., 2017; Ma et al., 2019). Our findings demonstrate that it is important to understand the relative magnitude, rather than the relative position, of the organizational context with respect to CI and viceversa. Moreover, it emerges that different levels of CI maturity, i.e., the degree of CI implementation, require different conditions of employees' involvement. By linking employees' involvement to contingency theory, we therefore highlight that the development of human deployment should not be pursued in isolation, but it should be balanced with the degree of CI maturity. Finally, our paper suggests managers to place resources and efforts to create a balance between the emphasis given to employees' involvement and the development of CI.

The present paper has a number of limitations that future research should investigate. First, CI's scope is not limited to the three bundles of routines that we included based on

Peng et al (2008) and future research might investigate which additional bundles of routines underlie CI capability. Second, people-oriented organizational context is measured using three bundles of human-related practices. Future research could investigate additional practices to provide a more in-depth understanding of the dynamics between the organizational context and CI. Finally, future research may use alternative methods to assess the organizational fit between CI and the people-oriented organizational context.

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Appendix A

Operational performance

Operational performance=W1*cost+W2*quality+W3*delivery+W4*flexibility.

Where W1, W2, W3, W4 are weights assessed in the following way:

Please indicate the importance of each goal for your company in its primary market:
1: Least important, 3: Neutral, 5: Absolutely crucial

- Low price (C)
- High performance quality (Q)
- Fast delivery (D)
- Ability to rapidly change over products on short notice (F)

Weights are computed in the following way:
W1 = C/(C + Q + D + F) (weight for cost performance)
W2 = Q/(C + Q + D + F) (weight for quality performance)
W3 = D/(C + Q + D + F) (weight for delivery performance)
W4 = F/(C + Q + D + F) (weight for flexibility performance)

And cost, quality, delivery and flexibility are the performance dimensions assessed in the following way:

Please circle the number that indicates your opinion about how your plant compares to its competitors in its industry, on a global basis.
1: Poor, much worse than global competitors, 3: Average, 5: Superior, much better than global competitors

Dimension	Items	Factor loadings	Alpha	CR
Cost	Unit cost of manufacturing	0.707	0.720	0.844
	Inventory turnover	0.851		
	Cycle time (from raw materials to delivery)	0.844		
Quality	Conformance to product specifications	0.875	0.695	0.867
	Product capability and performance	0.875		
Delivery	On time delivery performance	0.899	0.764	0.894
	Fast delivery	0.899		
Flexibility	Flexibility to change product mix	0.907	0.784	0.903
	Flexibility to change volume	0.907		

Exploring the relationship between soft lean practices and innovative work behavior: A case study approach

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Abstract

Taking soft lean practices into account, this exploratory study assesses their relationship with innovative work behavior (IWB) and demonstrates how soft lean practices affect the different dimensions of IWB (i.e. idea generation, idea promotion and idea implementation). Within an empirical case study, the results indicate that soft lean practices are conducive to different dimensions of IWB and that single soft lean practices can influence more than one dimension of IWB. The results provide managers with a better understanding of how they can create a breeding ground through soft lean practices for achieving higher levels of IWB.

Keywords: continuous improvement; lean sustainability; innovative work behavior

Setting the context

In general, continuous improvement (CI) involves ongoing endeavors to steadily improve the overall performance of the organization through incremental change. Through lean, organizations attempt to alter the way they operate in order to meet an ever-changing customer demand with as less resources as possible. Improvements, however, degrade over time and move back to their original state if they are not carefully managed (Bicheno and Holweg, 2016). For instance, many fail to implement lean successfully due to an overemphasis on the tools and techniques that it is associated with, disregarding the necessity for a cultural and a behavioral change (Liker and Rother, 2011). Although residual benefits due to implemented improvements may be retained indeed, the CI momentum degrades, which negatively affects the future CI capability of the business (Bicheno and Holweg, 2016). On that note, organizations often denote successes in the early stage in the form of guaranteed outcomes with minor efforts due to the application of lean tools and techniques. Yet, many still struggle with sustaining the CI momentum in the longer term (e.g. Bateman, 2005; Jørgensen et al., 2007; Bicheno and Holweg, 2016; Hirzel et al., 2017). Various studies that have been conducted in the UK report that no more than 10% managed to introduce lean effectively into their organization (Bhasin, 2012).

Lean soft practices

Recent literature emphasizes the importance of managing people (Hadid and Mansouri, 2014; Bortolotti, et al., 2015; Hadid et al., 2016), as lean itself is conceived as a socio-technical system, functioning as an interplay between hard and soft lean practices (Bortolotti et al., 2015; Hadid and Mansouri, 2014; Hadid et al., 2016). While hard lean practices involve tools and techniques that mainly help to identify and to eliminate waste (e.g. 5S or VSM), soft lean practices involve HRM practices that are conducive to behavioral change for the purpose of lean sustainability (e.g. training and development or recognition and reward systems) (Martínez-Jurado et al., 2013). A focus on soft lean practices promotes organizational change towards a lean-thinking culture (ibid) and is often suggested to be central to the success of lean (Jørgensen et al., 2007). In this regard, Hadid et al. (2016) discovered the positive synergistic effect on operational and financial performance when accompanying hard with soft lean practices. In addition, Bortolotti et al. (2015) identified that successful lean-adopting organizations make more use of soft lean practices than unsuccessful ones and could not ascertain a significant difference regarding the utilization of hard lean practices. Indeed, hard lean practices are seen to assist in removing non-value adding activities from the value chain but the use of soft lean practices is, however, indispensable when aiming for CI sustainability.

Innovative work behavior

When pursuing a lean philosophy, standard operating procedures provide the basis for incremental innovation as employees steadily seek improvement opportunities in their current-state operations. Initiatives that are conducive to generating and developing ideas are supportive to establish a culture of continuous change, which in turn is key to sustaining CI (Anand et al., 2009). Not surprisingly, there is consensus that people play a major part in sustaining lean (Hadid and Mansouri, 2014; Bortolotti et al., 2015; Hirzel et al., 2017; Bortolotti et al., 2018) because CI is highly reliant upon employee engagement through individual innovative initiatives, also termed as innovative work behavior (IWB). IWB involves intentional behavioral actions that an individual undertakes to engage in the CI process (de Jong and den Hartog, 2010). More precisely,

> IWB is the combination of three behaviours: idea generation, i.e. the development of novel ideas to solve problems or exploit opportunities; idea promotion, i.e. the search for potential allies to support the innovative idea; and idea implementation, i.e. the application of the innovative idea in the real-life context of the organisation (Mura et al., 2016, p. 1224).

While innovation consists of various sequential stages, beginning with the generation of the idea and ending with its implementation, IWB does not necessarily cover each of them. Instead, IWB is rather an employee-level approach where individuals participate in one or more of the aforementioned stages at any given time (Scott and Bruce, 1994). In other words, employees do not necessarily display each behavior but often leave some other matters to colleagues with corresponding skills. With that said, it becomes obvious that employees require different skillsets during each of the stages in order to excel. High levels of IWB are thus very likely to promote CI from 'bottom-up' (Mura et al., 2016). Since organizations seek achieving high levels of IWB in order to sustain the CI momentum, they endeavor encouraging their employees to engage in the innovation process (Hirzel et al., 2017).

Development of the research question

Many scholars from the field of lean accentuate the power of soft lean practices to foster lean sustainability (e.g. Jørgensen et al., 2007; Hirzel et al., 2017) and although a few researchers from other disciplines have addressed the positive impact of HRM practices on IWB (e.g. Prieto and Pérez-Santana, 2014; Bos-Nehles et al., 2017), the relationship between soft lean

practices and IWB in particular remains unclear. In other words, the current knowledge of the positive impact of HRM practices on IWB could shed more light on the challenges of lean sustainability. In addition, previous research on the relationship between HRM practices and IWB considered IWB as a one-dimensional construct (e.g. for simplicity reasons; Bos-Nehles et al., 2017). A recent literature review by Seeck and Diehl (2017) on HRM and innovation reported a lack of studies explicitly considering the different dimensions of IWB (i.e. idea generation, idea promotion and idea implementation), and similarly, Bos-Nehles et al. (2017) emphasize the necessity to investigate this relationship by considering IWB as a multi-dimensional construct. Seeck and Diehl (2017) further deduce from their review that there are only a limited number of qualitative studies (e.g. de Jong and den Hartog, 2007; Messmann and Mulder, 2011; Tuominen and Toivonen, 2011). They argue that existing ones, however, demonstrated access to 'the intangible and complex nature of […] innovation' (p. 929) in the past, which quantitative studies might lack of. Together, these studies effectively call for an explorative approach, investigating the relationship between soft lean practices and the different dimensions of IWB in order to develop a more grounded understanding how lean can be sustained. This study proposes the following research question to address this gap.

RQ. How do soft lean practices influence innovative work behavior?

To address this question, this study develops an analysis through the ability-motivation-opportunity (AMO) framework, suggesting that employee performance emerges from interplay between ability, motivation and effort as well as opportunities to contribute (Lepak et al., 2006; Jiang et al., 2012). As soft lean practices aim at a behavioral change through the development of skills, the stimulation of motivation and the creation of opportunities, the AMO factors align with many aspects that have already been discussed in the literature on lean sustainability. That is, for instance, the development of skills to enhance the abilities (Hirzel et al., 2017), the necessity of involving and empowering employees to enhance the opportunities for the adoption of their acquired skills (Bateman, 2005; Jørgensen et al., 2007; Hadid et al., 2016), and rewarding and recognizing employees to enhance their motivation (Jørgensen et al., 2007; Anand et al., 2009). In this regard, the authors propose that the AMO framework may provide closer insights into this relationship.

Methods

Case study design

Since the research objective was exploratory in nature, a case study design was adopted (Yin, 2014). With regard to the company profile, an internationally operating manufacturing company for electronic appliances was chosen (from now on referred to as InterCo), in which soft lean practices are extensively used as part of a wider lean program, accompanying hard lean practices. The research was undertaken at one of their UK sites.

Data collection

The case study used a mixed-method approach for the data collection and took place over four site visits. During the following two-hour site tour, as agreed, the first two authors observed twelve operators (O_{12}) at work and interacted with them. Interactions with operators occurred spontaneous, arose out of the situation and were thus not pre-determined. These data were recorded via field notes. Further supplementary data, including protocols of lean implementation and a company presentation were also recorded via field notes and photographs. Data from these sources were used for triangulation purposes (Eisenhardt, 1989). Then, the authors extended the dataset by conducting semi-structured in-depth interviews with three managers (Director of Manufacturing Support, M_1; HR Manager, M_2; Head of

Manufacturing, M_3) and three further operators (O_1; O_2; O_3) (Yin, 2014). The interviews with managers generated a wider picture of the current situation and past experiences, as they have responsibility for managing the shop floor (Aoki, 2008). Each interview was tape-recorded and transcribed verbatim.

Data saturation
After the interviews, there was much data overlap and just little more new material of substance was being added. Most interviewees demonstrated a considerable knowledge about the area of inquiry and, noticeably, the views of managers and operators often merely differed in a perspectival manner, that is, "managing" and "being managed" (Guest et al., 2006). In any case, data become sufficient to elucidate the aim of the research (Patton, 2015), that is, the exploration of the relationship between soft lean practices and IWB. In view of this, the researchers agreed on finalizing the data collection after complementing the dataset with six semi-structured interviews.

Data analysis
Prior to the analysis, interview transcripts and field notes were reviewed. First-order coding was conducted. Guided by the AMO framework for the data aggregation, codes that represented a soft lean practice were grouped to first-order categories (van Maanen, 1979; Corley and Gioia, 2004) and then mapped to the according theme within each single factor of the AMO framework (Lepak et al., 2006). For instance, 'cross-training' was mapped to 'training and development', which constitutes an element of 'ability'. In doing so, the third level of aggregation was indeed guided by each of the three factors within the AMO framework. Supplementary data were analyzed in the same manner or used for triangulation purposes (Eisenhardt, 1989). From this analysis, it became apparent that some codes match with more than one theme within the AMO factors and consequently were cross-coded.

Results
The following presents the results from the InterCo case. To begin with, operators on the shop floor are considered as a crucial source for novel ideas because they are the ones who are constantly doing the physical job.

> The ideas come from the people who are involved in the everyday process. Especially here, we don't work top-level down. It's more from bottom-level up because the guys who are working constantly know what is a hindrance or an inefficiency to them (O_1).

> The weird and whacky ideas because someone may think it's silly… an idea they are putting forward… 90% of that idea may be silly but then that 10% could be then involved into something phenomenal (M_2).

Thus, management does not only seek encouraging their operators to engage in idea generation but also in idea promotion so that operators bring their ideas on the table.

Idea-generating soft lean practices
Training and development. As the general basis for lean implementation, InterCo launched an in-house learning academy, aiming at the training and development of operators and other staff through a range of different activities in order to sensitize the workforce in any realm of CI. For instance, master classes involve a top-down instrument to convey knowledge from internal experts and rather comprise the theoretical knowledge to be conveyed while operators further acquire practical skills through simulated workbenches in the academy. In this regard, the Head of Manufacturing particularly accentuates that the acquisition of on-the-job skills is 'all about

self-learning' (M_3) and that these kinds of skills cannot be taught to operators as opposed to the theoretical knowledge. Besides that, higher levels of idea generation are particularly achieved as a result of job rotation and the participation in cross-trainings.

In addition, kaizen events facilitate on-the-job learning. Internally referred to as 'red-jacket events', they constitute cross-sectional meetings on the shop floor, in which employees with different expertise come together to collectively generate ideas for the sake of improvement and problem-solving. Lean champions, in particular, go around the factory and actively challenge existing procedures.

> We have people from different sections of the factory and then we go and observe your process. We ask, 'Why are you walking here? Why are you walking this way? What do you have to carry?' (O_2)

As soon as lean champions identify waste, they will never reveal what explicitly needs to be improved but rather give operators food for thought in order to encourage them to generate their own ideas.

Performance management. In view of kaizen events, the name 'red-jacket event' originates from the red jackets that are worn during the inspection. There are two particular reasons for this.

> One [reason] is, so that anybody who wants to go over and ask questions… we say, 'Be sensitive. They're now working on CI activity. Please don't interrupt them unless you're going to help them.' And the other reason for the red jackets is, it's highly visible. So, the rest of the department and the rest of the factory can see, 'Over there today, they are carrying out a continuous improvement event.' So, it raises the profile of what is happening (M_3).

Both the Head of Manufacturing and the Director of Manufacturing Support accentuated that the red jackets bring the CI activity into focus and encourage operators to think about ideas how improve their own workstation.

In retrospect, management learnt that production targets were not conducive to cultural change but rather pressurized their operators (O_{12}).

> We realized that [production targets] didn't change the culture. That was just people reacting to an instruction. Then we said, 'Now, forget about the targets – just do it'. And this changed it overnight. People don't really have to push it anymore. People just do it because they enjoy it. It's a break from the normal routine. It gets you off the line and then you actually do some things different to make your daily life easier – huge change (M_1).

In contrast to production targets, management developed a bonus scheme, which rather encourages operators to display behaviors that relate to the satisfaction of quality standards, attendance and personal development.

> To qualify for the bonus one third of that payment would be related to attendance and behavior – so, no disciplinary actions and no absence. Then, we introduced a quality measure where we said 'Your department needs to achieve this quality standard.' That was another third. Because we were growing and we wanted our people to engage in personal development. So, we added a learning requirement. It does sound a little bit like the carrot on the stick but without the stick because everything I just talked about is actually within their own control. So, they either want to or they don't want to (M_1).

Reward and recognition. Management perceives that reward and recognition are crucial success factors for keeping up the momentum of new ideas. InterCo, thus, draw upon various systems (e.g. peer-to-peer recognition, monetary rewards and a recognition wall). Monetary and non-monetary recognition are not only limited to individuals but also take place

collectively as a result of exceptional team efforts. That is, for instance, because idea generators are not necessarily the ones who also implement them (O_2).

Idea-promoting soft lean practices

Job security. Managers endeavor to help operators to think in terms of work simplification. Importantly alongside this, job safety is guaranteed, so that no one fears being replaced through new implementations, such as automation.

> We're very open with all the guys. Yes, we want a target to reduce from maybe ten down to eight people but we don't make people redundant. We introduced robotics recently and it did replace people. Robotics are carrying out very demanding and very repetitive jobs. So, therefore those people now moved into a probably more interesting and enjoyable role as opposed to the traditional on-line placing where three thousand pieces a day can get quite repetitive. So, they also can understand that we are moving them to higher skill levels (M_3).

In fact, InterCo experienced that being transparent in terms of job security makes operators more open to change and more willing to share their ideas as their fears of job loss are stilled.

Employee involvement. Upon inquiry, most of the operators reported that they mainly voice their ideas through the 'request-for-action' system. More precisely, the request-for-action system involves a standard form system that gives every operator the opportunity to make suggestions for an improvement in a formal way. Since operators are interested in receiving feedback as soon as possible (O_{12}), two people have been assigned to deal with the request-for-action forms as part of their daily role in order to ensure a fluent and timely processing. Management strongly emphasizes that feeding back to the operators is essential for sustaining higher levels of idea generation because it gives them a feeling of being acknowledged whereas delayed feedback conveys a sense of unimportance and disinterest and (even if unintentional) has a demotivating effect.

> We don't get in the situation where a person thinks, 'I've got all these ideas. I've submitted them all and nobody has come back to me with any information.' That stops that person putting forward the next thing (O_3).

The person who initially raised the idea will be asked to sign off the request-for-action form, either to double-check if he or she is satisfied with the change or to document that he or she has been informed why the idea will not be implemented.

The 'breakfast club' and a 'shared employee blog' constitute further communication channels, through which operators can share ideas or concerns with the Managing Director.

> The breakfast club is where our Managing Director takes up time. He will invite members from all parts of the business – the ones who do the job. He will invite them to a breakfast event in the canteen […] and then it's just a general chat around the table. Generally, he would say, 'Okay, what's going on? What things do you want me to know?' He has gained many good suggestions and ideas through hearing it from the people who have to do the job of making a product (M_3).

While the breakfast club is a face-to-face event, the shared employee blog provides the opportunity to share ideas and concerns anonymously. In retrospect, management noted that some employees seem to prefer different communication channels to raise their concerns.

> There's a blog on a shared PC in the canteen. They could write whatever they want. It's totally anonymous and that gets to the Managing Director. Therefore, if it's something they feel they don't want to be named against, they can still say it […] There are many forms of communication and many roots to get communication heard. We think we can capture everybody's opinion and certainly make sure that everybody will have at least one way that they prefer to speak out (M_3).

Idea-implementing soft lean practices

Kaizen events do not only constitute an opportunity for a collective discussion centered around a problem but also involve a platform where operators can promote and elaborate their ideas. In addition, they are also conducive to getting an idea directly implemented.

> Everyone from different departments gets together. People would pretty much gather in a meeting to try and find an improvement […] They will invite some people from engineering, some people from the line, maybe some people from training and different areas and then we all get together to come up with a solution and to come up with different ideas and then put those into practice (M_2).

Many operators confirmed that less pressure freed time and enabled them to think about ideas how to facilitate their daily job and the workplace overall and to implement them rather than being busy with chasing their production targets (O_{12}). In particular, one operator reported how this time-wise flexibility enabled him to form a coalition with colleagues and to implement and disseminate his idea.

> Just from a get-together the idea was implemented. We moved it from our department to another department and to another department. Then, all of a sudden, we've got ten of these systems around the factory. That all stemmed from four or five guys sitting with a cup of coffee (O_1).

Discussion and conclusion

Contribution to knowledge

The findings of this exploratory case study suggest that soft lean practices facilitate IWB amongst operators, and that together these can contribute to lean sustainability. The AMO framework helps to highlight both the role and the necessity of soft lean practices when striving to achieve lean sustainability. In addition, this study extends the scarce qualitative insights of research on IWB (e.g. de Jong and den Hartog, 2007; Messmann and Mulder, 2011; Tuominen and Toivonen, 2011), and identifies how soft lean practices have an influence on IWB through directly affecting single or sometimes multiple dimensions of IWB, catering to an employees' abilities, their motivation and their opportunities to contribute to CI throughout the different developmental stages of the idea. Since the study suggests that soft lean practices most often affect single stages of IWB, the findings support the view that IWB constitutes a multi-dimensional construct (e.g. Veenendaal and Bondarouk, 2015; Mura et al., 2016). Framing IWB as a three-dimensional construct enabled a more fine-grained behavioral analysis of IWB than is often the case when conceived as one-dimensional. In addition, this facilitated an understanding of the relationship between soft lean practices and employees' ability, motivation and opportunities in enhancing their engagement with the different stages of the idea development process on a daily basis.

Hutchinson and Purcell (2003) suggest that employee performance is achieved most effectively when organizations initially seek to develop the skillsets of individuals, then, to create incentives to utilize their abilities, and finally to introduce opportunities that facilitate the execution of individual actions. Likewise, the study demonstrates that the foundation to achieving lean sustainability involves training to develop a basic skillset and CI capabilities for idea generation (Hirzel et al., 2017). Bos-Nehles et al. (2017) concluded that training and development is the best and most-discussed ability-enhancing practice to nurture IWB. Besides that, however, being coached by a lean champion (individual level) and problem-solving groups, e.g. within kaizen events (collective level), are found to foster IWB in view of lean. In particular, the study confirms that learning itself does not only comprise the acquisition of theoretical knowledge but also a practical counterpart. On that note, both soft lean practices combine 'knowing' and 'doing' (Rother, 2010). While InterCo operationalized the necessity

for combining 'knowing' and 'doing' particularly via simulated training workbenches, challenging questions of lean champions were found to be conducive to transferring existing knowledge to new contexts, thus, encouraging idea generation. In particular, problem-solving groups are likely to engender collective learning cycles and constitute 'an environment which respects questioning and inter-professional discussion' (Bortolotti et al., 2018, p. 571). Aoki (2008) points out that successful organizations focus on collective approaches rather than on individual ones, as this facilitates that operators make suggestions. Kaizen events, in particular, provide evidence that soft lean practices can have an influence on all dimensions of IWB, that is, idea generation, idea promotion *and* idea implementation.

Similar to Gollan et al.'s (2014) case study, operators' bonus payments were reliant upon criteria that are within their own control. While Gollan et al.'s (2014) measures included 'teamworking, housekeeping, workplace organisation philosophy and standardisation of the workplace' (p. 6441), this study's findings extend this view and showcase that also the relevance of learning may enjoy a higher significance for operators once personal development activities become part of their annual targets. Likewise, Emiliani (1998) emphasizes the opportunities of linking personal development with organizational objectives when implementing lean in order to boost idea generation. Underpinned by key performance indicators, operators are not only encouraged to participate in ability-enhancing activities but also to submit a minimum number of idea suggestions in order to accelerate the input of novel ideas.

However, although stimuli generally aim at encouraging desired behaviors, they can also be misguiding, thus, leading to adverse effects and unintended consequences (Bhasin, 2008). For instance, the findings exemplified that former production targets were imbalanced, too ambitious and limited the capacities of operators to dedicate themselves to seek optimization opportunities at their workstation. In contrast, a change to a lesser focus on performance measures freed capacities to seek improvement and generate ideas. In other words, it was found that organizations should reconsider the balance between freedom for creativity and structured work. This suggests that less focus on production targets could support the operators during their daily work and ensure business profitability on the long-run, offering a counterview to many studies, which refer to the relevance of performance measures for the success of lean (e.g. Bhasin, 2008).

Contemporary literature on IWB emphasizes the importance of feedback but rather perceives it as opportunity-enhancing, which effectively means that its understanding is limited to its informative nature (Bos-Nehles et al., 2017). However, feedback does not only enhance the opportunities through useful information but it also affects the motivation level of individuals. As found in this research, prompt feedback on idea submissions helps to sustain the momentum of novel inputs and to foster idea generation, as a particular interest in the employee's inputs is shown. In contrast to this, this study has found that a lack of feedback is likely to demotivate employees, as a sense of unimportance or disinterest might be unintentionally conveyed. Likewise, the communication of job security was found to increase the willingness of operators to share and promote their ideas.

In terms of creating opportunities, the study indicates that an identification of the different individual needs along the developmental stages of the idea is necessary in order to develop a better understanding of the issues and challenges that an operator faces on a daily basis, and which they have to overcome to bring their ideas forward. For instance, the case illustrated the installation of various communication channels (i.e. suggestions boxes, the breakfast club and the shared blog) that offer different lateral ways to bring an idea forward, and proved useful and of value at InterCo. In addition, anonymous suggestion systems offer a way that serves an alternative for reserved employees to speak out and to get involved, as previous research

evidences that employees might come up with outstanding ideas, yet, they fear to share them (Zhou and George, 2001).

Managerial implications

Several different courses of action can be recommended from this research. Managers could strengthen the process of idea development by addressing each different stage of IWB through ensuring that adequate soft lean practices are in place. This would include qualifying operators to become CI-capable through the development of abilities, which may facilitate IWB-orientated attitudes. In addition, managers could stimulate individuals' motivation through incentives to encourage them to adopt acquired skills, and outstanding performance should be recognized and rewarded in order to keep the flow of novel inputs running. With this, as seen at InterCo, the motivational role of prompt feedback in order to avoid discouragement for contributing with new idea inputs is also important. While these factors concern personal development and the stimulation to apply lessons learnt, managers should also have to consider the factors that are external to the individual and that might hinder IWB. Employees might be equipped with the required skillset and might be even motivated but if they are not also empowered to display desired behaviors due to environmental constraints, upskilling and motivation will remain ineffective. In this sense, organizations are responsible for creating opportunities for operators so that they can utilize their skills and their motivation, and in so doing, should also consider individual needs. The study suggests that striving for lean sustainability requires a consideration of all three AMO factors.

Research limitations and future research

Since this empirical research builds upon qualitative data of a holistic single case within the manufacturing sector, it is usually fair to contest the generalizability of the results. It would be thus worthwhile to investigate soft lean practices in other sectors in the future to see if similar or varying results could be found in the service or in the public sector.

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Exploring the effect of digitalizing shop floor management

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Abstract

Shop floor management is an essential tool for manufacturing firms wanting to create a lean culture. Traditionally, shop floor management is operationalized through periodical meetings with the team on the shop floor in front of a visual management board (i.e., whiteboard). Some traditional lean researchers argue using such an analogue board improves employee engagement. However, others claim that digitalization offers new possibilities to lift shop floor management to the next level. To shed light on this discussion and provide empirical evidence, this paper explores the effects of digitalizing shop floor management in a multiple case study within a single firm.

Keywords: Digitalization, Lean, Shop floor management, Continuous Improvement

Introduction

Today's manufacturing operations are complex processes with an increasing number of product variants. To ensure performance, operations managers need to motivate employees to strive for excellence. A popular tool to facilitate such a culture of continuous improvement is shop floor management (Hertle *et al.*, 2015). This leadership approach stems from lean manufacturing and emphasizes continuous improvement (kaizen) among employees (Lanza *et al.*, 2018). As there is no consensus about the definition of shop floor management (SFM), in this study we adopt the view of Hertle *et al.* (2015), who present SFM as an "*integrated managerial system that facilitates the communication, control of performance, and implementation of lean methods on the shop floor*". Within the last decade, many manufacturing companies have been adopting some form of SFM to improve their processes (Lanza *et al.*, 2018). Firms typically operationalize SFM by holding frequent meetings in front of visual management boards on the shop floor, where teams discuss current operational performance information and improvement suggestions. However, little research has been conducted on the success factors of SFM (Kurpjuweit *et al.*, 2018). One reason for this is that the focus of SFM is the involvement of the employees (Hertle *et al.*, 2015): therefore, cause and effects relationships are not easy to observe and successful practices not agreed upon.

On the one hand, the traditional lean literature often suggests the use of physical, analogue material (i.e., pen and paper) when it comes to information acquisition in problem-solving and improvement activities (Enke *et al.*, 2018). They argue that digital technologies increase the complexity on the shop floor and thereby detach the operator from the problem-solving process (Parry and Turner, 2006).

On the other hand, advocates of digitalization and many consultancy firms favor the digitalization of as many operations as possible, including management activities. As digital possibilities increase, the shop floor must face the impending digitalization frontier, both embracing digital transformation and making use of the new opportunities it presents.

As the two streams differ in their perspective, the literature does not offer a clear guidance on whether or not to, or indeed when and how to, digitalize SFM. This research aims to enable improved understanding of how digitalization may affect SFM. Furthermore, it shall therefore shed light on the advantages and disadvantages of switching towards digital SFM.

RQ: How does the transition from an analogue to a digital form of shop floor management affect its performance?

Theoretical background

This chapter reveals an overview about the existing literature on digital shop floor management. To understand the rationale of shop floor management, this chapter first introduces its origins in the lean and the continuous improvement process literature. The paper continues with a brief review about the current trends in digitalization. Finally, it combines the two areas of shop floor management and digitalization by providing an insight on the current discussion about their synergies.

Lean management and CI

The history of lean management traces back to the research conducted by Krafcik (1988) on the International Motor Vehicle Program. This research has yielded in many following studies and contributions, in which *The Machine that Changed the World* and *Lean Thinking* were among the most popular ones (Womack *et al.*, 1991; Womack and Jones, 1996). The aim of lean is to *eliminate waste* thus deliver *more with less*, encouraging firms to strive towards perfection. Womack and Jones (1996) define five principles to achieve this. *Specify customer value* aims to ensure that only products that address a customer need are designed and produced. *Identify the value stream* intends to identify and eliminate non-value adding activities in the entire value stream. *Flow* production enables short cycle times, low WIP inventory and high flexibility to produce a variety of products. According to the *pull* principle, products are pulled through the value chain based on actual customer demand. Overproduction is prevented as products are only released in the process if the downstream processes step requires replenishment. Finally, *strive for perfection* demands the critical scrutiny and continuous improvement (CI) of the status quo based on active involvement of qualified and empowered employees.

The latter principle is reflected in the continuous improvement process (CIP) and has received research not only from the stream of lean literature but also from total quality management (Lam *et al.*, 2015). The CIP helps to constantly develop processes further towards an overarching goal or *next target condition* (Rother, 2010). The Japanese term *kaizen* is often seen as a synonym for the CIP. Kaizen was first introduced by Imai (1986). He differentiated the concept of kaizen into three different hierarchical areas of participation: management, group, and individual. On these different levels, kaizen aims

for small, incremental improvements. Bessant *et al.* (2001) define a maturity model for different levels of the CI. Starting from "no CI activity" through "strategic CI" up until "the learning organization" in which the CI is embodied in the organization. This latter stage not only includes the problem-solving at hand but also emphasizes the sharing of knowledge gained by that process throughout the organization. The literature further distinguishes between kaizen and kaikaku, the latter resembles step-change in contrast to the continuous, small improvements realized through kaizen (Bertagnolli, 2018). For instance, the implementation of a new manufacturing technology can resemble kaikaku, whereas the continuous incremental improvement of this technology can be related to kaizen.

To create a culture of CI, many organizations implemented shop floor management as a leadership method. The goal of SFM is to allow the participation of the employee and support him in his role as problem-solver. To operationalize SFM, companies lead regular (e.g.; every morning, every week) meetings on the shop floor. These SFM meetings shall help the leader to make important discoveries at the place where the value-adding processes happen (the gemba) and provide room for reflection and the exchange of ideas with employees on the shop floor (Peters, 2009). Such meetings on the shop floor often follow common patterns and discuss similar elements such as performance charts, resource allocation, or the continuous improvement process, for example (Lanza *et al.*, 2018; Hertle *et al.,* 2015). The meetings take place at a board on the shop floor where typically the production plan and status is displayed, together with key performance indicators (KPIs, eg. Right first time (RFT), delivery schedule achievement (DSA), overall equipment effectiveness (OEE), etc.) The current status of CI actions are also often visualized on these boards. Traditionally, however, simple analogue whiteboards have been used for the visualization of these measures.

Digitalization of the shop floor management

In recent years, the digitalization of manufacturing has received a high attention from both researchers (cf. Kusiak, 2018) and policy-makers (Prinz et al., 2018). It thereby constitutes one of the most significant trends in industry and society alike (Hagberg et al., 2016). Even though many of the digital technologies are not new, the rate at which they are recently finding their applications in manufacturing is increasing (Yoo et al., 2012; Brynjolfsson and McAfee, 2016). The potential of digitalization are able to increase revenue and productivity as well as innovation alike (Matt et al., 2015). This can be achieved by the successful implementation of existing and emerging digital technologies. Among other implications, these technologies allow for a horizontal and vertical connection of data within the production (Kagermann, 2014). This leads to an increased transparency over the processes within production.

With the technological possibilities of connectivity (e.g., manufacturing execution systems or cloud computing) and visualization (e.g. interactive screens and data analytics) organizations consider reducing the amount of paper within production by digitalizing such tasks instead. This often means that the traditional whiteboards used for SFM are considered as potential targets for digitalization. Several scholars have been discussing and studying the possibility and the effect of a digital SFM (Hertle et al., 2015; Lanza et al., 2018; Sven-Vegard Buer et al; Müller and Müller, 2018; Hambach et al., 2017).

Digitalization of SFM is related to the transfer of otherwise analogue tasks of data collection and / or visualization to automated digital solutions. Examples for data collection are obtaining daily production levels or the reoccurrences of certain failures. Even though this data might be collected digitally (e.g., through an ERP or MES), they can still be visualized analogue. For instance, when a shift leader prints retrieves the data,

prints it, and puts it on a white board. This analogue process is still widely happening within industry (Lanza *et al.*, 2018).

Transitioning to digital SFM not only changes both, the collection and visualization of data, but also the analysis during the meeting (Hambach *et al.*, 2017). Expected benefits from digitalizing the SFM tasks include increased transparency, quicker reactions on deviations, and improved decision making through data (Lanza et al., 2018). Hambach *et al.* (2017) also see potential in reducing time-consuming activities and further elaborate on visualizing the strategic alignment with company-wide goals as well as deviation management through real-time data.

Method

To investigate the effect of the digitalization of SFM we used a multiple case study within a single firm (Eisenhardt, 1989; Yin, 2013). The firm produces technological products for the maritime industry and is headquartered in Norway. At the site of the case study the firm has been implementing lean and shop floor management (SFM) since 2015 on teams at the shop floor and in 2017 scaled up to include the senior management team. It recently transitioned its SFM from analogue to digital throughout the organization, migrating its kaizen platform from whiteboards with paper cards to a digital, online solution. To increase the generalization, we conduct research at team level and investigate multiple teams. Thereby, we differentiate between different types of teams. In total, we investigate the CI activities of four teams, described in Table 1. The first two teams work on the shop floor at the headquarters in Norway. We choose two teams that differ in size (number of employees). The first team consists of a large number of employees whereas the second is a small team. The divisional management team forms the third team, representing possible differences from the hierarchical levels. We also choose a fourth team from a subsidiary in Germany.

Table 1 – The analyzed teams in the study

Team ID	Area	Employees	Year of CI introduction	Location
1	Shop floor	24	2015	Norway
2	Shop floor	5	2015	Norway
3	Management	10	2017	Norway
4	Shop floor	16	2015	Germany

We first quantitatively investigate the effect of digitalization on the CI performance. For constructing a relevant performance measure for the CI we use the number of completed (implemented) improvement suggestions from the employees per year. To compare the performance, we gathered data on the number of suggestions before and after the implementation.

In the qualitative part of the research, we conduct semi-structured interviews with the teams. We lead further interviews with other teams and employees of the company to obtain an external perspective and receive a holistic view. This enriches the quantitative analysis and helps to identify the antecedents for the changes. The interview guide can be found in Appendix A. We visit several shop floor management meetings and observe the meetings. This helps us in triangulating the data and ensures that what the interviewees answer can be found in the reality.

Table 2 – Description of the interviewees

Interviewee	Area	Team	Function	Length
1	Shop floor	Other	Change Agent	40min
2	Shop floor	Other	SC Lean Champions	45min
3	Shop floor	1	Change Agent	30min
4	Shop floor	2	Change Agent	30min
5	Management	3	QC Manager	40min
6	Shop floor	Other	Group Leader	45min
7	Shop floor	Other	Team Leader	40min
8	Management	Other	Production Manager	45min
9	Management	Other	Finance Manager	30min
10	Shop floor	Other	Planner	45min
11	Management	Other	Lean Program manager	30min

Analysis

Currently, the company has two types of shop floor management meetings. In the first one, called Kanban meetings, the teams meet every morning to define what they are working on today. The second meeting, called Kaizen meetings, takes place once every week and discusses the status of new and current improvement suggestions from the team. It is the kaizen process that has recently been digitalized – the firm currently maintains an analogue system for Kanban. The transition from before to after the digitalization is illustrated in Figure 1.

Figure 1 – Shop floor management meeting before (left) and after digitalization (right)

As such, the results of the quantitative analysis are illustrated in Figure 2. The digitalization of SFM (kaizen platform) seems to negatively affect the large team, resulting in a small reduction in improvement activity. We suggest that this may be due to a phenomenon we shall call *out of sight, out of mind*, which implies that the drop in performance of the larger team may be due to the fact that the larger the team, the easier it is for members to "disappear" into the digital world – with less perception of

accountability for not presenting / realizing improvement suggestions. For the other three teams, however, we find a (significant) increase in improvements. The ongoing qualitative analysis shall help to investigate the causes for the different patterns.

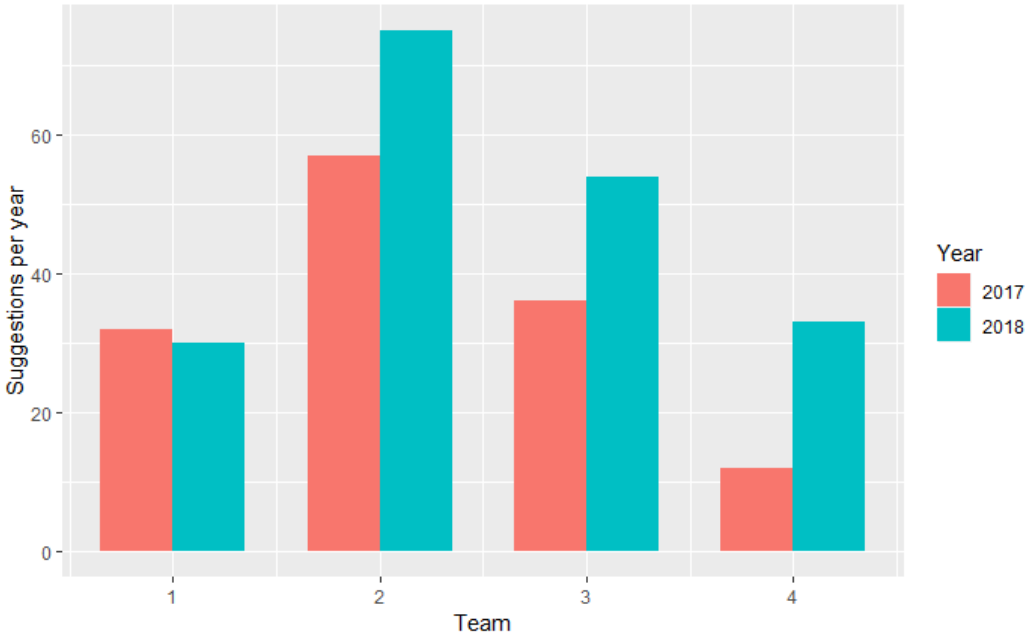

Figure 2 – Number of improvement suggestions per year and team (before and after digitalization)

Discussion

The analysis shows that there are multiple fields of improvement with the digitalization of the shop floor management. In the following section we present propositions that have been derived from our analysis of the case study.

P1: Digital CI systems can improve horizontal collaboration.

First, the digitalization of SFM allows for greater horizontal collaboration. Improvements that are suggested by the employees do not always only affect the team from which it stems from. Sometimes other teams are affected or do not support in the problem-solving process. Before the digitalization this would mean that the team manually transfers the improvement suggestion to the other department in which it is taken care of. By transferring the card, the team also lost track of it. It was not clear whether or not the improvement was realized and which actions were initiated in order to do so. As one interviewee stated "[...] *we did not know what happened to the suggestion when we were giving it to the other team*". After the implementation the team could digitally assign the improvement suggestion to another team without losing track on the progress of the card.

P2: Digital CI systems can improve the vertical escalation.

While some suggestions can be solved at the team level on the shop floor, some others might require the involvement of higher-level management. Such decisions might be related to higher investments or affect the strategic position and therefore need approval. An interviewee mentions this speed of escalation: "*We get a quicker decision on whether the improvement can be implemented*". As for the horizontal connection a digital shop floor

management system also allows for vertical escalation towards higher-level management. Suggestions can be tagged and forwarded to the management board meetings. This increases the speed of decision-making and transparency for the employee that identified the improvement suggestion.

P3: Digital CI systems can optimize workflows by reducing administrative time.

In line with Lanza *et al.* (2018) the case reveals the benefit of reduced preparation time through digitalization. Data collection and visualization (i.e., printing, posting, etc.) can take time of the team leader. As one team leader states: "*... before it took me around half an hour to prepare the meeting and assign tasks.*" Having the data in real-time, digitally, allows the team leader to focus on other important activities that add value to the team's performance. Follow up time

P4: Digitalization of shop floor management does not have to reduce employee engagement.

One of the central criticisms against the digitalization of shop floor management is the loss of engagement of the employee who cannot relate to the digital board in the same way as to the analogue. However, we did not find this in our interviews. The engagement was not affected by implementing the digital solution, neither negatively nor positively. As one interviewee puts it: "*I don't care whether I write it manually or on the screen. This doesn't affect my suggestions.*" The quantitative data supports this assumption. In contrast to the criticism, the amount of improvement suggestions went up after implementing the digital solution in most cases.

P5: Digitalization provides possibility for analyzing data on historical CI activities.

Even though some solutions promise benefits from analyzing historical CI data, none of the teams used that data. Potential benefits would include learning or suggestion prediction. Having the improvement suggestion written on paper restricts an automated inquiry. However, the digitalization allows for filtering and searching for specific historical suggestions. These previous suggestions could be used for revealing recommendations for current problems.

P6: Technological experience of the employees affect the transition.

Finally, the potential benefits are also influenced by the technological experience of the team. Being used to digital systems in private life helps to adopt to digital technologies at work as well. The case study revealed positive reactions of the employees on the digitalization of the shop floor management. However, this might have been different in other companies, especially in less technological developed countries. An interviewee confirms this by stating: "*For people that are not used to digital technologies, the effect may be different and they might be less confident with the system*". But at the same time, it is important for the company to make use of the employees capabilities to use digital tools. If they are able to use them in their personal life to make it easier and more efficient, why should they refuse to do so at work?

Conclusion

This research contributes to the discussion between lean traditionalists and digital advocates about the digitalization of shop floor management. It helps in exploring the changes and their underlying antecedents that occur when an organization decides to implement digital SFM. Building up on the existing discussion in the literature the study derives several potential benefits and challenges when digitalizing shop floor management. To validate these, we empirically investigated the transition of a company from analogue to digital shop floor management. Thereby, the study suggests six propositions for the suitability of digital shop floor management. For practitioners this research supports deciding whether a digitalization of their SFM should be undertaken and what to expect from it.

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Appendix A – Semi-structured interview guide

I Introduction

Characteristics of interviewee

1. Please briefly introduce yourself and your current position
    a. Position
    b. Career background
    c. Years of employment
2. What do you understand under the term SFM (meetings)? Which functions do you include under SFM.
3. How many of such SFM meetings do you attend in a working week?

II Application of digital shop floor management

General questions about SFM

4. How often do you perform SFM meetings? And who is involved? Does the SFM cascade?
5. Which topics do you address in SFM?
6. Why do you use SFM? What do you think would happen if you would stop doing it?
7. How do you measure the performance of your SFM itself?

Transition to digital SFM

8. Did you digitize parts of the SFM functions? If so, which ones?
9. What were the reasons for implementing digital functions into your SFM?
10. How did you digitize the SFM? Did you develop your own solution or bought an existing one?
11. How did the implementation work?
12. How is the data for the SFM collected? How do you visualize it?
13. Which KPIs do you track? How are they aligned with organizational goals (e.g., Hoshin Kanri)?
14. How do you feel has the SFM changed after the digitalization?
15. In your opinion, what are the benefits of the digital SFM in comparison to the analog?
16. What disadvantages do you see?
17. How did it affect the continuous improvement process?
18. How did the role of the employee change after the digitalization?

III Conclusion

19. Do you think the digitization of the SFM improved the SFM?
20. Do you want to add something?

Digital collaboration within the supply chain: New booster for hidden lean potential.

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Abstract
This paper explores the hidden lean potential exposed by manufacturers' usage of enterprise resource planning (ERP) systems. The potential can be classified into three types: unlocked lean potential in a connected ERP system, unlocked lean potential in an un-connected ERP system, and the lean potential for further unlocking in companies that do not use ERP systems when collaborating with suppliers/customers. Empirical data is obtained from two cases of manufacturing companies in Sweden and one ERP system company. The findings indicate that hidden lean potential can be unlocked through digital collaboration within the supply chain.

Keywords: lean manufacturing, digital technologies, supply chain

Introduction
Nowadays a significant number of manufacturing companies around the world have become influenced by lean philosophy and actively use its techniques to increase competitiveness and profits (Fritzen et al., 2016; Hoe et al., 2017; Womack, 1990). Supply chain success is based on collaboration and trust, with a common goal to create more value working in a synchronized manner for mutual benefit. The lean approach spread over the supply chain share a common goal of value creation through the reduction of waste through the whole supply chain (Christopher et al., 2006; Goldsby et al., 2011). Technological progress offers manufacturers ERP systems that are aligned with lean values and increase the efficiency of manufacturing companies through the accurate data management and transparency of the processes (Palaniswamy and Frank, 2000). ERP systems have taken leading role in developing strategic decisions within manufacturing companies (Yen and Sheu, 2004). However, it is still unclear how to gain maximum benefit from the technological options available for modern manufacturers. Does a digital supply chain allow lean manufacturers to become even leaner, by discovering new lean potential? McDermott (2016) provide statistics showing that overall, digital supply chains lead to a 20% reduction of procurement costs, a 50% reduction in supply chain costs, and an increase in revenue of 10%. The figures suggested by consultancy companies promise a reduction of costs through investments into technologies. However, it is still to be discovered, whether the usage of technologies at a supply chain level can boost the internal lean potential of manufacturing companies. The purpose of the study is to discover hidden lean potential through ERP systems and the supply chain.

Lean & Supply Chain

Goldsby et al. (2006), provide a description of three of the most common and debated supply chain strategies: lean, agile and hybrid (leagile). Supply chain strategy should be designed in a logical sequence from market identification to the establishment of performance metrics. The approach aims to improve competitive standing by achieving the real market winning criteria (Towill and Christopher, 2002). Christopher and Towill (2001), support the development of a hybrid strategy to create a cost-effective supply chain. The key success factor for lean or agile strategy derives from the market selection, where one of the strategies is the most convenient approach to reach competitive advantage. Christopher and Towill (2001) proposed a framework combining lean and agile philosophies to achieve a greater effect within the supply chain. The hybrid strategy should reflect on market conditions and is very context specific. Martínez-Jurado and Moyano-Fuentes (2014) evaluated the links among lean management, supply chain management, and sustainability. According to the authors, companies would like to adopt lean management, but they are also concerned about the impact they have on society through their activities. The impact is not an isolated scene within the organization. Instead, it is spreading through the whole supply chain directly or indirectly.

Value management within the supply chain is a challenging task. When the goal is to make the supply process lean for the benefit of the supply chain, then responsibilities should be distributed following a different strategy (Lamming, 1996). Christopher et al. (2006) discuss the importance of the supply chain strategy selection based on analysis of the product, market, and company. Key dimensions in the selection process should be based on replacement lead-times and predictability of demand, which can be enriched further with the nature of the product and its life cycle. Naylor et al. (1999), arguing that consideration of market knowledge is primarily important when integrating the lean or agile manufacturing paradigm. They suggest avoiding the isolated consideration of operations management in the manufacturing sector. Operations need to be considered in combination with a supply chain carefully combining both lean and agile paradigms towards “leagility” (Naylor et al., 1999).

Manufacturing & ERP

ERP implementation is a complex act that manufacturing companies face to improve the interaction between customers and suppliers. According to Duplaga and Astani (2003), smaller companies are more successful in implementing ERP systems in the manufacturing sector. However, companies are more likely to view ERP implementation as the beginning of the development. Linking customers and suppliers to the ERP system in a perspective is more likely to be implemented by bigger manufacturers (Duplaga and Astani, 2003). According to Palaniswamy and Frank (2000), ERP systems enhance manufacturing performance. An ERP system is a powerful tool for coordinating production, reengineering business processes, and establishing a competitive innovative environment for future survival in the global marketplace (Palaniswamy and Frank, 2000). Yen and Sheu (2004) discuss challenges that companies have faced in implementing ERPs and the uncertainty about the benefits expected after the implementation. On the other hand, research state that failures are the results of business problems, not technical ones. Yen and Sheu (2004), suggest aligning ERP implementation with a competitive strategy. Software customization, information sharing, data accessibility, software maintenance, proactivity of managers, national culture, and government/corporate policies are among the key factors that need to be considered for successful ERP implementation in manufacturing firms.

Raymond and Uwizeyemungu (2007), developed a framework to analyze the propensity of small and medium enterprises (SMEs) in adopting an ERP system. The framework is a set of relations between environmental, organizational and technological contexts, leading towards an ERP adoption profile. The authors suggest starting from the assessment of the manufacturing company to evaluate how an SME is ready to adopt computer-integrated manufacturing technologies and an ERP system. Muscatello et al. (2003) propose a set of planning activities during the ERP implementation process for SMEs, such as strategic objectives and top management involvement, reengineering efforts, enterprise system analysis, and ERP profiles of the companies. Another important set of activities in the case of SMEs relates to installation activities including education and training requirements, project monitoring and reporting, and overall project performance.

Baki and Çakar (2005) investigated Turkish manufacturing companies using ERP systems, where the majority of the companies used their own program to regulate the process. The second most popular result of their study was an absence of unified software. A minority used manufacturing resource planning software or materials requirement planning software. Manufacturing companies in the minority that used the ERP, had a list of selection criteria while investing in such a complex decision as an ERP implementation. Top tree criteria were system functionality, technical aspect and the cost of the software (Baki and Çakar, 2005). Ranjan et al. (2018), believes that the operations and performance of the manufacturing company is very much dependent on the successful implementation of the ERP system. There are 25 critical success factors identified in the literature, however only 9 of them authors recognizing as the most important factors. These factors are change management, user need definition and expectation, IT infrastructure and architecture, performance measurement and evaluation, top management commitment and support, enterprise-wide communication, selection of the ERP software, user training and education, effective project management (Ranjan et al., 2018). New forms of organizations are based on close cooperation and networking. Manufacturing companies can increase the competiveness by implementing ERP systems (Raymond and Uwizeyemungu, 2007). Powell (2013) was questioning if ERP systems and lean manufacturing are complementary or contradictory technologies. Authors developed a framework presenting ERR in lean manufacturing production with six major areas: Combining lean and ERP for competitive advantage; Methods for the concurrent application of lean and ERP; ERP support for lean production; Real-time information for intelligent planning and execution; ERP systems for the extended lean enterprise; e-Kanban as a platform for integrating ERP and pull systems.

ERP & Supply Chain

Many companies have successfully implemented ERP systems and gained competitive advantage through the strategic usage of the software. According to Chen (2001) the success of the ERP implementation is primarily associated with an adequate planning prior to installation, careful selection of an ERP product, prioritizing business process and organizational requirements when adopting the ERP, economic and strategic justification. Chen (2001) realize the potential of ERP systems to develop from being a link between suppliers and customers, to become a mediator managing supply chain management and customer relations management. Kelle and Akbulut (2005), discussing how the supply chain is impacted by ERP tools. First of all, ERP is positively impacting the information exchange process within the supply chain, with the most positive effect on negotiation procedures. Secondly, there are procedures to select and aggregate the data to share with partners within the supply chain. Thirdly, there is an opportunity to optimize existing

business models and enhance cooperation (Kelle and Akbulut, 2005). Búrca et al. (2005), investigated the challenges faced by SMEs when implementing ERP systems. Authors stating that strategic technology adoption is demanding ERP coverage over the whole supply chain. Change management should be applied through the whole supply chain when adopting the ERP (Búrca et al., 2005).

According to Forslund and Jonsson (2007), it is very common to share a customer's demand forecast with suppliers. Consequently, the information flow is making an impact on the whole supply chain. The quality and the accuracy of the forecast could be very subjective, but the impact on the supply chain is inevitable. Li et al. (2009), analyzed the impact of IT implementation on supply chain integration and performance. According to the authors, IT offers accurate and reliable information that improving supply chain integration and supply chain performance. From the other hand, ERP system became very standard element of the business, which was initially designed to fulfil the internal needs of the organization, but not the entire supply chain (Akkermans et al., 2003).

Even if the ERP system successfully adopted in a strategic level covered the whole supply chain, it is still unclear what should be the best approach to measure the supply chain performance (Akyuz and Erkan, 2010). Akyuz and Erkan (2010), proposed metrics to measure the performance. One of the points is requiring an adoption of a proactive approach creating the platform for continuous improvement. Another interesting point is related to measuring partnership, collaboration, agility, flexibility, information productivity and ability to define business excellence. Bagchi et al. (2005), discussing the experiences of ERP integration by European manufacturers and establishment of electronic links with their supply chain. The study shows that only a few companies providing an ERP open access to their supply chain partners. Sharing sensitive data is still a barrier for many companies to lift relations with customers and suppliers on a strategic level trough transparency and online access. Very few companies are overcoming the barrier and establishing joint decision-making with their key suppliers and customers (Bagchi et al., 2005). High level of complexity within the supply chain is another barrier to achieve high performance. Giannakis and Louis (2011), proposing a framework to manage the complex supply chain system with a support of IT. Multi-agent model allows real-time adaptability with analytical tools that offering integrated decision-making framework. The focus of the framework is on supply chain demand rather than the forecast (Giannakis and Louis, 2011). Framework application supporting a better decision process in disruption and risk management within the manufacturing supply chain.

Conceptual Framework

Manufacturing companies are working on waste reduction and continuous improvement to create more value from the available resources (Womack et al., 1990). At the same time, manufacturers are a part of a supply chain in which collaboration procedures take up a lot of resources. The lean approach influenced the whole supply chain as one of the strategies competing with agile supply chain strategy or being combined in hybrid strategy (Lamming, 1996; Towill and Christopher, 2002). The supply chain was influenced by lean, because lean was not expected to be observed as an isolated process (Martínez-Jurado and Moyano-Fuentes, 2014; Naylor et al., 1999). Collaboration could reveal bigger opportunities to be leaner through the whole supply chain.

For several decades it has been very common to use the ERP system to plan and control the processes in manufacturing organizations (Palaniswamy and Frank, 2000). The literature describes both failures and successful implementation of ERP systems in manufacturing companies of different sizes and production focus (Baki and Çakar, 2005;

Duplaga and Astani, 2003; Yen and Sheu, 2004). The reasons for failure in adopting system are not technical. They are related to challenging business processes, poor strategic decisions and low human resources motivation to reach high performance through the adoption of an ERP (Ranjan et al., 2018; Raymond and Uwizeyemungu, 2007).

The whole supply chain represents a set of linkages between suppliers and customers, where ERP systems can play a significant role in this complex process (Búrca et al., 2005; Kelle and Akbulut, 2005). Information technologies are the source of flexibility and leading to optimize and simplify the information flow within the supply chain. IT also leads to improved suppliers' forecasts, accuracy, reliability of collaboration processes, and performance (Akkermans et al., 2003; Akyuz and Erkan, 2010; Forslund and Jonsson, 2007).

Previous studies also describe the importance of information technologies and digital tools, such as ERP systems to optimize the internal processes within the manufacturing organization as well as having limited or open access through the supply chain network to increase the performance. There are only a few studies investigating if manufacturing organizations can be leaner internally through supply chain collaboration and the active usage of technologies, such as ERP systems. The conceptual framework in Figure 1 was developed to understand the phenomena.

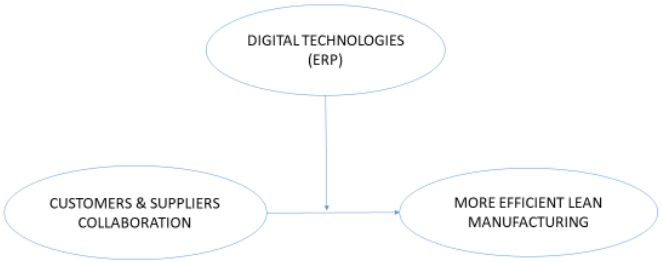

Figure 1 – Conceptual framework

Method

A multi-case study method was chosen as the approach to analyze the framework. The multi-case study allowed us to observe and analyze similarities and differences between the manufacturing companies that use ERP systems. The proposed framework include different scenarios with a hidden lean potential. The multi-case study method allowed us to observe the contrast between the companies that are using ERP system to collaborate with their customers/suppliers and the companies that are using the ERP system only within their organizations with no flexibility to collaborate on a digital level. Case research is a tool in the development of new theory and one of the most powerful research methods in operations management (Voss et al., 2002).The decision to choose two cases, was based on intention to increase the validity of the proposed framework (Caniato et al., 2018).

According to Handfield and Melnyk (1998), there are three stages of research in operations management. At the discovery (first) stage, companies were observed as a part of the Lean Management & Digitalization project plan. Semi-structured interviews were conducted with managers of the companies (CEOs, plant managers, IT managers, sales managers and etc.). In total there were 16 interviews and three workshops. Interviews were one to two hours long. The second stage was aimed at mapping and relations-building stage to find out common challenges or experiences the companies faced. At the final (third) stage, the framework was tested. The paper covers three key topics: lean manufacturing with a focus on waste reduction and continuous improvement, supply chain management with a focus on customer/supplier relations, and digital technologies with a focus on ERP systems.

Results

Company A & Customer/Supplier

Company A is an SME with a turnover SEK 42 million and 60 full-time employees. They want to be the most “customer-close” partner in the industry. The company is aiming to be the easiest to work with and to be perceived flexible and solution-oriented. Company A is working continuously to develop "customer value" by developing an internal process as well as common process and product. Lean-principal is the "baseline" in the company’s job and working method such as continuous improvements, pulse meetings, and flow optimization are everyday concepts in the company.

Company A is a manufacturing company where the whole supply chain network is represented as a loop, where about 95% of all company orders are coming from the same customer who is providing all the raw materials for production. The raw materials are processed into aluminum frames and are delivered back to the customer to become a finished product. The company has no stock and is using JIT. The customer/supplier of Company A is a big company with complex infrastructure and long decision-making procedures based on organizational policies with a low flexibility to changes on a digital level.

Company A is actively using lean techniques to reduce waste and continuously improve their processes based on employees’ feedbacks and observations. Company A has a whole potential to be lean internally, but very much dependent on their customer/supplier participation. For example, the raw material can be delivered in wrong color or size. Employees are quick in finding out a mistake and report about it. However, the response will take time. Purchase and quality managers from the customer/supplier side are working only day time. To fix the mistake might take the time of the whole shift. Company A would need to reschedule their activities and it will affect their productivity, efficiency, employee’s satisfaction and the profit.

Company A is using in house developed ERP system that allows running the processes internally. Customer/supplier using the ERP which was closed for the access for any partners within the supply chain. Company A brainstormed how to improve their processes to leaner and *reduce the waste in time* when collaborating with a customer/supplier. Data transparency was recognized as the most powerful tool to reach the goal. Company A persuaded their key customer/supplier to share access to their stock and monitor the availability of the raw materials through the ERP systems communication. A total number of mistakes (e.g.: wrong material colors delivery) is reduced dramatically, according to managers’ experience. Mistakes are classified since it is possible now to analyze the nature of the mistakes and develop scenarios to prevent them with an opportunity for *continuous improvement*.

Company B & Monitor ERP Systems AB

Company B has more than 16 high-quality CNC lathes managed by competent operators. The production handles everything from prototype and single-piece production to medium-sized series up to 40,000 pieces per year. The company has a complete department for post-processing, laser marking, grinding, honing, washing and tumbling. The high quality, flexibility, and efficient processes, create good profitability for Company B customers, with the least possible environmental impact. There is a special family spirit in the company where you allow differences and let people grow.

Company B have a large number of customers, however, most of the revenue is arriving from a few big companies. Company B is using the ERP system developed by Monitor, whereas their suppliers and customers are using different ERPs or software tools to run their internal activities. There is no digital interaction within the supply chain and data sharing process. Most of the information is shared by e-mail and often requires extra communication such as phone calls to prevent misunderstanding, delays or mistakes. There are cases when orders or demands of the customer are available to be downloaded from their websites. However, the information is in excel files and is not constantly updated or synchronized with stock and real needs. Any adjustments and changes are very time-consuming procedures affecting operations of Company B dramatically and creating waste in terms of time and reorganization of activities, human allocation, machine programming, and purchases of raw materials. Another interesting aspect is that every supply chain member is saving the data in a different format. When the information is spreader around the chain, Company B is always spending an extra time to convert (label) the products (data) in a format which is accepted to the ERP system for internal use. In other words, the whole supply chain is communicating different ‘digital languages’ and every time they are going thought the manual translation process, to keep the internal consistency and order.

Monitor ERP Systems AB was founded in 1974. Today's operations include Monitor business systems and consultancy services for manufacturing companies with a focus on SMEs. The company has more than 200 employees. The Monitor is currently installed at approximately 3,800 companies in over 30 countries and translated into 14 languages. In DataDIA's 2011 survey, Monitor had the highest customer satisfaction among the approximately 100 ERP systems in Sweden.

The Monitor is working in close collaboration with their existing and potential customers.The analysis lead Monitor team to extend the investigation of process beyond the borders of manufacturing plants. Since a lot of activities are based on collaboration, Monitor got interested in the supply chain of their customers. Putting Monitor customers on the map, managers realized that the vast majority of them are related to each other by being supplier of customers for their businesses. ERP developers established a feature called Monitor-to-Monitor (M2M). In a way, the ERP system created a buffer or ‘instant translator’ of the languages used by different companies using a Monitor ERP product. For example, when one send or receive an order or an order confirmation via e-mail in Monitor, an XML file is attached that the recipient can use in his/her Monitor system. One import/register the file by dragging and dropping it (using the mouse pointer) directly from the e-mail message to Monitor. There are also functions for maintaining basic data by sending and receiving part info, prices, lead times, annual volumes and suppliers' part numbers via e-mail. The only difference is that a TXT file is used for the import instead. Customers of Monitor found the feature as an extremely useful tool supporting their lean strategies. The main advantage is a reduction of waste in time, which was spent by different manufacturers to communicate. Another advantage is the opportunity for Monitor users to continuously improve their processes through the rapid data sharing and

the accuracy of the data synchronized with internal systems in local sides. Finally, the human factor as a valuable aspect of lean also was covered by M2M. Employees are more satisfied and feeling a better working environment by avoiding conflicts and trust issues when the data was lost or misinterpreted on the way causing financial losses.

Discussion

The frameworks developed (Figure 1) is proposing the idea of relations between customers and suppliers having a positive impact on lean manufacturing allowing the companies to be more efficient. The relations are stronger with the impact of digital technologies (Powell, 2013). This study is considering the ERP system as a digital technology. There is a lean potential in manufacturing company where the waste can be reduced, processes continuously improved, and the human factor can play one of the most significant roles in those activities. The processes of lean management is often quite isolated to let the improvements happen only within the manufacturing company. There is an approach to spread the lean management over the supply chain and let the customers and suppliers of manufacturing companies also to be leaner and more efficient during the collaboration process (Kelle & Akbulut, 2005). However, the hidden potential of the lean is also available to be explored and activated through the collaboration on a digital level (Akkermans et al., 2003), where each participant can benefit to become leaner (isolated) through the collaboration and use of technologies.

Unlocking lean potential with a connected ERP systems

The framework is supported by the Company A case where the hidden lean potential was identified and used. The company gained access to the customer/supplier ERP system (inventory) and improved the operations. Employees were able to independently predict and avoid many production mistakes by accessing customer/supplier inventory through the ERP systems communication. Based on managers' experience, the company reduced the waste of time and materials using the same resources with increased efficiency and profit. They also managed to continuously improve by rapid processes reorganization if the mistake in process flow was identified.

Unlocking lean potential with an unconnected ERP systems

The framework is supported by the Company B case, where the company realized the hidden lean potential through the digital interaction within the supply chain and data sharing process, though it is not functioning perfectly well yet. Company B can unlock the lean potential if they can connect the ERP system with their customers and suppliers. Data duplication, data confirmation by phone and e-mail, as well as data transformation in different formats are causing waste of time and duplication of action. Connecting the ERP systems with their customers/suppliers would also reduce this waste. If transparency were to increase, operation managers would have an ability to improve the actual production from the planning stage, using the most updated customer demands. Operations would be continuously improved and the human factor would play a key role.

Potential for further unlocking

Monitor, the ERP system developer, also support the framework developed, by extending the network of clients using the same ERP and offering functionalities simplifying data exchange procedures within the supply chain. Based on Monitor customer feedback when using connected ERP systems within the supply chain, the number of mistakes in orders has decreased. The ERP system guarantees transparency and accuracy, avoiding the waste of time and resources that previously happened due to the mistakes caused by having no ERP systems connected. Customer/supplier relations with connected ERP systems

improved continuously by better planning of orders with the real-time data availability about the inventory, machine operations and workload of employees.

Conclusion

This study contributes to the research of Powell (2013) in discussing the role and implication of ERP system in lean production. This study of Powell (2013) developed a framework presenting ERP in lean manufacturing production with six major areas. This paper contributes to at least two of the areas proposed by Powell (2013): ERP support for lean production and real-time information for intelligent planning and execution. The study also contributes to the research of Akkermans et al. (2003) discussing the need for flexibility through the IT within the supply chain.

This research presents a perspective for practitioners to extend or boost the hidden lean potential of manufacturing companies through supply chain digitalization. The study shows how manufactures can develop relations with their suppliers and customers through the active integration of ERP systems, which will allow them to become leaner as an isolated part of the supply chain. Collaborating more and increasing digital transparency with suppliers and customers enables companies to develop new opportunities to become more efficient and more profitable.

The study is limited to two cases of companies based in Sweden. The framework proposed needs to be validated with a bigger number of companies located in different countries. Lean manufacturing was only considered in three key aspects, such as continuous improvement, waste reduction, and the human factor. The study is limited by its very specific interpretation of lean manufacturing. For future studies, we suggest investigating what factors support successful collaboration between manufacturers, suppliers, and customers with usage of digital technologies to boost the hidden lean potential. Another direction for a future study is identification and validation of alternative digital technologies (besides ERP systems) supporting the framework.

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Configurations for Managing the Interplay between Process Improvement and Product Innovation

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Abstract

This paper explores how organizations manage the interplay between process improvement (PI) approaches and product innovation. Using a qualitative multiple-case study method, four different configurations for managing the interplay emerged - "strategic and holistic", "facilitating and empowering", "operational", "project-based"- and their associated mechanisms were identified. Under each configuration, the interplay is managed through integration or separation. PI has the potential to enable innovation if it is loosely integrated in the innovation processes. However, a tight integration of PI might constrain radical innovation. Findings provide empirical evidence on the varied and paradoxical use of PI in triggering different degrees of product innovation.

Keywords: process improvement, product innovation, ambidexterity

Introduction

For over a century, researchers in operations management have advocated the introduction of process improvement (PI) methods and standards to increase organizations' efficiency and productivity (Taylor, 1911, Womack et al., 1990). At the same time, strategy and innovation scholars have stressed the negative effects of efficiency and productivity gains on organizations' capacity to adapt and innovate. In this context, Abernathy (1978) introduced the notion of the *productivity dilemma* and "conjectured that short-term efficiency and long-term adaptability are inherently incompatible" (Adler et al., 2009, P.99). This argument has since been framed in different, but related ways, for example stating that "exploitation" crowds out "exploration", that stability conflicts with change, and that standardization hinders creativity (Schad et al., 2016). In line with these perspectives, several researchers in strategy and innovation have considered PI and product innovation and their associated processes, practices and concepts as conflicting if not incompatible (e.g. Benner and Tushman, 2003, 2015, Mehri, 2006). For example, PI approaches such as lean, six sigma, and total quality management (TQM), have been associated with exploitation, stability, efficiency, standardization, alignment and control, whereas innovation has been associated with exploration, change, flexibility, creativity and adaptability (Benner and Tushman, 2002, 2003, 2015). As a consequence, many scholars have questioned the benefits of PI approaches (Benner and Tushman, 2003, 2015).

On the other hand, a considerable amount of research in the operations management literature highlights the benefits that PI approaches bring to organizations, not only in term of greater efficiency and flow, but also in creating customer value, increasing customer satisfaction and innovating products and services (Modig and Ahlstrom, 2012,

Sousa and Voss, 2002). In doing so, several scholars have suggested that PI approaches consist of two distinct dimensions; for example, Schroeder et al. (2008) argued that "Six Sigma can be viewed from two different structural dimensions: structural control and structural exploration" (p. 544). Also, Sitkin et al. (1994) identified two distinct approaches for TQM such as total quality control and total quality learning.

Moreover, while some researchers adopted a primarily control-oriented view of PI and argued that PI approaches hinder product innovation, other scholars adopted a learning-oriented view, arguing that PI approaches create a learning environment that fosters innovation (Pekovic and Galia, 2009, Prajogo and Sohal, 2001). Nonetheless, empirical research shows mixed results regarding the relationship between different PI approaches and product innovation- in particular radical innovation- (see, e.g., Benner and Tushman, 2002, Kim et al., 2012). In addition to the varied theoretical and empirical arguments that exist in the literature, previous research focused on defining the elements of PI that affect different degrees of innovation. However, little is known about the mechanisms that shape the relationship between PI and product innovation (Raisch and Birkinshaw, 2008). Therefore, this research addresses the following question: *how do organizations manage the interplay between PI and product innovation?*

Theoretical Framework

The interplay between PI and innovation

Extant literature was conducted on the relationship between PI approaches and product innovation. Overall, the literature shows divergent theoretical and empirical arguments, and two main groups of scholars can be identified. The first group adopts a control perspective and consider PI approaches mainly as sets of efficiency-oriented practices that are based on discipline, conformity and adherence to rules, formalization, reduction of variation, standardization, and exploitation of existing knowledge (Benner and Tushman, 2002, 2003). From this perspective, PI approaches are seen as promoting incremental product innovation and hindering a more radical one for three main reasons (Benner and Tushman, 2003, 2015). First, these approaches aim to reduce variation in processes (Benner and Tushman, 2002), whereas radical innovation requires variation-increasing activities and slack resources (Troilo et al., 2014). Second, PI approaches often rely on standardization and formalization to maintain improvements and stability; however, standardization may impede flexibility, creativity and innovativeness (Zeng et al., 2015). Third, the customer-centric element of PI approaches can trap organizations in improving their existing products instead of creating radically new ones (Sadikoglu and Zehir, 2010, Slater et al., 2014). Emphasis on existing products establishes "a focus on easily available efficiency and customer satisfaction measures" (Benner and Tushman, 2003: 239), which goes against radical innovation and penalizes adaptation and the achievement of long-term goals (Adler et al., 2009).

The second group of scholars' views PI approaches as learning-oriented practices and suggests that PI can create a learning environment that is based on trust, collaboration, openness and knowledge creation. Consequently, PI approaches are regarded as mechanisms to support both incremental and radical product innovation (Gil-Marques and Moreno-Luzon, 2013, Gutierrez Gutierrez et al., 2012, Choo et al., 2007). Scholars that adopted this perspective have also regarded PI approaches as sets of principles and practices that create a fertile environment for innovation (Prajogo and Sohal, 2001). For example, these approaches use iterative cycles of continuous improvement (Slack et al., 2013) that involve employees in decision making (Prajogo and Sohal, 2001). This provides employees with a sense of responsibility, engagement and ownership (Slack et al., 2013), which enhance their creativity and their capacity to innovate (Gil-Marques and

Moreno-Luzon, 2013). Moreover, "control in process management is likely to assist firms to maintain stable goals, to reduce product development time, and to meet customer needs in both existing and emerging markets" (Kim et al., 2012: 304). Process management can also improve the product development process performance by reducing time-to-market (Kim et al., 2012).

While the first group focused on the tools and mechanistic side of PI, the second group used both the tools and the soft (behavioral) elements and suggests that using both elements of PI could facilitate innovation. However, apart from identifying the PI elements and tools that enable or hinder innovation, little is known about the contextual factors and the mechanisms that could help in facilitating both PI and innovation.

Paradox and ambidexterity

Over the past two decades a sizable literature has emerged around the concept of ambidexterity (Birkinshaw et al., 2016). The term "organizational ambidexterity" was coined by Duncan (1976). The use of the concept was renewed by March (1991), who stressed the importance and the difficulties in pursuing both "exploration" and "exploitation" in organizations. Exploration refers to activities related to "search, variation, risk-taking, experimentation, play, flexibility, discovery and innovation", whereas exploitation is associated with "refinement, choice, production, efficiency, selection, implementation and execution" (March, 1991, p. 71).

Authors investigating the concept of organizational ambidexterity have tended to frame the argument and operationalize the main constructs in two different ways. For some, exploration and exploitation are the two opposite ends of a continuum (Lavie et al., 2010) and managers are confronted with two mutually exclusive sets of options (Farjoun, 2010, Smith and Lewis, 2011). On the contrary, other scholars have argued that exploration and exploitation are separate (orthogonal) concepts (Birkinshaw and Gupta, 2013, Gupta et al., 2006). According to this view, pursuing more exploration related activities does not necessarily means engaging less with exploitative ones and vice versa (Birkinshaw and Gupta, 2013). In a similar vein, paradox theorists have advocated a fundamental shift in organizations from an *either/or* to a *both/and* perspective (Raisch et al., 2018, Schad et al., 2016, Smith and Lewis, 2011). In this context, paradox denotes a "persistent contradiction between interdependent elements" (Schad et al., 2016, p.10). It concerns "how organizations can attend competing demands simultaneously" (Smith and Lewis, 2011, p. 381) instead of examining separately the conditions under which a certain set of activities (e.g., innovation, flexibility, exploration) or another set of activities (e.g., standardization, efficiency, exploitation) can be effective.

Even though paradoxes cannot be resolved, research suggests various approaches for managing competing demands in organizations. Poole and Van de Ven (1989) described four approaches for dealing with paradoxes: acceptance (keeping and living with tensions), spatial separation, temporal separation, and synthesis (integration). While most of these approaches were discussed in the subsequent research, "integration" and "separation" are the most commonly used ones (Raisch et al., 2009, Schad et al., 2016). In relation to *separation,* extant research in ambidexterity suggests spatial separation as a solution for managing conflicting goals (Raisch and Birkinshaw, 2008). In this case two units exist in the organization: one focuses on explorative activities and the other on exploitative ones (Tushman and Oreilly, 1996). Similarly, other scholars have proposed the introduction of parallel structures. This includes having a parallel team or project who undertake explorative activities alongside regular ones (Raisch and Birkinshaw, 2008). Another type of separation – temporal - involves cycles of exploration and exploitation that happen sequentially over time (Eisenhardt et al., 2010).

Integration entails concentrating on complementarities (Schad et al., 2016). For example, building on Ghoshal and Bartlett (1997), Gibson and Birkinshaw (2004) introduced the concept of "contextual ambidexterity" and suggested that the tension between alignment and adaptability can be managed in one unit by creating a context that builds on trust, empowerment, discipline and stretch, that allows individuals to pursue different contradictory goals. Similarly, Adler et al. (1999) provides a comprehensive description of a combination of various strategies for managing the tension between efficiency and flexibility in Toyota, including meta-routines, switching, partitioning and job enrichment

The above review shows that there are two contradictory arguments and inconclusive empirical results concerning the impact of PI approaches on innovation. Drawing on the paradox and ambidexterity literature, this study aims to identify the mechanisms that organizations use to manage the interplay between PI and innovation.

Methodology

Case selection and Research context

This research adopted a qualitative multiple-case study method (Voss et al., 2002). where the selected firms were purposefully sampled with the aim of achieving maximum variation (Denzin and Lincoln, 2011). Specifically, four large international manufacturing companies were selected (Pseudonyms are used for confidentiality reasons). These firms are similar in terms of sector, size and location, but operate in different industries - automotive, aerospace and pharmaceutical. Two dimensions were used to purposefully sample the case organizations: the extent of PI usage and the degree of product innovativeness. While these criteria were identified at the beginning of the sampling phase, further validation of the initial assessment was sought during the data collection and analysis process. Table 1 summarizes the main characteristics of the case organizations and presents their position in the sampling matrix. PI characteristics were derived in two ways: first, the breadth and the depth of PI usage across the organization, as derived from the interviews and documentary evidence (Marodin et al., 2018, Netland and Ferdows, 2016). Second, key informants were explicitly asked regarding the use of PI in the organization. The degree of product innovativeness was evaluated in relation to both market and technology, consistently with extant research (e.g. Danneels and Kleinschmidt, 2001, Chandy and Tellis, 2000). A product that displays new technology, knowledge or capability and satisfies new customers was identified as a radical innovation. Conversely, instances where current technology, knowledge or capability were used, and the product satisfied existing customers were identified as incremental innovations. In order to derive this, informants were asked to provide examples of recent products and to classify them as incremental or radical[1].

Table 1- Research context and sampling criteria

		Fast-CarCo	**Excellent-AeroCo**	**PharmaCo**	**Cheap-CarCo**
Description	**Main Business**	Design, innovate, engineer, manufacture, market and service premium vehicles	A pre-eminent engineering company focusing on world-class power and propulsion systems	Create, discover, develop, manufacture and market pharmaceutical products.	Design, engineer and manufacture vehicles
	Sector/ Industry	Automotive	Aerospace	Pharmaceutical	Automotive

[1] A detailed description of the research context available from the authors

Main Similarities	**Size**	Large (about 40,000 employees)	Large (about 50,000 employees)	Large (about 100,000 employees)	Large (about 60,000)
	Time-to Market	Relatively long (5-7 years)	Long (7 - 12 years)	Long (12- 15 years)	Relatively long (5-7 years)
	Intensity of regulations	Relatively high	High	High	Relatively high
	Length of PI usage	More than 15 years	More than 15 years	More than 15 years	More than 10 years
Main differences	**PI usage**	High -Using PI across the organization -Using different types of PI approaches-lean, six sigma, TQM, etc. -There is a clear awareness and responsibility of PI across the company even in R&D	High -Using different PI approaches- such as lean, six sigma, TQM- across the organization -Having a formal process for PI -Having dedicated teams for facilitating PI implementation	Low -Using PI only in manufacturing -Using different PI approaches (lean & six sigma) -There is no formal program for PI -There is no awareness and clear responsibility of PI across the company except in manufacturing	Low -Using PI mostly in manufacturing and on projects in engineering -Using different PI approaches (mostly six sigma and lean) -Does not have a formal process for PI -Does not have dedicated teams for facilitating PI implementation
	Product innovativeness	Relatively high. -Different levels of product innovation (incremental, and radical)	Relatively low. -Mostly focused on improving current products (incremental innovation)	Relatively high. -Different levels of product innovation (incremental, and radical)	Relatively low. -Mostly focused on improving current products (incremental innovation)

Data collection and analysis[2]

Data were acquired through semi-structured interviews and internal documents; also, the first researcher kept a diary throughout the data collection and analysis phases (Voss et al., 2002). Over a 15-month period a total of 44 semi-structured interviews were conducted and 55 relevant documents were collected. The interviews were conducted with senior managers from different functional specialisms (strategy, R&D, manufacturing, engineering, design and marketing). A snowballing technique was used to ensure all key informants were included. Each interview lasted an average of one hour and field notes were taken throughout the research (Eisenhardt, 1989). The interviewing process continued until theoretical saturation was achieved. Data were analyzed within and across cases through a multi-stage iterative process which included several rounds of coding, categorization, and refinement using the NVivo software.

Findings

The cross-case comparison led to two main findings: first, two aspects appear to shape the interplay between PI and innovation: PI scope and its integration in the innovation processes, and PI formality. Second, configurations for managing the interplay between PI and innovation, each have different characteristics, associated mechanisms and potential outcomes.

Aspects that shape the interplay between PI and innovation

It is not a surprise that the case organizations deploy PI approaches differently. However, while one may expect greater use at Fast-CarCo and Excellent-AeroCo, and less use at PharmaCo and Cheap-CarCo to be associated to two separate patterns, this was not exactly the case. Indeed, the analysis shows that it is not only PI intensity that matters,

[2] Details on the analysis and coding process can are available from the author

but also its formality, scope and integration in the innovation processes. *PI formality* refers to the degree to which PI usage is documented in the organization. In particular, in the selected companies PI formality varied between "expected" and "voluntary". Expected means considering PI as part of the company's strategic direction, as everyone in the organization / business unit is expected to use PI practices, and employees' involvement in PI activities is monitored. Voluntary refers to individuals' autonomy in deciding when to use PI or not. *PI scope* reflects the spread of PI usage in the organization and it varies between "pervasive" and "confined to a specific context", as PI could be used everywhere in the organization, including the more innovative areas (e.g. R&D, product development, design and engineering) or be implemented mainly in one area, typically manufacturing. *Integration* captures the use of PI in the innovation processes and varies between "high integration" and separation (segregating PI from the innovation processes). (See table 2).

Four configurations for managing the interplay between PI and innovation[3]

Considering the four configurations that emerge from the analysis, under the strategic and holistic approach, PI is implemented as a company-wide strategy in which everyone should be involved in PI; under the *facilitating and empowering approach*, employees can decide which PI method to use; under the *operational approach*, PI approaches are used only in manufacturing and not imposed on people in the rest of the organization; under the *project-based* configuration, PI is occasionally used outside manufacturing. This section will compare the four identified configurations (see Table 2).

Table 2- Identified configurations for managing the interplay between PI and innovation

	Strategic and holistic	**Facilitating and empowering**	**Operational**	**Project-based**
Case organization	Excellent-AeroCo	Fast-CarCo	PharmaCo	Cheap-CarCo
Scope of PI	Pervasive	Pervasive	-Isolated: Confined to manufacturing	-Isolated: Dominant in manufacturing and occasionally used in other areas
PI formality	Expected	Voluntary	Expected in manufacturing	Voluntary
How the interplay between PI and product innovation is viewed	-Overall PI is regarded as an enabler for product innovation	-PI as indirect facilitator of product innovation	-PI regarded as irrelevant to product innovation	-PI is seen as applicable mainly in the back end of product development process and as a barrier in the front end
Mechanisms for managing the interplay between PI and innovation	- *PI usage*: PI adapted to the area that is used in. - *Management systems*: Balanced performance objectives for both PI and innovation, balanced training (PI and innovation training, knowledge sharing portal) - *Structural mechanisms*: Balanced PI and innovation teams	- *PI usage*: PI adapted to the area that is used in. - *Management systems*: Entrepreneurial orientation: flexibility to start new projects, balanced performance objectives for both PI and innovation - *Structural mechanisms*: process-oriented structure	- *PI usage*: PI not used in R&D and in product development - *Management systems*: Entrepreneurial-orientation: flexibility to start new projects - *Structural mechanisms*: PI and innovation happen in separate locations	*PI usage*: PI not used in R&D and in product development - *Management systems*: Innovation and improvement championships - *Structural mechanisms*: The processes for developing new and current technologies are kept separate

[3] Data coding structure and illustrative quotes are available from the author

Strategic and holistic configuration

Excellent-AeroCo uses a strategic and holistic configuration for managing the interplay between PI and innovation. The main characteristics of this configuration are pervasive PI scope and expected PI formality. More specifically, in Excellent-AeroCo, PI has been used for a long period of time and many people are trained in different PI programs. However, a few years ago, the company recognized that all employees should be involved in PI. Consequently, various PI programs were initiated, and PI was explicitly introduced in the company strategy. Thus, PI is considered as the current priority in Excellent-AeroCo as stated by the head of the production system: *"We're trying to move to a more standardized way of working…a standardized way of working is a more lean way of working"*. Overall, the interplay between PI and innovation is managed by integrating PI in the innovation processes and across functions. However, the level of integration varies between functions and at different stages of the product development process. For instance, in R&D, where ideas for new products are generated and selected, lean is integrated with innovation and problem-solving tools. At this stage lean is used as a filtering mechanism to distinguish good from wasteful ideas. For example, the head of engineering strategy and enterprise architecture elaborated: *"Where lean plays a part is spotting the good ideas and moving them efficiently to product. Where waste comes out is spotting the wrong one or spotting the right one and implementing it purely".*

PI is also adapted to the product development, design and engineering areas to maintain flexibility. This adaptation is achieved by mixing lean with agile and using standardization in a loose manner. This adaptation of PI helps to provide structure for product development, balancing flexibility and rigour, and allowing people space and time to innovate.

Additionally, other organizational mechanisms are used. Some of these are managerial mechanisms including the use of formal training and balanced performance indicators and objectives (both PI and innovation-related). For instance, some areas in the business have more PI-related objectives and others have more of innovation-related ones. Aligning the performance objectives with PI and innovation not only supports the expected PI formality in Excellent-AeroCo, but also helps in maintaining employees' commitment toward PI and innovation initiatives. Additionally, various types of training are used for different PI approaches including Kaizen and six sigma certifications. At the same time, other training is provided through innovation workshops. Structure-related mechanisms are also used in Excellent-AeroCo for managing the interplay between PI and innovation using specialized teams for facilitating PI usage and innovation development.

However, despite the efforts for maintaining flexibility through the adaptive use of PI and innovation related training and performance measurement, the extensive use of standardization seems to hinder employees' capacity to explore new ideas. Consequently, this appears to promote incremental innovation and to hinder radical innovation.

Facilitating and empowering configuration

Fast-CarCo has a high degree of PI usage and high level of product innovativeness and follows a "facilitating and empowering configuration" for managing the interplay between PI and innovation. PI is used everywhere in the organization, in different functions (HR, finance, manufacturing, research, product development and engineering) with voluntary formality. At Fast-CarCo, the current leadership decided to invest in PI, but made its use more voluntary than it used to be (under previous ownership, Fast-CarCo had adopted the same processes and standards of its then parent company). More recently, the firm created a central portal / toolbox that collects different PI approaches, examples

of improved processes from different functions and various "best practices." The portal can be accessed by everyone in the company, but no specific approach is imposed.

Under the facilitating and empowering configuration, the interplay between PI and innovation is managed by integrating PI and innovation-related activities. This is achieved through different mechanisms: the adaptive use of PI, PI voluntary formality and entrepreneurial orientation, process-oriented structure, and balanced performance indicators. As an example of adaptation, in R&D a lean visual factory tool is used to facilitate collaboration and six sigma is used to maintain rigour in the technology development process. The same is true with the product development area, where not using people's creativity is considered waste, a typical lean concept.

Some years ago, Fast-CarCo moved to a process-based structure: for example, there are codified processes for strategy and leadership, research, HR, etc. These processes are improved and reviewed regularly and added to the shared portal. This process-oriented structure helps in maintaining rigour in the company. At the same time, using this configuration, Fast-CarCo facilitates an entrepreneurial-oriented environment by allowing employees to autonomously use PI, start new innovative projects in the research area, and separate teams to develop innovations. As another example, in 2016 Fast-CarCo launched a high-tech start-up company to develop app-based transportation solutions. This company has provided the autonomy and flexibility for developing new technologies. Additionally, Fast-CarCo uses performance indicators to balance excellence- and innovation-related goals. For example, forward- and backward-looking objectives are used as performance indicators in marketing teams (internal document, Fast-CarCo).

Overall the voluntary PI formality, the adaptive use of PI in the area, together with the autonomy and flexibility that is provided to employees could possibly facilitate the development of various types of product innovation. Here, PI acts as an indirect facilitator for innovation through maintaining rigour and structure for the technology and product development processes while, at the same time, allowing employees the flexibility to innovate.

Operational configuration

PharmaCo displays high product innovativeness and limited use of PI. Here, the interplay between PI and innovation is managed through the use of an "operational" configuration whereby PI is used only in manufacturing. At the same time, PI is a priority and expected in that area; as a director in product design and development stated: "*PI is a religion in [manufacturing]".*

Under this configuration, the interplay between PI and innovation is managed through separation, as PI and innovation happen in different areas of the business and are disconnected from each other, as PI is considered inapplicable for the R&D and product development areas. For example, a director in product design and development argued: *"I would say our approach is night and day in terms of similarities".* In R&D, employees are given the flexibility and resources to generate and develop new ideas. This entrepreneurial-oriented environment is created through flexibility that is given to employees in R&D and is seen as contributing to the development of different types of innovation (radical and incremental). However, this is not without disadvantages, as it creates inefficiencies and delays in the innovation process. Moreover, this flexibility has led to initiating projects that proved not feasible.

Another contributor to this disconnection between manufacturing and R&D is the stage in which the manufacturing area gets involved in the innovation process. Manufacturing involvement is at the very end of the drugs development process (the last

2-0.5 years) while it takes around 15 years to develop a new drug. This late manufacturing involvement contributes to the separation between R&D and manufacturing and, therefore, the area in which PI is used in (manufacturing) areas that innovation is developed in (R&D and product development). Therefore, in PharmaCo, when using "operational configuration" for managing the interplay between PI and innovation, PI is irrelevant for innovation as the two happen in two separate locations and are disconnected to each other.

Project-based configuration

Cheap-CarCo displays low use of PI and focuses on improving current products. For example, the head of propulsion and innovation at Cheap-CarCo elaborated: *"[Cheap-CarCo] is typically a relatively low-end car manufacturer: We make cars that are very simple, not very feature-rich".* Cheap-CarCo uses a "project-based configuration" for managing the interplay between PI and innovation. This configuration is characterized by isolated PI scope and voluntary PI formality. Here, PI is mainly used in the manufacturing area and occasionally in other areas including engineering and product development. At Cheap-CarCo, PI usage is more present and expected in manufacturing, but its use is rather voluntary in engineering, design and product development. The use of PI outside manufacturing is enabled by employees' awareness and competence in it. At the same time, PI is used informally at Cheap-CarCo as it is believed that it may hinder innovation

Overall, the main mechanism that is used to manage the interplay between PI and innovation under this configuration is "separation", which is achieved through the flexibility that is given to employees, first by making the use of PI voluntary, and, second, by running improvement and innovation initiatives to encourage employees' engagement in innovation and PI activities. These initiatives aim to develop innovation and excellence in the company as Cheap-CarCo is developing its innovative and PI capabilities. In addition, Cheap-CarCo recently adopted a new technology development process from another automotive company. This process is used to develop new technologies that were not used before and another process is used to improve current technologies. By doing this, Cheap-CarCo started to separate radical from incremental innovation processes. Given the separation using a "project-based" configuration, informants in Cheap-CarCo view PI as more applicable at later stages (manufacturing) of the product development than at earlier stages (R&D, design and engineering).

Discussion and Conclusions

This paper makes two main contributions to theory. First, this study explored the ways in which different PI approaches - such as lean, six sigma and TQM - affect product innovation (Bourke and Roper, 2017, Kim et al., 2012). A considerable amount of research has been conducted on the impact of different PI approaches on product innovation. However, previous studies have proposed divergent arguments. For some, PI approaches are control-oriented practices that drive rigidity, efficiency and hinder innovation (Benner and Tushman, 2003, Abernathy, 1978). On the other hand, others considered PI approaches as learning-oriented practices that help in creating a context that facilitate an environment of trust, learning and creativity (Choo et al., 2007, Kim et al., 2012). The findings of this research depart from both streams and argue that the relationship between PI and product innovation depends on the used configuration. This research identified four different configurations for managing the interplay between PI and product innovation. These are: "strategic and holistic", "facilitating and empowering", "operational" and "project-based". The identified typology suggests four manifestations of the interplay between PI and product innovation in organizations that

vary in their scope and level of integration (PI integration in the innovation processes and areas) on one side and PI formality on the other side. Therefore, considering a positive or negative impact of the use of PI on product innovation may not be accurate. For instance, if the "operational" configuration is being deployed -where PI is confined to the manufacturing area and segregated from the innovation processes in R&D and product development- then PI is irrelevant to innovation. In other cases, where the "strategic and holistic" or the "facilitating and empowering" configurations are used, PI is integrated in the innovation process. Therefore, this research shifts the perspective on the interplay by raising a different question; rather than asking 'what is the impact of PI on innovation?', the questions should first be, 'how are PI and innovation getting deployed? And 'what is the configuration?' Only then can the effect of PI on innovation be examined.

Second, this research revisited several enduring debates on the productivity dilemma, efficiency and innovation tension (Abernathy, 1978, Adler et al., 2009, Benner and Tushman, 2003, 2015, Papachroni et al., 2016). This literature has been often considering the interplay between two generic set of concepts such as productivity, standardization, efficiency, formalization, exploitation, and innovation, adaptability, flexibility and exploration, as dilemma and opposite to each other (Benner and Tushman, 2002, 2003, 2015, March, 1991, Schad et al., 2016, Smith and Lewis, 2011). In part, this due to the underlying conceptualization of the relationship between these two poles of concepts as mutually exclusive and opposite to each other (Farjoun, 2010, Smith and Lewis, 2011). This research redressed this and challenged the dichotomy perspective (Farjoun, 2010, Smith and Lewis, 2011), by offering four configurations for managing the interplay between PI and innovation. This, in turn, brought more variety into the productivity dilemma debate and suggests that this relationship is more complex than it was dominantly accepted. In other words, the relationship between productivity and efficiency-enhancing activities (such as PI) and innovation very much depends on the deployment of PI (scope, formality, usage) and locus of interaction (where innovation gets developed).

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Lean Supply Chain: a bibliometric analysis

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Abstract

Lean Supply Chain Management is an emerging research field in Operations Management that is attracting attention from researchers and practitioners. This paper presents a comprehensive analysis of the influence and productivity of the Lean Supply Chain Management literature and reports trends in journals, institutions, countries, and keywords. This study uses BibExcel and VOSviewer software to conduct a bibliometric analysis of 525 papers published in the Web of Science database from 1996 to January 2019. This analysis has enabled us to draw a number of conclusions and propose a roadmap for further research in the field.

Keywords: lean supply chain, bibliometrics, literature review

Introduction

Lean Management (LM) has evolved and expanded significantly in recent years, with numerous authors researching the subject. Womack & Jones (1996) showed that a systematic reduction of non-value-added activities in an organization and across its supply chain could improve business performance and the ability to achieve a competitive advantage. The application of LM along the supply chain to optimize all activities is called Lean Supply Chain Management (LSCM) and enables waste elimination, quality improvement, cost reductions and increased flexibility along the chain (Womack & Jones, 1996; Martinez-Jurado & Moyano-Fuentes, 2014; Swenseth & Olson 2016).

The Lean Supply Chain (LSC) concept has attracted growing attention since Lamming (1996) first coined the term in 1996. Proof of this interest is the number of papers recently published in the field. Previous research has reviewed the literature with different objectives in the past few years. Some of these literature reviews of LSC have been general and cover the entire field (Ugochukwu et al., 2012), while others have focused on specific aspects such as practices, barriers and contextual factors (Berger et al., 2018) and links between internal and external lean management and sustainability (Martinez-Jurado & Moyano-Fuentes, 2014).

Although all of these studies provide valuable information about the state-of-the-art of LSC, an additional analysis of the literature using bibliometric tools can provide further

insights not previously evaluated in other reviews. Network analysis via bibliometric tools can be effective for identifying established and emerging research topics. To date, only de Sousa et al. (2018) have used a bibliometric study to review the topic. However, these authors designed a rather restrictive search string that resulted in a reduced field of research and the selection of only 57 papers on LSC.

The present study presents a comprehensive overview of the scientific production on LSC with a bibliometric approach that uses BibExcel (Persson et al., 2009) and VOSviewer (van Eck & Waltman, 2010) software. The analysis covers a 22-year period from 1996 to January 2019 and reveals trends in journals, institutions, countries, and keywords. Our study goes beyond previous literature reviews by providing additional insights into current research interests and laying down a roadmap for further research into LSC.

The remainder of this work is structured as follows. The following section introduces the methodology used to identify the literature reviewed in this study, as well as the bibliometric techniques applied throughout the paper. Next, a brief descriptive analysis is presented to provide some initial insights into the topic. A detailed analysis using the BibExcel and VOSviewer bibliometric tools is presented in the following two sections. The closing section summarizes the results, presents some limitations of the study, and discusses opportunities for future research.

Research methodology

A bibliometric analysis is adopted in this research for its advantages over other literature review methods. Unlike other text analysis methods such as content analysis, bibliometric analysis can easily handle hundreds of papers. Furthermore, a bibliometric analysis is very useful for analyzing relationships among papers, citations, co-citations, and keywords and providing comprehensive information about the research area. Additionally, the powerful visualization afforded by bibliometric analysis helps readers to clearly identify research interests in the field.

The methodology used in this study has followed two different stages: 1) data search for data collection and refinement, and 2) data analysis for a comprehensive evaluation of the field.

Data search

This work analyzes scientific documents in the Web of Science (WoS) Core Collection database. WoS is a comprehensive search engine that can provide full results for an accurate analysis of this field as it contains a wide range of detailed information about each document. The search was conducted between December 2018 and January 2019 using the keywords “lean” and “supply chain” in the “Topic” field. Our search string [TS=(“lean”) AND TS=(“supply chain”)] generated 1,081 initial results. However, some exclusion criteria were considered to refine the search results: publication year (only the 1996-January 2019 period), document type (only journal articles and reviews), research area (considering only operations management-related areas) and language (exclusively publications in English). This process yielded a total of 579 papers in the WoS Core Collection.

Then, to improve quality control, the authors reviewed the title, abstract and keywords of each paper and, when required, read the full text. This discarded a further 54 papers not related to lean and/or supply chain management. The 525 records and their full descriptions (author, title, source, abstract, keyword, institution, etc.) were exported to a *.txt* file to assemble all the essential information in one place.

Data analysis

BibExcel was used to perform bibliometric and statistical analysis and to prepare the input data for additional network study in VOSviewer. The BibExcel bibliometric toolbox was chosen for its great flexibility for both data management and analysis and its ability to modify and adapt input data from several different databases (Persson et al., 2009). VOSviewer was then used to generate graphs of the bibliographic material. VOSviewer collects data and generates maps and different types of bibliographic data-based analyses: co-authorship, co-occurrence, citation, bibliographic counting, and co-citation. It was selected for the construction and display of bibliometric maps due to its viewing capabilities, which are especially useful for examining data in intricate detail (van Eck & Waltman, 2010).

Descriptive analysis

Initial data analysis can be useful for capturing basic information in the literature and presenting a preview of the topic. Figure 1 reports publication trends in LSC from the first articles in 1996 to January 2019. This figure describes the time period distribution of publications in the field and provides insights into the year-on-year evolution of the research topic. The growing number of publications shows that LSC has been the target of increasing attention from academia. An especially meaningful upward trend can be observed during the last 5 years, with over 55% of all papers in the field. The trend indicates that the number of publications will continue to grow in the future.

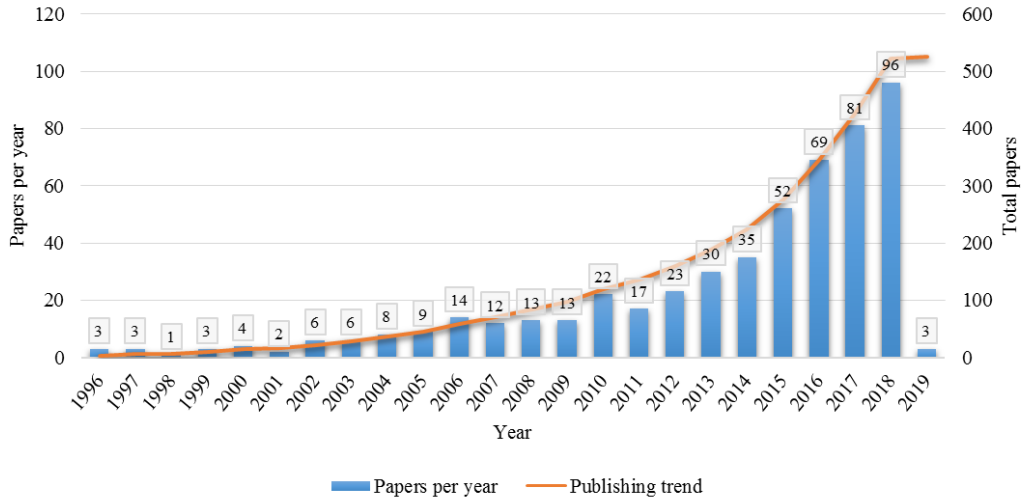


Figure 1. Publishing trend in LSC

These 525 papers are scattered across some 170 different journals, 80 of which have contributed around 83% of all the publications reviewed. Table 1 shows the top 10 journals for numbers of publications on LSC. It should be noted that these top 10 journals have published 244 out of 525 papers and account for more than 45% of all the selected documents. The *Journal of Cleaner Production* is the leading journal among the sources that have most contributed to the LSC area, with 38 papers. An interest in sustainable strategies in lean contexts can be observed since the most productive journal focuses on environmental issues. However, most of the sources are operations research journals.

Table 1. Top 10 journals contributing to LSC

R[1]	Journal	TP[2]
1	Journal of Cleaner Production	38
2	International Journal of Production Economics	31
3	International Journal of Production Research	31
4	Production Planning & Control	31
5	Supply Chain Management-An International Journal	27
6	International Journal of Operations & Production Management	23
7	Journal of Manufacturing Technology Management	22
8	Benchmarking-An International Journal	19
9	Journal of Operations Management	11
10	International Journal of Lean Six Sigma	11

Bibliometric analysis

In this study, BibExcel has been used to process the data with some initial bibliometric and statistical analyses and to prepare the input data for additional network analysis in VOSviewer.

Author production

BibExcel was used to analyze the papers and identify the authors with most publications in the LSC field. Table 2 lists the top 10 most productive authors and the number of publications that they have authored or co-authored. As can be seen, Garza-Reyes has produced the highest number of publications on LSC with 12, closely followed by Kumar with 11. These results indicate that there are no dominant authors in this field as yet, even though all these authors have extensive backgrounds in operations research/management and supply chain management.

Table 2. Top 10 most productive authors on LSC

R	Author	TP	R	Author	TP
1	Garza-Reyes, JA	12	**6**	Kodali, R	6
2	Kumar, V	11	**7**	Holweg, M	5
3	Cruz-Machado, V	9	**8**	Moyano-Fuentes, J	5
4	Tortorella, GL	9	**9**	Azevedo, SG	5
5	Govindan, K	7	**10**	Carvalho, H	5

Affiliation statistics

Authors' affiliation information was processed in BibExcel and the cities where the most productive organizations are located extracted for the analysis. Using the coordinates of these cities in gpsvisualizer.com, Figure 2 presents the geographic locations of the institutions that have most contributed to the LSC literature. Red circles indicate cities with at least two papers on LSC and the size of the circles indicates the degree to which the organizations have contributed. Those with greater contribution densities are in Western Europe and the Eastern United States. Nevertheless, the geographic dispersion of these institutions around the world indicates that LSC research and practice have received worldwide attention.

[1] **R**: Ranking
[2] **TP**: Total Papers

Figure 2. Geographic locations of the most productive organizations in LSC

The most productive institutions are shown in Table 3. Cardiff University in Wales is the organization in the list that has made the highest number of most contributions, followed by Universidade Federal de Santa Catarina in Brazil. Considering Table 2 and Table 3, there is a connection between the most prolific authors and the most productive organizations. Thus, the University of Derby, the Universidade Federal de Santa Catarina, the National Institute of Technology and the Universidade Nova de Lisboa can be observed to be represented by the most prolific authors: Garza-Reyes, Tortorella, Kodali, and Cruz-Machado, respectively.

Table 3. Top 20 most productive institutions in LSC

R	Institution	TP
1	Cardiff University (Wales)	14
2	Universidade Federal de Santa Catarina (Brazil)	13
3	University of Derby (England)	12
4	National Institute of Technology (India)	11
5	Michigan State University (USA)	10
6	Universidade Nova de Lisboa (Portugal)	10
7	University of Southern Denmark (Denmark)	9
8	University of the West of England (England)	8
9	Indian Institute of Technology Delhi (India)	7
10	Birla Institute of Technology and Science (India)	7
11	University of Nottingham (England)	7
12	Islamic Azad University (Iran)	7
13	Cardiff Business School (Wales)	6
14	Linköping University (Sweden)	6
15	University of Toledo (USA)	5
16	University of Cambridge (England)	5
17	Universidad de Jaén (Spain)	5
18	Universidade da Beira Interior (Portugal)	5
19	Lancaster University (England)	5
20	Worcester Polytechnic Institute (USA)	5

Table 4 presents the contributions of the most productive countries to the literature on LSC and its evolution over time with 6-year intervals (note that papers with authors from different institutions may have been assigned to multiple countries). The United States is the most productive country over time with 127 papers, closely followed by England with 102. In addition, India and Brazil show noteworthy rises in the numbers of papers

published on LSC in the last 6 years, which indicates that emerging countries are taking an increasing interest in LSC.

Table 4. Evolution of publications on LSC classified by top 10 most productive countries

R	Country	TP	1996-2001	2002-2007	2008-2013	2014-Jan 2019
1	USA	127	7	23	35	62
2	England	102	5	11	22	64
3	India	66	-	-	9	57
4	Peoples Rep China	31	-	2	12	17
5	Brazil	29	-	-	1	28
6	Wales	28	3	6	4	15
7	Italy	25	-	3	2	20
8	Spain	23	-	-	7	16
9	Iran	22	-	-	6	16
10	Australia	21	-	1	4	16

Keyword analysis

A similar analysis has been conducted to identify the most frequently used words/phrases in the list of keywords in the selected papers. Table 5 presents the top 20 most popular keywords in the LSC field. The top keywords include a combination of lean, supply chain, operations strategies (agile, green and six sigma), performance, and research methodologies. Interestingly, "automotive industry" has frequently been used in the literature, which indicates the strong relationship between the sector and LSC. Sustainability also stands out in LSC, with three keywords in the list related to the subject.

Table 5. Top 20 most popular keywords in LSC

R	Keywords	Frequency	R	Keywords	Frequency
1	Supply chain management	90	**11**	Literature review	15
2	Lean manufacturing	87	**12**	Performance	15
3	Lean	74	**13**	Case study	14
4	Lean production	61	**14**	Value stream mapping	14
5	Supply chain	32	**15**	Lean six sigma	13
6	Sustainability	24	**16**	Six sigma	13
7	Agile	20	**17**	Environmental management	12
8	Green	18	**18**	Lean supply chain	11
9	Automotive industry	16	**19**	Lean thinking	11
10	Lean management	16	**20**	Manufacturing	11

Network analysis

A network analysis was subsequently performed based on citation and bibliographic coupling analyses. Various tools are available for this purpose, the most popular of which are Gephi, Pajek, and VOSviewer. VOSviewer was chosen for this study because of its viewing capabilities and flexible visualization, which provide graphical representations of the bibliometric networks in an easy-to-interpret way.

Citation analysis

Citation analysis has been carried out to examine the influence of the papers published on LSC. Table 6 shows the 10 most cited published papers on LSC in journals since 1996, based on the total number of citations. Total citation analysis provides the overall number of citations in our database, including citations from other disciplines and research areas.

Regarding total citations, the most cited paper in this field, with 869 citations to date, was published by Zhu and Sarkis (2004) in 2004. The same paper is also the most influential according to the *"citations per year"* measure, with almost 58 citations

annually. However, it should be noted that all of the top 10 frequently-cited papers were published over 8 years ago, so they have had ample time to accrue citations.

In addition, most of the papers in the table have been published in the top 10 journals contributing to LSC, which indicates that there is a strong correspondence between sources and production in the field. Interestingly, it must be pointed out that the most cited papers on LSC tend toward the study of some specific LSC practices, coinciding with the fields of interest identified in the analysis of the most popular keywords in Table 4.

Table 6. Top 10 most cited papers on LSC

R	TC[3]	Title	Author/s	Journal	Year	C/Y[4]
1	869	Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises	Zhu, QH; Sarkis, J	J. Oper. Manag.	2004	57.9
2	551	Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain	Naylor, JB; Naim, MM; Berry, D	Int. J. Prod. Econ.	1999	27.6
3	528	Learning to evolve - A review of contemporary lean thinking	Hines, P; Holweg, M; Rich, N	Int. J. Oper. Prod. Manage.	2004	35.2
4	332	Development and validation of a measurement instrument for studying supply chain management practices	Li, SH; Rao, SS; Ragu-Nathan, TS; Ragu-Nathan, B	J. Oper. Manag.	2005	23.7
5	269	Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach	Agarwal, A; Shankar, R; Tiwari, MK	Eur. J. Oper. Res.	2006	20.7
6	249	Lean or agile - A solution for supply chain management in the textiles and clothing industry?	Bruce, M; Daly, L; Towers, N	Int. J. Oper. Prod. Manage.	2004	16.6
7	246	The impact of supply chain complexity on manufacturing plant performance	Bozarth, CC; Warsing, DP; Flynn, BB; Flynn, EJ	J. Oper. Manag.	2009	24.6
8	220	Green, lean, and global supply chains	Mollenkopf, D; Stolze, H; Tate, WL; Ueltschy, M	Int. J. Phys. Distrib. Logist. Manag.	2010	24.4
9	201	Extending the horizons: Environmental excellence as key to improving operations	Corbett, CJ; Klassen, RD	M&SOM-Manuf. Serv. Oper. Manag.	2006	15.5
10	175	An institutional theory perspective of business continuity planning for purchasing and supply management	Zsidisin, GA; Melnyk, SA; Ragatz, GL	Int. J. Prod. Res	2005	12.5

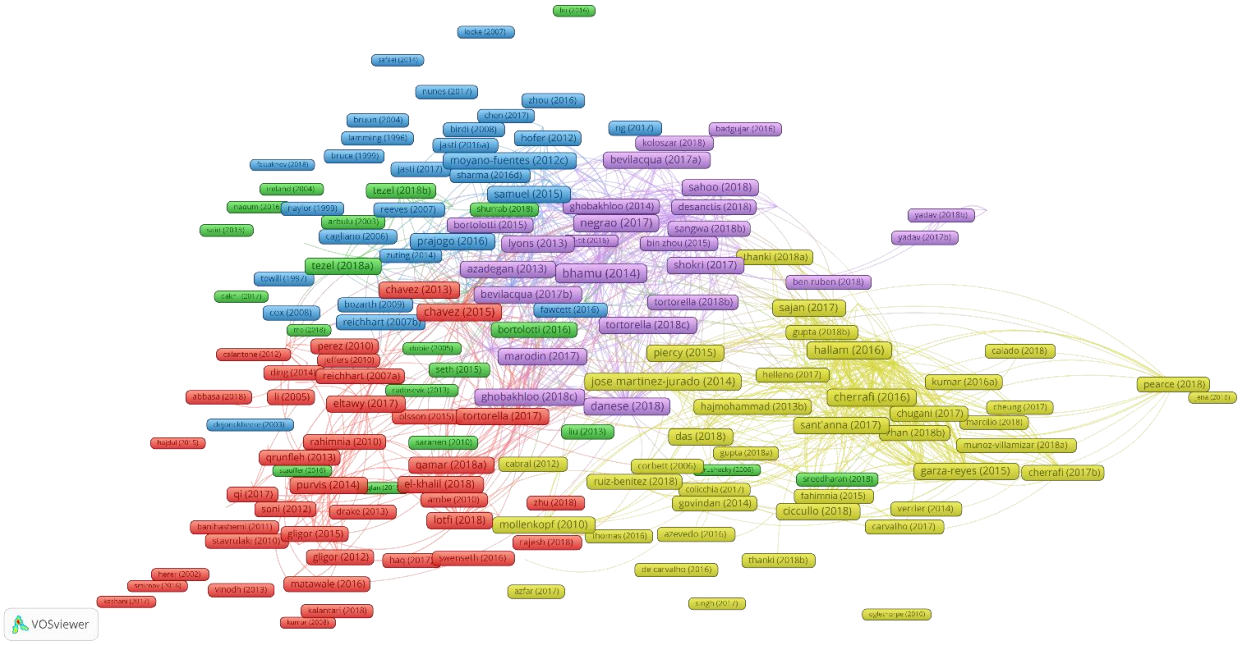
Bibliographic coupling analysis

Bibliographic coupling occurs when two documents have at least one reference in common (Kessler, 1963). In contrast, co-citation has been defined as the frequency with which two documents are cited together by others in the literature (Small, 1973). So, a co-citation is a similarity relationship between two cited publications, while bibliographic coupling is a measure of association between two citing publications. Bibliographic

[3] **TC**: Total citations
[4] **C/Y**: Citations per year

coupling is considered a suitable tool for detecting current trends and emerging research topics since it captures more recent contributions (Vogel and Güttel, 2013).

Bibliographic coupling has been used in this paper to identify current trends in the LSC field and provides further valuable information by conducting a content analysis. In the following, we outline the content of the publications that each cluster contains and the areas of research focus.


VOSviewer
moyano-fuentes (2012c)
bevilacqua (2017a)
sharma (2016d)
samuel (2015)
sahoo (2018)
ghobakhloo (2014)
desanctis (2018)
negrao (2017)
sangwa (2018b)
bortolotti (2015)
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sant'anna (2017)
das (2018)
rahimnia (2019)
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grunfleh (2013)
qamar (2018a)
cabral (2012)
garza-reyes (2015)
cherrafi (2017b)
purvis (2014)
el-khalil (2018)
ruiz-benitez (2018)
govindan (2014)
ciccullo (2018)
qi (2017)
zhu (2018)
soni (2012)
drake (2013)
lotfi (2018)
mollenkopf (2010)
carvalho (2017)
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thanki (2018b)
matawale (2016)
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azfar (2017)
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capiano (2006)
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li (2005)
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grunfleh (2013)
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slavrulakis (2010)
bani-hashemi (2021)
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de carvalho (2016)
thomas (2016)
azevedo (2016)
rajesh (2018)
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kumar (2018)
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Table 7. The five major research clusters and their areas of research focus

Cluster	Number of papers[5]	Research area
1 (Blue)	109	LSC basic concepts
2 (Purple)	73	LSC state-of-the-art
3 (Green)	109	LSC implementation
4 (Red)	115	LSC performance
5 (Yellow)	101	LSC and sustainability

The first group is formed of Clusters 1 and Cluster 2 and addresses the theoretical exploration process in the field. The lean management concept and its adoption through the supply chain are explored using the literature review as the approach *par excellence* that defines the basis of the research.

The second group is Cluster 3, which investigates the LSC implementation process. The authors have analyzed the complexity of the context, the existing barriers to LSC implementation, and some enablers that improve its impact on performance.

The third group is Cluster 4, which addresses LSC assessment. In this case, authors have focused on measuring operational performance. Some papers have studied the LSC strategy combined with an agile supply chain strategy with a focus on flexibility. The context has also been considered, e.g., emerging economies or uncertainty in the evaluation of LSC performance.

The last group, Cluster 5, focuses on green strategies. An increasing interest in sustainable issues can be identified, as a large number of papers have studied LSC from a sustainability approach.

Final considerations

In this paper, we have sought to use a bibliometric analysis to review the literature on LSC from 1996 to January 2019. All the papers published in impact journals from different countries and all the authors working in this field have been included, so the obtained results are as accurate and complete as possible. In addition, by analyzing 525 papers, this study has reviewed more papers on LSC than any previous work.

Our findings can help researchers to understand the evolution of research trends in the field. This bibliometric analysis provides comprehensive information on the LSC literature. The results show significant growth in the number of publications on LSC during the considered period, a trend that we can assume will continue in the future. This increasing interest in the LSC research field can be seen as a target to focus on in the future. This paper has also presented some well-regarded journals publishing articles on LSC and their influence in different research areas, as well as the most active institutions in the field. This information is helpful for researchers seeking to identify the best journal to address their papers to and the institution with which they should establish collaborative networks when publishing on LSC.

Our analysis enables some trends to be easily identified in the geographic distribution of LSC's influence and illustrates how different countries are conducting research in this field of knowledge. Furthermore, although English-speaking countries are the most productive, other countries are rapidly moving up the rankings, especially in Asia. This suggests that the study of LSC has not only begun but is spreading around the globe. Last but not least, content analysis has been conducted to identify current trends in the LSC field. This information is highly valuable since it enables future research directions to be

[5] Some of the 525 papers in our network were not interconnected. Therefore, only 507 papers have been included in the bibliographic coupling analysis, since it is the largest set of connected items.

established: the implementation of the lean supply chain strategy, evaluation of lean performance in the supply chain, and the combination of lean and other supply chain strategies to achieve a competitive advantage.

This study aims to present the information from different perspectives in order to reveal the volume of the research carried out into LSC and enable individual readers to understand data according to their priorities and preferences. Nevertheless, some limitations exist: the use of a single database has determined which papers were selected for our study, as have the subjectively-defined exclusion criteria. Expanding the search to more databases, such as Scopus or ABI, and establishing different inclusion and exclusion criteria could result in a more exhaustive review of the field. Researchers might then explore and extend the research area.

Despite the aforementioned limitations, we believe our study provides a path for future research and an incentive for scholars to further explore the lean supply chain field.

Acknowledgments

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Lean Management and efficiency: A study at the internal and supply chain levels

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Abstract

The purpose of this study is to investigate the impact of Lean Management on efficiency at the internal and supply chain levels. Three hypotheses have been formulated and tested in an empirical study of 285 companies in industrial sectors that occupy an intermediate position in the supply chain. The study revealed that there is an improvement in efficiency when Lean Management extends throughout the supply chain. In addition, Lean Management at the internal level was observed to impact positively on the firm's efficiency only when it contributes to enhancing the implementation of Lean Supply Chain Management.

Keywords: Lean Management, Supply Chain Management, Lean Supply Chain Management, Efficiency

Introduction

A number of researchers have detected a trend towards the adoption of Lean Management (LM) that not only affects companies internally but also the way that they are organised externally (Shah and Ward, 2007).

Using a chronological perspective and giving prominence to LM's impact on performance, this study first focuses on the internal level and then, with a broader-based focus, on the supply chain level. On the internal level, the contribution of LM implementation to improving operational performance is widely recognised (Shah and Ward, 2003; Marodin et al., 2019), although some authors find there to be no significant relationship between LM and performance (Browning and Heath, 2009; Zhu and Lin, 2018).

On the external level, one of the main challenges that companies face when they initiate their lean implementations is improving integration with their supply chain partners (Pérez et al., 2010); i.e., which LM practices can be applied right across the supply chain, from the placing of an order with suppliers to product distribution and delivery to the customer, so that all activities are optimised from the final customer's point-of-view. This is known as Lean Supply Chain Management (LSCM) (Swenseth and Olson, 2016).

Despite the crucial importance of jointly analysing and managing internal and external lean approaches, the literature has focused on analysing these independently and there are few articles examining their interrelationships (Moyano-Fuentes et al., 2012; Bortolotti et al., 2016; Marodin et al., 2017). Moreover, most analyses isolate lean supply chain components, instead of using a holistic approach to study LSCM.

The aim of this study is to investigate Lean Management's impact on efficiency at two levels of analysis: internal and supply chain. At the internal level, aspects of LM such as buffer minimisation, work systems and human resource practices lead to management practices that are more supportive of improvements in resource efficiency (Rothenberg et al., 2001). At the supply chain level, there are papers that analyse the impact of lean practices along the supply chain on operating results such as waiting time, inventory rotation and on-time delivery, and the influence on this relationship of factors such as the company's position in the supply chain and the time that LM has been implemented (Marodin et al., 2016; Marodin et al., 2019). However, none uses a holistic approach to investigate LSCM's impact on efficiency.

Hofer et al. (2012) and Qrunfleh and Tarafdar (2013) argue that Supply Chain Management (SCM) potentially mediates between LM and performance. Therefore, this paper examines LSCM's mediating effects in predicting the impact of LM's internal implementation on efficiency.

Following this introduction, the next section presents the theoretical framework. The methodology used is subsequently described. After a discussion of the findings the conclusions are set out.

Theoretical Framework

Empirical evidence supports a positive relationship between the implementation of internal lean practices and the implementation of external lean practices. For example, Furlan et al. (2011) suggest that lean internal human resource management practices may influence the successful implementation of LSCM practices, and Hofer et al. (2012) empirically support the tendency of firms with greater inventory leanness to implement external lean practices to a greater extent.

Prior research on the simultaneous study of the two complementary and synergistic lean approaches analyses internal LM influence on LSCM in the ways described below.

Internal lean implementation is considered to be a determinant driver or catalyst of LSCM (Bortolotti et al., 2016). Thus, individual supply chain members should first adopt and enhance the level of their internal LM implementation and then gradually deploy LSCM principles, practices and techniques (Lamming, 1996). Internal lean must therefore precede LSCM, since the lack of a high level of internal lean implementation is one of the reasons why LSCM initiatives derail (Furlan et al., 2011).

In addition, the reconfiguration of the supply chain structure in line with lean characteristics (e.g., supply base, supplier selection and evaluation, suppliers per item) and the establishment of a lean partnership model (e.g., long-term relationships based on mutual trust and commitment, frequent exchange of information, win-win relationship) with strategic supply chain partners (Lamming, 1996; Bortolotti et al., 2016) are essential

prerequisites for a lean company to effectively deploy LSCM principles, practices and techniques. In this regard, Bortolotti et al. (2016) found that the choice of LSCM practices and their aim and implementation mode are influenced not only by the state of the supply chain structure and its relationships but also by the level of supply chain members' lean internal implementations.

LSCM principles, practices and techniques deployed by supply chain agents (owners) depend on their own levels of internal lean implementation and on the levels of supply chain members' (recipients) (Bortolotti et al., 2016). If a supplier's and its customer's levels of internal lean implementation are high, advanced LSCM practices can be adopted to achieve streamlined and synchronised supply chain flows and, ultimately, to achieve greater integration of inter-organisational processes and lean systems (Cagliano et al., 2006).

However, the approach to LSCM implementation taken in the literature is observed to be lean practice and technique based alone, whereas an integrated or joint approach is needed for the implementation level of LSCM.

Combining all of this reasoning, the following hypothesis is formulated:

H1. A higher level of internal LM implementation leads to a higher level of LSCM.

LSCM aims to reduce costs and increase flexibility in the delivery of products through a process of continuous improvement that eliminates inefficiencies and activities that do not add value along the supply chain (Mollenkpof et al., 2010). Heikkilä (2002) points out that a good customer-supplier relationship contributes to reliable information flows, and reliable demand information flows, in turn, contribute to high efficiency. Simpson and Power (2005) and So and Sun (2010) find that supplier integration strategy has a positive influence on the long-term level of LM implementation for both suppliers and customers and improves global lean supply chain results. Prajogo and Olhager (2012) state that integrated logistics also allows firms to adopt LM, which leads to reliable order cycles, inventory reduction, and cost reduction, amongst other benefits.

Indeed, many authors (Marodin et al., 2016; Marodin et al., 2019) have analysed the impact of lean practices via the supply chain on a range of company operating results such as waiting time, inventory rotation and on-time delivery.

It must be taken into account that LSCM is not a set of isolated lean practices along the supply chain but a global strategy for the chain and that the extent to which this strategy is developed can greatly impact efficiency.

The following hypothesis is therefore put forward based on the above arguments:

H2: A higher level of LSCM leads to a higher level of efficiency.

Past research has found the potential existence of SCM-related mediating effects between internal lean implementation and performance (Hofer et al., 2012; Qrunfleh and Tarafdar, 2013) and LSCM may be the cause of these mediating effects. In this sense, as was stated above, the level of internal lean implementation drives the spread of LSCM principles and practices (Bortolotti et al., 2016). There is a temporal sequence in this process. Firstly, both the focal company and supply chain members should adopt and enhance their levels of internal lean implementation (Lamming, 1996; Towill, 1997; Bortolotti et al., 2016). Then, they should gradually but quickly deploy LSCM principles, practices and techniques along the supply chain (Swenseth and Olson, 2016). The success of managing a lean supply chain strategy depends on accumulated valuable knowledge, competencies and cultural change linked to internal LM implementation (Furlan et al., 2011). In this context, the indirect impact of internal lean implementation on performance would be expected to be greater via LSCM than its direct impact.

It would be advisable to investigate how efficiency would be affected when LM is simultaneously implemented at the internal and supply chain levels. Internal level implementation would be expected to be eclipsed by the greater impact of LSCM on efficiency indicators.

On the one hand, at the LSCM operational level (Moyano-Fuentes et al., 2018), the joint use of lean techniques and practices to eliminate waste and the reduction of sources of variability in the supply chain have a major added impact on these efficiency indicators (Danese et al., 2012). The unit cost of manufacturing decreases drastically when Value Stream Mapping (VSM) is used in lean supply chain environments (Wee and Wu, 2009; Oberhausen and Plapper, 2017). Likewise, the use of Kanban cards and pull flow systems in a JIT supply chain reduces manufacturing costs (Rossini and Portioli-Staudacher, 2016). Also, generally-speaking, integrated inventory management reduces inventory-related costs (Hooshang, 2010) and, in particular, the cost of preparing JIT purchase orders (Parveen and Rao, 2009; Hooshang, 2010), JIT distribution transport and delivery costs (Wang et al., 2004), and JIT delivery transport costs (Chen and Sarker, 2010), and achieves higher stock turnover while minimising inventory (Pagani et al., 2016; Rossini and Portioli-Staudacher, 2016). In addition, the joint use of lean techniques along the supply chain and the reduction of variability can increase efficiency by minimising cycle time (Apte and Goh, 2004).

In addition, efficiency improvements at the LSCM planning level (Moyano- Fuentes et al., 2018) would come from long-term customer demand forecasting and focusing exclusively on current market segments, resulting in a lower per-unit manufacturing cost, high stock turnover (Qrunfleh and Tarafdar, 2013) and the minimisation of cycle time (Apte and Goh, 2004). Also, using queues and buffers to protect sub-processes along the supply chain improves efficiency by reducing the variability associated with inventory.

Thus, integrating these two levels of LSCM (operationalisation and planning) (Moyano-Fuentes et al., 2018) would have a multiplier effect on efficiency greater than the impact that internal lean implementation has on efficiency on its own. LSCM implementation implies that chain members have internally implemented LM (Bortolotti et al., 2016; Swenseth and Olson, 2016). However, it is only when LM is implemented on both levels (internal and external) that LSCM gains prominence for efficiency. In this case, the cumulative effect of each supply chain member's contribution to efficiency and the synergistic effects of the joint use of multiple lean techniques and practices would eclipse the direct effect on efficiency of using lean internally in a company (Hofer et al., 2012). Therefore, LSCM may play a mediating role in the relationship that links internal lean implementation and efficiency.

Taking all these arguments together, the following hypothesis can now be proposed:

H3: LSCM implementation has a mediating effect between internal LM implementation and efficiency.

Methodology

Population, questionnaire and data gathering

The hypotheses have been tested using data gathered via a questionnaire with items drawn from the literature.

Before it was sent out, a draft version of the questionnaire was tested with a panel of five internationally-recognised SCM researchers and a pilot study was conducted with five heads of SCM to guarantee content validity. The questionnaire was directed at the head of SCM, logistics or operations management.

A population of 2,763 Spanish manufacturing companies from sectors occupying an intermediate position in their supply chain was taken from the SABI (Iberian Balance Sheet Analysis System) website.

The data gathering method consisted of a telephone survey using a computer-assisted telephone interviewing (CATI) system.

Fieldwork commenced on 30 January 2018 and ended on 20 July 2018. During the fieldwork period, 113 firms were determined not to form part of the population. The final population was therefore formed of 2,650 companies, with 285 of these responding (10.8% response rate). As several recent studies on SCM have had a similar or even smaller sample size (Qrunfleh and Tarafdar, 2013; Rojo et al., 2016), that used in this study is thus appropriate and does not jeopardise the reliability of the results.

A similar sector distribution of companies can also be observed. More precisely, the food, chemical and pharmaceutical, metal products, machinery and equipment and motor vehicles sectors are shown to jointly represent 71.6% of the companies in the sample and 69.2% of the companies in the population.

No evidence of response bias was found in a comparison of respondents with non-respondents. Thus, no significant differences were found between the population and the sample for distribution by annual sales, number of employees and gross operating profit (for 2015 and 2016).

Finally, the first forty responses and the last forty responses were compared and no significant differences ($\alpha = 0.05$) were found for any of the variables included in the questionnaire.

Variables

Internal Lean Implementation. The questionnaire included a question concerning the firm's overall level of lean implementation compared to its competitors, scored on a scale of 1-5 (1 = poor, low; 5 = much higher than average) (Bortolotti et al, 2015). This variable was scored as "0" when the firm had not implemented LM.

Lean Supply Chain Management. This is a reflective construct composed of 8 items that relies on multiple-item scales derived from a construct structure proposed and validated by Moyano-Fuentes et al. (2018). LSCM is measured according to three dimensions. The first two are related to lean supply chain operationalisation. Specifically, the first is related to techniques for eliminating waste in the supply chain and the second to the reduction of sources of variability in the supply chain. Finally, the third dimension is related to lean supply chain planning (Moyano-Fuentes et al., 2018). The informants were asked about the degree to which they agreed with a series of LSCM-related statements on a scale of 1-5 (1 = totally disagree; 3 = neither agree nor disagree; 5 = totally agree).

Efficiency. This is a measure related to operational performance and includes three items that measure the unit cost of manufacturing, inventory turnover and cycle time (from raw materials to delivery) (Danese et al., 2012). Following several authors, it was decided to focus on perceptual and relative measures of performance by asking respondents to compare their firms' efficiency with their competitors' on a five-point Likert scale (1 = poor, low; 5 = much better than average) (Liu et al., 2009; Danese et al., 2012).

Analysis and results

Measurement Model

Content validity was ensured by the pretesting of the questionnaire. Scale unidimensionality was assessed by exploratory factor analysis. This gave eigenvalues

higher than one, standardised factor loads greater than 0.5 and significant explained variance for each extracted factor, and high values for chi-squared/degrees of freedom in Barlett's sphericity test ($p < 0.05$). One second-order factor was used to measure LSCM. Results for the exploratory factor analysis and a description of observable variables are given in Table 1. Items with an asterisk (*) were dropped after exploratory factor analysis and reliability analysis. Reliability was tested using Cronbach's alpha with scores of 0.7 or higher considered acceptable and 0.6 adequate, since a high coefficient alpha does not always mean a high degree of internal consistency, as alpha is also affected by the length of the test or number of items per construct (Nunnally, 1978; Merschmann and Thonemann, 2011).

Table 1. Exploratory factor analysis

Factor	Variable	Standardised factor loading	Cronbach's α	Bartlett test	% Explained variance
Lean Supply Chain Operationalisation 1	Value stream mapping is used to identify and eliminate waste throughout our supply chain (LCS_1)	0.886	0.69	χ^2= 270.415	72.466
	Our supply chain uses lean manufacturing techniques (such as pull flow, Kanban systems, and setup time reduction) (LCS_2)	0.839		df= 15	
Lean Supply Chain Operationalisation 2	Our supply chain generates high stock turnover and minimises inventory (LCS_3)	0.821		Sig.= 0.000	
	Process and product standardisation is a common practice in our supply chain (LCS_4)	0.768			
	Our supply chain delivers in small lot sizes* (LCS_5)				
Lean Supply Chain Planning	Our supply chain does long-term forecasting of customer demands and only focuses on current market segments (LCS_6)	0.684			
	The strategy for handling uncertainty in our supply chain consists of using queues and buffers to protect sub-processes (LCS_7)	0.881			
	Our supply chain structure seldom changes* (LCS_8)				
Efficiency	Unit cost of manufacturing (EFF1)	0.690	0.63	χ^2= 102.183	57.205
	Inventory turnover (EFF2)	0.817		df= 3	
	Cycle time (from raw materials to delivery) (EFF3)	0.757		Sig.= 0.000	

Divergent validity was confirmed by two tests. Firstly, the Cronbach's alpha coefficients for the scales were greater than their correlations with other scales. Secondly, the average item-to-total correlations with items not in the scales were substantially lower than the average item-to-total correlations with items in the respective scales.
Finally, confirmatory factor analysis (CFA) was performed using EQS 6.1 software. The final fit of the CFA was highly satisfactory.

Structural equation model and mediating effects

A Structural Equation Model (SEM) was developed to test the hypotheses (Figure 1). EQS 6.1 software and the Robust Maximum Likelihood Method were used in CBSEM analysis. The baseline model in Figure 1 was run first. This included the effects of lean's internal implementation on LSCM and the relationship between LSCM and efficiency. This model yielded an overall good fit (Satorra-Bentler's scaled χ^2 = 51.94; df = 26; χ^2/df = 1.997; RMSEA: 0.060; CFI: 0.946; IFI: 0.948; MFI: 0.954). The relationships in H1 and H2 ($p < 0.05$) were shown to be significant.

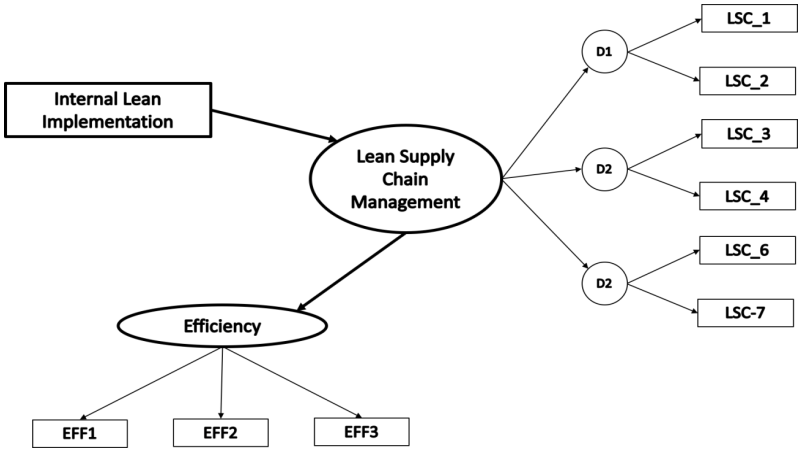
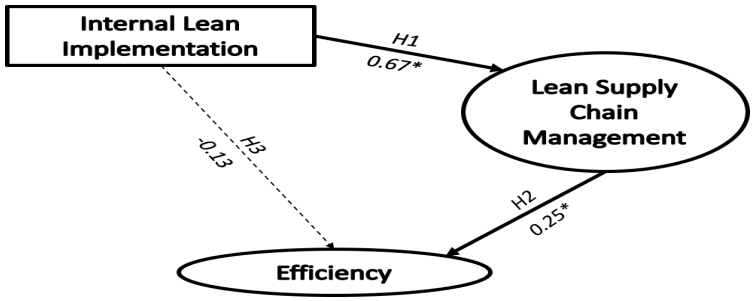


Figure 1. Baseline and measurement model

The baseline model was modified to measure the mediating effect considered in H3 with the addition of a direct path from internal lean implementation to efficiency (Model 1, Figure 2). The results of CBSEM analysis showed that Model 1 did not provide an adequate fit with the data (Satorra-Bentler's scaled χ^2 = 83.41; df = 29; χ^2/df = 2.876; RMSEA: 0.083; CFI: 0.886; IFI: 0.890; MFI: 0.905). The significant path coefficients again remained the same as in the baseline model with no significant coefficient for the new path between internal lean implementation and efficiency (see Figure 2). The χ^2 difference test was not significant for Model 1 versus the baseline model ($\Delta\boldsymbol{\chi^2}$ (3df) = 31.47, $p > 0.05$), indicating that the baseline model would be a better explanation of the data than Model 1.

In Model 1, the fit did not improve when the direct (non-mediating) effect was included. H3 is supported due to a significant effect in the baseline model and a lack of improvement in fit in Model 1, which considers the direct relationship between internal lean implementation and efficiency.



Note: *$p < 0.05$

Model	χ^2	df	$S-B\,\chi^2/df$	RMSEA	CFI	IFI	MFI	RHO	$\Delta\chi^2$
Baseline	51.94	26	1.997	0.060	0.946	0.948	0.954	0.756	n/a
Model 1	83.41	29	2.876	0.083	0.886	0.890	0.905	0.761	31.47

Figure 2. Structural baseline equation model and model to highlight mediating effects

Conclusions

This study has analysed the mutual influence between internal lean implementation and LSCM and demonstrates that there are differences in the importance of both for and in the contributions that they make to efficiency improvement. Thus, company efficiency is observed to improve when LM extends throughout the supply chain. This result is in line

with Azadegan et al. (2013) and indicates that firms must work with supply chain partners to reduce or minimise waste and achieve better performance.

Our findings are aligned with previous empirical evidence that states that LM on the internal level does not significantly impact on performance (Browing and Heath, 2009; Zhu and Lin, 2018). In other words, internal lean implementation alone is not enough to achieve the breakthrough improvements that lean offers, for which lean principles must be extended across the supply chain. However, our results indicate that internal lean implementation is a driver of LSCM, as has previously been found in the literature (Bortolotti et al., 2016).

Our results confirm the idea found in previous works (Hofer et al., 2012; Qrunfleh and Tarafdar, 2013) that SCM potentially mediates between LM and performance. In this sense, LSCM is confirmed to have a mediating effect in the impact of internal lean implementation on efficiency. This finding shows that LM strategy must be implemented sequentially if a firm wants to achieve the expected results that derive from its implementation.

Therefore, the results of this study indicate that a wider level is needed to investigate the impact of LM on performance and to provide a sustainable competitive advantage. Lean implementation needs to be a goal shared by all supply chain members for supply chain effectiveness to be improved through better efficiency outcomes.

In other respects, unlike previous studies that use partial approaches focused on lean practices applied along the supply chain (Berger et al., 2018; Tortorella et al., 2017; Tortorella et al., 2018), this study uses a holistic focus on LSCM. Thus, a validated measurement instrument is applied to LSCM for the first time (Moyano-Fuentes et al., 2018). This instrument is composed of three different dimensions related to the operational aspects of lean supply strategy implementation and to lean supply chain planning. This should push the boundaries of LSCM research and its relationship with outcomes such as efficiency.

From a practical perspective, these findings can help make managers aware of the major role played by LSCM implementation and prioritise their efforts to minimise the use of resources and improve efficiency by adopting a holistic approach to their lean implementations. To achieve the best operational performance derived from LM, managers should pay attention to the transfer of knowledge, competencies and cultural change linked with the level of internal lean implementation to their supply chain members.

In more general terms, this study provides a tool for managers to assess the operational aspects of lean supply strategy implementation and the aspects related to lean supply chain planning and, eventually, to identify some weaknesses that enable them to enhance their LSCM implementations.

Regarding the limitations of this study and further research lines, this work evaluates LSCM implementation from the perspective of the focal company, which may distort the analysis. So, further research on LSCM should consider the vision of the level of LSCM implementation from the perspective of a range of upstream and downstream members of the same supply chain.

Past empirical evidence points to the absence of an appropriate organisational culture or lack of trust among supply chain agents being vital factors for sustaining LSCM (Jadhav et al., 2014). So, examining the association between these factors and lean implementation at the internal and supply chain levels and their impact on efficiency is an additional opportunity with both theoretical and practical implications.

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Lean Journey of Healthcare Institutions: A Literature Review

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Abstract

We conduct a comprehensive review of lean journey in healthcare institutions to synthesize its key aspects along the three major stages of lean journey. Following a systematic delimiting criteria, research articles published in journals until December 2018 were considered. This study documents how performance measures improved due to rollout of lean and how healthcare institutions have adopted assessment procedures to reflect the entire lean journey. The current study is believed to be the first one to document the motives, practices implemented and performance measures evaluated while implementing lean in the healthcare context in a single paper.

Keywords: Lean Journey, Healthcare, Literature Review

Introduction

Healthcare institutions, in today's generation, need to strike a balance between two key objectives, namely efficiency and effectiveness (i.e. ensuring cost effective health care services to patients without compromising high quality care) (Dyrbye et al., 2017). These seemingly mutually opposite but essential objectives have pushed hospitals to reduce inefficiencies in its care delivery processes such that the cost of care comes down without compromising the quality of care (Trzeciak et al., 2018). Health care professionals have therefore attempted to address flow and waste issues by adopting process improvement strategies such as lean while focusing on variation and design to promote business and operational excellence (Wani et al., 2018). This explains the maturity of lean based process improvement literature in the context of healthcare institutions (Sunder et al., 2018).

Lean has been found instrumental in eliminating wastes throughout the healthcare institution especially in preventing medical errors (Jimmerson et al., 2005), decreasing mortality rates (Dimick et al., 2004), reducing patient's length of stay (McDermott and Stock, 2007), reducing patient's waiting time (Aherne, 2007), minimizing patient's movement (Kelly et al., 2007), and improving patient care (LaGanga, 2011). Therefore, lean has proven to deliver positive results by reducing non-value added processes (waste) and assisted healthcare institutions in improving process efficiency, thereby leading to affordable quality care coupled with patient satisfaction (Narayanamurthy and Anand, 2018). NHS Institute for Improvement and Innovation has identified important inefficiencies or wastes in the hospital sector (NHSIII, 2007).

Although conceptually simple, 'Lean' as a concept is not easy to define. The fundamental philosophy is to continuously improve processes within a system by removing non value added steps, which are commonly known as 'waste' (Poksinska, 2010). Womack & Jones (1996) defined lean through the adoption of "five principles". The basic assumption for adoption of these principles were that organizations are made of processes and adopting the principles in such processes would add value, reduce waste and thereby increase efficiency in the process (Radnor et al., 2012). Pettersen (2009), on the other hand, outlined key collective terms through which one may define lean and pointed individual characteristics of each collective terms (Burgess and Radnor, 2013).

The lean literature in health care is quite rich and diverse in terms of its objective behind the choice of lean journey. Deblois and Lepanto (2016) reviewed literature reviews concerning the application of lean in acute care setting. Holden (2011) illustrates the application of lean implementation in emergency departments in United States. Carter et al., (2012) described the application of lean in a teaching hospital in Ghana where health related resources are low. van Rossum et al., (2016) conducted a cross sectional survey in an operation theatre at a Dutch University medical centre to highlight the influence of leadership and workforce flexibility on change management perspective of lean. However, all studies in this literature can be plotted onto one or multiple of the three stages in lean journey spectrum – readiness (pre-implementation), rollout (implementation), and reflection (post-implementation) (Narayanamurthy and Gurumurthy, 2016). Studies discussing motives, barriers, and drivers for rolling out lean are contributing to readiness stage. Following it, a stream of lean rollout studies have discussed the lean practices implemented by healthcare institutions for the attainment of profit maximization (LaGanga, 2011) or process improvement (Aronsson et al., 2011) . Diverse studies have also discussed the different types of wastes targeted during lean rollout in healthcare institutions. For example, Papadopoulos et al. (2011) discussed about the issue of rework in hospital administration in the form of inefficiencies in collecting and diagnosing medical specimens in the hospital. Castle and Harvey (2009), on the other hand, identified all major wastes in a hospital, which includes over-processing due to inaccurate information flow, underutilization of human resources etc. Finally, post-implementation studies have focused on the reflection of lean rollout by conducting assessment through the comparison of performance measures before and after (Matthias and Brown, 2016) or through a mathematical technique (Dogan and Unutulmaz, 2016). Improvements attained through lean rollout are quantified in this stage by the healthcare institution travelling the lean journey. Therefore, clustering the discussion on lean journey in healthcare institutions literature into these three stages will help in synthesizing the various crucial aspects from motive to preparation,

implementation, and assessment of lean. Anchoring to this motivation, we conduct a comprehensive review of lean journey in healthcare institutions literature to understand and synthesize its key aspects along the three major stages of lean journey. We purposefully chose those articles which have used case study as a primary methodology in explaining lean implementation in health care. Analyzing case studies provides an option to understand how lean principles and techniques can be applied. In addition, it gives us additional information regarding different structural attributes such as role of top management, motive of lean and different types of waste eliminated etc.

In this study, we attempt to answer the following research questions:

Stage 1: *Readiness stage*

RQ 1.1 - Why do healthcare institutions adopt lean (motivation)?

RQ 1.2 - What are the barriers for adopting lean?

RQ 1.3 – How should different stakeholders be prepared for lean journey?

Stage 2: *Rollout stage*

RQ 2.1 – What are the different types of wastes targeted by healthcare institutions through lean rollout?

RQ 2.2 - What are the different types of lean practices implemented by the healthcare institutions to eliminate the wastes identified?

Stage 3: *Reflection stage*

RQ 3.1 – What are the performance measures used by healthcare institutions to assess the impact of lean rollout?

RQ 3.2 – How have the performance measures improved due to the rollout of lean?

RQ 3.3 – What are the different types of assessment procedures adopted by healthcare institutions?

The remainder of the paper is structured as follows. Section 2 reviews the literature review studies published so far on the topic “lean in healthcare”. Section 3 explains the methodology adopted for the literature review and the structural attributes selected for the review. Section 4 details the results and inferences gathered from the review analysis and answer the above-listed research questions. Section 5 concludes by proposing future research directions as well as a framework for health care practitioners as a guideline for lean journey in healthcare institutions.

Review of Literature Reviews

Kollberg et al. (2006) was one of the first few studies in lean healthcare context where the authors first introduced a performance measurement system in the domain of lean health care. Subsequently, the review focus primarily concentrated on four disparate areas, namely, patient care delivery (Butler, 2016), overall lean implementation in hospitals and/or health care domain (D’Andreamatteo et al., 2015), role of leadership and organization in lean healthcare context (Lawal et al., 2014) and tools currently applied in the overall lean journey (Curatolo et al., 2014).

We argue that our paper contributes to the existing research gap in many ways. First, we observe that no study, to the best of our knowledge, has focused on lean journey at a case study level in healthcare institutions from the perspective of past literature reviews. Second, we notice that almost all the published literature reviews have not followed a structured methodology. For instance, most of the studies have failed to mention either the time period of their study, criteria used for short listing papers, or number of papers finally shortlisted for review (Kollberg et al., 2006). Third, most of the studies have either revisited lean implementation in healthcare context with a perspective focus, giving less importance to the overall lean journey (Poksinka, 2010; Moraros et al., 2016; Aij and Rapsaniotis, 2017) or have focused the review from the clinical side of patient care (Butler, 2016). Fourth, many of the review papers are published in healthcare journals and not in the mainstream operations management journals, which conveys that a detailed focus to operational aspects of lean implementation in healthcare (e.g. practices, performance measures, etc.) have not been given (Trzeciak et al., 2018). Fifth, majority of the review articles have superficially explained how lean has helped in manufacturing and argued how the same logic can be relevant for healthcare (Zattar et al., 2017).

By anchoring to the above-listed gaps, we believe our paper would contribute meaningfully to the lean literature in health care by integrating and focusing on different stages of lean journey (i.e. starting from readiness stage to rollout stage, and finally to the reflection stage). Understanding how healthcare institutions progress in their lean journey by looking back at the literature is very helpful in identifying the common drivers, barriers, practices, performance measures, etc. Analyzing case study literature provides an additional advantage of documenting different structural attributes implemented in single or multiple healthcare institutions. It also helps in projecting a pattern based on the past experience documented in literature.

Methodology

Lean and health care are individually mature topics in OM literature and its knowledge base has developed and expanded for the last few decades. There is a corresponding growth in the size of the academic literature at the intersection of lean and healthcare. Because the knowledge base is large and diversified to clinical health, quality, operations, process improvement, and policy literature, an integrative literature review methodology will be prudent to capture the dynamics of the knowledge creation on the topic (Torraco, 2005). We achieve this by analysing and reviewing the literature followed by a systematic synthesis of the current state of knowledge through re-conceptualization of the literature (Torraco, 2016). In addition to the plethora of integrative literature reviews in human resource management literature, there has been a recent trend to do integrative literature review in both health care (Nibbelink and Brewer, 2018; Christmals and Gross, 2017; Jinks et al., 2011; Swider, 2002) and operations management (Gligor, 2014; Ringsberg, 2014; Bask et al., 2010; Mollenkopf et al., 2010; Young Kim et al., 2010). Following Gligor (2014), we present five distinct stages in an integrative literature review process. While research questions were formulated (Stage 1) in section 1, Stage 4 and Stage 5 will be explained in the subsequent sections. In this section, we explain the literature search and material selection (Stage 2) followed by the selection of structural attributes for evaluation of the literature (Stage 3).

Literature Search

To collect relevant literature for our review, we followed a systematic approach using different delimiting criteria anchored to the research questions. Research articles published in journals until December 2017 were gathered from search engines and databases, which include EBSCO, ScienceDirect, Springer, Taylor & Francis, Wiley and Google Scholar. We used different combination of keywords from lean (set 1 = {lean thinking, just in time, Toyota production system}) and healthcare (set 2 = {Healthcare, Hospital, Clinic, Medicine, pharmacy}) in our searches. The initial search yielded 3160 articles related to lean and healthcare. However, several of the articles did not pertain to the broad theme of lean journey of healthcare institutions (i.e. adopting case study methodology). For example, the search included articles discussing conceptually or by taking anecdotal evidences about why and how lean is applicable in healthcare (Keating and Heck, 2018; Barnabè et al., 2018; Waring and Bishop, 2010). Therefore, we restricted our search to articles that are capturing the actual experience of lean journey in healthcare institutions by adopting case study methodology. To achieve it, we added the keyword "case study" to all our searches. To ensure that all the relevant and impactful articles are included, we also adopted a systematic snowballing technique. We investigated the references and citations of all shortlisted articles to ensure that the relevant articles were included. After including all the relevant papers that satisfied the delimiting and inclusion criteria, we reviewed 227 abstracts to shortlist our final list of articles.

Structural Attributes Identification

We carefully identified the structural attributes for our paper. The first round of structural attributes was performed by the first author and third author. It was then cross-validated by the second and fourth author of the paper. Each structural attributes can be explained further by sub-attributes or choices of those attributes. For instance, research paradigm has two choices, qualitative or quantitative approach. On similar lines, lean motive has two choices, profit motive and process motive On the other hand, there are many attributes comprising of different sub-attributes. For example, assessed lean effectiveness can be further classified into nature of assessment (comparison of measures or mathematical technique) and the actual mathematical technique used for lean assessment. We present a detailed categorical analysis of such attributes in subsequent sections. However, we conducted a thorough classification of the attributes to answer our research questions. For instance, to answer RQ1, we need to understand the motivation of lean adoption in healthcare institutions, its barriers and the role of stakeholders for the lean journey. We therefore, chose lean motive and initiator and practice reports as broad attributes to answer the questions. Further, we segregated lean motive and initiator into two sub-attributes, lean motive and lean initiator which aid in answering the first and third part of RQ1. The practice report attribute was further segregated into two sub-attributes, performance improvement report and practice improvement report. The practice improvement report was used to answer the second part of RQ2 whereas the performance improvement report was used to answer second part of RQ3.

Analysis and Results

The section is divided into three parts. The first part presents the descriptive statistics of the papers gathered through the material collection step discussed in the previous section. After understanding the basic overview and trend of the papers through descriptive analysis, we performed categorical analysis with respect to the structural

attributes. Based on the results from the analysis, we answered the research questions of each stage (i.e. readiness stage, rollout stage and reflection stage).

Descriptive Analysis

The descriptive analysis presents an overview of the selected literature with the objective of providing relevant trends and discussions concerning journals, articles, citations, and authors. The papers were not concentrated in few journals but were spread across diverse set of journals. This also warrants the need for reviewing this topic to connect the bits and pieces for gaining a holistic understanding on the current status. This exercise will provide meaningful directions for future research focus by helping to avoid the redoing of same research. Our analysis brings us to our attention that *International journal of health care quality assurance, Journal of health organization and management, Leadership in Health Services, Health Affairs and Joint Commission Journal on Quality and Patient Safety* are the top journals where 5 or more articles have been published. It is interesting to note that all these journals primarily belong to the health care domain. However, there is no trend in terms of distribution of articles in such journals. For example, on one hand articles published in Leadership in Health Services are distributed somewhat evenly from 2007 to 2016, on the other hand, all six articles got published in Journal of health organization and management in 2014 (Drotz and Poksinska, 2014; Hayes et al., 2014; Mazzocato et al., 2014; Morrow et al., 2014; Timmons et al., 2014; Ulhassan et al., 2014). As a result, it is difficult to ascertain the trend of articles in the mentioned journals. Surprisingly, there has been a dearth of attention of lean health care papers in operations journals (Tay et al., 2017; Matthias & Brown, 2016; da Silva et al., 2015; Aronsson et al., 2011; Papadopoulos et al., 2011; LaGanga, 2011; Setijono et al., 2010; Castle and Harvey, 2009; Shah et al., 2008) (Refer Figure 4). Research as expected is being published in two different category of outlets – one related to operational excellence and process improvement and another related to healthcare management.

Six journals, namely *Emergency Medicine Australasia, International Journal of Service Industry Management, Journal of Hospital Medicine, Public Money and Management, Social science & medicine and The Journal of emergency medicine*, have citation count per article higher than 100 (Radnor et al., 2012; de Souza and Pidd, 2011; Waring and Bishop, 2010; Dickson et al., 2009; Esain et al., 2008; Radnor and Walley, 2008; King et al., 2006, Kim et al., 2006; Bowen and Youngdahl, 1998). From citation analysis, we observe that influential articles have been published in journals belonging to diverse disciplines such as medicine, policy, service, and management. It is surprising to observe that no influential article has appeared on lean in HC in OM journals. But seeing the results makes it somewhat intuitive because most of the implementers in hospital have medical background than managerial background. This might have made articles in medicine journals more popular.

Categorical Analysis

In terms of clinical focus, 83% of the selected literature focuses on multi speciality clinics. Among all, 39% of the hospitals are public and 15% are private. The rest of the literature did not mention the ownership of the hospital. Most of the studies (80%) have adopted a qualitative research paradigm focusing on the importance of evidence driven lean implementation in hospitals (Shojania and Grimshaw, 2005). The exact methodology adopted includes Interviews, Participant Observation, Primary Survey, Secondary Databases and different combinations of such mentioned methods thereby,

highlighting the importance of mixed methods in management research (Johnson and Onwuegbuzie, 2004). We also analyzed how quantitative and qualitative studies were performed over the years in private and public hospitals. Approximately 42% of the qualitative studies were conducted in public hospitals and only 14.5% of the same was conducted in private hospitals. The balance work on qualitative domain did not specify the type of hospitals in which the study was conducted. In the case of quantitative studies, 50% of the papers did not mention the type of hospital ownership and the balance 50% was equally distributed between private and public hospitals. With regard to the clinical focus, approximately 39% of the studies in the multi-speciality hospitals are public hospitals whereas, as observed before, 46% of the studies in the multi-speciality hospitals did not specify the type of hospital ownership. Out of 115 studies in multi-speciality hospitals, 86 papers have adopted case study methodology and 13 papers have adopted ethnography as their research methodology highlighting the role of pure qualitative tradition in the lean health care sector. Most of such studies have occurred from 2007 to 2014. The focus has been the same in the case of single speciality too where other than case study methodology, the next dominant research tradition is mixed methods. Surprisingly, there are very few studies on pre-implementation and post-implementation phase of lean. Most of the studies have adopted case based methodology. However the trend shows the emergence of mixed method in lean implementation studies in the last decade. 92% of the studies did not perform benchmarking. 96% of the studies focused on lean implementation with negligible importance to pre and post implementation scenarios. The studies mainly focus on operational aspect of lean implementation (61%) whereas only a small fraction of study (25%) focused on the strategic aspect of lean implementation. 56% of the articles analyzed lean implementation in hospitals from within whereas 28% of the articles had a macroscopic viewpoint while implementing lean in hospitals. This included analyzing the entire supply chain operations of the hospital rather than focusing on the internal processes. In terms of leanness index, there was no article except one that created a quantifiable metrics to assess lean (Pearsoon et al., 2006).

Lean Journey Analysis

A close scrutiny of the barriers suggests that employees are still not convinced regarding the potential benefits of lean implementation. Further, apprehensions such as job cuts can seriously derail the adoption of lean. It is the responsibility of the top management leadership to see through that such apprehensions do not occur. Further, if the top leadership is committed towards lean adoption, it is their responsibility to ensure proper financial incentives are in place especially if the work load of employees exceed beyond a certain limit over certain duration of time. One cannot expect employees to be highly motivated without financial leverage. Second, the leadership needs to create an efficient system where staffs and employees do not feel the pressure of constant changes in day to day processes. Further, intra-departmental cooperation is utmost necessary which can be only brought about from a top down approach. Third, doctors need to be instructed that hierarchical inhibitions can seriously impede lean adoption. Similar results are obtained from wastes (48 identified and analyzed), practice reports (35 unique practices analyzed for waste reduction) and performance improvements (50 unique indicators analyzed from manual content analysis). Further, we proposed a conceptual framework highlighting the do’s and don’ts of lean journey starting from the readiness stage, followed by the rollout stage and finally to the reflection stage.

Conclusion and Discussion

This study successfully integrated the entire lean journey by addressing important facets of each stage of the journey. Specifically, this study offers interesting insights on the differnet types of wastes targeted by healthcare institutions and how lean practices have successfully eliminated those wastes. In addition to acknowledging how different stakeholders should be prepared for lean journey, this study documents how performance measures improved due to rollout of lean and how healthcare institutions have adopted assessment procedures to reflect the entire lean journey. Even though the practices implemented were based on the principles of LT, they were adapted to the healthcare setting based on the problem faced and process studied. Performance measures used were observed to be completely contextual and most of them were unique to the problem addressed.

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The Evolution of Lean: A Bibliometric Network Analysis

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Abstract

The purpose of this study is the identification of the most influential contributors in the field of lean management research and the analysis of the changes that have occurred in the intellectual structure of the discipline over the last three decades. We employ a citation and co-citation analysis on a dataset of 8,081 lean contributions comprising 192,512 citations that we exported from the Scopus database. Our findings show the emergence of many knowledge groups within the recent years. We further identify a few central contributors with influence on the overall field or only within their specific knowledge groups.

Keywords: Bibliometric analysis, literature review, lean management

Introduction

Three decades after the term 'lean' was introduced by Krafcik (1988) and promoted by Womack et al. (1990), there seems to be no limit to the continued popularity of *Lean Management*. Today, we have a rich and ever expanding body of knowledge on "one of the most influential manufacturing paradigms of recent times" (Holweg, 2007). Research on lean management (LM) has evolved through different stages (Hines et al., 2004; Bhamu and Singh Sangwan, 2014; Netland and Powell, 2016), whereby different research streams have emerged, sustained, or died.

In its early phases, research on LM started to raise awareness by disseminating best practices and first benchmarking reports. Later, the approach started to spread out to other parts of the value chain (e.g., supply chain management, product development) (Hines et al., 2004). At the same time, other industries than only automotive manufacturing (e.g. service industry) started to adopt the approach as well (Stone, 2012).

Due to the widespread interest in LM from both, academia and practice, a new sub discipline within OM research has emerged. To trace its history, first literature reviews appeared already shortly after the term was coined. However, these articles mainly focused on single elements of LM, for example, on Just-in-Time (JIT) (Sohal et al., 1989; Golhar and Stamm, 1991), or Kanban systems (Berkley, 1992) with small sample sizes. Only by the turn of the millennium, the first reviews conceiving LM as a whole started to be carried out. Landsbergis et al. (1996), for example, reviewed the impact of lean production systems on various industries. Later on, researchers have started to also review

the body of knowledge about LM. Hines et al. (2004) reviewed the evolution of lean thinking and identified key criticisms related to it. Papadopoulou and Özbayrak (2005) as well as Holweg (2007) reviewed various LM definitions, summarized its main elements and also criticism on it. Especially in the last decade, the research community around LM experienced a wave of many more literature reviews (Moyano-Fuentes and Sacristán-Díaz, 2012; Marodin and Saurin, 2013; Bhamu and Singh Sangwan, 2014; Jasti and Kodali, 2014, 2015; Danese et al., 2017). A commonality of all these qualitative literature reviews is their limitation with regard to the covered time period or number of articles considered. Due to this, prior literature reviews were not able to objectively capture how different pieces of research on LM cohere and changed over time. A scientific analysis of the research on lean to reveal the evolution of its intellectual structure is lacking.

In this study, we evaluate the evolution of the field's intellectual structure in an objective and comprehensive manner. To achieve this, we take a new approach of reviewing the literature on LM from 1988 on and follow the suggestion of White and McCain (1998) to study how a discipline has evolved by performing a citation and co-citation analysis. Specifically, we aim to answer the following research questions:

1. Who are the most influential authors in the field of LM?
2. What are the major knowledge groups in the field of LM and how do they relate to each other?
3. How can the evolution of the identified knowledge groups and their relationships be characterized and illustrated?

In the following, this paper introduces the bibliometric methods and data we used for the study. Next, we present the results of the analysis and describe the intellectual structure of the field and its evolution over the last three decades. Eventually, we offer conclusions, discuss the implications for both, theory and practice, raise awareness for the limitations of the study and show potentials for future research.

Research method and data

Bibliometric analyses are a powerful measure to investigate and characterize a field of research. They can be distinguished into two categories depending on whether they yield *activity* indicators, such as citation analyses, or *relationship* indicators, such as co-citation analyses (Ramos-Rodríguez and Ruíz-Navarro, 2004). We employ both methods, citation and co-citation analysis, on author level. The former is based on the premise that highly cited literature is likely to have had more influence on the subject than literature less frequently referenced (Sharplin and Mabry, 1985; Culnan, 1986), and is hence representative for the activity or importance to the field. Bearing in mind that it represents "the field's view of itself" (White and Griffith, 1981), citation analysis can provide useful insights into which authors in the field of LM are considered influential. We use citation analysis to address our first research question.

Since citation analyses do not capture the structure of influence within a field (Leong, 1989), we also employ a co-citation analysis to address the second and third research question. Co-citation analysis is based on the distribution frequencies obtained from counting the number of articles or books that list the same pair of authors in their references. Due to this, it allows to identify the relationships among authors, evaluate their strength, and to illustrate structural groupings within the co-citation network (White, 1990) (see Figure 1).

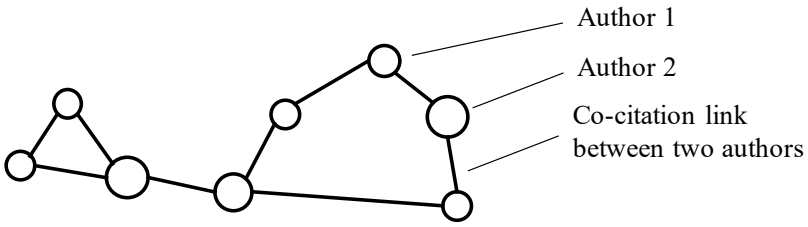

Figure 1 – Conceptual visualization of a co-citation network

To calculate and visualize the bibliometric networks, we use a software tool called VOSviewer (Van Eck and Waltman, 2014). Compared to similar software tools like Gephi or Pajek, it combines analytical and visual strengths and thus serves as an appropriate tool for mapping bibliometric networks (Leydesdorff and Rafols, 2012). VOSviewer takes a distance-based approach using stress-minimization as in multidimensional scaling (MDS). To show how authors within a network relate to each other, VOSviewer illustrates authors as circles, whereas the size of the circles represents the author's number of citations. The proximity to another knot (author) indicates similarity of the authors perceived by their citers (see Figure 1). By default, each node in the network is assigned to (exactly) one (individually colored) cluster, a set of closely related nodes. The number of clusters can be determined by a resolution parameter. With the help of these maps, we trace the relationships between the authors and identify different knowledge groups. By comparing maps from different periods with each other, we follow the evolution of these relationships over time.

Data

Since LM has spread out to many different disciplines, we aim to appreciate its full reach and to capture the whole picture of the LM research community. Therefore, we deliberately do not limit our study to any type of research contributions, be it books, chapters, research articles, theses, etc., though the majority consisted of research articles (86.3 %). For the same reason, we also include conference proceedings and less influential journals with regard to their citation scores. Instead, we conduct an advanced literature research in the Scopus web database and limit our search to a small number of keywords either used in the work's title, abstract, or keywords ("lean management", "lean production", "lean manufacturing", and "lean thinking"). We thereupon export the dataset including relevant information like *author*, *title*, *year*, *source*, and *references* as a csv-file. Before analyzing the data, we take extreme care to identify different variants of an author's name and use VOSviewer thesaurus files to ensure that these are merged and treated as one.

As it was our goal to track the changes in the research field of LM, we consider research contributions over the period of 1988-2018. However, we divide the studied time span into smaller sub-periods of decades and create a bibliometric network for each one to keep track of minor intellectual movements that might have faded out from the field.

The following figure illustrates a growing trend of research articles on LM over the last 30 years. Despite being introduced already three decades ago, the manufacturing paradigm has still kept on attracting interest from more and more researchers showing a particularly high momentum in the recent years. So far, most contributions were made in the year 2018 (919 articles). Overall, our research resulted in 8,081 contributions related to LM, comprising 192,512 citations in total.

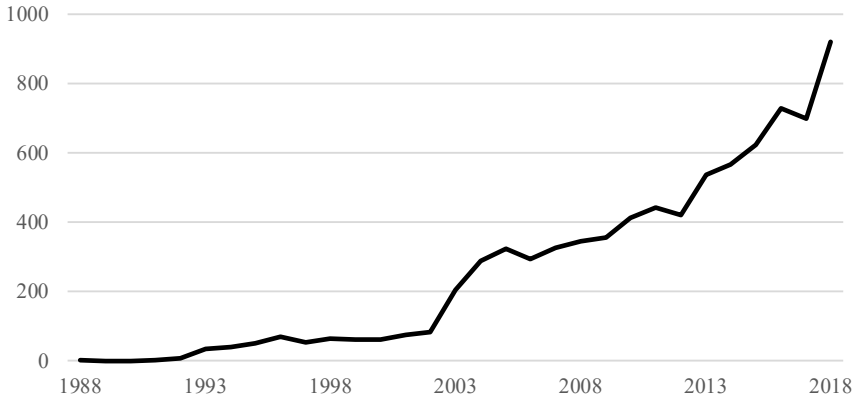

Figure 2 –Number of published LM contributions per year over the last 30 years

Findings

According to our methodological procedure, we also separate the findings section into two stages. First, we present the results on the top 10 most cited authors in the field of LM (see Table 2) to address our first research question. Then, we present the insights from creating the bibliometric networks of the last three decades to target our further research questions.

Most cited authors

The 10 most cited authors in the field of LM over the last three decades are listed in Table 2, along with their number of citations and rank per each period. The absence of a citation count means that the author was not among the top 500 most cited authors of the respective decade, most likely due to later publications.

Not surprisingly, Womack, Jones, and Roos are among the four most cited authors. Due to their books "The Machine that Changed the World" (Womack et al., 1990) or "Lean Thinking" (Womack and Jones, 1996), they made the idea of LM known worldwide. Liker, who is on third position, had a high citation count in the recent years thanks to his bestselling book describing 14 management principles that the Japanese automotive manufacturer Toyota applied (Liker, 2004). Further significant contributions on the understanding of lean production were made by Shad and Ward by characterizing and measuring it with the help of different groups of manufacturing practices (Shah and Ward, 2003, 2007).

Table 1 – Citation count and ranks of the top 10 most often cited authors in the field of LM

#	Author name	1988-1998		1999-2008		2009- 2018		Total	
1	Womack, J. P.	133	(2)	874	(2)	3335	(1)	4342	(1)
2	Jones, D. T.	143	(1)	875	(1)	3286	(2)	4304	(2)
3	Liker, J. K.	-	-	201	(4)	1829	(3)	2030	(3)
4	Roos, D.	110	(3)	394	(3)	1302	(4)	1806	(4)
5	Ballard, G.	-	-	196	(5)	1203	(5)	1399	(5)
6	Koskela, L.	-	-	160	(9)	1181	(8)	1341	(6)
7	Ward, P. T.	-	-	159	(40)	1202	(6)	1261	(7)
8	Shah, R.	-	-	49	(51)	1201	(7)	1250	(8)
9	Hines, P.	10	(64)	160	(8)	956	(9)	1126	(9)
10	Ohno, T.	14	(36)	189	(6)	896	(10)	1099	(10)

Bibliometric network of 1988-1998

For each decade we investigate, we create a bibliometric network and visualize it to better understand its intellectual structure and the evolution of the field. Our first network relates to the time span 1988-1998 and is characterized by three central contributors. Womack, Jones, and Roos do not only have a high citation count, but also strong co-citation links not only within their own cluster but within other clusters as well. Other main contributors of this cluster are Schonberger, Fujimoto, and Monden who also described the way how Japanese companies design and manufacture their products (Monden, 1983; Schonberger, 1986; Clark and Fujimoto, 1991).

Another cluster is located in the top right-hand area of the graph formed by a series of works related to flexible manufacturing. Central author is Hyötyläinen with co-cited authors such as Toikka, Schultz-Wild, or Kuivanen. In the lower part of the graph, we identify a cluster of authors who criticize LM, and examine how Japanese manufacturing techniques, such as JIT, contrast to Western/European manufacturing (Williams et al., 1990). Delbridge, Turnbull, Garrahan, and Stewart, among others, take on a human resource perspective, and discuss effects on management of labor and work organization (Garrahan and Stewart, 1991; Delbridge and Turnbull, 1992).

The remaining clusters of the graph show weaker co-citation links. Nevertheless, there remain some influential authors. Mathews, Badham, or Berggren, for example, also participated in the debate whether LM has the potential to overcome existing manufacturing paradigms (Badham and Mathews, 1989; Berggren, 1993).

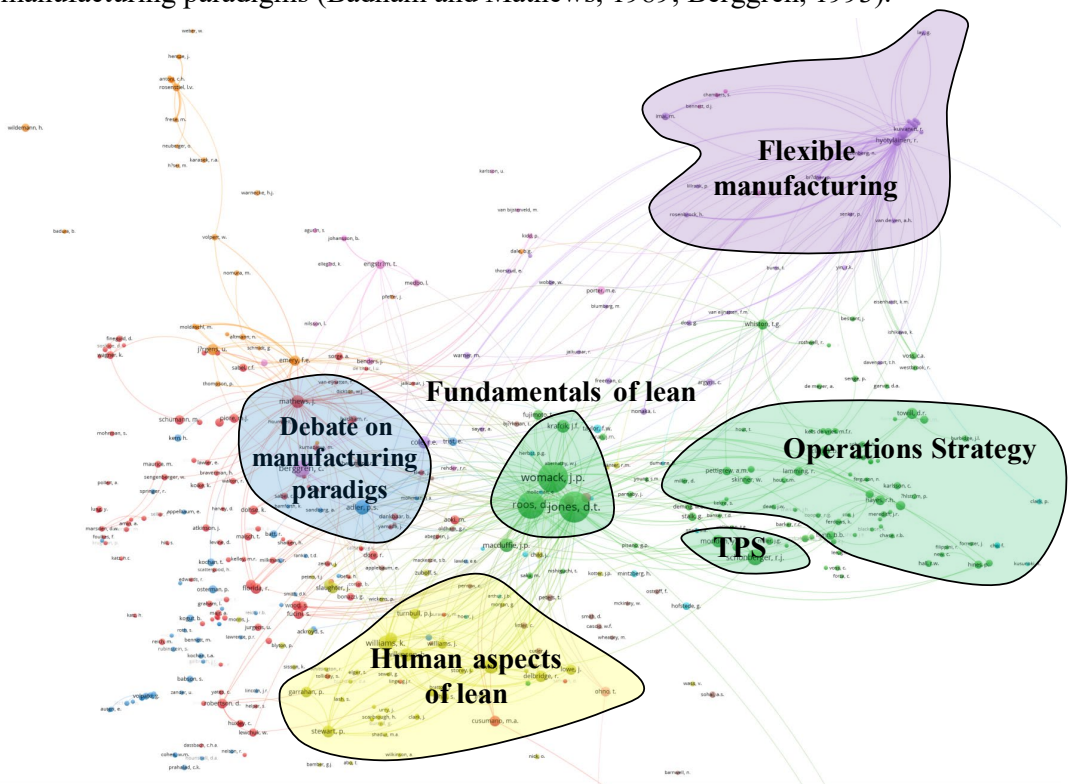

Figure 3 – Bibliometric Network of Lean Management Literature 1988-1998

Bibliometric network of 1999-2008

The bibliometric network representing co-citation data from 1999 to 2008 shows four main clusters. Again, Womack and Jones dominate the network with most co-citation links, whereby Roos appears farther away from the two authors with now significantly less co-citation links. This indicates the significant influence of the second book by

Womack and Jones "Lean Thinking" (Womack and Jones, 1996). Also, part of this cluster are many authors as Liker, Hines, Rich, Shook, and Rother, who have some consulting work in common and documented their experience on the application of LM by writing books.

In the top right-hand side of the graph, a new cluster emerged, comprising the authors from the field of lean construction. Notably, this cluster is the most distant cluster from the center of the network, which means that the authors represent a mostly independent knowledge group except for a few co-citation links with key authors like Womack, Jones, Roos, Ohno and Shingo.

The lower right-hand area of the graph is taken up by a large group of authors who cover a broad range of topics like organization theory, sociology, and the environmental impact of LM. It includes, among others, the cluster from the previous decade that discussed the implications of LM for human resources and collected criticism on the approach. Further, it extends it with authors like Florida or Adler who touch upon the intersection between manufacturing and the environmental respectively organizational aspects, but were previously outside of this cluster.

The lower left-hand area of the graph shows two more knowledge groups. One of them comprises, among others, the authors Wheelwright, Hayes, Schroeder, Flynn, and Schonberger, i.e. authors who contributed fundamental knowledge about operations strategy and how manufacturing approaches can affect firm performance. A further group of authors within this cluster, including Towill, Christopher, and Mason-Jones, is related to the combination of lean and agile manufacturing and supply chains.

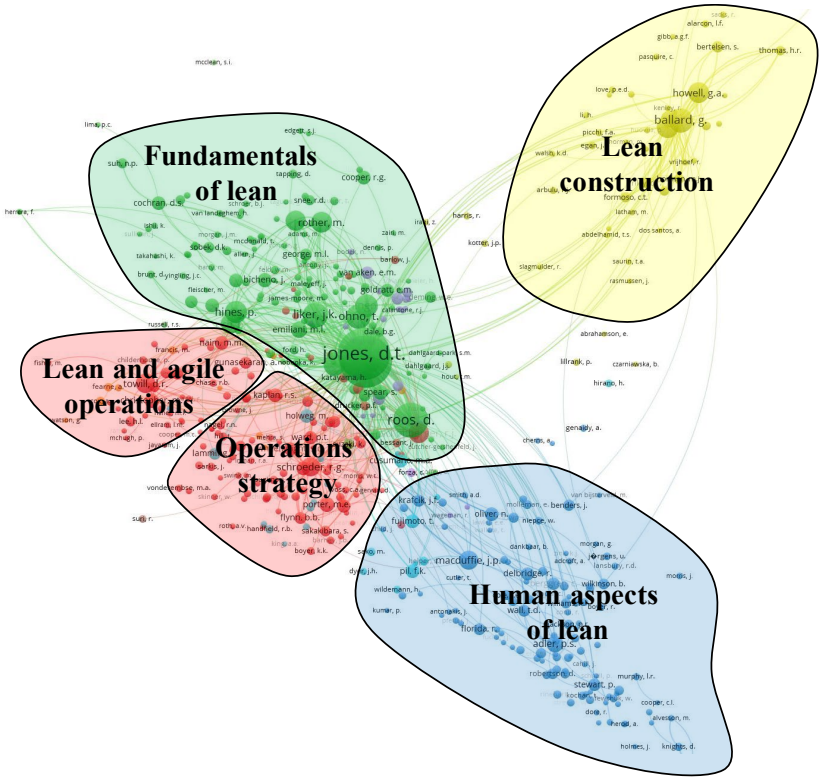

Figure 4 – Bibliometric Network of Lean Management Literature 1999-2008

Bibliometric network of 2009-2018

Our third bibliometric network is the most diverse network and notably very substantial for the overall body of LM knowledge. Due to the ever-growing interest in LM, most contributions and accordingly most citations were made in the respective period from

2009 to 2018. For this reason, we find many different knowledge groups in the network, which even exceed the maximum number of possible clusters (seven) VOSviewer can detect.

Similarly to the previous network, Womack and Jones, who still have most citations and co-citation links, are in the center of the graph. Further, we find a small group of authors located closely around the center, out of which some had a close research relationship with Japanese manufacturers but most of them had practical experience with Toyota such as Ohno, Shingo, Shook, or Hines. Farther right, there is a group addressing lean product/software development and even farther the lean construction community.

In the top of the graph, we identify a research group on lean services, with a focus on healthcare in the middle of it. In the top left-hand side of the graph, the knowledge group of lean six sigma is located. In between these two groups, we find some authors from one of the previous clusters we identified in the decade before. These authors, who discussed the different implications of LM for workers, like MacDuffie or Delbridge, show relatively little influence on the network now.

The bottom of the graph shows knowledge groups related to sustainable manufacturing, the application of value stream mapping (VSM), and a group of researchers who reported their case studies in SMEs. The lower left-hand side of the graph contains authors who worked on the combination of lean and agile manufacturing. In the left part of the network, we find a highly populated knowledge group that covers mostly empirical research on the implementation, assessment, and performance effects of LM.

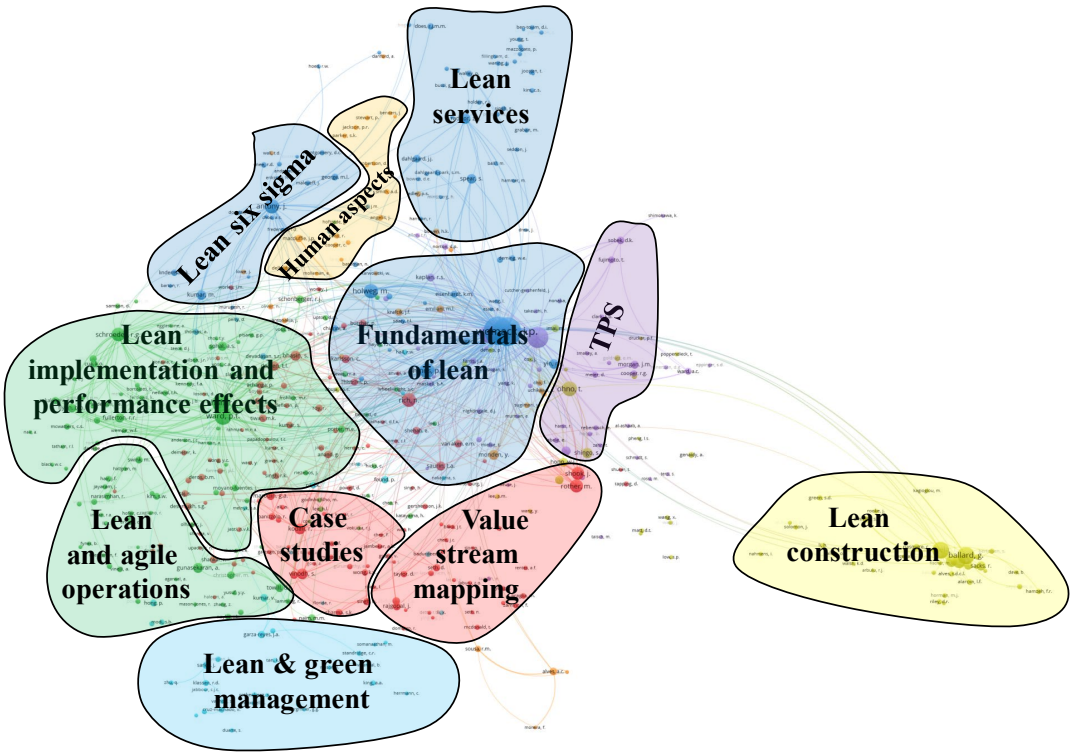

Figure 5 – Bibliometric Network of Lean Management Literature 2009-2018

Discussion

Most influential authors

The first research objective was to identify the most influential authors in the field of LM. Our results showed that Womack and Jones received most attention among LM

researchers in terms of both, total citation counts and co-citation links, and throughout all periods that we analyzed. Other than that, research on LM experienced quite some change regarding the influence of their authors. In the beginning, the LM approach was relatively unknown to the world and influential researchers like Adler, Oliver, Berggren or Williams, who perceived a change of manufacturing strategies, elaborated on the consequences LM might have for industry. Their studies did not only build on the work of Womack, Jones, and Roos, but also on others' as Monden, Ohno, or Schonberger who shared their perception of Japanese manufacturing techniques in books. Therefore, it was a mix of books and research articles that had influence on LM research.

In the later decades, practitioners and consultants showed much influence on LM research. Authors such as Ohno, Shingo, Liker, Hines, Rother, or Shook had high citation counts with their books. Moreover, many knowledge groups emerged that appreciated the various interpretations of LM. As research interests have become more specific, not only books appeared to be influential. Research articles from Shah, Ward, Ballard, Koskela, or Antony equally find their recognition and influence in the form of many citations and also co-citation links within their respective clusters. The relatively fast and recent increase of citation counts of researchers as Antony (lean six sigma) or Radnor (lean services) indicates how much potential lean management can still unleash in unexplored fields.

Evolution of knowledge groups

The identification of knowledge groups and their relationships was defined as the second research objective, and the description of their evolution as our third one. The bibliometric network of the first decade shows that in the beginning LM has just started establishing itself as a knowledge group among others. Besides Womack, Jones, and Roos who were spreading their interpretation of the Toyota Production System (TPS), also other authors described new manufacturing strategies, often inspired by Japanese manufacturers.

One decade later, the LM research landscape looked a bit different. New, more specific research groups directly related to LM were emerging. Authors within these groups appeared closer to each other and more interrelated with each other. In addition, a large group of authors had a controversial discourse about LM and its effects on the workforce, the organization of firms, and the environment. In the last decade, the skepticism and criticism on LM seemed to lose its significance as can be seen in the low influence of the respective group of authors. On the contrary, the latest graph shows that a large number of individual knowledge groups emerged.

Similarly to prior research (Hines et al., 2004; Danese et al., 2017), this study also shows that the research interests on LM are constantly evolving. The rapid increase of contributions and the evolution of different knowledge groups show that LM is not only still gaining attention, but also has particularly in the recent years found its way into different disciplines and evolved as much as never before. We see that research has moved away from asking what LM is and why it should be applied, to where and how it can be applied. Particularly, we expect to see more studies to follow the trend of uncovering new fields of application.

Conclusion

The purpose of this study was to identify central contributors and sub-disciplines that have emerged in the field of LM, to show how they relate to each other and to analyze their roles over the three decades. We fulfilled this purpose by applying a bibliometric network analysis, which is a novelty in LM literature research and thereby managed to capture the wealth of a great number of previous LM studies.

Our results show that there is a core of contributors with high influence on the individual knowledge groups of LM. Within these knowledge groups, single authors with internal influence exist as well. Particularly in the recent years, we experienced quite strong dynamics in the evolution of the field. Many contributions have been made and the management paradigm has spread from its origin in automotive manufacturing into many different fields covering not only different parts of the value chain but also different industries. Research has been following these trends and creating new knowledge groups that in some cases prosper autonomously and in other cases draw on other groups.

This study has several theoretical implications for lean management research. It presents visually how LM as a research discipline has evolved since its creation and gives other researchers an idea where the field is headed. The most recent bibliometric network shows how dispersed the field has become and can help to identify unexplored fields of application.

One limitation of this study is the separation of periods into decades. To grasp the recent movement in the field better, a more fine-grained separation would provide more insights. Another limitation resulting from the research design is related to the choice of keywords. Some work has been done on the TPS and might not be considered in this study because of the focus on the term 'lean'. The limitations of the method are the subjective interpretations of the bibliometric maps and the neglect of single studies due to the author level of our study.

Future literature research should aim to overcome these limitations. Potential for more further research seems to lay in the underrepresented areas of lean services, sustainable manufacturing, and the application of LM in specific processes or industries.

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Kaizen event effectiveness and problem-solving style awareness: A video-based field examination

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Abstract

Effective lean adoption requires running Kaizen events (KE) effectively. Yet, the behavioural tendencies of each of the team members involved in such events often hamper KE outcomes. This longitudinal study examines whether team members' awareness of their own and team members' problem-solving styles impacts KE effectiveness. After a survey about these styles, we video-filmed two events of nine kaizen teams: One prior to and the other after a team workshop intervention that boosted members' awareness of these tendencies. Our finding is that being aware of one's own and team members' problem-solving styles has an impact on KE effectiveness and behaviours.

Keywords: Lean/Kaizen, Problem-solving style, Team effectiveness

Introduction

A key aspect of lean management is the mastery of kaizen. Kaizen stands for 'improving for the better' and is a fundamental mind-set of the lean philosophy (Liker, 2004). Moreover, a Kaizen event (KE) (Bicheno and Holweg, 2000) is defined as "a structured project performed by a multi-disciplinary team with the aim of improving a targeted work area or process in a given timeframe" (Bortolotti *et al.*, 2018, p. 555). Being able to solve problems and implement improvements through KEs is critical for the effective adoption of lean (Bessant *et al.*, 2001). Typically, KEs are one-hour, half-day, full-day or, occasionally, five-day group events (Glover *et al.*, 2013). Effective KEs improve work-floor operations, stimulate employees' problem-solving capabilities and create a positive attitude towards continuous improvement (Bortolotti *et al.*, 2018).

However, if a KE does not lead to improvements, employees might get frustrated and resist participating in future KEs (Glover *et al.*, 2013). But why are some kaizen teams effective in solving problems whilst others are struggling? Farris *et al.* (2009) distinguished various team (input-process-output type) determinants of effective KEs. An

important team-process factor is intra-team member interaction (Farris *et al.*, 2009). The behaviours involved in such an interaction are known to affect (the emergence of) team processes (Kozlowski, 2015). One specific individual characteristic that may contribute to the effectiveness of behavioural interactions during KEs is team-member's problem-solving style (Buffinton *et al.*, 2002). The current study started by assuming that people's awareness of their own and peers' problem-solving styles can help (kaizen) teams increase their effectiveness (Gardner and Martinko, 1996). This paper offers an initial result of our examination of the question: *How does team-members' awareness of their own and peers' individual problem-solving style affect individual behaviour, the process and outcome of Kaizen events?*

Theory: Kaizen Phases and Personal Styles

Most kaizen studies consider kaizen to be a whole event (e.g., Bortolotti *et al.*, 2018; Farris *et al.*, 2009; Glover *et al.*, 2013). In practice, however, kaizen is a structured, phased team approach to problem solving. Table 1 summarizes a selection of popular problem-solving instruments. Each instrument uses different labels, and the number of phases range from four to nine. After content analyses of each of these and other seminal sources, six basic phases of kaizen were distinguished (Table 1: left column).

Table 1 – Overview of the Phases of Popular Kaizen Instruments

	Scientific thinking mechanism (Shingō, 2007, p. 94)	Kaizen Workshops (Liker, 2004, p. 256)	PDCA (Latzko and Saunders, 1996)	DMAIC (De Mast and Lokkerbol, 2012)	Rational manager approach (Kepner and Tregoe, 1965)	Kaizen circle (McKinsey&company, 2003)
1. Define the problem	1. Principle of division and problem awareness 2. Pursuit of purpose	1 Initial problem perception 2 Clarify the problem 3. Locate Area, point of cause	1. Plan	1. Define	1. Problem analysis and decision making	1. Problem definition
2. Analyse the current situation	3. Understanding the status quo 4. Better methods 5. Lock on to problems	4. Five times why investigation of root cause		2. Measure	2. Potential problem analysis	2. Root cause analysis
3. Generate ideas	6. Idea generation 7. Judgement			3. Analyse		3. Brainstorm
4. Plan implementation	8. Propose				3. Set contingency actions	4. Implementation plan
5. Implement the change	9. Implement	5. Counter measure	2. Do	4. Improve	4. Remove cause	5. Implement
6. Check and sustain		6. Evaluate 7. Standardize	3. Check 4. Act	5. Control	5. Set controls	6. Check and sustain

All reviewed instruments emphasize that to be most effective, the KE phases should be performed in a particular order. Hence, KE effectiveness is widely assumed to depend on the ability of the team to perform each subsequent phase in an orderly manner (Kepner and Tregoe, 1965; Liker, 2004). Orderly here means that the team, after reaching consensus about the result of each phase, continues to the next phase, without the need to return to a previous one. Each kaizen phase has a particular goal (Table 2). Although open team-member discussion is key during a KE, a specific orientation and related core question ought to be addressed during each phase (Kepner and Tregoe, 1965; Liker, 2004; Shingō, 2007). Asking and answering phase-specific questions appropriately requires

each team member to have specific KE capabilities. Team members' individual behavioural contributions, in terms of knowledge and skill, to each KE phase can thus be seen as crucial for KE's effectiveness (Hackman and Morris, 1975; Wageman *et al.*, 2005). The general team-effectiveness literature acknowledges the influence of team member's personal styles on the effective composition of teams (Mathieu *et al.*, 2017). Different personality types or styles develop different capabilities, skills and preferences that can show up in team behaviour (Jung *et al.*, 1964). The effectiveness of a KE is thus likely to be dependent on members' problem-solving styles and the consequent behavioural display in each phase (Buffinton *et al.*, 2002).

To link personal problem-solving behavioural tendencies to the kaizen phases, we used the Myers and Briggs model which operationalises Jung's seminal theory of psychological types (Gardner and Martinko, 1996). The four dichotomies denoted in the Myers-Briggs Type Indicator (MBTI) are: source of energy (extraversion vs. introversion), mode of taking in information (sensing vs. intuition), decision making (thinking vs. feeling), and lifestyle (judging vs. perceiving) (Gardner and Martinko, 1996). While the model has been critiqued for its explanatory value (Stein and Swan, 2019) it is widely used for increasing people's awareness of their own personal preferences at work (Gardner and Martinko, 1996). The different preferences within MBTI's four dichotomies seem to be closely related to the key questions in the kaizen phases (Hirsh and Hirsh, 2007). Although KE team members typically embody a (random) variety of MBTI preference styles, part of this research explores to what extent certain MBTI preferences ought to be more dominant in each kaizen phase. Given the predominance of task-orientation during KEs, only three of the four MBTI categories were mapped with the KE phases: taking in information, decision making, and lifestyle. Source of energy is not taken into account in Table 2 as it is assumed that both people with a more extraversion style and a more introversion style are just as good at showing the key capabilities described in Table 2. We expect that if people are aware of their problem-solving styles, the process and outcome of KE improves. Moreover, we expect that individuals will feel more capable in particular KE phases: those that match their own problem-solving style best.

Table 2 – The Goals of Each Kaizen Phase Linked to MBTI Styles

Kaizen phase	Goal	Orientation and core question	Intention of individual contributions	Key capability	MBTI style
1. Define the problem	Understand objective situation and future impact	What is the expected impact of this problem?	Exploring the context of the problem	Weigh options in terms of the possible consequences Seeing the potential Seek logical clarity	Intuition and thinking (NT)
2. Analyse the current situation	Explore the root causes	What causes this problem?	Discussing and weighting the causes	Weigh options in terms of the bottom line Prefer to know what is Seek logical clarity	Sensing and thinking (ST)
3. Generate ideas	Creatively develop possible solutions	Which ideas may help to remove the root cause?	Elaborating on ideas	Prefer flexibility Like to see what turns up Enjoy surprises	Perceiving (P)
4. Think about how to implement	Develop a plan of what is needed to	What should be done to	Exploring the commitment to change	Weigh options in terms of people's aspirations Seeing the potential	Intuition and feeling (NF)

	realise change	create change?		Know when support is required	
5. Implement the change	Execute the plan	Can you accept the change and perform the new standard?	Observing and discussing responses to the change	Weigh options in terms of individual's needs Have in interest in people Know when support is required	Sensing and feeling (SF)
6. Check and sustain	Set the new standard	Did the new way of working solve the problem?	Discussing the extent to which the problem is solved and the solution is standardized	Want things to be settled and ordered Draw conclusions Like goals and results	Judging (J)

Design/methodology/approach

We video-filmed KE team members' contributions to two KEs about real-life problems within their team. Figure 1 displays the time points, over a period of two months, in which we collected the survey data and engaged in the awareness-raising intervention.

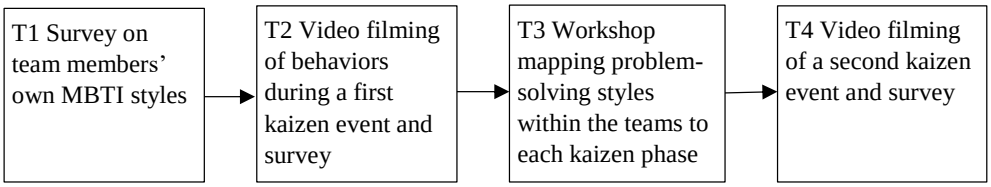

Figure 1 – Longitudinal Research Design, including the Workshop Intervention

Sampling

After a pilot, ten kaizen teams within two Dutch knowledge-intensive organizations were approached, based on convenience sampling (Barratt *et al.*, 2011). Nine teams (in total 42 members) participated in the study: on average five members per team, see Table 3.

Table 3 – Teams' Characteristics

No.	Industry	Team tenure	No. of team members (Male/Female)	Average years of work experience
1	University Design Lab	< 1 month	4 (2/2)	<1
2	University Design Lab	< 1 month	4 (0/4)	9
3	University Design Lab	< 1 month	4 (0/4)	23
4	Consultancy	1.5 year	5 (3/2)	3
5	Consultancy	1.5 year	7 (5/2)	3.5
6	Consultancy	1.5 year	5 (4/1)	3
7	Consultancy	1.5 year	4 (2/2)	4
8	University Student Affairs	12 year	4 (3/1)	28
9	University Human Resources	3 year	5 (2/3)	27
			Total: 42 (21/21)	

Measures

At T1, each *team member's personal MBTI style* was measured using the MBTI instrument (Hirsh *et al.*, 1992). The instrument consists of 88 forced-choice items. Best-fit types were determined following official MBTI procedures.

We video-taped each team's KE at both T2 and T4 in order to be able to code *members' behaviours per kaizen phase*.

Perceived KE effectiveness was assessed immediately after each of the two filmed KEs. Based on the Team Diagnostic Survey (Wageman *et al.*, 2005), a composite measure

that incorporated both technical and social KE outcomes was applied (Farris *et al.*, 2009): 1) productive process, three sub scales with a total of nine items e.g., "Our team often comes up with innovative ways of proceeding with the work that turn out to be just what is needed"; 2) team interpersonal process, two sub scales with seven items in total e.g., "Working together energizes and uplifts the members of our team"; and 3) individual learning and well-being, three sub scales with a total of ten items e.g., "I learn a great deal from my work with this team". All items were scored on a 5-point Likert scale, ranging from 1 "totally disagree" to 5 "totally agree". Although the instrument was chosen because of its proven validity, the Cronbach's alpha analysis of our study was poor so two sub scales and in total 13 items had to be removed. The reliabilities of the remaining sub scales at T2 were between .51 and .76.

The survey at T2 and T4 also measured *team member's perceived capability in each phase of kaizen*: with a newly-developed questionnaire consisting of 48 items with a 7-point Likert scale ranging from 1 "totally disagree" to 7 "totally agree"; six sub scales consisting of eight items per kaizen phase. The items dealt with the required type of behaviour within each kaizen phase. They were constructed with the help of five lean master black belt consultants each of whom had over ten years of lean experience. After eliminating two items, the six sub scales had acceptable to good Cronbach's alphas, ranging between 0.65 and 0.82 (T2) and between 0.65 and 0.84 (T4).

At T3, each team participated in a workshop during which the members first discussed the six kaizen phases. Then, they received feedback on their personal styles related to each phase of problem solving (as in Table 2). Moreover, a visualised KE-behavioural team assessment (of T2) was fed back to them. Immediately afterwards, they assessed the workshop quality with seven survey items e.g., "The provided knowledge is interesting", on a 7-point Likert scale ranging from 1 "totally disagree" to 7 "totally agree". The mean quality rating was 5.80 (*s.d.* = 0.43; 69% response rate).

Data-analysis

We calculated the means of each of the KE effectiveness variables and executed one-tailed t-tests to verify the expected improvement between T2 and T4.

The KE videotapes were transcribed and minutely coded in terms of members' contributions. Each remark from every single participant was categorized into one of the six kaizen phases, based on the code rules created in Table 2. These categorized member contributions were then plotted over time. The resulting team graphs visualised what happened during the subsequent phases of the two KEs (Figure 5).

Finally, we analysed to what extent members rated themselves as more capable at T4 compared to T2 in terms of the kaizen phases that we expected to fit their MBTI functional and lifestyle styles (Table 2). Each participant was thus categorized twice. We then performed a one-tailed t-test, since we expected an improved link, after the workshop, between best-fit MBTI styles and perceived capability in the related kaizen phases.

Results

Table 4 shows the perceived KE effectiveness per team, both at T2 and T4. Only three teams improved (marginally) significantly on some of the KE effectiveness variables. Surprisingly, in this table one may also notice some drops in perceived KE effectiveness: due perhaps to people's increased self-awareness of their own and team member's behavioural shortcomings.

To provide a more detailed example of the video-based analysis, Figures 3 and 4 show the result of the minute coding of team 4's video-taped KEs at T2 and at T4. Regarding KE process effectiveness it can be seen that after the intervention the team showed a more

Table 4 – Perceived Kaizen Event Effectiveness, Results of the T-tests Comparing T2 vs. T4

	Team 1		Team 2		Team 3		Team 4		Team 5		Team 6		Team 7		Team 8		Team 9	
Variables	T2	T4	T2	T4	T2	T4	T2	T4	T2	T4	T2	T4	T2	T4	T2	T4	T2	T4
Team interpersonal process																		
Quality of team interaction	3.50	**4.25**†	3.75	3.75	4.38	4.25	4.80	4.80	4.07	4.14	4.30	4.20	4.38	4.13	4.13	4.00	4.40	4.20
Satisfaction with team relationships	4.13	**4.46***	4.25	4.00	4.38	4.13	4.90	4.50	4.21	4.36	4.20	4.30	4.75	4.63	4.50	4.00	4.50	4.30
Individual learning and wellbeing																		
Satisfaction with growth opportunities	3.75	3.13	3.50	3.50	3.75	4.00	3.90	**4.20***	2.86	**3.07**†	4.30	4.40	4.38	4.13	4.25	4.38	4.20	3.90
General satisfaction	4.50	**4.88***	4.13	3.88	4.25	4.38	4.80	4.70	4.43	4.29	4.40	4.40	4.63	4.63	4.38	4.50	4.60	4.60
Productive process																		
Effort-related process criteria	4.13	3.88	3.63	3.63	4.25	4.13	4.00	4.10	3.71	3.71	4.60	4.50	4.38	4.38	4.13	4.13	4.30	4.20
Strategy-related process criteria	4.25	3.88	3.13	3.25	3.63	3.50	3.70	**4.00**†	3.79	3.79	4.40	4.20	3.38	3.63	3.75	4.00	4.00	3.70

Note. * $p < .05$; † $p < .10$ (one-tailed).

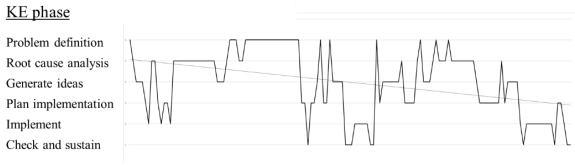

Figure 3 – Example Visualization of KE Members' Behaviour Before Awareness Training (Team 4 at T2)

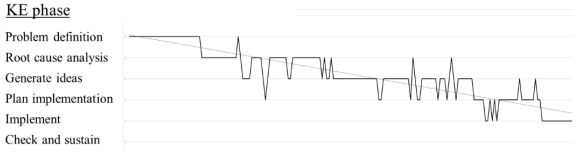

Figure 4 – Example Visualization of KE Members' Behaviour After Awareness Training (Team 4 at T4)

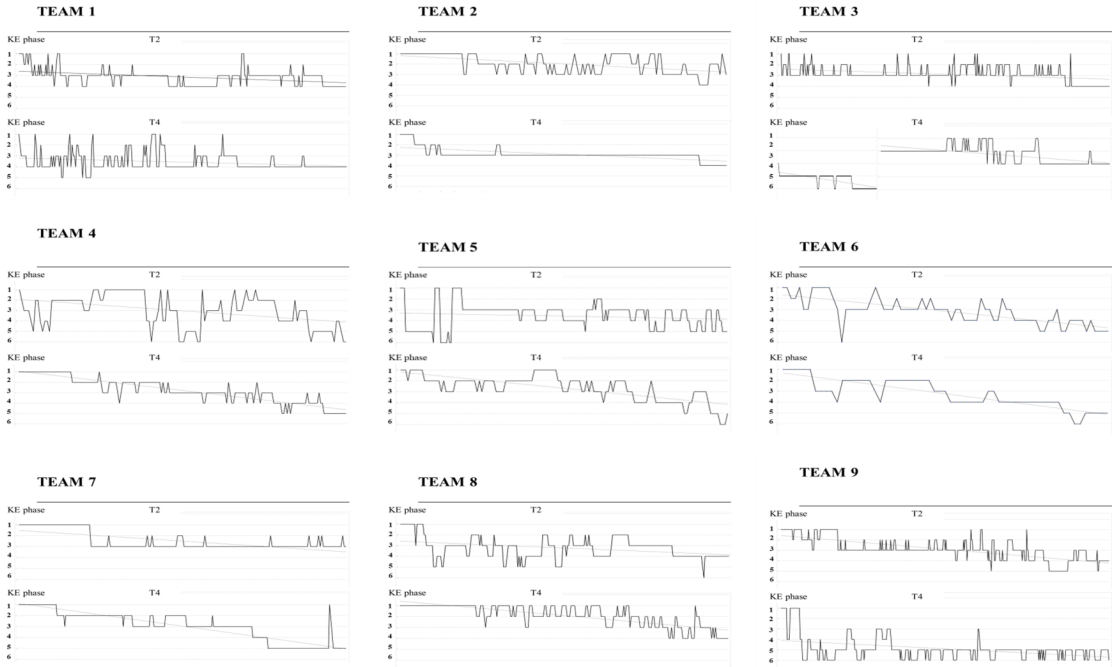

Figure 5 – Comparison of Members Contributions during Minutely Coded KE Events (Upper Graphs: T2; Lower Graphs: T4)

phased approach. Specifically, at T4 (in Figure 4) the team engaged in a root-cause analysis phase after its problem-definition phase. A root cause analysis phase was not clearly visible at all at T2 (Figure 3). Figure 5 shows a visual comparison of the video sessions at T2 and T4 of *all* the studied teams.[1] From this Figure we find that, at T4, teams typically spent more time on defining the problem, and most teams took a more structured or gradual approach: according to the ideal-typical KE phases.

Table 5 reports the results of the changes in the respondents perceived capabilities in their preferred phase (linked to their best-fit MBTI style). Significant changes were found for the functional styles, esp. for the team members who indicated a preference for the 'Plan implementation' phase. An even stronger intervention, or more (or less) time between T3 and T4, is likely to lead to more remarkable changes in terms of the exposed preference style (see Table 5). Although not always visible in their perceptions, the people certainly showed an increased individual awareness of personal problem-solving style during the KEs at T4. Various quotes from the participants during and after the workshops at T3 and T4 support this (Table 6).

Table 5 – Perceived Kaizen Phase Capabilities in Terms of Function and Lifestyle MBTI Styles

	n	*M* (T2)	*M* (T4)	*s.d.*	*t*	*p*
Functional styles linked to kaizen phase	42	5.27	5.40	0.48	-1.85	0.04*
NT – Define the problem	8	5.16	5.42	0.43	-1.75	0.06†
ST – Analyse the current situation	9	4.90	4.82	0.50	0.50	0.32
NF – Plan implementation	13	5.43	5.64	0.43	-1.80	0.05*
SF – Implement the change	12	5.43	5.57	0.55	-0.85	0.21
Lifestyle styles linked to kaizen phase	42	5.07	4.97	0.57	1.16	0.13
P – Generate ideas	25	5.03	4.88	0.65	1.19	0.12
J – Check and sustain	17	5.12	5.10	0.44	0.24	0.41

Note. * p < .05; † p < .10 (one-tailed).

Table 6 – Illustrative Team Members' Quotes after the Workshop

Team 5 at T4	"I am not interested in defining and discussing the problem, because I have already done it in my head." (remark when he was asked to join the discussion. After a laugh he realised that he had to share his thoughts with his colleagues)
Team 8 after T3	"I used to ask my peers about this because I am not that good at it and always felt some frustration. With this knowledge I will still ask my colleague, but with less frustration."
Team 5 at T4	"Come on, this is your phase. Help us out." (with a smile)
Team 6 after T4	"On knowing my preferred phase I now dare to score that I am not good at everything. I dare to emphasize my preferred actions."

Discussion

We explore how KE member's awareness of own and others' problem-solving styles affect the effectiveness of KEs. We undertook a multi-case analysis of combining behavioural profiling with an innovative micro-behavioural video-method as well as customized feedback and an awareness-rising workshop. After the workshop, whose aim is to raise members' behavioural styles awareness some teams demonstrate a positive effect in terms of a more phased KE process. In terms of KE outcome effectiveness: both positive and negative changes are found regarding different elements of team effectiveness. Moreover, individuals feel increasingly capable related to their preferred phase of problem solving. The preliminary findings are linked to Buffinton *et al.'s* (2002) suggestion that problem-solving styles and project teams' interpersonal dynamics are critical factors for effective team functioning. Moreover, Kozlowski (2015) refers to the critical role of team processes in resolving team task demands. Hence, this exploratory

study shows the potential for further investigations of how people's awareness of their own and team members' styles may contribute to KE effectiveness. Possible pathways are expanded below.

The video data could be analysed more extensively. The video analyses of the KEs at T2 and T4 show interesting visual changes in terms of KE process. We may need to come up with a more objective comparison between T2 with T4 across the teams. Coming up with a measurable indicator (i.e., a slope coefficient) that justifies the phased approach should be part of future discussions and research with statisticians and academic peers.

In terms of limitations, all the measurements occurred immediately after the intervention hence, the long-term impact of personal problem-solving style awareness on KE effectiveness has not been taken into account yet. Another point is that we left the source of energy (extraversion/introversion) out of the scope. This should be included in future research. It can be argued that one's source of energy will influence KE process performance in line with a team's action orientation (Farris *et al.,* 2009). Of course, larger-scale studies that include control groups are warranted. They may enable further fine-tuning and validation of the self-developed scale which we used to assess team member's perceived capability in each kaizen phase, plus more robust statistical analyses with more reliable KE outcome measures.

Although this study uniquely focussed on the factor of problem-solving style awareness within teams, no other factors were taken into account, e.g., KE's goal clarity (Farris *et al.*, 2009); The teams were instructed to solve a problem of their own day-to-day work. Each team session had to start with the question: "How do we solve...?" In effect, the videos showed members' mutual collaboration as well as the maturity with which teams were able to perform kaizen. The established fact that not all teams followed a neat KE process, as shown in Figure 5, might be related to the degree of team kaizen experience (Farris *et al.*, 2009). In future behavioural KE research, specifications of the problem-solving phases to be followed by a team might need to be matched to the nature of the status of the particular problem at hand. Explicit articulation of the required phases on each KE agenda might indeed help the members to stick better to what the problem requires rather than to let their behavioural preference determine the KE process.

This study contributes to our understanding of the individual as a component of kaizen and to what extent awareness of team members' diverse problem-solving styles should be present in a team to be successful in kaizen. While most prior kaizen research focused on team *functional* heterogeneity (Farris *et al.*, 2009), perhaps focusing on member's contributions per KE phase would illuminate *problem-solving style* heterogeneity. Although it may not always be possible to compose teams based on members' problem-solving styles in practice, people's awareness of their own and peers' styles is found to contribute to KE effectiveness. The practical relevance of our work is further evidenced by the positive responses of our respondents and their requests for additional tools to make effective use of their behavioural preferences in team settings. Understanding kaizen as a *phased* approach, including its enablers at the individual and team level, provides a new line of research in which many interesting questions can be explored.

Notes

1. A better readable version of Figure 5 will be provided by the first author upon request.

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Value Stream Management: From Dysfunctional Organization to Cross-Functional, Collaborative Learning and Improvement

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Abstract

A value stream is defined as the set of all the specific actions required to bring a product through the three critical management tasks of any business: the *problem-solving task*, the *information management task*, and the *physical transformation task* (Womack and Jones, 1996). However, the popular *Value Stream Mapping* tool (c.f Rother and Shook, 1999) simply reduces the value stream to the information management and physical transformation tasks. In this paper, we present an alternative method for value stream mapping that also incorporates the problem-solving task. What emerges is a cross-functional approach to learning and improvement.

Keywords: Lean Production, Value Stream Management, Continuous Improvement

Introduction

Lean Production was popularized as an alternative approach to production management in the 1990s. In *The Machine that Changed the World* (Womack *et al.*, 1990), the Lean Production paradigm was presented as five parts of a system (i.e. the Lean Enterprise): Dealing with the customer, Designing the car, Running the factory, Coordinating the supply chain and Managing the enterprise. The cross-functional nature of the Lean Production model was therefore well-defined from the outset. However, in subsequent years, Lean Thinking has in many instances simply been reduced to 'something for factory operations and shop floor management'.

As such, Value Stream Mapping (VSM) has become one of the default tools for organizations embarking on a lean journey. Spawning from what is referred to as *Big Picture Mapping* or *Material and Information Flow Mapping* at Toyota Motor Company, VSM was popularized in the book *Learning to See* (Rother & Shook, 1999), which unfortunately covers only the "door-to-door" production flow inside a plant. Though this is perhaps a good level at which to begin a *"mapping and lean implementation effort"*, many companies neglect to scale up their efforts in order to see value streams across the entire enterprise, focusing simply on value analysis and disregarding value engineering. For example, more recently, Sakai (2018) highlights the Toyota Product Development

System (TPDS) as the key to Toyota's success, suggesting that an overemphasis on Toyota Production System (TPS) alone has resulted in many failed lean transformations in the West. Sakai presents TPS simply as an "efficient duplication system" and indicates that developments around the Shusa (Chief Engineer) System and use of Obeya in the product development process is the real secret behind the success of Toyota – through creating constancy of purpose and cross-functional clarity and alignment.
In this paper, based on the authors' practical experiences from an action research initiative, we present an alternative approach to value stream mapping that encompasses the organization in its entirety with the aim of fostering cross-functional collaboration, learning and improvement.

Value Stream Management
A value stream can be defined as "the set of all of the specific actions required to bring a specific product (whether a good, service or, increasingly, a combination of the two) through the three critical management tasks of any business: *the problem-solving task* running from concept through detailed design and engineering to product launch, *the information management task* running from order-taking through detailed scheduling and inventory, and *the physical transformation task* proceeding from raw materials to a finished product in the hands of the customer" (Womack and Jones, 1996). Seeing, understanding, managing and improving value streams as they cut across the different functions (often starting from traditional, functionally organized enterprises) is fundamental to lean thinking and practice. As such, Value Stream Mapping (VSM) has become one of the default tools for organizations embarking on a lean journey and a core requirement for effective Value Stream Management.
However, VSM efforts often fail to cut across such functional borders, typically covering only the "door-to-door" material- and information flows inside a plant. In doing so, organizations omit a wealth of improvement opportunities that are to be found at the interfaces between functions – for example Research and Development, Engineering, Supply Chain, Sales, and Customer Support. As such, a major weakness that we observe in this traditional approach to VSM is that many companies neglect to scale up their efforts in learning to see value streams in their entirety, i.e. scaling efforts from what Womack and Jones (1996) define as the information management and physical transformation tasks to also include the problem-solving task, as well as capturing additional important information once the product has indeed found its way into the hands of the customer, what we shall refer to as the maintenance and end-of-life tasks. This effort requires input and collaboration spanning the entire organization in order to encourage value stream learning and improvement at the organizational level rather than purely at the business process / function level.
While value stream maps are powerful tools for improving manufacturing / production workflows (Martin and Osterling, 2014), we advocate that they are even more powerful when used to visualize entire value stream "work systems", often uncovering organizational disconnects and unnecessarily complicating business processes and practices, that are otherwise unknown to other functions / stakeholders and make for a dysfunctional organization. This is particularly relevant for engineer-to-order (ETO) manufacturers, that do not typically exhibit highly linear material and information flows Powell and van der Stoel, 2017). Therefore, in the following sections, we develop and present value stream mapping as a collaborative, enterprise-wide initiative to see, understand, manage and improve value streams in their entirety.

Research Design

As this investigation involves research *in* action rather than research *about* action (Coughlan and Coghlan, 2002), we adopt action research for our enquiry into the development and application of collaborative value stream mapping at the enterprise level. Action research can be considered as a reflective process of progressive problem solving led by individuals working with others in teams or as part of a *community of practice* to improve the way they address issues and solve problems (Stringer, 2014). As such, the authors have led a "reflective problem-solving process" with an ETO manufacturer. We take insight into the current lean transformation activities within a global division of a Norwegian technology and solution provider to the maritime industry in order to develop a value stream mapping tool based on swim lane diagrams. Powell and van der Stoel (2017) suggest that swim lane diagrams are a visual management tool that can be used to visualize value streams in ETO and take into account non-linear and returning material and information flows, as an alternative to traditional value stream maps. The technique was developed in order to visualize enterprise workflows and identify improvement opportunities within and between the organizational functions that constitute product-centric value streams.

Towards a Means for Cross-functional Value Stream Mapping

One of the authors has been actively involved in the lean transformation at KM Subsea since 2014. What began as a pilot implementation of lean thinking and practice in the production department quickly transpired into an organization-wide lean transformation, which subsequently earned the company the *Norwegian Lean Enterprise of the Year Award* in 2017. VSM has been used from the outset, first focusing on the door-to-door material and information flow using traditional VSM, and more recently encompassing all business functions throughout the enterprise using a swim-lane diagram type technique for mapping product-centric value streams.

A traditional, current-state value stream map can be seen in Figure 1:

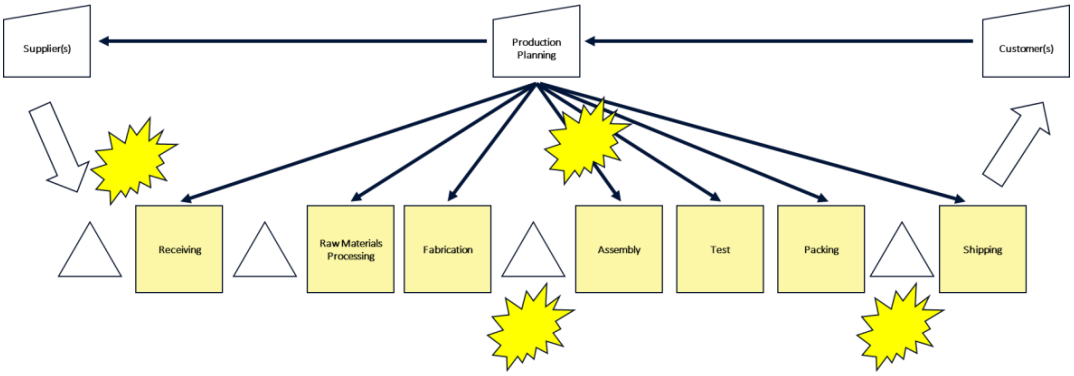

Figure 1 – Current-state value stream map

Notice the linearity of the door-to-door material and information flows, as well as the 'kaizen bursts' (improvement suggestions arising from the mapping exercise). From such a current-state map, one would typically continue to develop a future-state map (Figure 2):

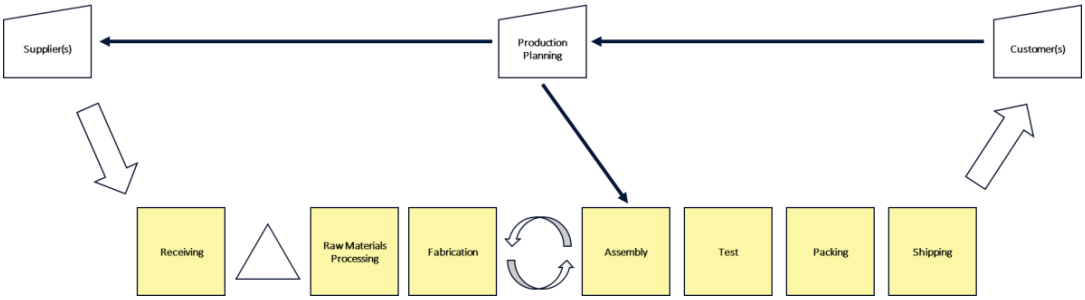

Figure 2 – Future-state value stream map

Notice here the grouping of two cells – what we may call the fabrication cell and the assembly and test cell. The idea of course is to create continuous flow, in this case decoupled by supermarket between the two cells. Notice also that the Assembly process has become the single pacemaker process, utilizing a pull system upstream and continuous flow downstream. This of course generates satisfactory results – increasing efficiency in the duplication process and maybe also favourably impacting the cost-of-goods-sold (COGS) on the balance sheet. However, when we begin to adopt an organization-wide view, we quickly begin to see that there are in fact many more improvement opportunities that can be realized, some of which automatically influence the decisions and requirements that are otherwise later needed in the shop floor operations.

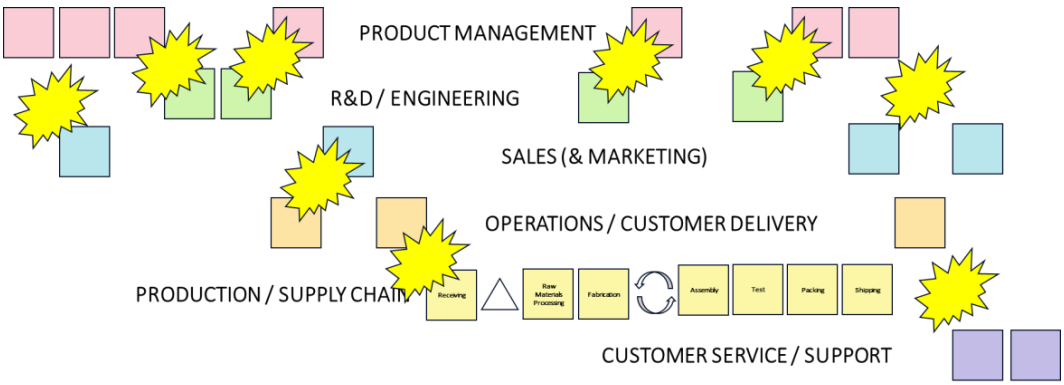

Figure 3 – Enterprise-wide value stream map

Figure 3 represents a simplified *enterprise-wide value stream map*. Regardless of the efforts made in improving the duplication process (here labelled Production / Supply Chain) through value analysis, what we in fact discovered in the lean transformation efforts of KM Subsea was that there is much greater potential to be realized in re-focusing the improvement efforts to include other areas of the business as well, in particular the value engineering (value creation) processes consisting Product Management, R&D / Engineering, Sales and Marketing, and even Customer Support, functions which, together with Production / Supply Chain constitute the product-centric value stream (and in particular the interfaces between such functions).

Discussion

Rather than settling for the adoption of the popular "door-to-door" production flow perspective of value stream mapping, representatives from all business functions (product management, research and development / engineering, operations, supply chain, sales and customer support) at KM Subsea were assembled to map entire "product-centric" value streams as holistic work systems. The investigation showed that the *physical transformation task* and associated *information management task* that constitute the supply chain (or manufacturing) function were in fact the most streamlined and effective "tasks" within the enterprise. More importantly, during the process of "learning to see" the enterprise as a complete work system distributed across one or more value streams, the most significant improvement opportunities appeared to be found at the interfaces between different functions (e.g. product management and supply chain; sales and engineering; customer support and operations), or indeed within functions other than production / supply chain. This highlights the potential for adopting a more holistic approach to VSM, what we will refer to as *enterprise-wide value stream mapping*.

Conclusion

Value Stream Mapping (VSM) is a practical and highly effective way to learn to see and resolve disconnects, redundancies and gaps in how work gets done (Martin and Osterling, 2014). Unfortunately, however, there has been an all-to-common focus on applying value stream mapping as a tool for operational improvement in production (and in some instances supply chain) operations. In this paper we present swim lane mapping as an alternative technique for enterprise-wide value stream mapping. In line with Powell and van der Stoel (2017) we see the potential for such a mapping technique in ETO manufacturing in particular – engaging all stakeholders in cross-functional, collaborative learning and improvement.

This article presents the yet unexploited potential for *enterprise-wide value stream mapping* as a tool to foster cross-functional, collaborative value stream management – allowing all stakeholders in an enterprise to see, understand, manage and improve value streams in their entirety. We adopted a simple, effective tool (swim lane diagram) for visualizing value streams as complete systems of work, rather than simply focusing on the physical transformation of materials; and suggest that such a tool can be used by researchers and practitioners to promote organizational learning and improvement, particularly in technology- / R&D-intensive, engineer-to-order environments.

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Impact of Regional Contingencies on the Implementation of Lean Production: Two Romanian Case Studies

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Abstract
Whereas lean production is widely adopted in industry, there is a gap in the current literature regarding studies that consider implementation of lean production from a regional context. Hence, this study addresses the impact and contingencies of regional context on the implementation of lean production. More specifically, the results of two case studies in Romania are presented and discussed. Data collection included in-depth semi-structured interviews as well as observations of processes. The results show that using four dimensions of regional context does influence the implementation of lean production and the operational performance of the company.

Keywords: Lean production, regional dimensions, case study

Introduction
Lean production has been widely implemented by companies in different regions with the aim to improve performance. However, the impact of regional context when implementing lean production remains a gap in the literature (e.g. Bortolotti et al. 2015, Bhasin 2013). Few studies (e.g., Hines et al. 2004) that have looked into this issue lack sufficient in-depth analysis. Therefore, this study sets out to investigate in detail the impact that regional context may have on the implementation of lean production.

Research Objectives
Thus, this study aims at asserting the influence of the regional context on the implementation of lean production. It has become apparent that a few number of firms that adopted lean production, which relates to organisation culture (Bhasin 2013). In this

respect, regional context covers what members of society share and what leads to behaviour of the people, i.e. employees, suppliers and managerial mind (Wiengarten et al. 2015). More generically, some (e.g. Yadav et al. 2010) assert that firms struggle with implementing the concept of lean production, thinking that Toyota's success lies in their cultural roots and, hence, the concept is not transferable. However, Toyota has been successful in multiple countries, and not only Japan. Moreover, some (e.g. Kull et al., 2014; Wangwacharakul et al., 2014; Wang, 2008) have noted that the implementation of the concept of lean production varies for different regions, albeit without going into much detail. This study will address the gap about the adoption of lean production in regional contexts. Hence, the study addresses three research review questions:

1- To what extent the regional context contingencies affect the implementation of lean production as set of practices.
2- Are regional contexts a contingency for the design of lean production system?
3- How the regional context differs from a company to another?

To answer these questions, two case studies have been investigated in Romania, including an in-depth interviews and observation.

Outline of Paper

This paper is structured as follows. First, the literature review, which includes lean production and the regional context, is presented. Next, the methodology section, followed by an analysis of the papers. After that, there is a discussion of the findings. Then at last, conclusion of the study.

Literature Review

Before looking at the regional context, is necessary to look at what the concept of lean production constitutes. Although Womack et al. (1990) were the first researchers to propagate the conceptualisation of lean production, they never gave a specific definition for 'lean thinking'. This lack of definition in literature about lean production has reverberated until today, as Petterson (2009) notes. The only ones that have given a more specific description (rather than definition) of lean are Shah and Ward (2007), who have mentioned that lean production is about socio-technical system. However, even lean production practices and principles vary; some researchers list as few as five principles (Womack & Jones 1996), whereas others list over twenty practices or principles with more details for every aspect (e.g. Kull et al. 2014; Shah & Ward 2003; Shah & Ward 2007; Yadav et al. 2010). This implies that the concept of lean production is relatively undefined.

Hence, this lack of definition for lean production offers a unique opportunity to evaluate literature; the distinction of two strands of research into lean production serves as base for the further analysis. Therefore, this section of the paper will look with more detail into two different lenses: (i) lean production as a set of practices, (ii) lean production as design of production systems and to the regional context.

Two Lenses for Lean Production

The first lens, lean production as a set of practices, considers the process that a firm follows for implementing lean production, its methods, and tools, and practices. The practices can be defined as 'an activity or action which is performed to a standard which is better or equal to the standard achieved by other companies' (Davies and Kochhar 2002, p. 290). The tools that can be applied on Just-In-Time, total quality management, kanban, total preventive maintenance (e.g. Flynn et al. 1995; Shah & Ward 2003; Shah & Ward

2007). Lean practices lens is what most studies are addressing, what are those practices, what should be considered fundamental practices for implementing the lean production.

More specifically, some studies categories practices for lean production (e.g. people, process, tools). Shah and Ward (2003) grouped the practices into four categories: Just-In-Time (JIT), total quality management (TQM), total preventive maintenance (TPM), and human resource management (HRM), while this has 22 lean practices. Rahman et al. (2010) enumerate 13 practices out of the practices identified by Shah and Ward (2003) and they have grouped them in four categories. Moreover, Shah and Ward (2007) divide 10 factors into supplier-related, customer-related and internally-related (the process inside a firm). Chavez et al. (2013) descripting the internal lean practices that is mostly used on a shop floor of a firm, in another word hard practices and its effect on other dimensions such as quality and flexibility. Several studies have addressed lean practices in a different way by dividing them into two: soft practices and hard practices, such as (Kochan & Lansbury (1997); Rahman & Bullock (2005); Shah & Ward (2003); Yang et al. (2011)). Whereas, soft practices are focusing on people, for example, managerial practices and relationships (i.e. continuous improvement, top management leadership, and customer and supplier involvement), hard practices are concerned with technical and analytical tools, for instance, statistical process control and Kanban (Bortolotti et al. 2015). The latter also noted that the reason that most companies struggle with adopting lean production or getting the success they are looking for, resides mostly in ignoring soft practices and applying only the hard practices. Some practices may not be suitable for other region's employees; in this respond, Oudhuis and Olsson (2015) noted that regional differences should be taking in to account before implementing a production system. This all indicates that contingencies related to regional context may have a noticeable impact on the implementation of lean practices.

The second lens concerns the application of lean production principles (Bhasin 2012) to the design of production systems. For example, Low et al. (2015) study how to apply the lean principles to the design of a factory. In this strand of research, some studies use the principles for designing the firm, whereas (Black 2007 and Sobek II et al. 1999) fall back on the 'pure' Toyota production system. In addition, there are studies mentioning the lean principles for production as key to the design of production system (Black 2007; Mund et al. 2015; Low et al. 2015; Sobek II et al. 1999; Yadav et al. 2010). According to Yadav et al. (2010), the Toyota production system can be captured by four basic rules: (i) activities (how people work); (ii) connections (how the people connect); (iii) how the production line is constructed (pathways); and (iv) continuous improvement. According to Low et al. (2015), there are 11 key principles for lean production and the core is reducing the non-value-adding activities.

Some studies addressed applying the different principles on different regions without generalisation of the regional contexts such as Low et al. (2015) and Yadav et al. (2010). On the other hand, Sobek II et al. (1999) believed that applying the design principles of the Toyota production system is not related to the regional contexts. This all points to the necessity for evaluation whether contingencies related to the regional context have an impact on the design of production system.

Regional Context

For both lenses - lean production as a set of practices and lean as design of production system – contingencies related to the regional context need to be further specified, four dimensions could serve as initial classification (Aldossary et al., 2016). More specifically, the distance between a supplier and a manufacturing company to expand the most benefits from JIT (Cook 2001); also Arkader (2001) mentioned the location as barrier to JIT.

Culture differences between two nations (Wangwacharakul et al. 2014) or different cultural perspectives in an organisation, which includes the employees' relations and issues; which leads to cultural dimension. Another dimension concerns that get in the way of doing the business or smoothing the flowing of goods from a location to another or from a supplier to a company, as few studies described it as regulation and certificates (see Maleyeff et al. 2012; Rodgers & Wong 1996), which can be named as legislative dimension. Finally, considering the different ways that an organisation can look at its financial performance that may be a challenge in the implementation, as well as not having the right investment to help with the implementation change (Ketokivi & Schoeder, 2004), which can be linked to a financial affect. The geographical, cultural, legislative, and financial-economic dimensions can serve as classification of contingencies within regional context.

Research Methodology

Given the limited literature on this topic, and with the aim to achieve a deeper understanding of the effects related to regional context on the implementation of lean production, the study applied an exploratory multiple-case study methodology (Creswell 2003; Yin 2009). According to Eisenhardt (1989), case studies are useful when the phenomenon has not yet received appropriate ascertainment within the literature and when theoretical knowledge lacks clearness with respect to underlying issue. Moreover, multiple cases may help to understand the meaning and nature of real-life events, such as processes, relations and changes on organisational and individual levels (Yin, 2009).

In this respect, and for the explorative purpose aimed towards understanding, the empirical data for the case studies was collected through multiple methods and sources (Miles & Huberman, 1994; Yin, 2009). These included mainly semi-structured interviews and observations. Multiple interviews with top management and shop floor employees were conducted which lasted between 60 and 75 minutes. The interview data were supplemented with data collected through secondary sources, such as, project documentation, company guidelines, and web sites, and observations during the guided tours in the companies.

Case Study R1

The first empirical case (R1) concerns a manufacturing company in the aerospace industry. The company is in the medium size range with number of employees between 200 to 300 employees. R1 was founded in 2010 and the design of lean production was implemented from the beginning, adopted since they are a subsidiary of a conglomerate. Company R1 a full-service company includes extrusion, machining, and assembly into a single facility. Which serve customers all over the world from the far west as the United states to the far east Japan and China.

The value chain process followed by the company involves five main steps: (i) billet casting, (ii) extrusion, (iii) machining, (vi) surface treatment, and (v) assembly. In those steps for the analysis of the case study, they were assessed and investigated based on the dimensions mentioned before. Taking in perspective the plant size of the company, which almost includes three plants in one, which are the main three extrusion, machining and assembly. The delivery time of the company if the external suppliers are not involved the time is 8 days, however, when external suppliers get involved the time varies with no certainty.

Case Study R2

The second empirical case study (R2) is also a company in the aerospace industry, they focused on overhaul. Also, the company is a medium-sized company with the number of

employees being between 200 and 300. The company started implementing lean production with aim to cut waste, identification of internal benchmarks and giving ideas and concepts for specific problems.
Therefore, they are using five steps of the product line; starting with (i) the product comes in to the plant, (ii) the company assessed the product, (iii) orders placed for needed parts, (vi) components get reassembled, and finally (v) components are shipped back to the customer. The delivery time varies in between minor to major remanufacturing on the unit. The delivery time from the unit register to the plant to the time of leaving the facility ranges between 3 months to 18 months.

Results and Findings
The analysis followed the general thematic analysis approach indicated by Braun and Clarke (2006): i) familiarisation with data, ii) coding, iii) searching for themes, vi) reviewing themes, and v) defining and naming themes. Interview and focus group transcriptions were coded, checked and rechecked throughout the coding process for consistency. Whereas some themes were already latently found in literature discussed at the previous section, the analysis of the data gave rise to additional themes. The themes were reviewed and re-categorised resulting in to four main themes (Table 1), also can see Aldossary et al. (2016). The following sections will discuss in detail the findings of each dimension. The themes also

Geographical Dimension

The geographical dimension, is concerned with the location of companies, location of suppliers being in a cluster (Porter 1998), the relationship between the company and their supplier, and any geographical barriers related to the implementation of lean production. Whereas company R1 can manufacture all the necessary parts in site, there are cases when it is required to order these from external suppliers. More specifically, there are certain customers who may require from R1 to use specific external suppliers. These suppliers can be based in different places either in the U.S. or in Europe, consequently, R1 faces constant challenge with time deliveries. For example, a delivery to the US may take up to six weeks, which exceeds standards of R1of time deliveries to customers. Similarly, is the situation when a shipment goes to the far East (e.g. China).

Company R2 manufactures some parts, meaning that their inventory level has certain parts that are used commonly. However, when it comes to certain parts related to the core of engines, these are all supplied from two external suppliers based in central-west Europe. These two suppliers, based in different countries, will have to be involved for the remanufacturing of one component. As a result, depending on the condition of the unit received, the delivery time from the external suppliers can take 2-3 months for minor remanufacturing and up to 18 months for major remanufacturing. As a senior manager of R2 explained, that makes it very hard to meet the delivery time; mainly because most of the times the suppliers will take longer time in delivering the parts.

Hence, due to geographical proximities, both companies R1 and R2 are facing challenge with the delivery of parts. In company R1 the main issue appears to be the distance, and for company R2 distance as well as uncertain delivery coming from suppliers' contingent on the state of parts. Finally, both companies are also affected by the poor infrastructure of the region they are based in; which can significantly increase the lead-time for logistics.

Cultural Dimension

The second theme concerns the cultural dimension which is focusing on the employees' behaviour towards lean implementation. In the case of R1, from the beginning

of the company's found the company was designed to implement lean production system; and therefore, the employees did not go through any transformation period. Irrespectively, it is important to note that R1 operates in the north of Romania. Specifically, in this part of the country, people have a high level of education, and at the same time, they are very family-oriented meaning that employees prefer to work close to their hometown with most of them willing to do so, even if it means there will be less pay. This is clear in the case of R1 where more than 90% of the employees come from the same region. But the company is having very skilled and well-educated employees, due to the strong family oriented mind-set in this part of the country, businesses do not operate during the weekends. That means that R1 is not able to receive or send deliveries of parts during the weekends, which reduces the flexibility to respond to logistic perturbations.

Opposite to first case, R2 did not have a lean production system from the beginning, and therefore, when the management decided to implement lean production practises and lean design of production system, all the employees had to go through a transformation period. As a result, management faced challenges with employees accepting the change. As a senior manager explained, it has taken a lot of time and effort to smoothly transit to lean production and even now (at the time of the interview), they are still dealing with some negative attitudes from employees who find this system more demanding.

Legislative Dimension

The third theme, legal dimension, is mainly related to certification of some aerospace parts and the intellectual property agreements that the companies must obey. This means that without the necessary agreements, the company cannot produce certain parts they need. The legal dimension also concerns with the legal agreement that links each company with suppliers overseas. These legal issues contribute on the factors that affect the implementation of lean production. Whereas, companies R1 and R2, have this dimension as a contingency on the implementation of lean production, the legal factors are recognised as a way for controlling in this industry. For instance, in R1 there are fixed contracts with certain customers indicating that the customer's suppliers must be used on producing a product to that customer. Furthermore, they are certifying the products and some parts the companies R1 and R2 produced by the top customers in the industry.

Financial Dimension

The fourth and final theme, financial dimension, concerns the investment of implementing lean production and the plants' layout. In this regard, company R1 has invested heavily on the plant, and they are expanding the volume of production for the plant to reach its full capacity. Moreover, R1 is planning strategically to have another plant ready when the capacity of the first plant hits the maximum. At the same time, also tries to have duel source of producing all the parts needed to cut their costs and save time. However, the extrusion part of the company is in full capacity, and it causes delays to the other parts of the plant such as assembly line.

In Company R2, the case is slightly different. The budget for investing on the design of the production system is very limited, and the company tries to develop year by year. The flow of the units is not as smooth as it should be, but the company is making the most of the resources they have. Despite all the shortages in budget regarding the design, R2 is functioning is high-quality outputs.

The results of the two case studies confirm that the regional context does have an impact on the implementation of lean production. For instance, the cultural dimension within company and country shows a variety of aspects that have an impact on the implementation, such as; the employees' acceptance of change. Moreover, from the

geographical perspective, it is shown that the location of suppliers plays a considerable role in the implementation of lean production since both companies had first-tier suppliers abroad. Also, looking at the financial dimension of the companies, the support for the transformation of the production system varied from one company to another. Finally, the analysis of the legislative dimension in this study revealed challenges regarding intellectual property rights; more specifically, exclusive suppliers that were holding these rights for certain parts impeded on the flow of the production line, as the parts are only allowed to be produced from certain company.

In comparing the two cases, cross-case analysis was used to identify similarities and differences. Table 1 shows the findings of each case as well as the cross-case analysis of the two cases conducted.

Table 1 cross-cases analysis of contengencies related to regional contex

Theme	Case R1	Case R2	Cross-case
Geographical dimension	• Difficulty in connecting with customer and suppliers outside of EU, 6 weeks' shipment • Ideally one week is delivery time out of the plant • Delivery time sometimes gets delayed if external suppliers involved • Unpredicted the external suppliers with deliveries • Some customers prefer to be in reach with them location wise (not possible)	• The company deals with customers all over the world • Delivery time is not that accurate as dealing with multiple local and external suppliers • Using mainly external suppliers in EU • Issues in delivery with customers in outside of EU • Overall, quality wise is top in EU few times	• Delivery time goes beyond expected if shipping outside of EU • Using external suppliers that slows JIT
Cultural dimension	• In this region '*up north'* workers prefer to work at the same place as where their family (parents) live • Workers are family oriented • All workers here 'north' are educated • Minimum with a bachelor's degree, no less • Weekends are out of business for the company as well as delivery • Sometimes teamwork between plants are difficult, '*they would give each other hard time to help out'* • 12% is the workers turnover (*avg. in region*)	• Employees not happy with the change • Took time and effort to get into the change • Supportive top management but lower level workers nor cooperative with the change • Employees wanted to free times they had with the previous system • Number of training to be added • Knowledge of lean in not quite high between the workers	• Employees prefer living where the family lives (hometown) • Highly educated in the North • For old workers accepting the change to lean was not very successful • Shipments are limited to mid-week
Legislative dimension	• Fixed contracts to have customers' parts to be used in product they ordered. • Having the company dealing with the customer's suppliers • Some parts have to be delivered by externals suppliers in IP rights • Produced any parts they need if no IP restrictions • Big customers to visit plant and check quality themselves	• Certifying parts by big companies • All crucial mechanical parts from external certified suppliers outside of Romania • Company R2 authorise local suppliers	• Having main certified suppliers in EU – close in distance • Customers to certifies new products, as well as top companies in the industry • Contracts to link companies with certain suppliers of customers
Financial dimension	• Fully supported financially • Manufactured what they need to cut off costs and relatability on suppliers • Intended to improve the production line by cutting off extra 'check points' • Having dual source of getting parts • Intention of extended the plant To improve capacity	• Budget and investment of change is limited • Developing slowly • Using the plant layout as best for the budget • Layout is semi flow smoothly • Needs more development	• Design of plant is sufficient; it is developing to the best standard • Cut on costs as possible with local suppliers or manufacturing parts

Discussion of Findings

The first finding of this study is related to the financial investment of R1 and R2 on the design of the lean production operation system and the layout of the plant. In R1 the philosophy of was introduced when the company was founded; therefore, the company is accustomed to the system from the beginning, as well as having the footprint set for the production system. In the case of R2, the company started implementing lean production in 2012, and due to poor financial support they had a limited design developed to have the best design of the production system. The R1 has very slight disruption in the flow of the products, where the reason relates to the full capacity reached of the extrusion part of the plant and the unadjusted machines in the machinery side of the plant. However, in R2, the disruption in the flow of the units is caused due to the design structure not being on the highest standard, and not having considered and included all the necessary aspects as discussed by Black (2007) and Sobek II et al. (1999). Hence, the financial dimension plays a crucial role and more specifically, the limited investment affects in a high degree the design of the lean production system and therefore the operational performance of the companies.

The second finding concerns the effect of the geographical dimension has on the implementation of lean production. The location of the suppliers and ease of the supplier access play huge role in the success of applying the lean production. It was found that JIT is the practice mostly affected by the supplier access and location. For instance, company R2 is dealing mainly with two main external suppliers outside of Romania, which proves to be as one of their biggest challenges causing shortages in delivery time and delays. The situation is slightly different in company R1, it goes mostly the other way around which is the delivery to the customers. In both cases, once the supplier is located outside of the country and with the weekend work restrictions, that makes the impact on this dimension more tangible on the implementation. Therefore, the geographical dimension is found to be a barrier for successful implementation of lean production practices such as JIT, Kanban and Kaizen. This finding of the role of geographical dimension on the lean production practices supports the findings in literature of Cook (2001, p. 967) and Arkader (2001, pp. 91-2). Moreover, according to the analysis of the data gathered from both case R1 and case R2, it is evident that the role of the geographical dimension is the most challenging one for successful implementation of lean production.

The third finding is related to the organisational and regional culture. Our findings agree with the suggestions of Bortolotti et al. (2015) and Semeds (1994) that the organisational culture of a company may have significant effect on the successful implementation of lean production. More specifically, in case R2 the management faced the challenge of having the change to the lean production system. The acceptance is not easy from the employees' side. The company had to face some issues they have dealt with in some ways as they explained. Moreover, regarding the cultural dimension, the people who live in the north part of the country tend to be more educated and family oriented, who does not prefer to be working away from their hometown. As a cultural background of Romania with some ties of the religious beliefs, the weekends in the country is blocked, the compananies R1 and R2 are affected by this, as they are unable to make deleveries during the weekends.

The fourth and final finding in this study is about the legal dimension and how it may affect the implementation of lean production. The two companies mainly dealing with companies for the parts needed. Some of the companies are involved in certifying a product to be sold to top customers. Furthermore, some of the top customers relate their suppliers to be in link with Company R1. For example, if R1 want to have business with one of the leader in the industry, that customer requires R1 to deal with all materials

needed from the same supplier they deal with. Company R2 on the other hand, the suppliers they deal with are externals, and they are the ones who certify the R2 products based on legal ties. The reasons for having the connection only with these external suppliers is the intellectual property (IP) holders for certain parts; and therefore, the parts must come from them. Hence, whereas it is acknowledged that this dimension may affect in some degree the implementation of lean production, the companies have little to no control on most of the legal issues.

The four findings of this study show how regional dimensions can have different effects on the successful implementation of lean production. It is concluded that the most dominant regional dimension with the highest degree of effects is found to be the geographical dimension and the one with the least important effects is the legal dimension; it has effect but it could be mitigated.

Conclusion

The results of the case studies show that successful implementation of lean production is affected by dimensions related to the regional context they operate in. Therefore, this investigation study overcomes shortcomings of previous studies that have not considered this in sufficient detail. Hence, the conjectures and findings add new insight to the current literature. These findings are expected to give direction to managers about the successful implementation of lean production using the four dimensions.

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Job demands and job resources in a lean company: The influence on employee well-being

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Abstract

This study aims at investigating the effect of lean-related work aspects on employee well-being. Based on the job demands-resources theory, we propose that soft lean practices (SLP), acting as job resources, and negative lean-related job characteristics, acting as job demands (JD), interact each other in affecting employee work engagement and exhaustion. Data from 147 shop-floor workers from a multinational manufacturer supports SLP positive effect on engagement and JD negative effect on exhaustion. Moreover, there is evidence of a significative interaction supporting that SLP may reduce JD negative effect on exhaustion, and that JD may enhance SLP effect on engagement.

Keywords: Lean Management, Soft Lean Practices, Employee Well-being

1. Introduction and Purpose

The impact of Lean Manufacturing (LM) on employee well-being has been discussed in many fields such as OM, applied psychology and industrial relations (Hasle et al., 2012). In spite of many contributions from different literature streams, the debate is far from being closed. Scholars have recently assumed a fine-grained perspective onto the question, going beyond the simplistic view that LM is either totally good or bad.

This research intends to contribute to this debate by analysing whether and how positive and negative lean-related job characteristics in a lean company can influence employee well-being, in terms of work engagement (ENG) and exhaustion (EXH).

In comparison to previous research, a first element of originality of this study is the adoption of a relatively novel psychological model to address this research question: the Job Demands-Resources model (JDRM - Bakker and Demerouti, 2017). This is particularly valuable since the purpose of the present research is to account for both positive and negative lean-related work characteristics – called job demands (JD) and

job resources (JR), respectively. The JDRM provides interesting arguments to develop precise hypotheses on how negative and positive lean-related aspects can influence work engagement and exhaustion. In human resource management literature, we found some few works (not published in OM journals) (i.e., Cullinane et al., 2014; Huo and Boxall, 2018) which try to investigate the lean-well-being relation through JDRM. However, results are not conclusive, and they showed important limitations in their research frameworks, since they consider very few lean-related job resources and, in Huo and Boxall (2018), lean-related job demands focus only on job requirements due to problem-solving pressure. A second element of originality of this research, instead, is the attempt to develop and test a more holistic model including several soft practices as lean-related job resources and two distinct types of lean-related job demands: JIT-related hindrance job demands (JIT-JD), and problem-solving-related challenge job demands (PS-JD).

Section 2 introduces the literature on the lean effect on employee well-being. Section 3 provides the theoretical framework and section 4 presents the hypotheses. In section 5 we present the methods and the results and in section 6 we discuss our findings.

2. Lean and Employee Well-being

Since initial studies on lean manufacturing, its effect on workers has been a crucial subject of discussion (Landsbergis et al., 1999). Even Womack and Jones (1990, pp. 99–103), in their seminal book on the Toyota Production System, discussed about the hypotheses that lean may have a negative effect on working conditions, reassuring that in a lean plant, team working and autonomy are fundamental aspects able to replace mass-production "mind-numbing stress".

Generally, in scientific literature evidences supporting both positive and negative effects of lean can be found. On one side, lean opponents reported that the systematic waste elimination (e.g., buffer reduction) through process analysis and standardization may have an impact on employees, reducing their autonomy and increasing work pace and interdependence, leading to psychological strain and musculoskeletal disorders (Landsbergis et al., 1999). On the other side, in agreement with Womack and Jones, other researches showed that working conditions may be improved by LM in comparison to previous Tayloristic systems, since employee participation in continuous improvement teams and suggestion campaigns may increase experienced autonomy, positively affecting employee well-being (Hasle et al., 2012).

Recently, scholars proposed to move beyond the simplistic view that lean is entirely good or bad, suggesting to assess the impact of different lean dimensions on employee well-being and the role of specific contextual factors such as lean implementation strategy, in modifying this relationship (Hasle et al., 2012).

In particular, some researchers investigated the specific contributions of soft lean practices (SLP - i.e., practices focused on employee involvement - Bortolotti, Boscari, et al., 2015) and hard lean practices (e.g., kanban, JIT, etc.) suggesting that just-in-time (JIT) may increase negative work characteristics (e.g., work pace) and damage employee well-being, specifically when overlooking human-related elements that may act as balancing factors (Hasle et al., 2012). A first piece of evidence on this claim can be traced back to the early study of Parker et al. (1995) in the British automotive industry. They reported that lean led to negative effects where introduced without employee participation, whilst a positive impact was found when employees were actively involved. In this direction, Longoni et al. (2013) in a qualitative exploratory study, propose again that Lean HR

bundle is fundamental in reducing the harmful effect of JIT, suggesting further research efforts in confirmatory large sample studies.

3. Theoretical Framework: The Job Demands-Resources model

One relatively novel psychological model that can help to shed light on the contradictory results available in literature is the job demands-resource model (JDRM - Demerouti et al., 2001). This model hypothesizes two distinct but interrelated mechanisms, named health-impairment process and motivational process, that concurrently affect burnout and work engagement, respectively. The health impairment mechanism is activated by those physical, social, or organizational aspects, called job demands, that require sustained physical or mental effort and are associated with a psychological or physiological cost. In contrast, the motivational process suggests that job resources, defined as those physical, psychological, social or organizational job aspects, functional in achieving work goals, reducing job demands and their costs, stimulating personal growth and development, have a motivational effect and foster work engagement.

In addition, consistently with other stress theories (Hobfoll, 2002; Karasek, 1979), the JDRM hypothesizes that resources and demands interact each other, reciprocally modifying their impact on burnout and work engagement. Specifically, it posits that job resources can buffer the impact of job demands on burnout and that job resources plays a higher salience on work engagement when job demands are high. The underlying idea is that positive work characteristics acquire relevance for well-being particularly under demanding conditions. Moreover, they can offset the negative impact of other stressors in fostering burnout.

Recently the JDRM has been updated introducing an important distinction between two types of job demands: hindrance and challenge job demands (van den Broeck et al., 2010; Crawford et al., 2010). Whilst both job demands are considered as positively affecting burnout (in agreement with JDRM health impairment mechanism), hindrance job demands are even negatively linked to engagement, while job demands that are interpreted as challenging, are positively related to engagement.

Moreover, even job resources main impact on exhaustion has been subject of investigation. Indeed, recent reviews provided pieces of evidence on a weak direct impact of job resources on exhaustion (Bakker and Demerouti, 2017; van den Broeck et al., 2010; Crawford et al., 2010).

4. Lean and the Job Demands-Resources model

The JDRM can be used to explain lean literature previous findings and particularly the crucial role of SLP in affecting employee well-being. In general, lean literature agrees to consider SLP as positive work aspects that may improve employee well-being, generally through specific work characteristics (Conti et al., 2006; Cullinane et al., 2014). For example, researches often link SLP with an increase of workers' autonomy and skill variety thanks to workers' participation in small group problem solving activities or employee suggestion campaigns, that in turn are associated with employee well-being (Conti et al., 2006; Cullinane et al., 2014; Huo and Boxall, 2018). Moreover, other lean aspects like management leadership for lean, management presence on the shop-floor and coaching can enhance other positive work aspects like feedback from the job, feedback from the others and work facilitation, positively affecting employee overall engagement (Drotz and Poksinska, 2014; de Treville and Antonakis, 2006).

Given these considerations, we posit that SLP act directly as organizational job resources and thus, in agreement with the JDRM, we hypothesize that:

H1: SLP are positively related to ENG.

H2: SLP are negatively related to EXH.

Regarding the health impairment mechanism, empirical research suggested that JIT tools are associated with an increase of specific negative work characteristics such as work pace and task interdependence (Hasle, 2014; Landsbergis et al., 1999). In particular, this is due to an excessive focus on *muda* reduction such as inventories that may intensify workforce pace and interconnections. Since these job characteristics have been associated with an increase of stress by organizational psychology literature (Karasek, 1979; Wong et al., 2007), we hypothesize that these JIT-related job demands (JIT-JD) act as hindrance demands. Therefore, we posit:

H3: JIT-JD, acting as hindrance job demands, are positively related to EXH.

H4: JIT-JD, acting as hindrance job demands, are negatively related to ENG.

Another work characteristic that has been recognized by previous studies as a potential negative lean element, is problem-solving-related job demand (PS-JD), defined as the degree to which the worker perceives that his/her job requires unique ideas or solutions (Cullinane et al., 2014). However, there is no agreement on PS-JD positive or negative impact on employee well-being. In line with Huo and Boxall's recent study (2018), we posit that PS-JD may act as a challenge job demand fostering work engagement but even having a potential exhausting effect on workers:

H5: PS-JD, acting as challenge job demands, is positively related to EXH.

H6: PS-JD, acting as challenge job demands, is positively related to ENG.

In agreement with the interaction mechanism hypothesized by the JDRM we even suggest that job demands and SLP interact each other. We hypothesize that SLP have a higher impact for those workers experiencing more demanding conditions, either in terms of JIT or problem-solving. Furthermore, we posit that JIT-JD and PS-JD impact on exhaustion is mitigated by SLP, acting as job resources:

H7 (a and b): SLP reduces the positive impact of JIT-JD (a) and PS-JD (b) on EXH.

H8 (a and b): JIT-JD (a) and PS-JD (b) increase the positive impact of SLP on ENG.

Figure 1 represents the framework underlying this research and the developed hypotheses derived from the Job Demands-Resources model and LM literature.

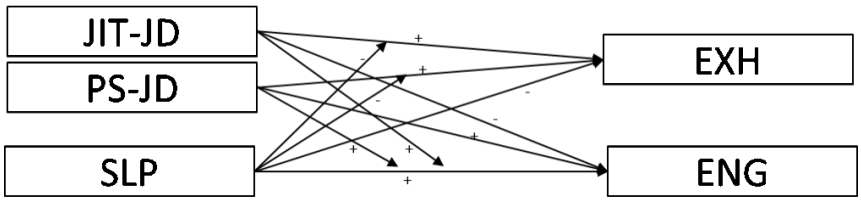

Figure 1: Theoretical model

5. Methodology and Results

Context and methods

This study was performed in an Italian subsidiary plant of a multinational home appliance manufacturer which employs 530 production workers. Lean manufacturing was

introduced in 2006 as part of the group operations strategy. The plant was chosen for the research since it has a stable financial position and it has embraced all lean bundles and it has a good lean reputation, certified by the lean group audits.

We verified lean implementation visiting the plant, checking company audits and interviewing change agents and management, following a protocol based on Shah and Ward's (2007) lean bundles. Regarding SLP, the company has extensively invested in employee involvement in lean. Implemented practices include multifunctional groups to solve production and quality problems, suggestion system, top and middle management involvement in lean implementation and lean coaching inspired by Toyota Kata approach (Rother, 2009). Despite the broad application of these SLP, managers recognize an internal variability in perception of these practices among employees, due to the heterogeneous workforce involvement.

Based on lean-employee well-being scientific literature and the JDRM, we developed a survey questionnaire with most relevant SLPs, lean-related job demands and employee well-being measures, validated with company managers and pilot tested with employees. All utilized items were adapted from previously validated scales in order to measure, at individual level, all relevant constructs. The survey was administrated to 147 randomly selected workers that filled in a paper-based version during their work shift. During analysis 9 respondents were dropped due to unproper completion.

Table 1 reports utilized first-order constructs, their definition, mean, standard deviation and the final number of items kept.

*Table 1 Included constructs. *constructs measured as second-order factors*

CONSTRUCTS		**DEFINITION**	**N° ITEMS (*KEPT*)**	**MEAN (SD)**	**CR**
Work Engagement (ENG)		Perception of a positive, fulfilling work-related state of mind	8 (*5*)	4.74 (1.28)	0,86
Exhaustion (EXH)		Perception of intensive physical, affective and cognitive strain, as a long-term consequence of prolonged exposure to work stressors	8 (*4*)	3.93 (1.18)	0,71
SLP*	Small Group Problem Solving	Perception of how much effective problem-solving teams are perceived, based on individual participation	5 (*4*)	5.47 (0.93)	0,86
	Employee Suggestions	Perception of encouragement, participation and feedback for improvement proposals	5 (*4*)	5.44 (0.95)	0,83
	Shop Floor Contact	Perception of presence and support of management in production	5 (*3*)	5.25 (1.07)	0,77
	Top Management leadership for Lean	Perception of leadership for Lean	5 (*3*)	5.81 (0.87)	0,86
	Coaching	Perception of received coaching as a form of facilitating learning to encourage growth and development	8 (*5*)	5.24 (1.21)	0,90
JIT-JD*	Work pace	Perception of work rate	3 (*3*)	5.28 (1.21)	0,86
	Interdependence	Perception of the degree to which employee's own job depends on others' jobs and others' jobs depend on his/her individual job to be completed	6 (*4*)	5.14 (1.04)	0,66
Problem-solving related job demands (PS-JD)		Perception of the degree to which a job requires unique ideas or solutions and reflects the more active cognitive processing requirements of a job	4 (*3*)	4.37 (1.34)	0,66

Dependent variables are work engagement and exhaustion in agreement with previous studies adopting the job demands-resources model (e.g., Demerouti et al., 2001) and the two mechanisms hypothesized by the model. Both variables were measured using OLBI scale (Demerouti et al., 2010). SLP were measured as a second-order construct that included five specific first-order soft lean practices: small group problem solving, employee suggestions, shop floor contact, top management leadership for lean and coaching (Bortolotti, Danese, et al., 2015; Chi Anh and Matsui, 2011; Ellinger et al., 2003; Flynn et al., 1994; Ugboro and Obeng, 2000). JIT-JD were measured using a

second-order construct including two work characteristics: work pace adapted from Pejtersen et al. (2010) and task interdependence from Morgeson and Humphrey (2006). Problem-solving demand was measured using Morgeson and Humphrey (2006) scale.

For each item, respondents indicated their level of agreement on a seven-point Likert scale, from 1 (strongly disagree) to 7 (strongly agree). In addition, we included age, gender, shift vs. day work, organizational tenure, experience with the current position and current work unit, as control variables in our hierarchical regression analysis.

We verified items normality checking kurtosis and skewness and, in agreement with other previous studies (e.g., Bou-Llusar et al., 2009; Wu et al., 2015), to additionally protect our structural equation analyses from possible deviations from normality, we used Satorra and Bentler (1994) scaled goodness- of-fit test statistics, that, under non-normality conditions, generally outperform traditional fit indices (Byrne, 2016).

We control for common method bias *a priori* via items shuffling and *a posteriori* we statistically verified the poor fit of a single-factor model (χ^2=1327; χ^2/df= 1,99; CFI=0.65; RMSEA=0.0963; SRMR=0.096).

In order to validate our measures, we performed maximum likelihood confirmatory factor analysis (CFA), running a single-factor-model for every first-order construct (Jöreskog and Sörbom, 1989). All models showed adequate fit (χ^2/df<3.0, CFI >0.90, RMSEA<0.08, SRMR<0.08) and convergent validity in terms of significance and magnitude of factor loadings (>0.50), except for one interdependence item (loading 0.45) that was kept for content validity reason.

Then, we tested our second-order soft lean practices and JIT-related job demands constructs together in a single model since JIT-related job demands is composed by only two first-order factors. The model showed good fit ($\chi^2(292) = 358{,}6$; $\chi^2/df = 1.228$; CFI=0.950; RMSEA=0.047; SRMR=0.067) and all first-order factors loaded on the specified second-order latent construct with factor loadings significant at p-value <0.001 and higher than 0.50. In agreement with some previous studies (Bortolotti, Danese, et al., 2015; Sila, 2007), after second-order construct validation, we parcelled first-order constructs belonging to second-order constructs, to get an simplified testable structural model (Little et al., 2002).

Finally, we tested a simplified model containing all constructs related to our hypotheses. The CFA model showed a good fit ($\chi^2(143) = 213{,}8$; $\chi^2/df = 1.495$; CFI=0.932; RMSEA=0.066; SRMR=0.066), providing further evidence of convergent validity (all loadings >0. 50 and significant for p-value<0.001).

Discriminant validity was assessed through Bagozzi and Phillips's approach (1991), using Chi-square difference among two nested models for each pair of constructs, adjusted for Satorra and Bentler Chi-square values. All tests were significant for p-value< 0.01. Reliability was assessed through composite reliability (CR). For all constructs CR exceeds the minimum level of 0.60 suggested by Bagozzi and Yi (1988) (see Table 1).

Results

We tested our hypotheses through hierarchical regression (HR) and structural equation modelling (SEM). HR results are reported in Table 3. For HR, we controlled residuals normality and homoscedasticity graphically checking P-P plot residuals against predicted values distribution. We controlled for multicollinearity, mean-centering interaction variables (Jaccard et al., 1990) and checking variance inflation factors.

Predictors	Dependent variable Y: Work Engagement M1	M2	M3	M4	Dependent variable Y: Exhaustion M5	M6	M7	M8
Constant	5,489***	4,612***	4,772***	4,973***	3,266***	3,861***	3,672***	3,786***
Age	0,037	0,178	0,173	0,139	0,172	0,063	0,069	0,071
Employment period at the current company	0,074	-0,132	-0,112	-0,129	-0,055	0,095	0,071	0,094
Experience with current type of job (including other companies)	-0,137	-0,075	-0,091	-0,104*	-0,032	-0,069	-0,050	-0,063
Sex	0,227	0,196	0,274	0,241	-0,150	-0,108	-0,199	-0,117
Shift	0,069	0,178	-0,057	0,188	-0,296	-0,483	-0,204	-0,485
Work Unit	-1,216***	-0,221	-0,221	-0,289	0,912***	0,364	0,364	0,378
Soft Lean Practices (SLP)		0,854***	0,898***	0,809***		-0,579***	-0,631***	-0,569***
JIT-related job demands (JIT-JD)		-0,237**	-0,179*	-0,224**		0,243*	0,173†	0,240*
Problem-solving-related job demands (PS-JD)		0,239***	0,212***	0,237***		-0,071	-0,038	-0,070
SLP*JIT-JD			0,254**				-0,301**	
SLP*PS-JD				-0,169*				0,035
R^2	0,249	0,655	0,681	0,669	0,146	0,331	0,374	0,332
R^2 adjusted	0,215	0,631	0,656	0,643	0,107	0,284	0,325	0,279
ΔR^2		0,406	0,026	0,014		0,185	0,043	0,001
F- value change	7,244***	50,207***	10,345**	5,457*	3,734***	11,813***	8,674**	0,138

Table 2 HR results. † p-value < 0.10; p-value < 0.05; ** p-value < 0.01; *** p-value < 0.001.*

HR results are reported in Table 2. In Models 1 to 4 results regarding work engagement are depicted and in models 5 to 8 results refer to exhaustion.

Results found show that hypotheses H1 and H2 are supported, being SLP positively linked to engagement and negatively to exhaustion. Moreover, there is empirical support to H3 and H4, being JIT-JD positively related to exhaustion and negatively related to work engagement. PS-JD is positively related to engagement (H6 held) but not to exhaustion (H5 not held). Finally, the findings support H7a and H8a. In particular, we found that soft lean practices may be more effective under more JIT-demanding conditions and JIT-related characteristics are less exhausting for those workers that experience higher SLP.

It is worth noting that the hypothesized interaction between SLP and problem-solving-related job demands is significant but negative for the effect on engagement, in contrast with H7b, and that there is no significant evidence for H8b as regards exhaustion.

To triangulate our HR findings, we performed moderated structural equation modelling (MSEM) to test our hypotheses. The interactions were computed through Ping's (1995) two-step procedure. Given that in previous HR models, there wasn't a consistent effect of any of the included control variables, for parsimonious reasons we didn't include controls in SEM.

Figure 2 reports SEM results. Fit indices prove an acceptable fit ($\chi^2(172) = 243{,}94$; $\chi^2/\mathrm{df} = 1.418$; CFI=0.934; RMSEA=0.060; SRMR=0.0621).

SEM results mostly confirm HR results. An exception is the negative impact of the interaction between SLP and PS-JD on engagement in HR, that is non-significant in SEM. For this reason, we do not consider as significant this interaction.

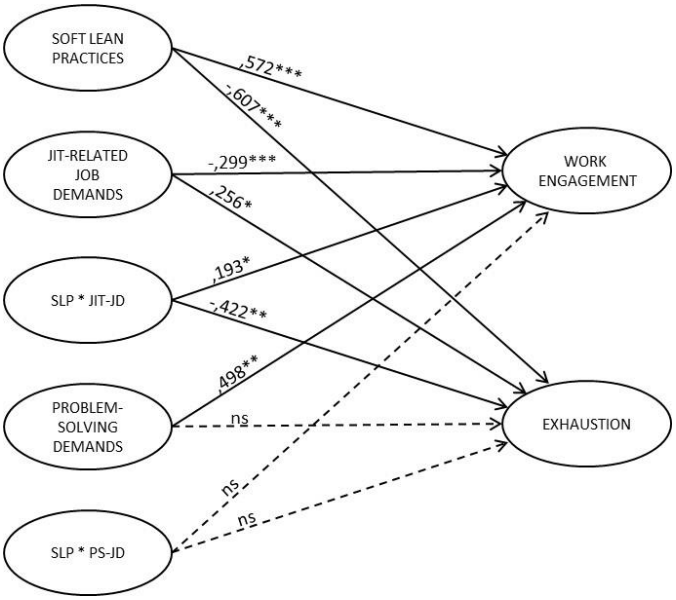

Figure 2 MSEM results. Standardized regression weights are reported.
** p-value < 0.05 level; ** p-value < 0.01 level; *** p-value < 0.001*

6. Discussion and conclusion

Our findings confirm that SLP significantly increases employee well-being, being positively related to engagement (H1 held) and negatively related to exhaustion (H2 held). Regarding job demands, JIT-JD has a negative impact on engagement and positive on exhaustion, as hypothesized (H3 and H4 held). In addition, its interaction with SLP has a significant impact on both exhaustion and engagement, as expected (H7a and H8a held). As concerns PS-JD, instead, while it is positively and significantly related to engagement, it hasn't a significant effect on exhaustion, nor its interaction with SLP significantly impacts exhaustion and engagement (H5, H7b and H8b not held).

This research contributes to research and practice in different ways.

Firstly, by applying the Job Demands-Resources model, we developed and tested precise relationships, confirming that soft lean practices act as job resources by increasing employee engagement and reducing exhaustion. As regards engagement, our result extend Cullinane et al.(2014) findings, providing empirical evidence that SLP have a higher impact on engagement when job demands are high. This means that SLP acquires incremental relevance for those workers that cover more demanding conditions and are more exposed to JIT negative effects. Most importantly, SLP seems to play a crucial role in reducing the negative effect of JIT-related job demands, such as work pace or interdependence, on exhaustion. This is a novel finding, not quantitatively confirmed in previous research. It offers support to anecdotal evidences claiming that soft side of lean is crucial to avoid a negative effect on workers.

Secondly, the result that problem-solving demand is significantly related to engagement and not to exhaustion opens a debate on whether problem-solving demand in a lean company really represents a challenge job demand.

Thirdly, this research shows that the link between lean and well-being cannot be studied at a plant level. In our case, hard and soft lean practices were well-diffused and widely implemented in the whole plant, but workers' perceptions about lean-related job demands and resources varied significantly at an individual level, and as a consequence also employees' wellbeing.

From a practitioners' perspective, our research provides a scientific basis regarding the fundamental role played by SLP in LM implementation for worker well-being. This research advices managers that workers experiencing higher JIT-JD may benefit more from SLP, since these extra-resources are more needed in more demanding working conditions. Instead, an improper lean implementation, without adequate SLP, may harm employee well-being due to JIT negative effect.

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Gemba walks in service operations: Useful or useless?

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Abstract

The gemba walk is a common management practice that differs in service operations from production. We explore the concept of gemba walk with a multiple case study in the service sector. We study the application within a utility service provider, a telecommunication company and a hospital. We investigate different service settings and find relevant conditions for its suitability. We find that gemba walks are useful when processes are codified and visual. Gemba walks seem not suited for geographically distributed service teams. In addition, the organisations' lean maturity level, management turnover and agile transformation streams affect the walks' form, scope, purpose and efficiency.

Keywords: Gemba walk, management-by-walking-around, go and see

Introduction

Management-by-walking-around (MBWA) is a leadership practice that emphasize visible leaders (Peters and Waterman, 1984). In the lean production literature, this leadership practice is known as the 'gemba walk' (Imai, 2012, Womack, 2013). 'Gemba' is a Japanese word for 'the real place', meaning the place where value is created. A common English term for gemba walks is 'go and see'. Managers go to the place where value is created to observe work processes and talk with the people conducting the work. The purpose is to enable managers to lead based on facts and provide them an opportunity to motivate and coach employees for the work. Gemba walks are a widespread and integrated part of many lean transformation programs (Womack and Jones, 2010) and believed to be essential for their success (Mann, 2014). However, how effective is this management practice if the work cannot be observed?

Many services are intangible, heterogeneous, perishable and inseparable from consumption. Does the gemba walk concept still apply? Many authors of lean books suggest that the answer to this question is 'yes' (Petruska, 2012, Womack, 2013). However, common sense suggest that the answer may be 'no' in many service contexts. First, if an important part of gemba walks is that managers observe work in order to learn about it, it requires that the work can actually be observed. In difference from the physical process in manufacturing, it can be difficult to observe service processes that are done on computers. Second, if service processes are taking place in the field where the customers are located, it can be impractical for managers to conduct regular gemba walks. Third,

when service processes include close customer interaction, managers must be careful not to disturb the service process (Hampson and Junor, 2005, Tucker and Singer, 2015). Fourth, because service processes vary, it can be difficult for managers to assess the quality of the work. Fifth, many services processes are high-level cognitive processes, often knowledge intensive and tacit, which makes is hard for leaders to coach the work (Leonard-Barton, 1995). All these arguments question the applicability of gemba walks in different service contexts.

We set out to explore the suitability, forms, challenges and opportunities of gemba walks in service operations. We start with a literature review before presenting our qualitative research method and setting. Subsequently we analyse the data for each case before discussing findings and developing propositions. In the last section, we conclude.

Literature review

MBWA was proposed in Peters and Waterman (1984) bestselling book *In search of excellence*. They studied 43 companies deemed as "excellent" and observed that successful managers were often purposefully wandering in the offices or factories to observe work processes and talk with and listen to their employees. CEOs and managers engaging in the *field* instead of their offices are considered a 'technology of keeping in touch, keeping in constant informal contact' (p.123.), a better way of solving problems on the job and therefore an essential management practice for successful business organisations. In the lean manufacturing world, MBWA is known as *gemba walks*. 'Gemba' (sometimes, 'genba') is a Japanese term that means 'actual place' or 'real place', meaning where work that adds value for the customer takes place (Imai, 2012).

Gemba walks aspire managers to verify facts over data (Rother, 2010, p. 135), to lead from the workplace and prevent virtual isolation (Ballé, 2014, Serrat, 2017) and to promote and track lean transformation (Mann, 2014, Liker and Ross, 2017). Go and sees achieve also understanding of the purpose and underlying processes of managers and their subordinates' work, develop and empower people (Bremer, 2016, p. 15) and practice desired leadership behaviours with biggest impact on employee and customer satisfaction (Folkman, 2016, Bicheno and Holweg, 2016). The gemba walk's most essential purpose however is to teach people, to learn from *on the job* and to achieve improvement while 'doing' (Rother, 2010). This teaching practice is typically in alignment with Toyota's 'master-apprentice' model: the master or in Japan 'sensei' going to the floor, asking questions promoting the subordinate's lean thinking ability and triggering consistent improvement (Mann, 2014). The idea is that the apprentice learns 'through experience and consequences in live situations' (Mann, 2014).

The forms and characteristics of gemba walks are diverse and build on intention, scope and extent of the walk. According to Bremer (2016, p. 53) there are four different types: the department walk, the leadership team walk, the value stream walk, the outside executives walk and the fake walk (Table 1). Fake walks should be prevented as they represent an untruthful view of the gemba.

Table 1: Gemba walk types (Bremer, 2016)

Type	Purpose	Scope	Executer	Frequency
Department walk	Standard work practice validation, performance management, issue and resolution management, progress reconciliation, employee engagement and coaching	1 cell	Manager, supervisor, team leader, key support person	Up to 3 times a day
Leadership team walk	Promotion of cross-functional collaboration, elimination of flow and critical thinking barriers	1-2 cells of a larger production area	Leadership team of a larger production area: general manager, engineering, maintenance etc.	Weekly
Value stream walk	Overall waste identification, including 'white space', i.e. between departments, coaching of higher-level strategic thinking and problem solving,	Entire product or service value stream	Leadership team of a larger production area: general manager, engineering, maintenance etc.	Weekly
Outside executives walk	Overall waste identification, coaching of higher-level strategic thinking	Entire organisation	External executives	Undefined
Fake walk	Show, 'royal tour', blame walk, gemba walk preparations, e.g. cleaning, data provision etc.	Undefined	Undefined	Undefined

Gemba walks in service operations differ from production. In services, the gemba is nothing physical and observation therefore constricted or impossible (Drucker, 2012, p. 44). Managers must rely on 'reduction, isolation and codification' to turn service products into something tangible which can lead to misjudgement and false directions (McColl-Kennedy and Schneider, 2000).

Service gembas are often geographically dispersed and visits to retail outlets, the field or offshore teams time consuming and sometimes infeasible (Corso et al., 2006). Leaders must therefore rely on technical evaluation means to facilitate a gemba walk at distance or compromise on visit frequency.

With the inseparability of service production and consumption and the direct customer involvement (Hill, 1977) a gemba visit can affect service operations negatively. Walkers have to find ways of 'observing without disturbing' and at the same time avoid distrust and stress in customer and service supplier (Hampson and Junor, 2005, Baggs and Kleiner, 1996). Some organisations hire 'mystery shoppers' to assess customer satisfaction (Finn and Kayande, 1999). Could they perform gemba walks on the manager's behalf?

Service quality is essential to go and sees. The determination and assessment of service quality is however highly complex as perceived differently by executives and employees plus dependent on employee's individual performance. Furthermore, the service provision is highly variable and the definition of service quality standards therefore nearly impossible (Parasuraman et al., 1985).

With these service peculiarities in mind, we will explore the gemba walk in different service settings and verify its practice.

Research method

We investigate the applicability of gemba walks using a qualitative case-based design (Voss et al., 2002). We chose a multiple case allowing the exploration of different contexts, within case and cross-case comparison (Baxter and Jack, 2008). We looked for 'extreme cases' that applied gemba walks in service settings. We selected three companies from three sectors that have all won awards for the lean transformation programs. A utility service provider (hereafter referred as 'UtilityCo'), a telecommunication company ('TelCo'), and a hospital ('SpitalCo'). All organisation have been championing lean services for the past five years. They have recently received external awards for their efforts. All organisations prescribe gemba walks as one of their lean practices, but none of them has defined a corporate standard for how to conduct them. The gemba walk of each case is our unit of analysis (Yin, 2013, Patton, 2014). Following 'perceptual triangulation' (Bonoma, 1985) we analysed multiple data comprising of interviews, observations, discussions and findings from reviewing documents and field notes. Applying a purposeful, intensity sampling strategy (Patton, 2014, p. 267), we chose departments who have conducted information-rich go and sees. In total, we examined seven gemba walk practices in three Swiss organisations.

During site visits, interviews, discussions and observations we gathered significant amount of information relevant to our research. In order to increase the reliability of the study the interviews were carried out with different stakeholders. Interviewees included managers, staff and lean coaches. We conducted 10 interviews. The interviews were partially conducted face-to-face during on-site visits and partially through telecom conferences. An interview guide was carefully designed and pre-tested. The interviews were semi-structured allowing the 'reconstruction of the interviewee's subjective view' about gemba walks (Flick, 2014). Interviews ranged from 20 min to 50 min and were conducted in German and Swiss German. With approval of the interviewees, we tape-recorded all interviews and shared recordings or transcripts on request. Besides the interviews, we attended three gemba walks and a half-day workshop consolidating the findings from all the walks within one department of one organisation. Observing walks, discussions and feedback sessions provided rich information about perceptions, challenges and employee-supervisor relationships.

Further, we assessed secondary data that included team descriptions, gemba walk reports and the lean practices of the three cases.

As suggested by Eisenhardt (1989) we combined the data collection with data analysis enabling early data assessment and allowing flexible data collection. To facilitate data analysis we created a data inventory and edited interviews and notes electronically. We condensed data by organising, labelling and summarising. The use of tables, charts and networks allowed some early conclusions, which we continuously verified with existing field notes and further data collections.

Findings

We structured the findings by case. For each case, we briefly describe the service setting, the gemba walk application, followed by the walk's success stories and challenges.

Case 1: UtilityCo.

UtilityCo is a leading international company in its industry, headquartered in Germany, employs 43,000 people, serves over 33 million customers and has an annual revenue of approximately 40 billion Euros. The company focuses on renewables, energy networks

and energy-related customer solutions. UtilityCo introduced their corporate lean programme in 2014 and has since made regular use of the gemba walk practice.

We visited a German *call centre* dealing with customer care, complaint management, error handling and customer intention initiatives. The centre occupies around 300 employees within 14 divisions. We interviewed the centre leader, a local lean coach and a division manager. Depending on the management level in scope we find different go and see forms and intentions.

The call centre leader handles fortnightly unannounced 'side-by-side walks', visiting the division managers on-site, attending a performance dialogue with their teams and followed by interviewing his subordinate with a set of Kata questions (Rother, 2010, p. 155). While the division manager is moderating his team's performance dialogue, the centre leader observes his subordinate's leadership behaviour. The centre leader observes the way he challenges the division's objectives, ongoing or outstanding actions and issues recorded on the team's performance board. He reviews the division manager's drive for problem solution activities, his sense for employee coaching and development. Further, he verifies the team leader's function as a role model for considering work standards. After completion of the performance dialogue, the call centre leader tracks the division's continuous improvement stream by interviewing his subordinate with a set of Kata reflection questions (Rother, 2010, p. 155). Any actions resulting from those questions are either incorporated into the division's action log or the overall call centre actions, which are apparent on the performance board on-site. The purpose of the side-by-side walk at the call centre is to foster knowhow exchange within the centre and to improve continuously. Formerly this walk used to be conducted every week. With the site's increased lean maturity, a fortnightly assessment seems sufficient.

Executives and subordinates reported the closeness to the individual teams, the associated work appreciation as well as the removal of hierarchies of the side-by-side walk positively. Some teams perceive the visit as a disturbance and pure control mechanism. A team manager explains. 'There are certain team internals that only concern the team. And if you suddenly have the centre leader in front of you, no one will dare to speak up.' The centre leader therefore sees a need for 'management by perception' and sensitivity.

In addition to the 'side-by-sides', department or team leaders also conduct weekly gemba walks by visiting one or two employees at their workstation. They verify the call agent's adherence of work standards by using checklists to assess the workplace's tidiness, the individual routine or telephone scripts. Any discrepancies are directly addressed with the employee and associated measurements incorporated into the team's actions list.

Employee coaching seems an essential element of the weekly department gemba walk. The division leader provides examples for improvement and ensures knowledge transfer. We heard that thereby call agents achieved significant improvements in their sales conversations with distribution clients. This type of go and see used to take place daily but since the division has achieved a higher lean maturity level a weekly walk is sufficient. The team leader explains, 'in the beginning of our lean journey we checked whether everyone's desk was tidy. Today it's more about reviewing and coaching the employee's knowhow.' We learned that the department walk supports the supervisor's personnel development initiatives as it provides clarity on the staff's strengths and weaknesses. Besides the go and see also increases the transparency across other divisions. Using the same checklists and assessment means enables knowledge transfer with other teams. From the division manager we heard: 'if a colleague talks about an issue in his

team, I can share my experiences when dealing with similar issues in the past.' Negative consider managers the high amount of documentation. Transferring the right intentions of the walk to the employees seems also challenging. A team leader explains, 'I don't want to control them. I want to help them. That's why I always announce my visits.'

We also inspected a German *power grid centre* with 21 employees, responsible for grid (electric and gas) operation, maintenance and development. We interviewed the grid centre leader.

We learned from the centre leader that he ceased go and sees in the field. In the past, only before an upcoming lean maturity assessment, he would accompany a technician into the field, evaluate his adherence to safety guidelines, and work standards. Due to the grid centre leader's perceived interference with staff's privacy, he never performed any gemba walks in the office.

Despite the walk's benefits, he never repeated the practice in the past year. 'When you are out there you get a great sense for the work of the colleagues in the field. However, spending half a day away from the desk is simply too time-consuming. We have a thousand other things to do'. An English field services team we spoke to shared similar findings. The manager explains 'we are spread out across the whole country. Doing a go and see would take up 50% of our times.'

Case 2: TelCo.

TelCo, a Swiss leading telecoms company, occupying 20,000 employees, generating sales of more than 11 billion, is considered as one of Switzerland's most sustainable and innovative companies. TelCo's lean journey dates back to early 2013 and the company is currently developing a standard for gemba walks to be integrated into the on-boarding training of executives.

We visited a *datacentre and connectivity division* responsible for server infrastructure and firewall setup. We interviewed a lean coach, gemba walk executer and recipient. The team consists of 114 employees, occupies a mix between consultants, engineers and coordinators. Overall, the division has conducted 12 gemba walks in the past three weeks. In consultation with TelCo's central lean experts and to obtain a baseline study of his team, the division manager initiated the go and sees. The gemba walks were conducted unannounced and carried out either by line managers or TelCo qualified lean experts. The walk consisted of a presentation of the employee's main tasks on his screen at his workstation and lasted four hours. The walker asked many questions. Instead of the direct supervisor, it was another line manager or lean expert doing the visit. Apparently to prevent the employee's 'intimidation' and to allow him to speak openly.

The main objective of the walk is to review current issues, actions, contributions to objectives and to identify waste. With some of the company's lean experts conducting the visits, the gemba walk also has a lean coaching purpose. The walker does not adhere to a strict checklist. He rather observes the employees work, asks clarifying questions and takes notes to track calls for action. After the gemba walk, the visitor provides written feedback to the employee and the division manager. With support of the company's lean experts, the division manager derives necessary measurements. The department sees no need for frequent gemba walks currently. 'The agile transformation needs to be completed first…there are too many conflicting interfaces.'

We sensed mixed feelings towards go and sees. Walkers like the closeness to the employees and establish appreciation for their work. They also find it beneficial not to examine their direct subordinate as 'you get to see a lot more'. We recorded a lot of

'moaning' during the gemba walk and question whether this is due to a lacking reporting line. Recipients do not see any benefits. An employee illustrates, 'it is too abstract. I am not able to demonstrate all of my problems. I feel disturbed'. He wondered if a higher visit frequency would improve the circumstances. Both parties reported a clash of the promoted adherence of lean standards with the company's agile efforts. Given TelCo's agile environment, most measurements resulting from gemba walks seem therefore 'unplannable'.

Case 3: SpitalCo.
SpitalCo is a leading Swiss hospital with over 33 disciplines. The clinic occupies 2200 employees, treats over 17000 stationary and 75000 ambulant patients a year. In response of the 2012 introduced national diagnosis related flat fees, SpitalCo embarked on their lean journey in 2014.

We visited one of the 16 *wards* the clinic maintains. The ward specialises in care of internal and general medicine with focus on stroke patients, consists of 28 beds and occupies 32 employees. According to the hospital's lean programme master, SpitalCo has not established a go and see routine yet. Besides, the organisation has undergone a high management turnover. Without the clinic's lean management initiative, gemba walks would not take place. Therefore a third go and see cycle was launched. As part of this 're-gemba' initiative three walks per ward take place. The gemba walks are conducted announced and carried out by ward management personnel and partially by SpitalCo's lean programme master. The go and sees last half a day where a care team is followed and all value adding tasks, value supporting tasks and non-value adding processes are recorded. For this, the walkers maintain a list capturing all jobs and deficiencies. In order to ensure cross-departmental improvement the gemba walks are not solely executed by direct supervisors but also by executives from other wards. The focus of the walk is to observe the value process and register deficiencies. With SpitalCo's lean programme master accompanying many go and sees the gemba walk maintains also a lean coaching and training intention. The walkers do not follow a standard checklist. Instead, they observe the carers work processes and discuss in a feedback session any necessary measurements.

The gemba walks at Spital Co. are mostly positively perceived. Employees appreciate the one-to-one feedback as valuable leadership and career input. Go and sees prevent departmental 'island solutions' and enable quick-fixes and little improvements directly on-site. Some employees however consider the visit negative. 'All seems a bit staged'. A ward manager wonders if this could be prevented by means of higher gemba walk frequency. Sometimes leadership lack process knowhow, which can question their assessment and problem-solving skills. According to a ward manager it requires a lot of sensitivity when 'walking that thin line' and providing feedback. We learned that gemba walks cannot be conducted everywhere in the same way. The accident and emergency department for example struggles to follow standards and uniform waste definitions. Ward managers visiting departments other than their own can also cause a negative impression on other teams. A ward manager explained: 'my colleague suddenly does not greet me anymore.'

Discussion
This study aimed to explore the suitability of gemba walks in service operations. The analysis of the gemba walk practice at our three cases, Utility Co, TelCo and SpitalCo,

has led us to some potential answers. We will discuss these further and propose some research propositions.

Proposition 1a: *Gemba walks are useful if service value is apparent.*
This hypothesis sounds obvious but not always viable in service settings. UtilityCo call centres use recordings of customer care calls, which managers can assess and align with customer care standards or scripts. At SpitalCo we found that the patient's direct response to the carer's service, such as pain, relief, happiness, discomfort etc. corresponds to the service's product.

On the contrary, our research at TelCo has shown that invisible services being performed within workers' mind or computers cannot be observed and lead to extended and sometimes false presentation of problems instead of normal work processes. We therefore suggest:
Proposition 1b: *Gemba walks are not suited if service value is not apparent.*

Proposition 2: *Gemba walks are useful if service supply metrics are apparent.*
Gemba walks include the measurement of service supply. Intangible services can however only be measured by means of strict 'reduction, isolation and codification' of service operations and by making these codes or standards for everyone visible (McColl-Kennedy and Schneider, 2000). UtilityCo and SpitalCo use performance boards or checklists containing gemba walk relevant standards and metrics accessible and apparent for the entire team.

Proposition 3: *Gemba walks are not suited for distributed service teams.*
Visiting the service gemba of geographically dispersed teams is not sustainable (Corso et al 2006). UtilityCo's grid field operation showed that managers could not maintain the go and see practice due to long travel time and individual dispersed field technicians with a high degree of autonomy.

In addition, we have fond some additional factors that influence the application of gemba walks in services.

Lean maturity level
Different lean maturity levels affect the form, purpose and scope of gemba walks (Jones et al., 2017). A more mature service setting requires less standard measurement walks as standards are in place and staff aware of value adding and non-value adding processes. The focus shifts from *policing* to *learning*. UtilityCo's lean maturity context showed a decrease in gemba walk frequency.

Management turnover
A high management turnover affects the gemba walk's efficiency. Teams cannot improve and learn as the *view* of the gemba changes with every new *sensei* (Mann, 2014). Due to a high management turnover, SpitalCo has not managed to establish a stable go and see routine and had to launch a third re-gemba walk cycle.

Agile transformation
With the information technology industry's increasing interest in combining agile with lean transformation (Rodríguez et al., 2012) gemba walks experience conflicts in complexity, visibility, people relationships, understanding of customer needs and metrics (Maguire, 2016). Some of these conflicts were also apparent at TelCo.

Conclusion

Despite the widespread practice of gemba walks across service operations, there is almost no scientific evidence of its effectiveness. The concept has been left completely to the popular literature. This paper has investigated how and if gemba walks apply in different service settings.

We argue that even though many organisations drive the practice, it is not well suited to every service setting. We propose to apply extra attention to the visibility of service value, metrics, team dispersion, lean maturity level, management turnover and agile transformation initiatives.

This study has limitations in theoretical framework, methodology and data collection. A significant methodological limitation of this study is the case study design. This contradicts with the general validity of our findings and propositions. Additionally, this research is still ongoing and therefore lacks sufficient data to support our findings further.

In order to test validity of our gemba walk propositions, we suggest quantitative studies of many service operations with established and operating gemba walk practices.

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Pathways to develop a lean organization: configurations of lean practices for different business strategies

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Abstract

This paper identifies pathways to develop a lean organization. Previous research identified complementarity between supplier related, customer related, just-in-time, total productive maintenance, and human resource management bundles. This research identifies strategy related configurations of these bundles linked to substantive operational performance. Data on operational performance and lean bundles were gathered from 44 manufacturers using multiple respondent self-assessments and analysed using Qualitative Comparative Analysis. Three different pathways to substantive operational performance were identified. Our findings provide focus to both research and practice as they suggest that lean bundles are not consistently linked to each other nor equally important for different organizations.

Keywords: Lean bundles; Operational performance; Qualitative comparative analysis

Introduction

To develop a lean organization, it is important to focus on the most important lean bundles for that organization. This focus is ill addressed in the literature. Most research studies the link between lean bundles as well as their link with operational performance (like McKone, Schroeder and Cua, 2001; Rahman and Bullock, 2005; Fotopoulos and Psomas, 2009; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012; Danese and Bortolotti, 2014). Some incorporate generic contingencies like country or age (like McKone, Schroeder and Cua, 1999; Cua, McKone and Schroeder, 2001; Dal Pont, Furlan and Vinelli, 2008; Furlan, Dal Pont and Vinelli, 2011; Furlan, Vinelli and Dal Pont, 2011; Alsmadi, Almani and Jerisat, 2012; Bortolotti, Boscari and Danese, 2015). And a few take market conditions like demand variability into account (like Sakakibara et al., 1997; Ketokivi and Schroeder, 2004; Bortolotti, Danese and Romano, 2013). This paper sets out to explore strategy related configurations of lean bundles that are linked to substantive operational performance.

From its introduction onwards, the lean philosophy of increasing customer value and decreasing waste through just-in-time production and respect-for-employees (Sugimori *et al.*, 1977) has been important for organizations trying to improve their organizational

processes (Naylor, Naim and Berry, 1999; Shah and Ward, 2003; Liker and Morgan, 2006; Radnor and Walley, 2008; de Souza, 2009). Lean however constitutes a diversity of bundles regarding total productive maintenance (TPM), just-in-time (JIT), human resource management (HRM), suppliers and customers (Shah and Ward, 2003, 2007). This diversity of bundles adds to the challenge of developing a lean organization (Hines, 2010; Mann, 2014).

It is shown that not all lean bundles are equally important for every organization (Sakakibara *et al.*, 1997; Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Brown, Squire and Blackmon, 2007; Ward, McCreery and Anand, 2007). For example, a customer link might be more important for organizations striving for customer intimacy while TPM might be more important for organizations striving for operational excellence (Treacy and Wiersema, 1996; Ward, McCreery and Anand, 2007). Rather than equally important it might be that lean bundles are best performed in configurations (Ward, Bickford and Keong Leong, 1996; Cua, McKone and Schroeder, 2001). Configurations are "multidimensional constellation[s] of conceptually distinct characteristics that commonly occur together" (Meyer, Tsui and Hinings, 1993, p. 1175). Related concepts are typologies (Miles *et al.*, 1978), gestalts (Miller, 1981), types (Mintzberg, 1990) or forms (Short, Payne and Ketchen, 2008). A configurational approach identifies dominant types of observable characteristics of behaviour which appear to lead to a particular performance.

Given the configurational approach, it is proposed that configurations of lean bundles can be developed depending on how an organization strives to distinguish itself (Filippini, Forza and Vinelli, 1996; Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007; Galeazzo and Furlan, 2018). Only one study explored configurations of lean bundles in relation to performance (Galeazzo and Furlan, 2018). Using data from 78 informants from 19 manufacturing medium and large firms, they found configurations of lean bundles that were linked to successful financial performance; JIT combined with total quality management *or with* TPM and HRM. However, their study focusses on internal related lean bundles only, neglecting bundles regarding the supply chain (supplier and customer related) and their study linked lean bundles to financial rather than operational performance. This study tries to add to this literature as it aims to *explore strategy related configurations of lean bundles that are linked to substantive operational performance.*

An overview of business strategies and related configurations of lean bundles is followed by an explanation why and how we used Qualitative Comparative Analysis (Ragin, 2008) to analyse our data and come to different pathways to develop a lean organization.

Configurations of lean bundles

To explore strategy related configurations of lean bundles that are linked to substantive operational performance, we identify different business strategies which we link to different lean bundles to conceptualize configurations that are linked to operational performance.

Business strategies

Brown, Squire and Blackmon (2007) showed that world-class plants link lean operations to business strategy. Many approaches to business strategy have been taken (like Miles *et al.*, 1978; Porter, 1985). Treacy and Wiersema (1996) distinguish three basic ones; product leadership, operational excellence and customer intimacy. In line with these, Ward, McCreery and Anand (2007) identified three types; broad-based competitors,

differentiators and price leaders. As Treacy and Wiersema (1996) focus specifically on customer value (Zacharias, Nijssen and Stock, 2016) and as they show considerable overlap with the types of Ward, McCreery and Anand (2007) we will continue with these.

First, according to Treacy and Wiersema (1996) product leadership aims to excel on product quality, innovation and brand marketing. The focus is on design and development of a variety of good products, produced in low volume, with high margins and a quick time-to-market (Ward, McCreery and Anand, 2007). Second, operational excellence is about an outstanding production process with superior operations and execution. The focus is on efficiency and streamlined operations and supply chain management as the organization tries to offer a reasonable quality for a very low price (Ward, McCreery and Anand, 2007). Third, customer intimacy aims to excel in customer focus and customer service. The focus is on delivering customer specific products and services on time and above customer expectations as the organization adapts products and services for the benefit of individual or almost individual customers (Ward, McCreery and Anand, 2007).

According to Treacy and Wiersema (1996), organizations should strive to meet the threshold of all three strategies but at the same time excel at one of them. Research (Sakakibara *et al.*, 1997; Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007) has shown that proper alignment of business strategy strengthens the connection between lean bundles and operational performance. So lean bundles can help to meet strategic aims and market demands on an operational level.

Lean practices and lean bundles

Shah and Ward (2003, 2007) identified lean bundles from ten lean practices. Their practices are widely used in the literature because of their comprehensive view; they include people, process and technology aspects as well as supplier, internal and customer aspects. Following others, we grouped these lean practices into five internally consistent lean bundles. The supplier related bundle consists of supplier feedback, JIT delivery and developing suppliers (Shah and Ward, 2007). The customer related and HRM bundles each consist of one lean practice (Shah and Ward, 2007). Deviating from Shah and Ward, we split the internally related group into TPM consisting of controlled processes and productive maintenance, and JIT consisting of pull, flow and low setup (McKone, Schroeder and Cua, 1999, 2001; Cua, McKone and Schroeder, 2001). Like the ten lean practices, these five lean bundles are widely used in the literature (Mackelprang and Nair, 2010).

Configurations of lean bundles

The lean bundles can be conceptualized in the following configurations. First, to achieve product leadership short delivery times are paramount. To this end, the most important bundle seems JIT as this mainly helps to reduce product lead time (Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012). Prerequisites for JIT appear to be the bundles TPM for a steady production process (Swink, Narasimhan and Kim, 2005) and supplier related for steady deliveries (Panizzolo, 1998; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012). Bundles of lesser importance, though not irrelevant, seem customer related (Furlan, Dal Pont and Vinelli, 2011) and HRM (Furlan, Vinelli and Dal Pont, 2011). There appear to be no bundles counterproductive for this configuration.

Second, to achieve operational excellence low variety and high volume is produced for low margins. To this end, a steady marketing mix combined with a stable production

line seem most important. This is achieved by the bundle TPM (McKone, Schroeder and Cua, 1999, 2001). Bundles of lesser importance seem JIT (Danese, Romano and Bortolotti, 2012) and supplier related (Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012) as the high volume permits production to be done in small batches rather than single pieces. Some even find JIT (Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007) and supplier related (Ward, McCreery and Anand, 2007) to be counterproductive for this strategy. The customer related and HRM bundles (Ward, McCreery and Anand, 2007) might be too expensive for this configuration as the low variety permits steady designs and production. Though for these two bundles too, some researchers find otherwise (Ketokivi and Schroeder, 2004).

And third, to achieve customer intimacy direct contact with customers is most important making customer related the most important bundle (Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Ward, McCreery and Anand, 2007). Furthermore, because of the complexity in production, the bundles HRM (Swink, Narasimhan and Kim, 2005) and JIT (Swink, Narasimhan and Kim, 2005) seem to be required as well. TPM might be of lesser importance as unicity of the products does not require very high levels of productive maintenance or process control (Swink, Narasimhan and Kim, 2005). The supplier related bundle might be least important in this configuration as lead time oftentimes is not an order winner in this strategy (Furlan, Dal Pont and Vinelli, 2011). These configurations are also given in Figure 1.

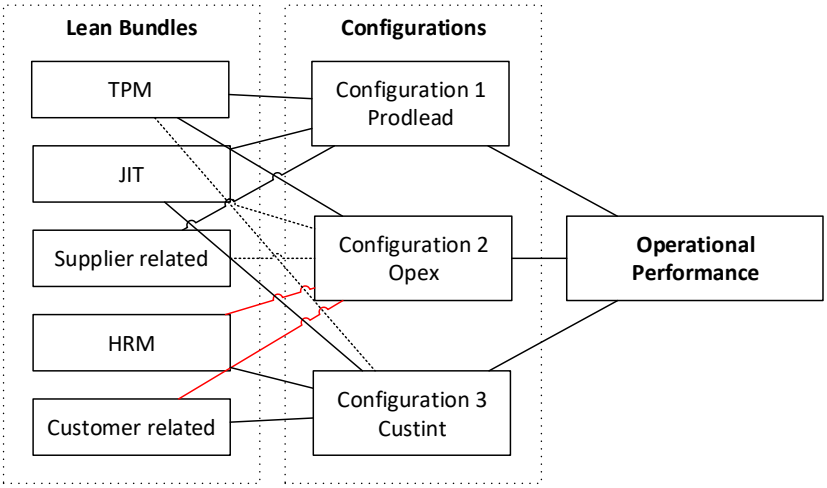

Figure 1, Configurations of Lean Bundles for Operational Performance
Note: black lines show a strong link, dotted lines a weak link and red lines an inverse link

Methodology

To analyse the identified configurations of lean bundles that are linked to substantive operational performance, we first explain why we used multiple respondent self-assessments to gather data on operational performance and lean bundles before we explain why and how we used Qualitative Comparative Analysis (Ragin, 2008) to analyse this data and come to different pathways to develop a lean organization.

Data gathering

Data was gathered from 44 Dutch manufacturing SMEs through the network of the research group World Class Performance/Lean of the HAN University of Applied Sciences in The Netherlands. Multiple respondents (6 on average, over 250 in total) from

different levels (executives till team leaders) and functions (Sales till Expedition) filled in a questionnaire on their operational performance (costs, quality, delivery speed, delivery dependability, product flexibility and volume flexibility) (White, 1996; Slack, Chambers and Johnston, 2010) and lean practices (See Shah and Ward (2007) for details). The lean practices were grouped in five bundles to enable data analysis with QCA; supplier related (supplier feedback, JIT delivery and developing suppliers), customer related, HRM, TPM (controlled processes and productive maintenance) and JIT (pull, flow and low setup).

Data quality

To estimate construct validity, an exploratory factor analysis (EFA with varimax) and a confirmatory factor analysis (CFA with direct oblimin) were performed for operational performance and lean practices respectively and given in **Fout! Verwijzingsbron niet gevonden.** and
Table 2. KMO's were >0.5 and Bartlett's tests of sphericity were both <0.001 hence all were significant. All meet the excellent threshold of >.7 while costs, JIT delivery, developing suppliers, pull and productive maintenance meet the very good threshold of >.6. Also following judgemental criteria (Wieland et al., 2017) and considering the content of the deflecting items (content validity) we decided to keep all items to maintain coverage of the identified groups.

Table 1, Exploratory Factor Analysis of operational performance

Bundle	Indicator	Factor loading	Average performance
1	Delivery speed	.928	6.0
	Delivery dependability	.947	6.4
2	Costs	.688	5.1
	Quality	.795	6.9
3	Product flexibility	.827	7.0
	Volume flexibility	.782	6.6

Table 2, Confirmatory Factor Analysis of lean practices

Bundle	Practices	Average factor loading	Average performance
Supplier related	Supplier feedback	.714	3.5
	JIT delivery	.663	2.5
	Developing suppliers	.647	2.3
Customer related	Involved customers	.760	3.2
HRM	Involved employees	.764	2.7
TPM	Controlled processes	.729	2.0
	Productive maintenance	.684	2.6
JIT	Pull	.689	3.1
	Flow	.833	3.1
	Low setup	.822	2.6

Data analysis

Data were analysed with QCA (Ragin, 2008; Schneider and Wagemann, 2012) in fsQCA 3.0 (Ragin, Drass and Davey, 2017). QCA is a technique which allows a systematic comparison of cases. Rather than statistics, it uses Boolean logic to find configurations of conditions for a certain outcome (Fiss, 2007). To do a QCA, several steps must be performed.

In preparation, both bundles of operational performance and lean practices were calibrated as shown in Table 3. Operational performance was measured on a nine-point scale with 1-3 being lower, 4-6 equal and 7-9 better than competition. Therefore, 6.5 was chosen as the threshold for cases outperforming competition. As there were no cases above 8 nor below 5 these acted as full and non-membership thresholds respectively. Lean practices were calibrated based on groups identified in our own dataset. As lean bundles for most cases were below 4 and above 2 these acted as full- and non-membership values respectively.

Next, the actual QCA was performed. Necessary or sufficient conditions were identified, a truth table was made with each row representing each possible configuration, and for each outcome consistency and coverage were calculated. To improve confidence in the identified configurations, two robustness tests were performed. These tested whether the findings were the same for different cross over points; one based on groups identified using the average per lean bundle and one based on the industry average from three studies (Alsmadi, Almani and Jerisat, 2012; Hofer, Eroglu and Rossiter Hofer, 2012; Bortolotti, Boscari and Danese, 2015).

Table 3, Calibration of outcome and conditions

Lean practice	**Threshold full-membership (0.95)**	**Crossover point (0.51)**			**Threshold non-membership (0.05)**
		Groups in data	**Data average**	**Industry average**	
Operational performance	8	6.5	6.4	NA	5
Supplier related	4	3.2	2.8	3.5	2
TPM	4	3.0	2.3	3.5	2
JIT	4	3.4	2.9	3.4	2
HRM	4	3.2	2.6	3.6	2
Customer related	4	2.6	3.2	3.8	2

Results

To find which configurations of bundles of lean practices were linked to increased operational performance for different business strategies, we first performed the QCA-test for necessity but found no bundles that were necessary for each configuration. We then performed the truth table algorithm to identify which bundles of lean practices were sufficient for cases to outperform competitors. Results are given in Table 4 and show that there are three configurations of lean bundles with substantive operational performance. First, JIT combined with supplier related and TPM. Second, TPM combined with supplier related but with absence of HRM and customer related. And third customer related and HRM combined with supplier related and JIT. These configurations of lean bundles show considerable overlap with the configurations identified from the literature.

Table 4, Configurations of lean bundles sufficient for substantial operational performance

Configuration	**1**	**2**	**3**
Supplier related	●	●	●
TPM	●	●	
JIT	●		●
HRM		⊗	●
Customer related		⊗	●
Raw coverage	.393	.600	.461
Consistency	.888	.889	.870

Note: Black circles denote the presence of the lean bundle and crossed-out circles denote the absence of the lean bundle. Blank spaces denote irrelevant lean bundles meaning that neither presence nor absence was linked to the outcome.

Discussion

The aim of this paper was to explore strategy related configurations of lean bundles that are linked to substantive operational performance. This section will elaborate on our results and their theoretical and practical contributions.

Pathways to develop a lean organization

Our results confirm earlier work on configurations of lean bundles linked to operational performance (Filippini, Forza and Vinelli, 1996; Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007; Galeazzo and Furlan, 2018) while we specify these configurations into three specific pathways to develop a lean organization. It appears that for product leadership, JIT is the most important bundle (Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012) while the TPM (Swink, Narasimhan and Kim, 2005) and supplier related bundles (Panizzolo, 1998; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012) are required as well. Like others, we too find that the customer related (Furlan, Dal Pont and Vinelli, 2011) and HRM bundles (Furlan, Vinelli and Dal Pont, 2011) are not required for this configuration.

Regarding operational excellence there is less agreement. We too find that the TPM (McKone, Schroeder and Cua, 1999, 2001) and supplier related bundles (Ketokivi and Schroeder, 2004; Swink, Narasimhan and Kim, 2005; Romano, Danese and Bortolotti, 2010; Danese, Romano and Bortolotti, 2012) are important for this configuration. However this contradicts findings of others (Ward, McCreery and Anand, 2007) regarding supplier related. Furthermore, we too find that JIT is *not* important for this configuration (Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007) contradicting those that find it is (Danese, Romano and Bortolotti, 2012). This might be due to lower variety and higher volumes hence less setups, pull and flow. Contradicting findings of others (Ketokivi and Schroeder, 2004), our results show that HRM and customer related are not required for this configuration (Ward, McCreery and Anand, 2007) as these might be too expensive.

Regarding customer intimacy, we mostly confirm earlier findings. The customer related bundle was most important (Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Ward, McCreery and Anand, 2007) while HRM (Swink, Narasimhan and Kim, 2005) and JIT (Swink, Narasimhan and Kim, 2005) were required as well. However, contradicting others (Swink, Narasimhan and Kim, 2005) our results show that TPM was not required

for this configuration. This might be because unicity of the products does not require very high levels of productive maintenance or process control. Finally, contradicting others (Furlan, Dal Pont and Vinelli, 2011) our results indicate that supplier related was important for this configuration. This might be due to the increasing importance of lead time. In sum our findings refine our understanding of configurations of lean bundles for substantive operational performance.

Contributions and future research

This paper confirms that not all lean bundles are equally important for every organization (Sakakibara *et al.*, 1997; Ketokivi and Schroeder, 2004; Brown, Squire and Blackmon, 2007) while it specifies a previously identified direction for analysis (Filippini, Forza and Vinelli, 1996; Panizzolo, 1998; Cua, McKone and Schroeder, 2001; Swink, Narasimhan and Kim, 2005; Ward, McCreery and Anand, 2007). Managers trying to develop a lean organization can use these findings to focus their efforts depending on their external environment and related business strategy. Future research could take the same approach to elaborate and refine our findings using different samples from different industries or cultures as well as samples with different combinations of lean bundles.

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A lean approach in calculating product direct cost; utilizing cost-time profile in SAIPA automotive manufacturing group

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Abstract

One of the main aspects in creating the competitive advantage of organizations and the survival condition in the competitive market is to reduce the product cost. Accurate calculation of the components of product cost, can lead to help the organizations to identify potential opportunities for their business improvement. Some of these components in product cost like: monetary value of time are hidden and are not usually found in the traditional accounting methods. By emerging the lean production and implementation of the principles of lean thinking in the area of manufacturing and services, significant improvements have been found in reducing waste, creating value-added activities and consequently reduction of product cost in various organizations. The main aim of this paper is using a lean approach in order to accurate calculation of product direct cost (PDC) as a main component of product cost. In this paper, lean tools such as value stream map (VSM) and cost-time profile (CTP) have been utilized and the effect of the monetary value of time have been considered in PDC calculation. By drawing the current state and future state maps of VSM and CTP as well as calculating the cost-time investment of a product for the both states, organizations will be able to have a reasonable analysis of monetary effect of reducing waste and time corresponding to non-value added activities. Hence, the PDC amounts for current and future state maps can be calculated and compared to each other. Furthermore, these PDC amounts can be compared to the PDC amount which is calculated through traditional accounting method which has not considered the monetary value of time. At first glance, this approach might not seem sensitive and substantial for a unit of product in a manufacturing organization, but for a large volume of products in a long-run period of time, it will be much too considerable. Finally, this approach has been implemented in SAIPA automotive manufacturing group as a second largest automotive manufacturer in Iran in order to explain the efficiency and applicability of the proposed method and the obtained results have been analysed.

Keywords: Lean Production, Cost-Time Profile, Product Direct Cost

Introduction

The accurate estimation of product costs has a direct impact on the performance and effectiveness of a business since unrealistic estimation can lead to the outflow of the organization financial resources. Hence, product cost estimation is considered as one of the key factors in designing operational strategies and management policies as well as business decision making due to this critical role in the organization. There are different techniques for estimating and accurately calculating product costs according to Figure 1 (Niazi & Dai, 2006).

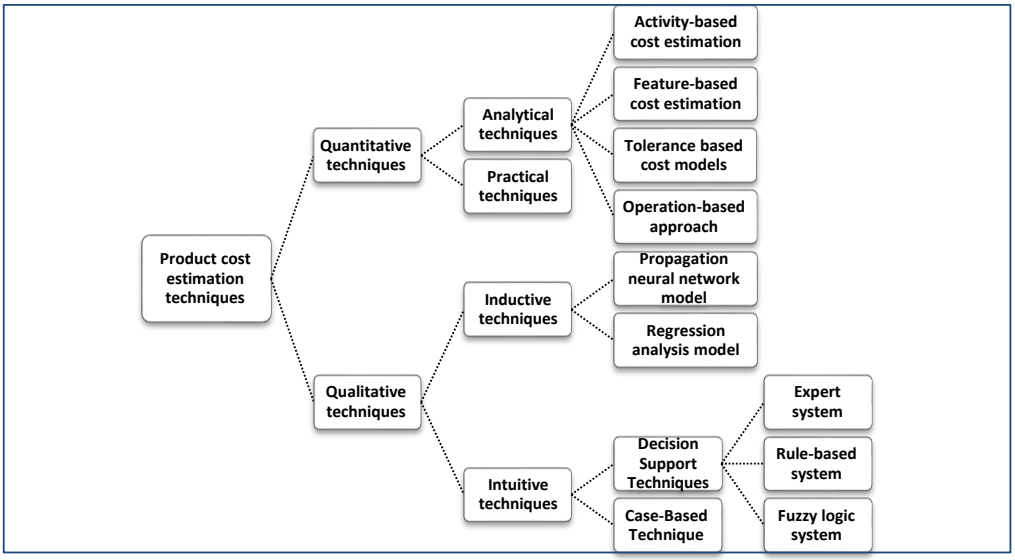

Figure 1 – Classification of product cost estimation techniques (Niazi and Daei, 2006)

According to the categorization presented in Figure 1, product cost estimation techniques are divided into two main categories: 1. Quantitative product cost estimation techniques, 2. Qualitative product cost estimation techniques.

Quantitative product cost estimation techniques are mostly used in the new analysis and product that is currently being produce while, Qualitative product cost estimation techniques are based more on the detailed analysis of product costs from product design to production processes and are not based on past information or prior estimates.

Excluding the time factor, only the product cumulative cost was considered in traditional costing systems. Value stream mapping (VSM) tool provides a very good image of the time needed to produce a product, however it cannot take into account the cost factor. The cost-time profile is an applied tool to show the product cumulative cost over production time within the cost-time-investment and product costs indices (Rivera & Chen, 2007)

Literature review on product cost calculation

A number of studies carried out in this area have been mentioned in the following:
(Zhang, et al., 1996) Pointed out the critical role of Product Cost Estimation (PCE) in the product development cycle and emphasized that the correct cost estimation can help balance product structures, raw materials, and production processes with designers' decisions. They also divided the methods of estimating product costs into 5 categories according to the research in this area: 1) Traditional Detailed Breakdown 2) Simplified Breakdown Cost Estimation 3) Group Technology-Based Cost Estimation 4) Regression-

Based Cost Estimation, 5) Activity-Based Cost Estimation. (Shehab & Abdalla, 2001) Interpreted a product cost estimates as the prediction of a product operations costs before implementation and provided three categories for cost estimation methods: Intuitive method, Parametric Techniques, Variant-Based Models and Generative Cost Estimating Models. (Ben-Arieh & Qian, 2003) Provided four categories of cost estimation methods including: Intuitive, Analogical, Parametric and Analytical. Intuitive methods are based on past calculations of cost estimates. Analogical methods are used to estimate costs using similar product information with specific costs. Parametric methods for estimating product costs are based on product parameters that are most commonly used by product designers. The parameter is effective on costs and is usually calculated based on simple formulas. Analytical methods, such as the activity-based costing decompose and break down the sub-activities to the level at which the resources and financial costs are measurable. (Niazi & Dai, 2006) Examined various techniques and methods to calculate the cost of the product, as well as to categorize and review the related literature in this field during a 10- year period. (Rivera & Chen, 2007) Investigated and measured the impact of lean manufacturing tools on cost-time investment of a product using a cost-time profile.

Value Stream Mapping

The VSM, also known as the "materials and information flow map", is a graphical device that displays the process map of a production system using standard icons and firstly introduced by (Rother & Shook, 2009) in a book entitled: "Learning to see". This map, covering the production movement from the factory entrance door to the exit door, the door to door value flow, is a good start for mapping and leanness. There are two types of mapping in the VSM: 1. Current State Map (CSM), which indicates the leanness of the current plant system. 2. Future State Map (FSM) or improved state map that indicates the system's leanness after improvements (Womak, et al., 1990) (Seyedhosseini, et al., 2013).

A brief overview of the literature on VSM is provided in the following: (Abdulmalek & Rajgopal, 2007) used the simulation process to provide improvement scenarios to reduce production waiting times and as a result, they could evaluate the use of lean manufacturing tools in the steel industry. (Ebrahimi-Talaghani, et al., 2013) Could reduce the time and the total waiting time of production using a non-deterministic VSM tool by the PERT technique to take into account the uncertainty of the activity of a part automobile manufacturer. (Sasikumar & Kumar, 2013) Succeeded to reduce the total waiting time of production and the number of production operators and process time by implementing the VSM tool to detect the loss in manufacturing processes of an electromechanical circuit breaker manufacturer in India. (Singh, et al., 2015) Reduced supply time by warehouse, reduced overall production waiting time and process time utilizing VSM tools in the automotive-related small industries through drawing on the current situation, analysing and presenting improved conditions. With the aim of improving customer service performance management, (Morlock & Meier, 2015) reduced the response time and customer service time by implementing value streaming mapping in the service area. (Kasava, et al., 2015) Improved repair time and calculated the sustainability through mathematical modelling using the VSM tool in the aircraft repair industry in the Boeing 737 aircraft repair department to reduce repair time and calculating the index of sustainability of the VSM in the form of a numerical index.

Cost-time profile

The term cost-time profile (CTP) developed by Westinghouse Corporation. CTP is a graph displaying the Cumulative and gradual Costs of a product over time. The total costs in the cost-time profile graph are equal to the height of the graph, when the product is completed. Actually, the total cost represents all the direct costs of the product, regardless of the impact of the cost-time of the investment (Rivera & Chen, 2007). In simple terms, the CTP calculates how much money and how much time is spent in the production process to produce a product (Rivera, 2006). The CTP graph includes elements such as activities, materials, expectations, total cost, Cost-time Investment and direct costs. These elements are represented in Figure 3 (Seyedhosseini & Ebrahimi-Taleghani, 2014).

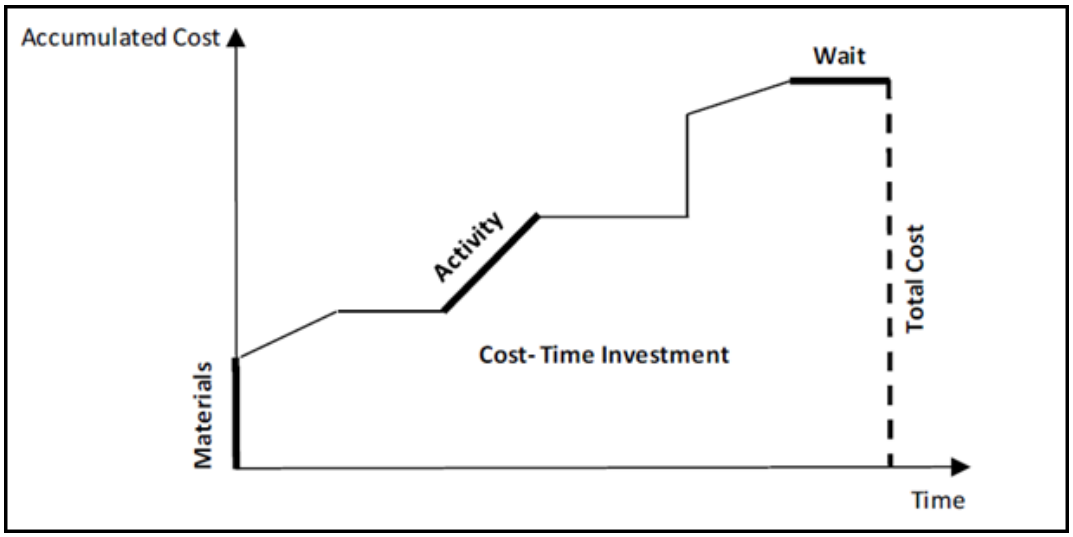

Figure 3 – Cost-Time Profile, (Seyedhosseini and Ebrahimi Taleghani, 2014)

Activities: Activities are displayed as a positive-slope line, representing the cost of them, in the graph of the CTP. Activity Cost Rate is the amount of money spent on a activity during the event time.

Material: the materials are displayed as a vertical line in the CTP graph because the materials and components are received at the beginning of the process. Materials costs are part of the cumulative cost.

Waiting costs: Costs occurred when no activity is performed during the production process which is not accounted as cumulative costs. These costs are displayed as the horizontal line.

Total cost: the total cost is equal to the height of the graph when the product is complete in the CTP graph. The total cost includes all direct costs of the product, regardless of the impact of Cost-time Investment and the time value of money (Rivera & Chen, 2007).

Cost-time Investment: The area below the graph is cost-time investment and indicates how much cost, and how long is accumulated during the production process. This area is effective on both cost and time factor.

The product direct cost: CTI represents the amount of cost-time investment by the organization; however the organizations also expect the return on investment cost, so this critical issue can be considered by adding the Minimum Attractive Rate of Return (MARR) or the Internal rate of return (IRR) and the product direct cost can be obtained by adding the total cost (Rivera, 2006).

Therefore, it is possible to calculate the direct cost according to relation 1 by calculating the amount of time-cost investment, considering the internal rate of return and adding the total cost (Seyedhosseini & Ebrahimi-Taleghani, 2014).

$$Direct\ cost = Total\ cost + (Cost - time\ Investment \times Internal\ return\ rate) \quad (1)$$

The CTP is based on the idea that any business can be investigated in terms of organization cumulated cost over time (Gracanin, et al., 2013).

Research method

As mentioned earlier, the VSM tool can represent the production time of a product from raw material to the delivery time including the total time of the production process and the total waiting time of the production, and also the CTP tool makes it possible to simultaneously display the time and cost indicators in order to accurately estimate the product direct cost.

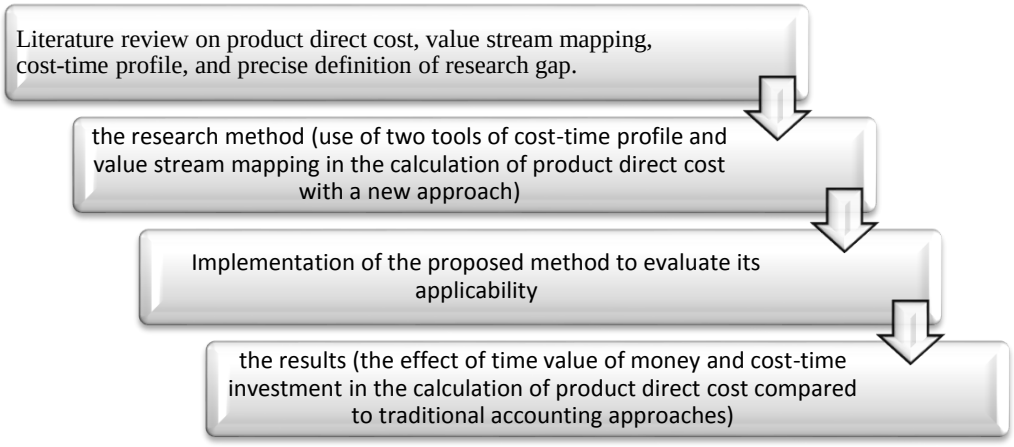

Figure 4 – research framework and steps

Actually, the simultaneous analysis of the two indicators of cost and time, as the main factors of the competitive advantage of organizations.

Implementing the method in the SAIPA automotive group

About SAIPA Automotive Group

As one of the largest industrial groups in Iran with more than 80 sub-companies and nearly 40,000 human resources, the SAIPA Automobile Group started operating as the Iranian Citroën Co. in 1964. The company is currently cooperating with more than 1,000 suppliers in the country and has an annual production capacity of 950,000 vehicles. The method provided in this paper is being implemented in the SAIPA Company press room and in the side door hemming production line. According to engineering layout, this unit has two main sectors, each with eight workstations. Four products of front right side door, left front, rear right and rear left doors are manufactured in this unit by the operators at all stations and at the last station, the hemming operation is performed by Robot. In this research, the front left side door is selected as the product family under study.

Current State Map

Comprehensive information such as information flow, number of machines and manpower, customer demand, turnover, etc. should be collected in order to draw up the

CSM. At the moment, there are 180 units of production demand per day. Time Study has been done for the side door manufacturing activities. The CSM is presented in Fig. 5 according to the available information.

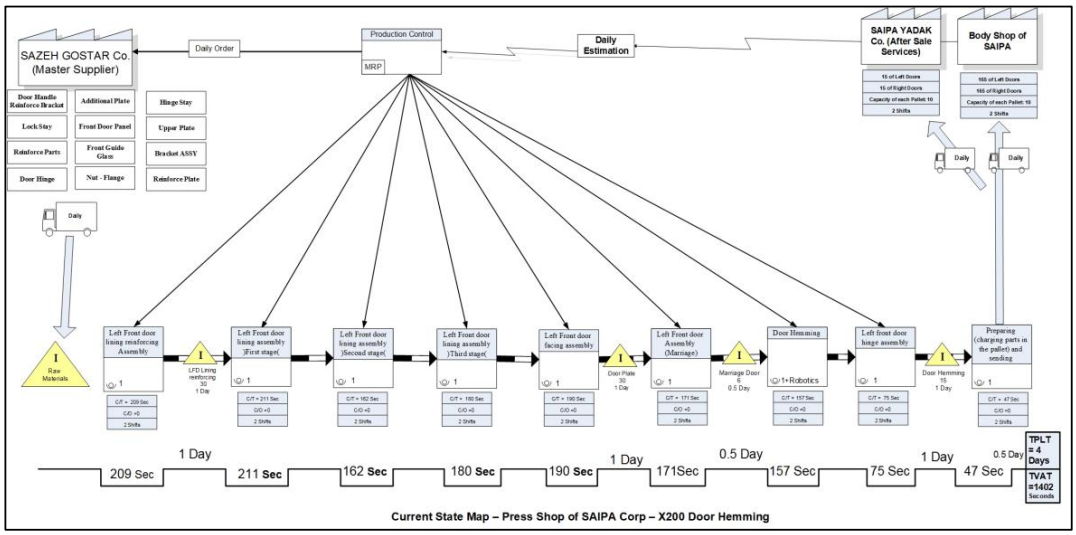

Figure 5 – Current State Map (CSM)

Cost-Time profile for current state map

The amount of product cumulated costs can be calculated using the CTP, over the production time and according to the information provided in Table 1, the total costs and product CTI is calculated, and the CTP is presented in Fig. 6.

Table 1 – Cost information for CSM

Cost information						Time information				code
CTI dollars - minute	Cost in dollars	total Cumulative cost (Rials)	Total cost (Rials)	Material cost	activity Cost	Cumulative time	Time in minute	Process time	Time (second and day)	
16	$5	194,802	194,802	134300.00	60,502	3.48	3.48	209.00	209	PP1
6,679	$5	194,802	0	0.00	0	1443.48	1440.00	86400.00	1	ST1
58	$16	692,110	497,308	255300.00	242,008	1447.00	3.52	211.00	211	WP1
45	$17	700,616	8,506	4150.00	4,356	1449.70	2.70	162.00	162	WP2
74	$25	1,040,310	339,694	82100.00	257,594	1452.70	3.00	180.00	180	WP3
96	$30	1,276,576	236,266	230641.00	5,625	1455.87	3.17	190.00	190	WP4
43,768	$30	1,276,576	0	0.00	0	2895.87	1440.00	86400.00	1	ST2
108	$38	1,595,259	318,683	312741.00	5,942	2898.72	2.85	171.00	171	MP1
27,347	$38	1,595,259	0	0.00	0	3618.72	720.00	43200.00	0.5	ST3
100	$38	1,599,509	4,250	0.00	4,250	3621.33	2.62	157.00	157	DM1
61	$49	2,040,241	440,732	8300.00	432,432	3622.58	1.25	75.00	75	AP1
69,951	$49	2,040,241	0	0.00	0	5062.58	1440.00	86400.00	1	ST3
46	$59	2,480,973	440,732	8300.00	432,432	5063.37	0.78	47.00	47	PP2
42,531	$59	2,480,973	0	0.00	0	5783.37	720.00	43200.00	0.5	ST4
190,881										

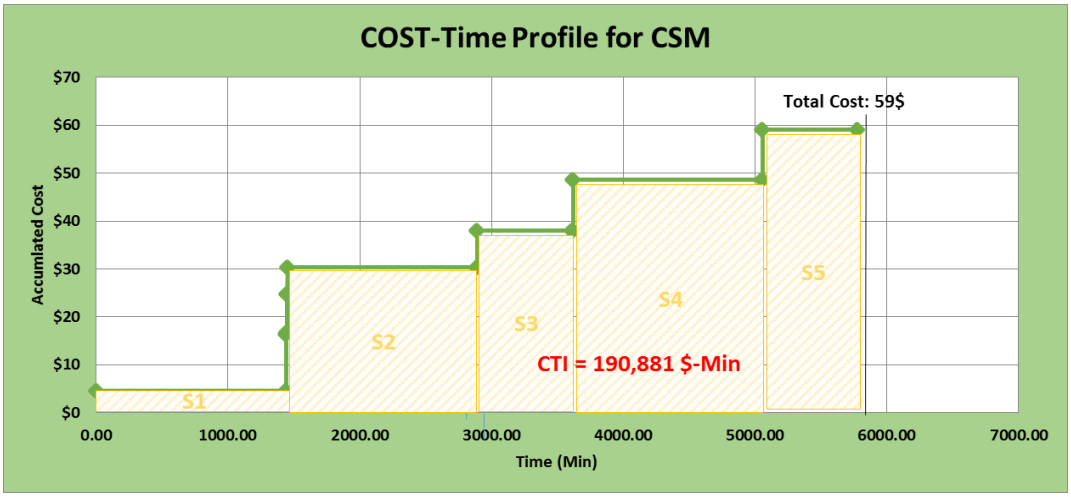

Figure 6 – the product direct cost for the CSM

Calculating the product direct cost in the Current Stream Map

Product direct costs are calculated using the sum of the product total cost with the cost of the product-time investment, which should also include the return rate on internal investment in the investment-time cost. It should be noted that the return rate on internal investment is considered 20% in this paper. Hence, according to relation (1), the direct cost of a product is $ 85.65 in the Current Stream Map.

Direct cost = $ 59 + (190.881 $-min × 20%) = $ 59.07

Future (Improved) state map

It is possible to improve significantly the existing wastes with the lean principles by a full review of the CSM processes, and a careful review of the production activities at the floor of the workshop. The operator's distance with the primary components that will be charged in the production line is one of the main wastes that exist in the company's side door production line. Production operators at different stations are forced to travel, then return to the manufacturing fixture location for the purpose of producing pre-assembly parts by taking the parts, that takes a part of their time that can be considered as a transportation waste. At station 1 (namely the door reinforce assembly), the operator travels a distance of about 4 meters to reach the primary parts pallet. Then, by the picking of the piece, he puts on assembly of reinforce door. It is possible to use one of the lean production strategies called the supermarket pull system. For instance, the operator can easily assemble his pre-assembled parts in order to assemble at its closest distance, which can significantly improve the cost with a very low cost of the production process by creating a smaller pallet near the manufacturing fixture, considering the ergonomic conditions. Another time waste is the lack of timely supply of the first input that occurs in the warehouse and between the workstations. Failure to comply with the FIFO system will cause the components to remain in the input parts warehouse and production stations for a long time.

One of the main goals of the lean principals can be achieved by improving the above mention items, which is to synchronize the takt time with the operations time. The rate of the assembly of the press room has improved. The FSM is also presented in Fig. 7.

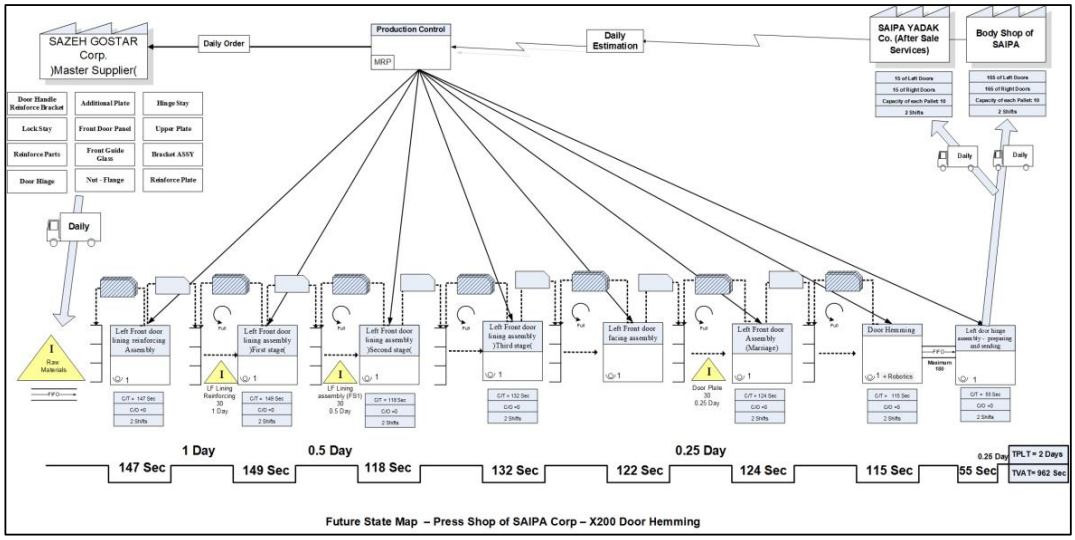

Figure 7 – the future (Improved) state map

Implementation of cost-time profile for future state map

According to the improved value stream of the production process, the total cost and product CTI are calculated in this section based on the information provided in Table 2 and the CTP of FSM is presented within the Fig. 8.

Table 2 – cost information for FSM

Cost information						Time information				code
CTI dollars - minute	Cost in dollar	total Cumulative cost (Rials)	Total cost (Rials)	Material cost	activity Cost	Cumulative time	Time in minute	Process time	Time (second and day(	
11	$5	194,802	194,802	134300.00	60,502	2.45	2.45	147.00	147	PP1
6,679	$5	194,802	0	0.00	0	1442.45	1440.00	86400.00	1	ST1
41	$16	692,110	497,308	255300.00	242,008	1444.93	2.48	149.00	149	WP1
11,865	$16	692,110	0	0.00	0	2164.93	720.00	43200.00	0.5	ST2
33	$17	700,616	8,506	4150.00	4,356	2166.90	1.97	118.00	118	WP2
54	$25	1,040,310	339,694	82100.00	257,594	2169.10	2.20	132.00	132	WP3
62	$30	1,276,576	236,266	230641.00	5,625	2171.13	2.03	122.00	122	WP4
10,942	$30	1,276,576	0	0.00	0	2531.13	360.00	21600.00	0.25	ST3
78	$38	1,595,259	318,683	312741.00	5,942	2533.20	2.07	124.00	124	MP1
73	$38	1,599,509	4,250	0.00	4,250	2535.12	1.92	115.00	115	DM1
45	$49	2,040,241	440,732	8300.00	432,432	2536.03	0.92	55.00	55	AP1
17,488	$49	2,040,241	0	0.00	0	2896.03	360.00	21600.00	0.25	AP1 - ST1
46,974										

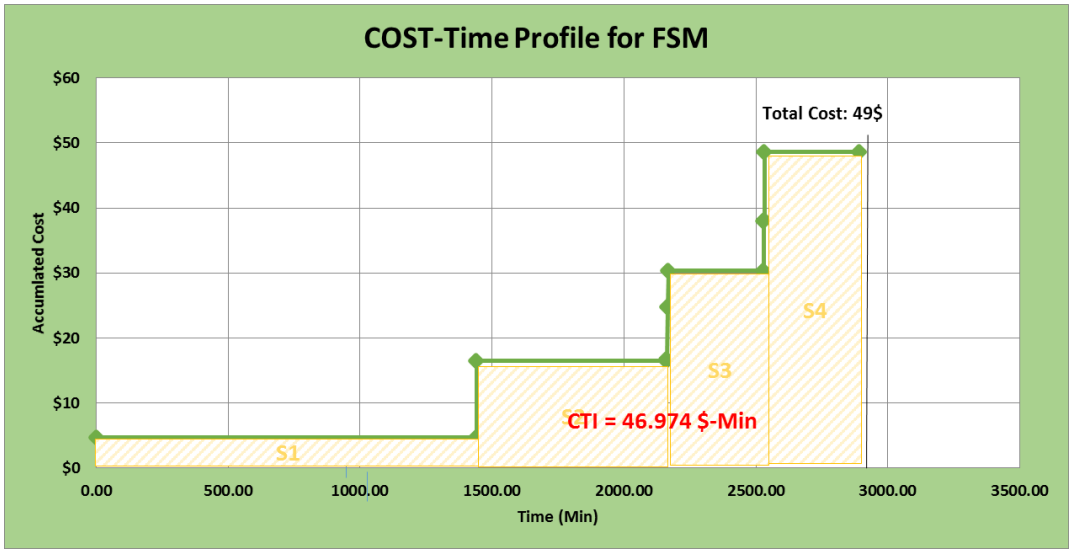

Figure 8 – Cost-Time profile for future state map

Calculating the product direct cost for the future state map

According to the information obtained from the CTP of the FSM, and by calculating the cost- time investment, considering the internal rate of return and adding the total cost, the product direct cost is calculated in this section according to the relation (1).

Direct cost = $ 49 + (46,974 $-min × 20%) = $ 49.017

Conclusion

Since the traditional system approach of calculating product costs is not responsive to the time effect of money and the cost-time investment in the accurate calculation production costs, this makes the calculated product direct cost different from its real rate that challenges the strategic decisions of the organization. In the present study, the product direct cost was $ 59 on a CSM, regardless of the time effect of money and time-cost investment; while its real value is calculated at $ 85.65 considering the time effect of money and cost-time investment. Also, the product direct cost in the future state map was $ 49 regardless of the time effect of the money and the cost-time investment; this is while its real value is $ 55.52 considering the time effect of money and cost-time investment. The improvement in the product direct cost was 35.17% in the future state map.

Disregarding the cost of carried out activities in a production process and the cost of consumable raw materials, are among the limitations of flow-charting tools that this paper tried to resolve them by combining cost-time profile and VSM tools and considering two important indicators of cost and time in order to provide a precise estimate of the producing cost a product, a different approach from traditional systems and a new method for calculating the product direct cost. Using this different approach, manufacturing organizations can reduce the Total Production Lead Time (TPLT) and increase the Total Value-Added Time (TVAT) in addition to identify wastes and non-value added activities, and consequently, more precisely calculate the products direct cost by considering the cost-time profiles, the time value of money and cost-time investments.

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Logistics Management and Physical Distribution

Does size matter? Impact of key supply chain competitive drivers on firm performance in the Valle del Cauca region in Colombia

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Abstract

This paper aims to determine the effect that key competitive drivers like human capital, quality, and cost have on supply chain performance, whether this effect is in turn related to the firm's outsourcing strategy, and whether firm size is relevant in explaining such relationships.

Structural equation modeling was used to test the hypothesized relationships for small-to-medium enterprises and large organizations. Initial findings show that human capital strategies are essential for an effective deployment of quality and cost management, which in turn impact supply chain performance by means of effective outsourcing strategies. These relationships, however, are dissimilar for different sizes organizations.

Keywords: Supply chain performance, Outsourcing, Human Talent.

Introduction

To be competitive, firms implement value-adding strategies that build on key competitive drivers (M. V. Ferrer, Santa, & Almadani, 2013; Sha & Chen, 2008). To better understand competitiveness at the firm level, it is necessary to identify the key drivers that impact the performance of the supply chain. Therefore, this research looks at the strategic role of a skilled workforce influence on key competitive drivers such as quality and costs, and seeks to test the

effect of these drivers on supply chain performance, and determine whether outsourcing activities mediate such an effect.

Based on a review of extant literature on supply chain cost, quality, outsourcing practices, and supply chain performance, this research found that human capital strategies are essential to ensure cost-effective and high-quality operations. Also, that outsourcing is important to facilitate the effectiveness of such drivers, and that effective deployment of these key drivers positively influences supply chain performance and a competitive supply chain.

Literature review

Human capital

Strategic human capital management is inherent to business strategy, and greatly determines a firm's supply chain and, in the long run, competitive advantage (Narasimha, 2000). Not surprisingly, the interest in talent management has grown consistently over the last decade. Human capital is widely assumed to be a key driver of firm and supply chain performance (Jabbour & de Sousa Jabbour, 2016). Human capital is spawned when organizations deploy resources for the development of people who work in the business. Similar to other investment choices, human capital investment is targeted to higher returns as long as the organization is rational.

The effect of human capital on supply chain performance, however, is not always clear. Human capital management is afflicted with misunderstandings, uncertainties, and lack of clarity, implying that the field is not grounded in practice and thus reinforcing why it is viewed by many experts as a puzzle (Stahl et al., 2012). The effect that human capital management has on the outcome of an organization remains an issue particularly in situations where only highly ranked staff is considered to be an asset to a business (Kehinde, 2012). It is on this basis that this paper aims to clarify the effect of human capital management on the outcomes of the supply chain and, consequently, the business performance and competitiveness. Rather than directly impacting performance, it is through its role in facilitating the adoption of value-adding organizational practices that human capital management can indirectly impact firm and supply chain performance and competitiveness. In particular, this research contends that human capital is a significant driver of firm and supply chain performance through its combined relationship with other, more direct drivers, such as cost and quality strategies.

Costs

The cost is the financial expense incurred in engaging in business which is essential to evaluating a firm's performance. Effective supply chain management will reduce the costs for a firm. Cost can be measured in terms of the total supply chain, each supply chain process, or the logistical costs only (SÖderber & Bengtsson, 2010). Supply chain cost is defined as all relevant costs in the supply chain of the company or organization in question. Analysis of supply chain cost can be performed in different ways. Different kinds of cost groupings can be found in the literature including transportation, production, inventory, packaging, materials holding, and order processing (Sachan, Sahay, & Sharma, 2005).

In this research, we are especially interested in two important, and often overlooked, cost elements: transaction costs and switching costs (Williamson, 1985). Information becomes available to supply chain participants at a cost. Firms incur in costs when searching for information and safeguarding against opportunistic behavior from other participants. When information is shared more frequently, searching costs and information-sharing transaction costs tend to decrease (Simpson, Power, & Samson, 2007), which in turn decrease the overall cost of

products and services (Brynjolfsson & Smith, 2000). On the other hand, asset specificity tends to increase as information is shared more freely and more frequently. Thus, interestingly, the reduction in transaction costs come as a trade-off to an increase in switching costs, given that it becomes increasingly costly for supply chain partners to seek new partners in the marketplace.

Quality

There is no unique definition of quality, and different meanings might be equally appropriate under different circumstances. The manufacturing literature, for instance, refers to quality as the conformance to standards (Elshennawy, 2004; Heizer & Render, 2006), a product-based approach that ensures that goods are manufactured well from the beginning. From a marketing perspective, quality relates to meeting or exceeding customer's expectations (Dean & Bowen, 1994; Slack, Stuart, Johnston, & Betts, 2006), a challenging definition indeed given that identifying such expectations is a complex task, to say the least.

From the point of view of quality management, supply chain could be recognized as providing quality products and services across every organization in the supply chain, to clients' expectations. Improving the quality of all supply chain processes leads to cost reductions, improved resource utilization, and improved process efficiency (M. Ferrer, Santa, Storer, & Hyland, 2011). There are a few studies that investigate how quality management can be used to improve the performance of the entire supply chain and also solve some problems within the supply network (Lin & Gibson, 2011) and other studies that identify various theoretical and methodological characteristics of the way in which knowledge management applications are proposed in the supply chain context.

Some authors suggest that further research is needed to provide more understanding about quality practices in the supply chain context and the association between quality practices and a system's overall performance, so there are suggestions for future research that could be very helpful for the companies (Marra et al., 2012; Craighead et al., 2009). For example, Terziovski and Hermel, 2011, in their exploratory study on the role of quality management practice in the performance of integrated supply chain, proposed that future research should focus on why quality practices are strong predictors of an integrated supply chain. Notably, relatively little research has been conducted on the association between quality and supply chain performance with the mediation of strategic practices such as outsourcing.

Outsourcing

Outsourcing of activities has been historically linked to cost-saving, third-party logistics (3PL) procurement strategies in manufacturing firms (Elango, 2008). With increasing frequency, though, outsourcing is becoming an important strategic option for all types of firms, and its benefits transcend the usual cost reductions associated with economies of scope and productivity by specialization. Outsourcing can take various forms, including outsourcing for some components, computer programming, services, tax and accounting services, customer services, transportation and logistics, compensation and human resources activities. Logistics outsourcing is one of the most common outsourcing forms that has attracted the attention of firms, academics, and researchers in recent years. According to Erturgut (2012), logistics outsourcing serves five basic purposes: providing the cost leadership, capable to use the basic perfections, providing the competitive edge, harmonizing with technology alterations and downsizing. The following section summarizes the expected logistics outsourcing advantages and disadvantages.

Hsu et al. (2012) find that logistics outsourcing can reduce fixed costs and increase flexibility, allowing greater focus on the core activities, reduce heavy asset investments and

improve the quality of service provided. Because logistics service providers (LSPs) are more efficient than logistics service users (LSUs) in terms of warehousing and transportation, costs reduction is the major benefit that LSPs offer to LSUs (Deepen, 2007). LSP outsourcing directly affects the LSUs cost position through reducing capital investment requirements. Additionally, LSPs help LSUs to avoid any unnecessary investment in workforce and to manage their supply chain at an affordable cost. Another major benefit is the increase in flexibility. LSPs help firms to become more responsive to the customers' requirements. Furthermore, a survey has found that the primary reason for outsourcing is the capability to focus on the core competencies, not cost reduction.

Most Fortune 500 firms are involved in some form of outsourcing, a pattern that is growing throughout industries and regions around the world. Such popularity notwithstanding, there are still untapped areas where outsourcing still has to prove its full potential, such as small and medium firms, outsourcing in emerging economies, and exploiting leveraging capability development on outsourcing strategies. In a globalized marketplace, small-to-medium enterprises (SMEs) are increasingly pressed to proactively seek and develop strategic partnerships in the supply chain (Kumar, K. Singh, & Shankar, 2014). Outsourcing can be a catalyst for innovation, quality, and supply chain flexibility, and thus contribute to level the battlefield and attain competitive advantage, provided that cross-functional in-house activities within the firm are effectively linked to externally executed processes (M. Beheshti, Oghazi, Mostaghel, & Hultman, 2014).

Supply Chain performance

As global economic order unfolds, firms are increasingly aware of measuring their performance outcomes and the impact of strategic supply chain on competitiveness. Researchers have argued that more often firms implement quality management initiatives to improve the overall quality of operations by the reduction on operational cost and the increase of agility practices. Hubbard (2009) suggested that measuring performance is likely to become more complex as stakeholder expectations about companies' economic, environmental, and social responsibilities are constantly shifting.

Supply chain management assists organizations to control the flow of information, materials, and cash from suppliers, manufacturers, distributors, and retailers to customers. Through an effective planning, controlling, and coordination of the supply chain activities, organizations are able to accomplish fast response, low inventory, high quality, and customer satisfaction, which in turns lead to a competitive advantage (M. V. Ferrer & Santa, 2017). Therefore, performance is the measure which aims to benchmark and evaluate the effectiveness and efficiency of any organization. Different stakeholders require different performance indicators to enable value-adding reporting, starting improvement activities to outperform competitors, and understanding customers' reading of the services and products offered by the firm.

The SCOR model approach directly addresses the needs of supply chain management with balanced measurements. These measures are characteristics of a supply chain that permit it to be analyzed and evaluated against other supply chains with competing strategies. Supply chain goals express the balanced needs of a supply chain's stakeholders including suppliers, manufacturers, distributors, and retailers at different levels (Najmi and Makui, 2011). Through SCOR, companies try to release financial resources, reduce costs, lighten the company management, and improve global performance. Hence, SCOR is close to the outsourcing concept, because the latter also supposes the restructuring of the organization by relocating a part of its

activities outside the company to reduce costs. Similarly, Ellram and Stanley (2008) discuss various performance measures applicable to strategic as well as in tactical outsourcing which include cost reduction, time to market on new products/services, meeting customer needs, product/service performance, new product/service launches, responsive supply chain, working capital and cost savings/increased profitability.

A number of disadvantages and challenges related to outsourcing as a strategic performance enhancer are also mentioned in the literature. Dabhilkar and Bengtsson (2008) argue that outsourcing has negative effects when used as a main strategy for performance improvement. Similarly, Broedner et al. (2009), states that the reliance on outside suppliers may lead to a loss of overall market performance and, according to Gilley and Rasheed (2000), the consequence of outsourcing is lower innovation capacity and the cost savings associated with outsourcing may be overestimated. Some other reasons why companies are against outsourcing include sacrificing their competitive base, opportunistic behavior, rising transaction and coordination costs, limited innovation, and higher procurement costs.

Hypotheses

Based on our literature review, this research contends that human capital strategies are essential to ensure cost-effective and high-quality operations; that outsourcing is important to facilitate the effectiveness of such drivers; and that effective deployment of these key drivers positively impacts the performance of the supply chain and, consequently, the competitiveness of the organization. Therefore,

H1: There is a positive relationship between human capital and a firm's quality strategy

H2: There is a positive relationship between human capital and a firm's cost strategy

H3: There is a positive relationship between human capital and a firm's outsourcing strategy

H4: There is a positive relationship between a firm's cost strategy and its outsourcing strategy

H5: There is a positive relationship between a firm's quality strategy and its outsourcing strategy

H6: There is a positive relationship between a firm's cost strategy and the supply chain performance

H7: There is a positive relationship between a firm's quality strategy and the supply chain performance

H8: There is a positive relationship between a firm's outsourcing strategy and the supply chain performance

Figure 1 illustrates the hypothesized relationships, and the corresponding structural equation model.

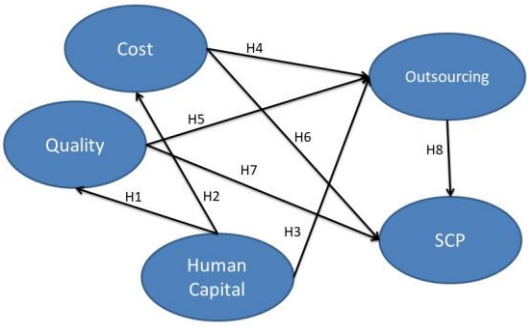

Figure 1. Research model with hypotheses.

Research methods

To test our hypotheses, we submitted an online survey to 600 multi-sectorial firms in the Valle del Cauca agro-industrial region, in Colombia. Similar studies that consider the impact of human capital on operational strategies focused on cost, quality, and outsourcing initiatives have been conducted in other countries (M. V. Ferrer & Santa, 2017). However, to the best of our knowledge, there are no precedents to this kind of study in our region.

A five-point Likert-type scale, ranging from 1—strongly agree to 5—strongly disagree, was used to rate statements related to the operationalization of the model's variables. In total, 435 participants submitted their responses, for a 72.5% response rate. We discarded 31 surveys owing to inconsistencies or significant missing data, for a final count of 404 usable surveys (67.3% effective response rate). We used the average mean values of the statements' ratings to construct the structural equation model's variables. To gain a better understanding of how competitive priorities relate to firm size, we split the collected surveys into two distinct groups, small to middle enterprises SME (N=167) and largo organizations LO (N=237).

The analyses included confirmation of the conceptualized model shown in Figure 1 by estimating the model variables' predictive relationship and the model's fit indices to determine overall confidence level. We also conducted confirmatory factor analysis (CFA) to assess the relationships between the observed and continuous latent variables, and to determine the measurement model's overall fit (Cooksey, 2007; Hair, Black, & Babin, 2010). We estimated factor loadings, confirming that items loaded on only one construct (i.e., no cross loading), and correlated our latent constructs (equivalent to conducting an oblique rotation in exploratory factor analysis). We assessed internal consistency using Cronbach's alpha coefficient and the items-to-total correlation.

To support the model, we computed goodness-of-fit indices (GFI). The resulting indices (SME: CMIN/DF=2.945, probability=0.000; and LO: CMIN/DF=4.168, probability=0.000) fall within the accepted criterion of CMIN/DF≤5.0 (Wheaton, Muthen, Alwin, & Summers, 1977). Whereas Marsh and Hocevar (1985) recommended using ratios as low as two or as high as five, Carmines and McIver (1981) suggested ratios in the range of 2:1 or 3:1 as indicatives of an acceptable fit between the hypothetical model and the sample data. Also, a comparative fit index (CFI) <0.9 is usually accepted as supportive of the model (Bentler, 1990), which is the case in our hypothesized model (SME: CFI=0.915; LO: CFI=0.901). Finally, the baseline comparisons fit indices suggest that the hypothesized model fits the observed variance-covariance well, relative to the null or independence model (see Table 2).

Table 1. *Baseline comparison.*

	Small-to-Medium Enterprises (SME)					Large Organizations (LO)				
Model	NFI Delta 1	RFI Rho 1	IFI Delta 2	TLI Delta 2	CFI	NFI Delta 1	RFI Rho 1	IFI Delta 2	TLI Delta 2	CFI
Default	.880	.854	.916	.897	.915	.838	.810	.865	.841	.865
Saturated	1.000		1.000		1.000	1.000		1.000		1.000
Independent	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

Results and Discussion

Table 2 and Figure 2 summarize the structural equation modeling (SEM) results in the relationships between human capital (HC), quality strategy (QS), and cost strategy (CS). For SME, there is a strong and positive relationship between HC and the two types of strategy (QS: b=0.42, p <0.001; and CS: b=0.39, p <0.001), thereby supporting hypotheses H1 and H2. Findings for LO were similar, also indicating a strong and positive relationship between HC and the two types of strategy (QS: b=0.58, p <0.001; and CS: b=0.34, p <0.001), thereby supporting hypotheses H1 and H2. Concurring results for SME and LO endorse the importance of implementing adequate human resources practices to ensure quality and cost management, regardless of firm size.

Table 2. *Regression weights.*

			Small-to-Medium Enterprises (SME)				**Large Organizations (LO)**			
			Estimate	S.E.	C.R.	P	Estimate	S.E.	C.R.	P
QS	<---	HC	.294	.056	5.302	***	.615	.064	9.668	***
CS	<---	HC	.381	.076	5.031	***	.366	.072	5.060	***
OS	<---	HC	-.282	.197	-1.434	.152	.226	.148	1.526	.127
OS	<---	CS	.025	.101	.249	.803	.288	.089	3.224	.001
OS	<---	QS	.039	.138	.279	.780	.177	.104	1.702	.089
SCP	<---	CS	.314	.090	3.487	***	.321	.084	3.846	***
SCP	<---	QS	.082	.120	.682	.495	.385	.087	4.405	***
SCP	<---	OS	.132	.072	1.832	.067	.107	.063	1.704	.088

On the other hand, there is no effect of HC on outsourcing (OS), neither for SME (b=-0.23, n.s.) nor for LO (b=0.16, n.s.), therefore rejecting hypothesis H3 on the positive effect of human capital on a firm's outsourcing strategy. Hypothesis H4, that there is a positive relationship between a firm's cost strategy and its outsourcing strategy, was also rejected for SME (b=0.02, n.s.). Note, however, that the results support H4 for LO (b=0.22, p < 0.005), which suggests that small firms do not seek cost efficiency by means of outsourcing activities, compared to larger firms (at least in the Valle del Cauca region). Hypothesis H5, which suggests that firms that prioritize quality strategies will tend to implement outsourcing initiatives, was rejected for both SME and LO. The findings showed a positive relationship between cost strategy and supply chain performance, for both SME (b=0.29, p <0.001) and LO (b=0.26, p <0.001), thereby supporting hypothesis H6. Hypothesis H7, that there is a positive relationship between quality strategy and firm performance, was rejected for SME (b=0.05, n.s.) and supported for LO (b=0.30, p <0.001). Finally, hypothesis H8, which suggested that firms will improve performance through the use of outsourcing practices, was rejected for both SME and LO. Figures 2, summarize the structural equation modeling results .

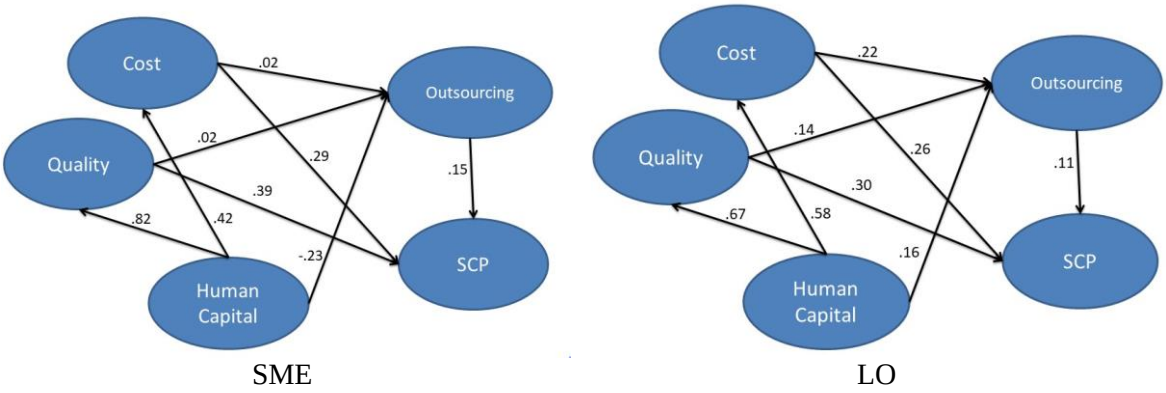

Figure 2. *Structural model results for SME and LO.*

Conclusion

The findings from this research suggest that human capital strategies are essential for an effective deployment of quality and cost management strategies, which in turn impact positively on the supply chain performance. Furthermore, these results hold for both SMEs and LOs. Aligned with much of extant literature on human resources, human capital's impact on firm and supply chain performance is therefore indirect, and results are rather attained by means of effective quality and cost strategies.

The relationship between such key drivers and supply chain performance, however, is not equally significant or as strong for SMEs as it is for LOs. Whereas cost strategy is indeed important for both SMEs and LOs to achieve competitiveness through superior supply chain performance, quality strategies seem to be related to supply chain performance only for LOs. Costly total quality management (and other, similar quality-related systems) could be the main reason.

Another interesting inference from our results pertains to the firms' preferences towards outsourcing strategies. Contrary to widespread, international business sense, the firms studied seem to disregard outsourcing practices as a source of competitiveness. Indeed, the relationship between cost strategy practices and outsourcing strategies holds only for large firms. When SMEs outsource their activities, they are more driven by lack of access to the types of know-how, technologies, capital, and other resources that the bigger organizations enjoy. This could be explained by the notion that outsourcing decisions in Colombian SMEs may be made on the basis of a management team's skill level or personal interest. In comparison to LOs, the management teams of SMEs most likely already recognize the areas in which they have interest and ability and since they are small, it would easier for them to focus attention on those activities. As a result, the outsourcing decision may be made on the basis of talent, interest in performing an activity, or convenience rather than how it supports the whole organizations' strategy.

Similarly, it could be argued that Colombian SMEs are still in the process of establishing routines and hence lack competitive advantage as compared to larger organizations. It is therefore difficult for them to determine which functions are necessary to support the organization. In view of this, outsourcing decisions for SMEs would likely be premature and could result in the destruction of capabilities. In consequences, many SMEs would be less likely to pursue outsourcing for the many reasons global SMEs do it.

Taken together, our results hint that local companies should strengthen their alliances with third-party logistics (3PL) partners to be internationally competitive. The benefits usually associated with 3PL practices (e.g., service levels control, systems integration, access to a variety of specialized resources, cost reduction) are important for competition in a globalized marketplace. Such practices, however, do not seem to be the norm in the analyzed region. Organizational culture, national or regional culture, limitations in financial or human resources, and other factors could be hindering more proactive outsourcing strategies, especially amongst SMEs. This said, our study also shows that creation of firm value (i.e., performance) is indirect. That is, effectively implementing quality and cost strategies combines synergistically with outsourcing strategies to improve supply chain performance, perhaps compensating for the lack of other resources or capabilities.

Certainly, the key drivers studied are not the only ones affecting the performance of the supply chain. Beyond diving deeper into the nuances of the relationships hypothesized in this paper, future studies could also explore cultural or regional specificities that better explain the competitive drivers (or lack of them) amongst our local firms. For instance, local firms might lack the capability to obtain quality information related to 3PL's best practices, and therefore ignore the strategic value of an effective supply chain partnership, the potential for risk reduction and risk sharing implicit in smart outsourcing strategies, and the synergies to be attained when important resources are freed—through 3PL—to be invested in other, core-related, valuable ventures.

Our contribution to the literature is threefold. Upon exploring the relationship between predictors and outcomes of supply chain performance through outsourcing, we are contributing not only to a more complete understanding of key competitive drivers, but we are also highlighting regional specificities that could help to bring these matters into the managers' radars and help them consider more effective strategies. In addition, we are contributing to research methodologies by proposing a quantitative approach that helps to fill the numerical void common to many studies on competitiveness.

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A decision support system (DSS) to study the impact of dynamic vehicle routing for whitefish

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Abstract

To distribute high-quality fish throughout the food supply chain is a challenging task for the fishing industry. To deliver fish to the appropriate processors, in this work, we propose a decision support system (DSS) based on agent-based simulation and optimization for delivery of the right product to the right processor. The proposed DSS helps the organization in a) reducing losses in Whitefish supply chain, b) making a higher profit, and c) improving the supply chain performance.

Keywords: Vehicle routing, Agent-based simulation, Whitefish supply chain

Introduction

The fishing industry in Norway has significant contributions to their trade (SSB, 2018). In 2017, it contributed approximately 11% of their total export (OEC, 2019). However, the sector is experiencing declining profitability (Qualifish, 2018). Whitefish supply chains are complex in nature due to seasonal variations, high supply uncertainty and rapid quality deterioration due to handling and temperature variations. In Norway, catch volumes for whitefish including cod, saithe and haddock amounted to 721 525 tonnes in 2014. This included 473 478 tonnes of cod with a value of approximately 520 million Euros.

Most wild cod is exported as lower-value products preserved in salted, dried, and frozen forms. In season whitefish processors typically buy from coastal vessels that deliver fresh fish and in off-season, they mostly buy from sea-going vessels that deliver frozen fish. So, delays and inefficiencies in the distribution of whitefish from sourcing stations to appropriate processors after landing is cost-intensive and any delays in distribution can also contribute to food losses.

In this paper, dynamic pickup and delivery routing from different sourcing stations to the processors is investigated in the whitefish supply chain based on the quality of fish. We have limited our study to cod *(Gadus morhua)* which provides the most value among the wild caught fish in Norway (NSC, 2017).

The fish arrives at the sourcing stations in bulk mostly by coastal vessels that deliver fresh fish in season or seagoing vessels that provide fresh and/or frozen fish in off-season (Thakur, 2017). The arrival times of coastal and seagoing vessels at sourcing stations are uncertain, and for the most part this is also true for the quantity and quality of whitefish on the vessels. After the arrival of fish at the sourcing stations, each batch of bulk whitefish is marked with a current quality. The remaining shelf-life of that batch represents the condition of the fish, or the current quality in days until the fish can no longer be transported to appropriate processors. It is assumed that the processors prefer receiving the fresh fish, i.e., with maximum remaining shelf-life and that the sourcing stations have full knowledge about the quality of each batch of whitefish that arrives in bulk. Over time the quality of fish deteriorates based on the temperature and its intrinsic characteristics. We have considered three different temperatures in this study, namely, at sourcing stations, during the loading and unloading process, and on the vehicle during transportation.

Problem Description

In this study, we have considered two types of processors based on the capacity and products at different locations:

1) primary processors that produce packed fresh and frozen whole fish and fillets,

2) secondary processors that mainly produce a mix of consumer products such as ready meals, sushi, etc.

Processors place an order to the nearest sourcing stations based on their demand and processing capacity. Each requested order has to be served by the sourcing stations as early as possible to maintain the freshness and the quality of the fish. Fish from the sourcing stations is transported by trucks to different processors based on the quality. Availability of vehicles at each sourcing station varies over the day depending on the transporter preferences. Transporter has to select the pickup location (i.e., sourcing stations), and routing of the trucks based on the order, to minimize total travel distance and maximize the remaining shelf-life of fish at delivery to the processors. The focus of these objectives is to reduce the cost and maximize the customer satisfaction by the processors respectively. Therefore, an optimal solution needs to be found as per the requested order from a set of available solutions with a combination of the accessible vehicle route, the limited number of trucks in the fleet, and the current locations of each truck in the supply network.

Figure 1 describes the problem settings as investigated in this paper. To fulfil an order requested by the processors, the sourcing station manager or transporter has to make the following decisions:

(i) which type of vessels are delivering the fish to the sourcing stations;

(ii) which sourcing station should serve a requested order; and

(iii) selection of the vehicle route.

These decisions impact both objectives, i.e., fish quality and travel distances. Additionally, processors get a competitive advantage by delivering fresher products to their customers.

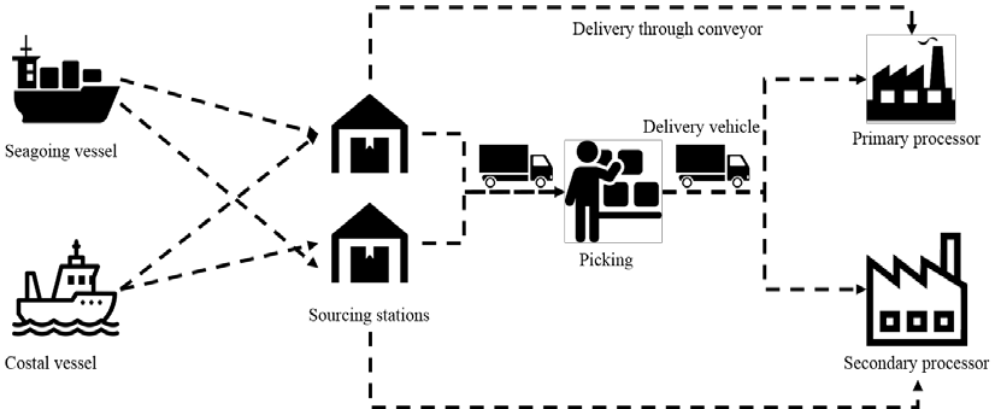

Figure 1 Delivery of whitefish under consideration of fish quality and available vehicle routes

Design of the decision support system

To investigate the problem described in this paper, we introduce a DSS based on agent-based simulation and optimization. This system combines the Geographic Information System (GIS) data from OpenStreetMap, (2018) with vehicle routing procedure, based on the existing architecture described in Fikar, Gronalt, & Hirsch, (2016). Figure 2 depicts the overview of the developed DSS. The user sets the input parameters and data and further defines the study region.

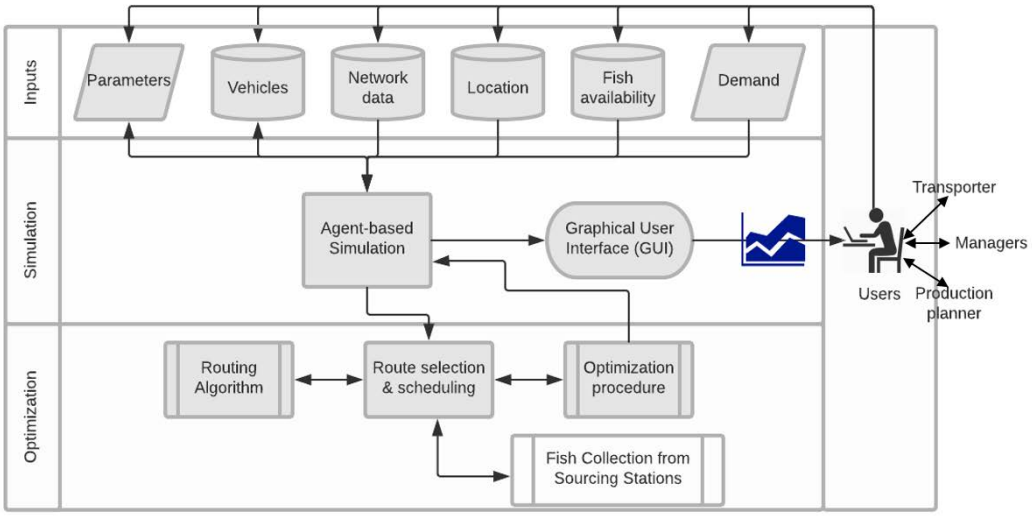

Figure 2 A DSS to investigate dynamic vehicle routing in whitefish supply chain

Once sourcing stations receive an order from a processor, it sends fresh or frozen fish available at the sourcing stations via truck. In this study, we consider that each sourcing station has a cold storage facility to reduce losses. Transportation states can be depicted in Figure 3, diagrammed in AnyLogic 8.3.2. Initially, a truck located at the sourcing stations waits for a shipment request sent by the processors. Once it gets the request, it loads fresh or frozen fish as per the order and delivers them to the appropriate processors. Travel time between sourcing stations is computed based on driving speed. We considered the speed of a truck is 60 Km per hour (60 Km/Hr) and distance is given by GIS module in AnyLogic 8.3.2. The truck unloads the fish at a processor and returns to the souring station. Finally, a truck is located at sourcing stations and waits for the next order. The advantage of the proposed agent-based simulation model is that it accurately estimates the dynamic ordering process between sourcing stations and processors.

Selected candidate sourcing stations, primary processors, and secondary processors sites in AnyLogic simulation software are in a wide range of locations in Norway.

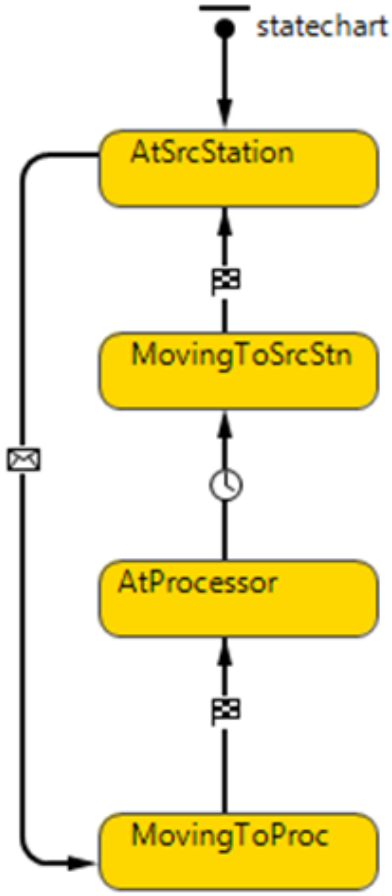

Figure 3 State chart for vehicle routing between sourcing stations to processors

Table 1 - Parameters used in simulation modeling and its value

Parameter name	Description	Parameter value
NoTrucks	Number of Trucks	100
Gas_Constant	Gas Constant (J/mol. K)	8.314
ReferenceTemperature(K)	Reference temperature in (K)	275.15
ActivationEnergy	Activation energy	103000.0
qualityReactionRate	Quality reaction rate	1.0
SelfLifeatRefTemp	Shelf-life of whitefish at reference temperature (Days)	10
currentQuality	Current quality of the whitefish	Uniform (0.8, 1)
qualityLimit	Threshold quality of the whitefish	0.2

Results

To study the defined problem setting in the above section regarding whitefish delivery to processors from sourcing stations in Norway, we implement the proposed DSS with AnyLogic 8.3.2. An overview and description of the parameters used in the DSS are given in Table 1. Further, we have set the value of the parameters used in this DSS simulation modeling based on literature and the secondary sources. The remaining shelf-life of the whitefish is calculated by Arrhenius equation (Laidler, 1984). The route from the sourcing stations to processors are taken from the OpenStreetMap (OpenStreetMap, 2018), and the shortest routes are calculated based on the GraphHopper features of AnyLogic 8.3.2. The visualization of the DSS is done based on GIS.

The performance of the DSS is shown in Table 2. We can see that the waiting time of the vehicle at sourcing stations is about 13 hr which is maximum as compared to processors. The average time to complete a tour from the sourcing stations to the processors is approximate 8 hr and the average distance travelled by a vehicle is approximate 473 Km/day in our setting. So, we can make changes in the strategies to minimize the waiting time of the vehicle at sourcing stations. The limitations of our study are that we have not considered the congestion on the route and also the working timing of the drivers.

Table 2 - Performance of the simulation-based vehicle routing

Average time for Vehicle (hours/ Vehicle)	**At_Processor**	2.498936
	At_SrcStation	13.05693
	MovingToProc	7.890513
Average Travel distance (Kms/ Vehicle)		473.4308

Conclusion

In this paper, we proposed a decision support system (DSS) based on agent-based simulation and optimization to the delivery of the right product to the right processor basically regarding the whitefish delivery from sourcing stations to the processor in Norway. The main focus is on the quality of whitefish which is the influencing factor in

the dynamic vehicle routing. It will help the decision makers in the vehicle routing by consideration of the quality of whitefish which is not the case in traditional vehicle routing. Future work can focus on extending this model by including traffic congestion on the route.

Acknowledgments

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Solving attended-home-delivery problem of Indian PDS using iterated local search approach

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Abstract

In the modern era of e-grocery, attended home delivery (AHD) has been identified as a crucial problem for the last-mile delivery problem (LMD). This paper deals with a real-life LMD problem in the context of Indian public distribution system (PDS). In this study, we propose a meta-heuristic algorithm based on iterated local search (ILS) to obtain a routing solution. By computational experiments, we show that the proposed approach performs significantly well for large size problem instances, and can be implemented to solve delivery problems faced in Indian PDS.

Keywords: Indian PDS, attended home delivery**,** iterated local search

Introduction

In recent years, last mile delivery has drawn significant attention in research and real-world practice, due to its importance in the modern era of e-commerce. The last mile delivery problem is a variant of the vehicle routing problem (VRP). This problem is well known for being NP-hard and extremely difficult to solve optimally. Attended home delivery is the most challenging part of the last mile delivery problem. In the modern society, this class of problem has substantial importance to several real-world problems ranging from drug companies and home health care services to telecommunication sector, e-grocery, and online retail (Campbell and Savelsbergh, 2005).

For a typical case of attended home delivery (AHD) under the last mile delivery (LMD) problems, the customer must be present to collect the delivery item. The presence of the recipient may be required due to several reasons, say for payment, security issues, or difficulties with leave the parcel unattended. In the present study, we consider a unique AHD problem faced by the Government of India, Delhi, to aid a problem of door-step delivery of rations under the Indian Public Distribution System (PDS). According to a proposal made by the Department of Food, Supply and Consumer Affairs of the Government of Delhi, PDS beneficiaries of Delhi can now opt for doorstep delivery of monthly ration. This action is hugely beneficial for the persons

of old age and with a physical disability (Botekari 2017). However, as discussed before, real-life doorstep delivery problems are NP-hard and extremely difficult to solve optimally. Thus, to aid the real-life problem of door-step delivery of rations in India, we formulate a multi-objective mathematical model and design a meta-heuristics algorithm to solve it.

Literature review

The work by Dantzig, Fulkerson, and Johnson (1954) was one of the first literature discussed on the VRP, followed by the work by Clarke and Wright (1964), where they incorporated more than one vehicle in the mathematical formulation. Since then, several other versions of VRP emerged. To name a few, one can see the paper by O'Connor & De Wald (1970) on transportation network design, work by Levin (1971) on fleet routing problem, and the study on distribution management by Eilon, Watson-Gandy, & Christofides (1971). The concept of time-window was later introduced by Solomon (1983) to the classical VRP problem. After 1990, researches on VRP accelerated rapidly, mostly due to the availability of computational resources. During this era, a number of search algorithms evolved as meta-heuristics to aid VRP and several other NP-hard combinatorial problems (Eksioglu et al., 2009). Since 1990, researchers discussed several meta-heuristics algorithms to solve VRP problems. To discuss a few, Renaud et al. (1996) were one of the first to propose a meta-heuristic for the VRP problems. Filipec et. al (1997) first proposed a genetic algorithm for the travel distance minimization. Later, Vianna et al. (1999) incorporated an evolutionary algorithm in iterated local search framework to minimize the total cost. Wu et al. (2002) proposed a simulated annealing approach and Polacek et al. (2005) proposed a variable neighbourhood search procedures for the capacitated VRP. Maya et al. (2012) adopted a greedy randomized adaptive search procedure to minimize travel distance and cost. Alaïa et al. (2016) combined clustering algorithms with genetic algorithms to optimize a pick-up and delivery problem. Cai et al. (2018) adopted an iterated local search based meta-heuristic for solving a real-life last mile delivery problem of an express delivery company in China.

All the above mentioned literature discuss the single-objective variant of VRP. However, literature on multi-objective VRP are relatively scarce. Montoya-Torres et al. (2015) pointed out that among the substantial literature on VRP, less than fifteen present was on multi-objective VRP. To highlight a few, Lin and Kwok (2005) studied a location routing problem considering simultaneous decision making on the location of depots, vehicle routing and assignment of routes. Tan et al. (2006) studied a truck and trailer vehicle routing problem (TTVRP) to minimize routing distance and the number of vehicles by a hybrid multi-objective evolutionary algorithm (HMOEA). Weise et al. (2010) presented an interesting real-life VRP problem involving the maximization of resource utilization and minimization of travel distance. They used an Evolutionary algorithm to solve the multi-objective problem. Dharmapriya and Siyambalapitiya (2010) considered a multi-objective VRP with time windows and split delivery, and adopted an artificial intelligence based computational technique to optimize the problem. A hybrid electromagnetism algorithm for multi-depot periodic vehicle routing problem was proposed by Mirabi (2014) to minimize travel distance and customer waiting time. Finally, the concept of carbon emission reduction in a multi-depot VRP was discussed by Rodrigues et al. (2014).

Problem Formulation

In the present scenario of Indian PDS food grains and other essential commodities are distributed to its beneficiaries via Fair Price Shops (FPS). As per the calculation of Chakraborty and Sarmah (2019), each FPS is on an average associated with about 500 families. As per the proposal of the Delhi Government, the households entitled for their monthly food grains under NFSA 2013 Act can now choose to get their ration delivered at their doorstep at an additional service charge. Figure 1 shows a general framework for the aforesaid problem.

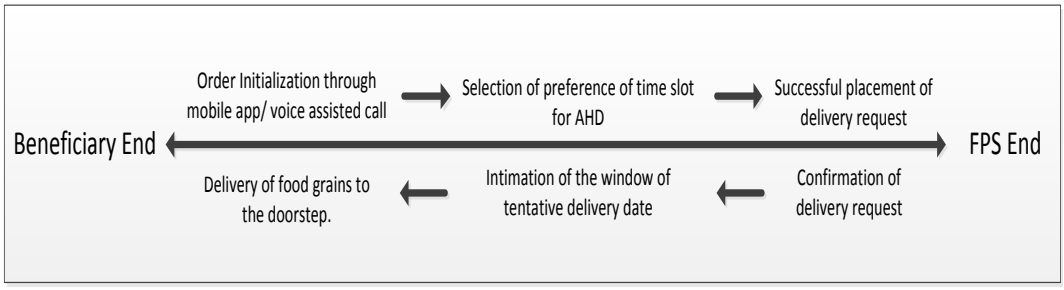

Figure 1: Framework of a door-step delivery problem of Indian PDS

Here, the beneficiary initiates a delivery request through a mobile application or voice calling. In the process, the beneficiary also chooses a time slot for the delivery request. Upon receipt, the fair price shop processes the order and attempts to deliver the grains in the aforementioned time slot to avoid failed delivery due to non-availability of the recipient. This kind of problem can be broadly identified as single-depot capacitated vehicle routing problem with time windows (SDVRPTW). The provision to let the recipients choose the delivery time slot is one major aspect of SDVRPTW. Thus, the major challenge of the problem lies in the framework of the door-step delivery model (Agataz et al. 2011), as it is extremely important to minimize the randomness and no-show probability of the beneficiaries by abiding the time slot selected by the beneficiary. The nature of this kind of problem is NP-hard (Cai et al., 2018) and is extremely difficult to solve optimally. Therefore, in this study, we formulate the problem as a multi-objective mathematical programming model and solve by using the iterated local search (ILS) framework (Lourenço et al., 2003).

Mathematical model

Given a set of beneficiaries $V = \{1,2, \dots, n\}$ with known demands of q_i for any $i \in V$. The maximum vehicle capacity is Q. The FPS is considered to be a source node and marked as 0. The directed graph can thus be noted as $G = (V^+, A)$, where $V^+ = V \cup \{0\}$ is the set of nodes and A is the set of arcs. Each arc $(i, j) \in A$ is associated with a travel time $T_{ij} > 0$. Each customer is subject to a service time s_i. The preferred time window in hours opted by a beneficiary is defined as m_i and n_i. The formulation of the problem is as follows.

Minimize

$$Z_1 = \sum_{i,j \in V^+} T_{ij} x_{ij} \quad (1)$$

$$Z_2 = \sum_{i,j \in V^+} (\max[(m_i - t_i), 0]) + (\max[(t_i - n_i), 0]) \quad (2)$$

Subject to:

$$\sum_{j \in V^+} x_{ij} = 1 \quad i \in V \quad (3)$$

$$\sum_{i \in V^+} x_{ih} - \sum_{j \in V^+} x_{hj} = 0 \quad h \in V \quad (4)$$

$$q_i \le u_i \le Q \quad i \in V \quad (5)$$

$$u_i - u_j + Q x_{ij} \le Q - q_j \quad i, j \in V \quad (6)$$

$$t_i + (t_{ij} + s_i) x_{ij} - N(1 - x_{ij}) \le t_j \quad i, j \in V \quad (7)$$

$$x_{ij} \in \{0,1\}, \quad i, j \in V^+ \quad (8)$$

$$u_i, t_i \ge 0 \quad i, j \in V \quad (9)$$

x_{ij} is 1 if arc is included in any route, otherwise 0; t_i is the time at which delivery is made for every node i. N is a very large number and u_i is the accumulated demand for node i. Equation 1 minimizes the total travel time, equation 2 minimizes the deviation of the actual delivery time from the beneficiary specified delivery time. Equation (3) and (4) ensures every route to begin from the depot and the visit of each customer to be exactly once. Equation (5) and (6) is the route capacity constraint and ensure that the amount of delivery on a route has to be less than vehicle capacity Q. Equation (7) ensures that the route schedule remains feasible for every route.

Proposed solution methodology

An iterated local search (ILS) has been employed as the algorithm framework to solve the aforementioned problem of SDVRPTW. Initially, we use the weighted sum approach to convert the multi-objective problem into a single objective problem. The ILS framework consists of three major components, namely initial solution generation, improvement and the perturbation. At the beginning of the process, an initial feasible solution is generated for the problem. This method relies on traditional hill climbing algorithms as given in algorithm 1.

Algorithm 1: Initial Solution generation

```
Initialize an empty route r;
for all days
        current time ← 0;
        Initialize current node I ← 1;
    for each node
        Calculate time required to reach all other nodes from current node A;
        for all nodes accessible from current node
            calculate the time deviation B;
        end for
    end for
Find minimum of feasible weighted sum of A and B;
i ← new node the vehicle goes to;
Insert newly found node to node in route r;
Assign the column of time for that node to zero;
end for
```

In the improvement phase, several relocate and exchange operators are used for generating a better solution. In the relocate function, one or two vertexes is removed from the initial route and compared from the original solution. In the exchange operator, on the same route, two orders are interchanged. The solutions are discarded whenever they lead to infeasible solutions and the steps are shown in algorithm 2.

Algorithm 2: Solution Improvement

```
Use route to generate initial solution S0
Set Sc ← S0
for all days
    Employ improvement operators;
    if f( Sc ) > f( So )
        Si ← Sc
    else
        Interchange by and update solution Sc;
        if f( Sc ) > f( So )
            So ← Sc
        end if
    end
end
Repeat same process by interchanging nodes for 2 random days
So is now the optimized solution
```

In the perturbation phase, we employed a large neighbourhood search algorithm to explore the solution space. Several removal and insertion operators are used in this process. The removal operators included in the process are consists of Random removal (Random removal of some orders of a route), Worst removal (Remove highest cost order) and Route removal (Remove a complete route) from the solution. The Insertion operators are Random insertion (Random insertion of some orders of a route), Greedy insertion (Insert the smallest cost increment) and Route insertion (Random insertion of the removed route). The perturbation algorithm is shown in algorithm 3.

Algorithm 3: Perturbation

Find a solution that has to be perturbed;
Find a removal operator to be used;
Find a insertion operator to be used;
Generate solution S_p
Apply solution optimization on S_p
if $f(S_p) > f(S_o)$
$S_o \leftarrow S_p$
else
Accept original solution S_o
end

When a better solution is generated in the process, the previous solution is discarded and the new solution is stored. We run the operation for a pre-specified number of iterations, the program is terminated and the best solution is reported.

Computational Results

Here, in this section, we discuss the computational results for the aforesaid problem. The ILS was encoded in MATLAB 2015b on an Intel Core-i5 processor with 8 GB RAM and Windows 7 Professional edition. We applied IBM CPLEX Optimization studio on the same platform with a run-time limit of one hour to compare the solution gap for the mathematical programming problem. We have assigned equal weight of 0.5 for both the objective functions for the weighted sum average method. This converts the multi-objective model into a single objective optimization problem.

Two test instances were randomly generated considering a planning horizon of five days and seven days. Each instance was run for five different random scenarios. All the input parameters were randomly generated and the time window was considered to be of two hours. Vehicle capacity was assumed to be of 500 KG and service time was considered to be random numbers within [10, 20] minutes. Customer demand was calculated as per NFSA 2013 (Chakraborty & Sarmah, 2019) and family size was considered to be random within [1, 6].

To calculate the solution improvement, we compare the best solution reported by CPLEX after one hour of runtime. From table 1, it is seen that ILS performed better than CPLEX in one-hour time limit for almost all scenarios. It is also seen that, although CPLEX failed to solve the problem instances optimally for both the five and seven-day scenarios in the one hour time, the optimality gap shown by CPLEX was much lesser for the five-day instances, than the seven-day instances.

In order to compare the solution improvement, we use the following formulation:

$$Improvement = \frac{CPLEX\ solution\ Value - ILS\ solution\ value}{CPLEX\ solution\ value} \times 100 \qquad (10)$$

Table 1: Computational results for solution improvement

Sl. No.	No. of Days	Solution Time (Seconds)		Objective Value (Normalized)		Improvement (%)	Average Improvement (%)
		ILS	CPLEX	ILS	CPLEX		
1	5	250	3600	96.72	96.77	0.05	
2	5	253	3600	95.27	93.5	-1.90	
3	5	247	3600	95.72	126.11	24.09	10.29
4	5	261	3600	96.83	113.78	14.89	
5	5	258	3600	93	107.55	13.53	
6	7	323	3600	97.37	124.41	21.73	
7	7	326	3600	100.38	141.20	28.90	
8	7	324	3600	98.45	131.5	25.12	25.06
9	7	323	3600	94.5	121.37	22.14	
10	7	322	3600	93.93	129.45	27.44	

Conclusions

In this paper, we investigate a real-life SDVRPTW problem faced by the Government of India. An iterated local search (ILS) approach integrated with an adaptive large neighbourhood search has been proposed to solve the problem. The effectiveness of the algorithm has been evaluated through a set of randomly generated instances. We show that the ILS approach can effectively aid the door-step delivery problem in the Indian PDS. In this scope of work, the present research only explores a real-life door-step-delivery problem of Indian PDS. However, this study, by its nature, is generic and can be extended to many real-world SDVRPTW problems.

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Truck sharing in the spotlight of current research streams - a literature review

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Abstract

The road freight transportation-industry in the German speaking countries (Germany, Austria and Switzerland [GAS]) faces high margin pressure (resulting from the competition pressure) on the one hand and empty capacities on the other hand. The ecological pressure from e.g. regulatory measures, competition or public due to reputation reasons should not be under-estimated. The market for road freight transportation, however, lacks possibilities to foster utilization of physical resources through a sharing approach such as truck sharing[1] that would lower costs and enable logistic service providers (LSP) to achieve higher margins.

Keywords: Truck sharing, road freight transportation, literature review

Motivation

The road freight transportation-industry in the German speaking countries (Germany, Austria and Switzerland [GAS]) faces high margin pressure (resulting from the competition pressure) on the one hand and empty capacities on the other hand. The ecological pressure from e.g. regulatory measures, competition or public due to reputation reasons should not be under-estimated. The market for road freight transportation, however, lacks possibilities to foster utilization of physical resources through a sharing approach such as truck sharing that would lower costs and enable logistic service providers (LSP) to achieve higher margins.

Applications of the sharing economy can be found in various areas such as accommodation- and car-sharing (NYT, 07.12.2018; NYT, 31.05.2018). As the sharing economy offers various advantages such as fostering utilization of idle capacities or the reduction of the ecological footprint (higher utilization of trucks leads to a reduction of total distance driven and trucks needed to carry out the same volume of shipments), these should be levered. The road freight transport-industry is an eligible field for truck sharing, as trucks not seldom run empty or not fully loaded. However, literature regarding some forms of sharing economy-applications in the road freight transportation is marginally available (i.e. best practices and challenges in resource sharing in [multimodal] hinterland transportation) and a literature review considering truck sharing could not be determined.

The above given information shows that the truck sharing can benefit the distressed

[1] Truck sharing can be defined (working definition) through the following constitutive attributes: 1) provides the possibility to share, 2) underutilized trucks (as a physical asset), 3) that are owned by logistic service providers, 4) via a community-based (digital) platform and 5) with other logistic service providers (Botsman, 2015 & Zervas et al., 2016). For further information, see Stölzle & Wildhaber (2019).

road freight industry through a higher truck utilization and that the research field still lacks in maturity. The literature review provides the truck sharing fertile soil by giving a comprehensive overview about relevant literature to the field. The latter can e.g. highlight research gaps and determine approaches that support (future applications of) resource sharing.

Methodology

This papers' literature review methodology is based on the systematic literature review that follows a set of transparent and reproducible steps and thus improves the quality of the review process (Crossan & Apaydin, 2010 – X1). The approach chosen follows the steps covered by Tranfield et al. to select, extract, analyze and synthesis data (2003). As it covers resource sharing in the road freight transportation that still is an emerging field of study, the author considered peer-reviewed journal papers and conference proceedings published until 2019, regardless their impact factor (Seglen, 1994). The articles were retrieved via a structured key word search performed on major databases and published websites like Ebsco ECONLIT, Elsevier SCIENCEDIRECT, ProQuest ABI/INFORM COLLECTION, Thomson Reuters WEB OF SCIENCE. The goal of the review was to capture the research addressing resource sharing in the road freight industry.

As it is still an emerging field of study the author choose to cover major research streams that matter to sharing logistic resources and not only apply a common systematic literature review as suggested e.g. in Tranfield et al. (2003). However, the research streams are understood as accesses to literature that layer-per-layer provide important insights and are bundled in the following sections appropriately. To cover the major research streams, major composites of the sharing logistic resource-concept, e.g. important constitutional definition elements set the cornerstones. The three most important research streams therefore are

- …the *horizontal logistic cooperation*, that provides the environment, where
- …*utilization* advancements can be achieved via
- …the *(digital) platform* to connect the logistic service providers and thereby
- …foster *sustainability*, where economic and environmental factors be paramount.

Therefore, the following keyword[2] structure was applied:

- "logistic*" AND "horizontal cooperation" (for the *horizontal logistic cooperation*)
- "logistic*" AND "utilization" OR "optimization" (for the *utilization*)
- "logistic*" AND "exchange platform" OR "sharing platform" (for the *digital platform*)
- "logistic*" AND "sustainability" OR "economic improvements" OR "sustainable developments" (for sustainability)

After the preliminary identification and an initial filtering (only articles in English published in peer-reviewed journals), the subsequent steps were followed (to be continued):

1) selection according to inclusion and exclusion criteria (removed were *qualitative step*),

2) coding (research purpose [descriptive/normative], research nature [conceptual/empirical], research method [case study/literature review/quantitative modelling/survey/theoretical and conceptual]) and

[2] The paper follows the bag of words approach in combination with a forward and backward search that was performed on WEB OF SCIENCE.

4) supplementary web and hand searches on thematic areas.
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Bibliometric analysis (year, publication type, geographic regions, [authors and networks], [most referenced literature], synthesis of bibliometric analysis)
In the following the paper presents the bibliometric analysis in form of the distribution of articles over time, publication type, geographic region and other relevant aspects.
Draft mode / non-finished

Content analysis (theoretical underpinning, methodological basis, road freight industry and physical resources, synthesis of content analysis)
In the following the paper gives insight into the content analysis by highlighting the research streams' common motivation, barrier, facilitators and further relevant information towards truck sharing.
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Respective literature streams:

- Horizontal logistics cooperation

The area of horizontal logistics cooperations has been thoroughly studied and widely discussed (Caputo & Mininno, 1996; Schmoltzi & Wallenburg, 2012 – H5) and is a critical factor in a LSPs' performance (Naesens et al., 2009).

- Motivations (Cruijssen et al., 2007 – H2)
  - Improving cost and productivity through e.g. joint planning and the use of more skilled/more efficient use employees
  - Increasing customer service through complementary services, comply with higher SLAs or specialization
  - Improving the market position by penetrating new markets, serve lager clients, protecting the market share or the faster speed to the market

  - The aims of horizontal logistic cooperation's are cost reduction, customer service, increased responsiveness, social relevance (especially environmental), value creation, improved productivity, growth, innovation, etc. (Pomponi et al., 2015 – H5).

- Barriers (Cruijssen et al., 2007 – H2)
  - System partners with difference in interests, high coordination cost or the search cost to find a trusted party
  - Determining and dividing the gains: fair distribution also of work
  - Negotiation in case of a disagreement over decision
  - Coordination and high indispensable ICT-costs
- Facilitators (Cruijssen et al., 2007 – H2)
  - Information sharing e.g. information integration or sharing performance data
  - Incentive alignment e.g. trust, common interests, mutual help
  - Relationship management and contracts e.g. clear expectations, strategic fit
  - Information technology e.g. data interfaces or collaborative planning. Also Özener et al. (2011 – H4) mentiones that information sharing is beneficial since it permits carriers to identify the best possible collaboration opportunities on the basis of

anticipated order or capacity offers from partners.

- Order sharing
  - The form of order sharing depends upon the
    - Approach (Verdonck et al., 2013 -> H4)
      - the industrial context – FTL/LTL
      - the willingness to share information
    - Joint route planning
      - The key impact factor in the horizontal logistic cooperation is the joint route planning through reducing inefficiencies, redundancies and overlaps allowing cost savings up to 30 percent by improving the load factor, pooling, fleet reduction (Cruijssen et al., 2007b; Krajewska et al, 2008 – H1). To get the trade-off between waiting for a more affordable collaborative capacity and incurring higher holding cost, the reliable and sufficient exchange of data is necessary (Cruijssen et al., 2007a – H1). Through the joint planning and scheduling, operating cost can be reduced and profits increased (Yan & Chen, 2007 – H1). According to Bilotkach (2007 – H1), cooperating in cost-structures and scheduling leads to lower prices, higher quality (SLAs).
      - Another important within a horizontal logistics cooperation is a fair benefit allocation in terms of distribution of realized cost savings and profit gains (Cruijssen et al., 2007b; Krajewska et al., 2008).
- Capacity sharing (verdonck et al., 2013 -> 2013)
  - The capacity sharing has strong interaction with the route planning

- Through order and capacity sharing enhanced technologies in planning and auction-based matching, as well as load swapping, shipment dispatching policies can save significant transportation costs (Verdonck et al., 2013 -> H4).

- Schmoltzi and Wallenburg (2010 – H3) describe the horizontal logistic cooperation as follows: bonded through a contractual agreement, having a multilateral organizational scope, a quasi-concentration (of shared production, marketing/sales and supply), having a nation-wide or international geographical scope, focusing mostly on the road freight industry and operating with similar resources. There similarities are performed in market competence and at times in market penetration.

- Utilization
  - Cornerstones
    - The use of optimization techniques is constantly gaining importance (Volland et al., 2017 – U1).
    - Outsourcing logistics activities to third party logistic providers can generate significant efficiency advantages for both parties due to economies of scale and scope, fixed cost reduction and focus on core competencies (Azzi et al. 2013; Iannone et al. 2014).
    - In all cases, where the planning and use of a resource is not happening in the same time, a certain form of forecasting is useful

to achieve an accurate picture of what has to be ordered (compare Volland et al., 2017 – U1)
        - Various technologies come into play when optimizing: a platform (with central functions such as matching or where further applications such as a geographical information system or routing are run on), localization sensors (e.g. GPS) and intelligent load carriers (e.g. RFID) (Mar-Ortiz et al., 2011; Kinobe et al., 2015; Lee & Chan, 2009; Gamberini et al. 2009 – U4)
        - Optimizations are mostly based on mathematical optimization such as routing, location or networks (Banyai et al., 2019 -> U4).
        - A SLR-solution (decentralized perspective) is required to improve the utilization (incl. truck appointment system). If one would take in the centralized perspective only the optimization of resources remains (Islam et al., 2013 – U5)
    - To reduce the emissions various means to optimize can used: transportation mode (Hoehn et al., 2014 – U3), freight size (Rudi et al., 2016 – U3), routing (Validi et al., 2014 – U3), transport consolidation (Loon et al., 2015 – U3), location analysis (Musavi & Bozorgi-Amari, 2017 – U3) or energy conservation (Müller et al., 2014 – U3).
    - Optimization of routing and loading operations
        - Time and distance are meant to be minimized (Vega-Mejia et al. 2019; Kramer et al., 2015 – U6).
        - Minimize waste (Vega-Mejia et al., 2019 – U6)
        - Minimize over-costs such as late deliveries by complying with time windows to ensure a high service level (Yang et al 2015a; Zhang, et al., 2016 – U6)
        - Proper weight distribution to improve fuel efficiency (Liu et al., 2008 – U6)
- Platform
    - Multi-sided digital platforms emerged as a business model innovation in the past two decades through advances in ICT and changes in the user-demand and expectations towards the digital offerings. Research on platforms has generally focused on technology management rather than assessing the implications of platform-based businesses for platform users and business managers. Platforms have evolved from identifying competitive strategies over conventional business models (Eisenmann, 2006 – P1) to improve platform management strategies trough envelopment and mutation (Tiwana, 2014; Mukhopadhyay – P1). Whereas platforms were understood as dynamic, co-creating value, platforms have become ecosystems that include more stakeholders (e.g. owner, complementors and users) (Smedlund, 2012; McIntyre & Srinivasan, 2017 – P1).
    - Even though there are more and more platforms coming up and these deserve attention and have importance, the level of penetration of these solutions is still limited to well-established technologies, whereas web-based systems and mobile/wireless solutions are still scarce (marchet et al., 2009 – P4)
    - Among others, platforms offer/advantages
        - real-time visibility, efficient data exchange and better flexibility to react to unexpected changes during shipment (Durr & Giannopoulos, 2003; Coronado et al., 2009; Prajogo & Olhager,

2012 – P2).
- real-time oriented control approach to improve load consolidation, vehicle utilization and handle dynamic disturbances (Bock, 2010 – P2).
- Freight resource management systems supports the efficient and effective use resources. By this function matches between supply and demand should optimally created at minimum cost of information consolidation between the dispatcher and the order-to-vehicle-allocation (TAP, 2000 – P2).
    - Improved operational efficiency, route planning, utilization of transport infrastructure, customer satisfaction, overall cost (vehicle optimization)
- Integrated operational/information exchange platform enables a seamless and secure information system as well as an integrated platform to like actors creating important information streams (GIFTS, 2004 – P2).
    - Electronic one-stop-shop for all parties
    - Allow all related authorities to interact with operators and exchange
- Cost/time savings and service level improvements – improved operation cost and time, accuracy, data quality and facilitated payments (Button et al., 2001; Pokharel, 2005; Piplani, 2004 – P4)
- Increased efficiency of operations, better use of resources (Kia et al., 2000 – P4)

- Barriers
    - User-related: economic (e.g. financial) reasons (Hollenstein, 2004; Zeimpekis et al., 2006 – P2), operations-related barriers (Hollenstein, 2004; Zeimpekis et al., 2006 – P2), management-related barriers (Evangelista & Sweeney, 2006 – P2)
    - Policy-related: Lack of related policies (Tsamboulas et al., 2007 – P2), coordination and harmonization (INTEGRITY, 2011 – P2), standardization (PROMIT, 2009 – P2)
    - Technology-related (DISCWISE, 2012 – P2): Compatibility and interoperability, ICT-integration and standardization, confidentiality

    - Internal barriers:
        - Cost/investment risk (Evangelista & Sweeney, 2006 – P4), implementation period (Pokharel, 2005 – P4), technological opportunity cost (Jakobs et al., 2001; Pokharel, 2005 – P4)

- Sustainability
    - Initiatives:
        - First, sustainable transportation execution with the objective to reduce the emissions through technological innovation (such as cleaner vehicles and alternative fuels) and management strategies are widespread (Lieb & Lieb, 2010 – S1).

        - Second, in the last three decades reverse logistics have become another mean to reduce emissions, to which LSPs have become committed by offering services to capturing goods after their point of consumption and returning those for proper disposal (Murphy et al., 1994; Lieb & Lieb, 2010; Meade & Sarkis, 2002 – S1)
        - Third, internal management initiatives aim to involve employees to develop an organizational sensitivity towards environmental sustainability issues through personnel training (Lieb & Lieb, 2010; Jumadi & Zailani, 2010 – S1).
        - Fourth, cooperation with customers reach out to involve the shipper to collaborate and engage with the sustainability offerings of the LSP (e.g. reverse logistics) (Lieb & Lieb, 2010 – S1). Web-portals can be used to share and visualize the emission-impact of the shipper (Cholette & Venkat, 2009 – S1).
        - Fifth, external collaborations address the LSPs' suppliers, such as the sub-contractor. The latter can be selected e.g. by applying certain emission goals apart from economic factors (i.e. price) regarded (Humphreys et al., 2003; Bai & Sarkis, 2009 – S1). According to Vachon and Klassen (2006 – S1), it is important to integrate technology to monitor the collaboration goals, also to report these to the shipper.
    - Motivations to adoption
        - External factors can be reaching an intended signaling effect using environmental audits (Darnall et al., 2009) or pressure from e.g. regulation, customer, competition or public, or (Azzone et al., 1996; Hervani et al., 2005; Lieb & Lieb, 2010 – S1).
        - Internal factors aim to improve the LSPs reputation through environmental improvement or increasing efficiency resp. reducing cost (McIntrye et al., 1998a; Wolf & Seuring, 2010 – S1). The LSPs most often perform the environmental actions via e.g. the improvement of the vehicle efficiency, applying environmental collaboration, waste reduction (incl. reverse logistics) or intermodality. In the micro level of the vehicle efficiency the focus lays on eco driving and the vehicle efficiency (Evangelista et al, 2018 -> S2).
            - Reduction of distance leads to a reduction in emissions (Garren et al., 2011).
    - Criticalities and barriers to adoption
        - Internal barriers are related to economic risks (e.g. investment risk), the long implementation period or trained personnel that is required (McKinnon, 2010; Lieb & Lieb, 2010; Hervani – S1).
        - External barriers that primarily addresses uncertainty about evaluation and measurement of the environmental initiatives (Wolf & Seuring, 2010 – S1)
    - Evaluation and measurement of environmental initiatives
        - Measuring sustainability efforts has become more and more important in the recent years. Several kpi-sets based on energy consumption or pollutant emissions to measure sustainability efforts have been defined (McKinnon, 2010; Geens-Leenes et al., 2003; Schvaneveldt, 2003; Hilty et al., 2006 – S1). In most cases, the KPI-sets focuses on the economic or environmental impact at

the LSP and just in some cases the focus lays on environmental measures (e.g. emissions) (Evangelista et al, 2018 -> S2).

Capacity sharing:

- In case of enhanced utilization through capacity sharing besides less fuel consumption per shipment, also the driver cost accrue to the cost savings (Audy et al., 2007; Jacobson & King, 2009).

However, as premises on logistics resource sharing such as the mindset of LSPs, data security and legal liability still constitute barriers and functioning sharing economy-applications are not available, the potentials cannot be levered.

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Future agenda

The section future agenda brings together insights from the before analyzed research streams with an impact on truck sharing and respective important emerging trends. Therefore, the paper distinguishes between market-level and firm-level trends.

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- Market-level trends
  - Technological trends:
    Even though technologies such as transport management systems form the core of current ICT applications used in the field of transportation (ENABLE, 2010a – P2), there are important future trends of rapid development such as (Harris et al., 2015 -> P3)
    - Cloud computing: offering greater flexibility, also through
    - Wireless communication technologies (smartphones, qr-code, rfid, telematics): increasing use and capabilites – also computing power is increasing exponentially – devices getting smaller/more affordable – people more connected (ubiquotus) -> extends visibility in transportation

    Big data and decision support systems with the aim of real-time, dynamic and integrated enable sophisticated analytics that improve decision-making. (Harris et al., 2015 -> P3)
- Firm-level trends
  - In terms of the economic sustainability and its impact on financial performance sustainable road freight transportation can have several cost benefits (Carter & Rogers, 2008 – S3). Similar to these cost benefits, from the perspective of container freight transportation, there are several advantages of truck sharing to achieve economic sustainability. Other than with the utilization improvement when distributing operating costs to more shippments in the case of freight capacity sharing (compare Islam, 2016 -> S3), the truck sharing for example allows the distribution of fixed costs such as truck amortization among more than one shipper.
  - Regarding the environmental sustainability, truck sharing can be attributale to a reduction in traffic movements due to fewer trucks being on the road (compare Islam, 2016 -> S3). The decrease of trucks also means, that there is less congestion (compare Baldacci et al. 2004; Noland et al., 2006; Bento et al., 2013 - S3).
  - When considering social sustainability as the sustainable management of social resources (Ashby et al., 2012 – S3), the LPS' sustainability efforts

also affect employment stability what refers to good welfare of employees (Gladwin et al., 1995 – S3). Comparing to Islam and Olsen (2014 – S3) and Lynch (2001 – S3), truck sharing would also contribute social benefits through lower cost per truck and thus lessor turnover per driver required. Besides the driver has a higher job security (induced through lower cost-pressure and the LSP being more competitive through the possibility to enable lower prices)

- According to Midoro and Pitto (2000 – H1), horizontal logistics cooperations should develop the capability to enable leveraging the system partners resources and competences pooled within the horizontal logistics cooperation and orchestrating effectively the acivities.

- Comparing Verdonck et al. (2013 – H4), mathematical programming and negotiation protocols enable (truck) sharing in the most efficient way.

- According to Mehmood and Graham (2017 – U2),
  - Resource sharing uses technology such as localization sensors, a connecting platform, supported by mapping, coordinating and payment infrastructure. The first two technologies are used to enable visibility among the partitioning LSPs.
  - Big data and collaboration applications enable decentralized transport optimization and therefore are in many cases better organized.

Results

Based on the before mentioned analyses, market-level and firm-level trends the paper found that …

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Through first indications, the author presumes that the relevant research streams regarding truck sharing could lead, among others to the following areas: 1) governance, 2) business models and 3) platforms.

Conclusion, limitations and outlook

The paper concludes that …

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The paper among others, faces the following limitations:

- Thanks to the multi research stream and layer-per-layer approach the paper presents a literature review on truck sharing. However, the chosen approach does not fully fit with common approaches, what makes the robustness of the literature review critiziable.

Draft mode / non-finished

The literature review shows, what research streams support truck sharing to which extent. However, the author aims to depict and concretize further research areas regarding the research project “Towards the Use of Truck sharing in the Road Freight Transportation-Industry”.

The results, however, could be limited by little sources available in the road freight transportation and research streams provided by accompanying fields (transportation [in general], environmental and computational research).

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Servitization and logistics: Building a service-based typology

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Abstract

Considering the challenges LSPs are facing, the state of logistics services in the mainstream service literature, its fragmented nature, and provider-centric service classifications in the logistics literature, the purpose is to develop a new classification of logistics services in order to understand their evolution in relation to servitization that takes place in the customer's supply chain. The study uses generic service frameworks and servitization criteria to illustrate how logistics service providers move towards advanced services.

Keywords: Logistics service providers (LSPs), Advanced services, Service supply chains

Introduction

Trends such as sustainable development and digitalization give rise to disruptive changes in logistics industry as a *service business* (Cerasis, 2017; DHL, 2018; Logistics Bureau, 2016). For LSPs, this reflects in the form of new logistics services and new ways of servicing customers, which in turn facilitates their own customers in transforming their business models to respond to challenges by advancing their aftermarket offerings and increase focus on in-use phase of their products. Such transformation of business models requires a response from LSPs that support or enable the change.

Whilst this development has led to an emergence of new perspectives in service management (inclusive operations and marketing), the literature on logistics services has not responded accordingly. Extant literature has provided a list of logistics services described with respect to logistics capabilities (Lai, 2004), industry characteristics (Berglund et al., 1999) or value creation patterns (Berglund et al., 1999; Prockl et al., 2012). Logistics services are though more commonly referred in terms of type of providers (e.g. Berglund et al., 1999; Lai, 2004; Prockl et al., 2012; Scarsi & Spinelli, 2017).

Service markets have moved towards a service-dominant logic (Vargo & Lusch, 2004; 2008), and customer offerings have been transformed through servitization, commonly described as a process of transformation from a product-centric mindset to a service-centric mindset (Kowalkowski et al., 2017). As offerings advanced, the need for service classifications is widely acknowledged (Jaakkola et al., 2017; van der Valk & Axelsson, 2015). Interestingly, in the service literature, logistics services are regarded as routine-intensive services (Jaakkola et al., 2017), instrumental services (Wynstra et al., 2006) or

consumption services (van der Valk & Axelsson, 2015), associated with a single activity such as transportation or warehousing. Neither dated (Fitzsimmons et al., 1998; Judd, 1964; Lovelock, 1983) nor more recent classifications (Jaakkola et al., 2017; Mathieu, 2001a; van der Valk & Axelsson, 2015; Wynstra et al., 2006) acknowledge the multi-faceted and dynamic nature of logistics services or the transformation in the industry's offerings as a response to changes in demand from supply chains.

Considering the challenges LSPs are facing, the state of logistics services in the mainstream service literature, its fragmented nature and provider-centric classifications in the logistics literature, the purpose of this study is to develop typology of logistics services in order to understand their evolution in relation to servitization that takes place in the customer's supply chain. The study adopts generic service frameworks (Cova & Salle, 2008; Mathieu, 2001a) and operationalizes the purpose through two research questions: (1) How can logistics services be classified in relation to services supporting the products (SSPs), services supporting the customers processes (SSCs), services supporting the network (SSNs) and services supporting the end-users (SSU)? (2) How do logistics services evolve from the perspective of servitization?

Theoretical Framework

Firm vs. supply chain level of servitization

Organizational change and new market offering: In manufacturing, servitization entails offering advanced rather than basic services (Baines & W. Lightfoot, 2013) where the mindset of organizations shift from product-centric business models to service-centric business models (Kowalkowski et al., 2017). Extant literature focuses on forms of servitization (e.g. Gebauer et al., 2008; Oliva & Kallenberg, 2003) and drivers of servitization (e.g. Mathieu, 2001b; Wise & Baumgartner, 1999) such as achieving income stability, competitive advantage or extended marketing opportunities (Baines et al., 2009). Both early (Mathieu, 2001a; Oliva & Kallenberg, 2003) and recent studies (Story et al., 2017) illustrate how the types and scope of market offerings change when manufacturing organizations servitize. Whilst often addressed from a firm-level perspective, the implications of servitization reach beyond the boundaries of the provider's organization by changing e.g. the firms position in its value stream, types and scope of its market offerings, and even structures, relations or capabilities within the organization or its networks (Brax & Visintin, 2017).

Supply chain level: To achieve their servitization goals organisations must enter new supply networks and service networks. This can, however, change the firm's position within its value stream in that an integrator may take over the supplier's role in having direct contact with the customer (Finne and Holmström, 2013). The supply chain level of servitization has been investigated with respect to supply network structures (e.g. Chakkol et al., 2014; Finne & Holmström, 2013), practices and technologies (Baines & W. Lightfoot, 2013), customer- supplier relationships (e.g. Selviaridis & Norrman, 2014).

Relevance of logistics services: Much servitization literature concerns the context of technology-oriented manufacturing firm (Eloranta & Turunen, 2015) and its supply network. However, servitization of manufacturing is not achievable without a similar transformation of the service network of which it depends on (Gebauer et al., 2013). Service network actors face unique challenges while trying to support the servitization of manufacturing firms (Gaiardelli et al., 2014; Reim et al., 2019), which has though primarily concerned downstream linkages of distributors. Hakanen et al. (2017) justify this with the resonance between servitization and marketing discipline. However, by extending this down-stream focus to towards the wider supply chain provides further insights for understanding the servitization of service networks.

Logistics services: Evolution and existing typologies

Logistics has a long history of engaging with the concept of service in various ways; as a performance *measure*, e.g. "customer service" and "quality" (Mentzer et al., 2001), as an *activity* (Autry et al., 2008), as an integrated service *offering* (Lieb & Lieb, 2010; van Laarhoven et al., 2000), and in relation to *actors*, i.e. providers of freight transport and logistics services (Lieb & Lieb, 2010; Persson & Virum, 2001). However, not much literature focuses particularly on logistics services with a service management lens. Several definition and classification efforts have taken different perspectives but in common state that TPL is composed of either simple or complex service bundles (Prockl et al., 2012) that require tangible asset base or knowledge resources (Muller, 1993; Sheffi, 1990) which try to satisfy a large portfolio of service needs (Autry et al., 2008) ranging from simple transactions to integrated solutions (Berglund et al., 1999; Hertz & Alfredsson, 2003).

Classification efforts focusing on the type of logistics services provided distinguish between services providers and solutions providers (Berglund et al., 1999) where mostly solutions are required as the complexity of the market offering and asset specificity increase (Persson & Virum, 2001). For this latter category, LSPs build on problem-solving abilities where LSPs might need to be service developers or even customer developers (Hertz & Alfredsson, 2003).

LSPs operate in triads where they link buyers and sellers in supply chains (Bask, 2001). Connecting actors between supply networks and logistics service networks (Andersson et al., 2014) and LSPs act as a support supply chain where product flow is facilitated through information or finance (Carter et al., 2015). The distinct supply chain role of LSPs refers to them as external logistics process integrators (Bolumole, 2003) or even fourth-party logistics service providers (4PL) (Saglietto, 2013). Considering the changes in requirements of the buyer market with servitization, it is of importance that LSPs as a service network transform their capabilities to meet the demand.

Synthesis and framework

Understanding the dynamics and evolution of service definitions in logistics has been called up for (Selviaridis & Spring, 2007). Servitization literature underlines that there is a need to transform the mindset of the service network in line with the servitizing supply network to achieve success (Reim et al., 2019). A framework of servitization of logistics services has the locus of service effort as focal point.

Mathieu (2001a) describes SSPs as services that enable proper functioning of or customer's access to the product. Logistics services such as transport and warehousing support the exchanges between a seller and a buyer by providing an access to a product. When logistics services "advance the mission" (Mathieu, 2001a, p. 40), they act as SSCs. When they extend their scope to supplier or customer networks they function as SSNs (Cova & Salle, 2008). In addition to those, some logistics services extend beyond industrial markets and support end-users (SSUs) or consumers with suppliers' products like last-mile or waste collection services which might be labelled as SSUs.

This study adopts the view of servitization as a continuum perspective to indicate the transition of manufacturing into services (Kowalkowski et al., 2017; Oliva & Kallenberg, 2003). On the one side there are logistics services offered with a productization mentality. These are highly standardized services offered to price-competitive markets. On the other side there are highly servitized offerings that fulfill one or more of the four servitization characteristics proposed by Brax and Visintin (2017) mentioned above. Figure 1 presents a continuum where relative importance of SSPs are higher on the productization end, a

transition takes place through SSCs in the middle and SSNs and SSUs reflct advanced, servitized logistics services.

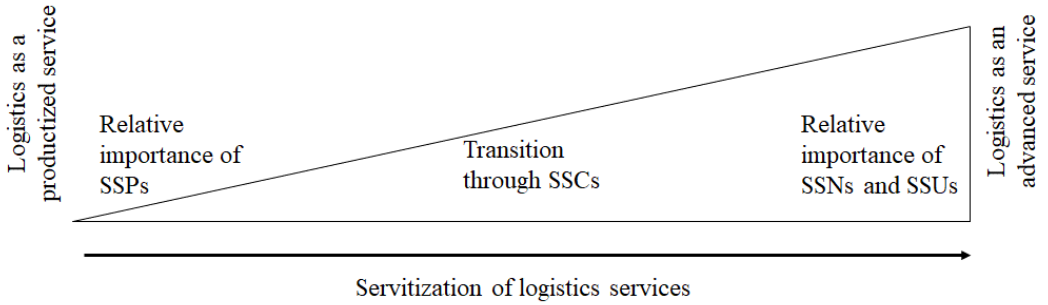

Figure 1- Servitization of logistics services – a continuum

Methodology

Sampling and data collection

A qualitative research design approach is adopted to address the exploratory nature of the study. A content analysis is applied on the web pages of top 50 global LSPs to map logistics services and categorize with respect to servitization. Content analysis enables making "replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use'' (Krippendorff, 2004, p. 18). Web pages as secondary evidence have been used in logistics and supply chain management research (e.g. Bask & Kuula, 2011; Martinsen & Huge-Brodin, 2014). They describe services that are promised to customers, however, it has been noted that this material has been prepared for marketing communications purposes and might not provide an in-depth understanding of company behavior or action (Bryman & Bell, 2011).

The process from Weare and Lin (2000) is followed for the content analysis. For reliable sampling, several industry and consultancy reports were investigated. Taking a global perspective improves the generalizability of the findings, a publicly available ranking list of top 50 global LSPs[i] that is based on logistics gross revenue was used for sampling (Armstrong & Associates, 2018). The global web pages of these LSPs were visited between December 2018 and April 2019. The unit of analysis in this study is the services that are provided by the sample. Following Weare and Lin's (2000) unitization process the context units were selected as the market offerings of these LSPs which were labelled differently such as "products", "services" or "solutions".

Data analysis

Data was categorized based on cases; each LSP was treated as an individual case in order to monitor for potential patterns within LSPs. A deductive coding approach (Crabtree & Miller, 1999) was adopted where generic service frameworks from Mathieu (2001a) and Cova and Salle (2008) were used. In addition, four servitization criteria were borrowed from Brax and Visintin (2017) to divide the services between the main categories of productization and servitization. At the end of the deductive coding process, findings were exhibited on a comparison table together with illustrative service definitions. Then emergent coding approach (Boyatzis, 1998), was adopted to code various services that were classified at different sections of the table.

Findings

The categorization of logistics services with respect to levels of servitization results in a typology of four distinct levels: Offerings supporting customers' *products*, their

processes, their *networks* or the final *users*. Table 1 presents examples of offerings for each of the four categories and illustrates what servitization feeds into logistics and how logistics responds to servitization.

Table 1. A new classification of logistics services

	Productization	**Servitization**
SSP	Chartering services	Advanced customs services
	Customs services	Advanced delivery services
	Express, parcel, mail delivery services	Combined transportation services
	Haulage services	Documentation services
	Intermodal transportation services	Services for special-need products
	Return services	
	Support services for SSPs	
	Traditional transportation services	
	Warehousing services	
SSC	Accounting services	Eco-efficiency logistics services
	Customer training services	Event logistics services
	Quotation, booking and tracing services	Freight purchasing services
	Shipment preparation services	Management process services
	Traditional transportation services for a range of shipments	Packaging process services
		Production process services
SSN	LCL Transportation services	Regulatory process services
		Security process services
		Transportation process services
		Customer network management services
		Disaster logistics services
		Network visibility services
		Second order supply chain services
		Supplier network management services
		Transportation network management services
SSU	Express delivery services for consumers	Aftermarket services
	Return services for consumers	Disaster management for citizens
		Passenger logistics services
		Regulation and quality services for users
		Retail management services for consumers

A new classification of logistics services: Logistics services as **SSP**s focus mainly on enabling of access to a product that is exchanged between a customer and a supplier. These services consist to a large extent of physical resources and are to a large extent transactional since they are bought as a discrete purchase along with physical products. **SSC** entail a more longitudinal focus and an extended scope since they help customers with their processes of deciding, buying, preparing and executing logistics services have a more longitudinal focus and an extended scope. In addition, providing access for customers, SSC support their actions in relation to logistics services. Here the focus is

either on characteristics, inputs or outputs of logistics service provision process or it is on internal processes of a customer. These internal processes could be part of a function of a customer organization or an entire process that the customer organization chooses to outsource.

SSN carry SSC characteristics but provide value for not only a single customer but also for a customer's customer network or a customer's supplier network. They are integrative in nature, collecting and managing information flows between multiple actors, and even combining and sometimes distribute resources from and to a selected set of actors. The buyer of such services is a single organization, the value proposition is directed to a network. Accordingly, the service encounter is with multiple actors of this customer's network, either upstream or downstream, who also evaluate the service outcome.

Majority of the logistics services that are analyzed are exchanged between business organizations. They facilitate the flow of goods and services between supply chain members. However, some of these offerings provide value for the final users (**SSU**) of these products and services. Final users can be consumers or users in the buyer's organization.

Servitization of logistics services: Traditional logistics services that a large part of the market offering is composed of the services provided by physical assets such as trucks, shelves, facilities carry a product mindset, i.e. these build upon a product-centric business model. The value is based on specific inputs such as ton/kms travelled or cubic meters that are stored. Majority of these services carry the characteristics of SSPs where a slightly smaller portion of them are classified as SSCs.

Findings indicate that advancement of logistics services can take place in at least four ways. First, LPSs servitize by *changing or extending their core offering* and hence their position in their value stream by offering of e.g. financial services. LSPs can also overtake a specific function of their customer and by doing so they occupy an additional stage in the supply chain. A good example is managing packaging or inbound flows at a customer organization. A second way of servitization is *changing the types and scope of market* offerings by e.g. offering management of multiple flows with the combination of multiple resources besides basic transportation services. Here, traditional logistics services are customized for specific industries such as energy, mining, textiles, and retail. Service types are extended by reconfiguration of existing services with new services as well. Carbon reporting in transportation services, innovative combination of transportation modes for better transit times are examples to such reconfigurations. Such market extensions provide sector-specific solutions that are highly heterogenous. A third way of servitization takes place with a *change in business model*, shifting to a service-centric mindset. LSPs extend their value proposition to their customers' value-in-use phases, concerned with outcome such as better process performances or improved availabilities either for a single customer or for a network of customers. Supply chain wide solutions such as inbound flows management, production logistics solutions, transportation network management services are examples for this type of servitization. Performance-based offerings include temperature stability and high visibility for sensitive products. Finally, a fourth way is *changed capabilities or structures within LSPs or their networks*. Digital logistics services such as high-end tracking and tracing allow LSPs to connect to and align with new networks and develop environmental performance monitoring capabilities. In this work, LSPs may become asset-free but that rely upon network-management capabilities and gain access to capabilities needed through strategic alliances with different partners in different markets such as quality assurance companies, certification companies, life-cycle assessment companies,

information technology companies besides their traditional partners such as carrier operators.

These findings also indicate that some types of services are relatively dominant in LSPs servitization strategies. Majority of productized services are SSPs. SSCs play a transition role. Some of them just support productized SSPs where some are offered in a completely changed business mind-set. SSNs and SSUs are mostly observed in relation to servitization strategies. This is expected because such services focus on the value in use phase of the market offering and extend the offering's scope to a group of actors.

Discussion

This study aimed to provide a new classification for logistics services with a servitization perspective. While doing so, the study used the generic service frameworks to classify the highly diversified portfolio of logistics services that are offered to global markets. Findings point towards at least three main contributions. First, current servitization studies are highly focused on the technology-oriented manufacturing firm (Eloranta & Turunen, 2015) and how manufacturing companies transform into service-oriented organizations with and advanced portfolio of service offerings. Whilst, literature acknowledges the importance of having a supply chain perspective to understand this transformation (Bustinza et al., 2013; Finne & Holmström, 2013; Lockett et al., 2011), studies of logistics providers that engage in services that enable a supply chain perspective is scarce. Recent studies recognize the importance of service network's alignment with servitizing companies, but focus mostly on the downstream flows, distributor networks (Hakanen et al., 2017; Reim et al., 2019). Manufacturing companies operate in supply chains that require service networks that support them both in upstream and downstream flows. LSPs are one of those service suppliers and understanding how they are servitizing is of importance for both supply chains and their service networks. LSPs servitize together with supply chains and in this process, they tend to change their mindset towards services supporting the network of their customers.

Second, servitization provides a great opportunity to LSPs to diversity offerings, and in that work, a multi-actor perspective on customers must be taken. Unlike the current perspective that relates logistics services with a single service category (Jaakkola et al., 2017; van der Valk & Axelsson, 2015; Wynstra et al., 2006), results show that logistics services provide value in many ways. LSPs servitize through sustainability (e.g. Centobelli et al., 2017) by providing eco-efficient services, through digitalization (e.g. Hofmann & Rüsch, 2017) by providing end-to-end visibility services, through customization and understanding the business customers' context (e.g. Hakanen et al., 2017) by providing sector-specific solutions or through reconfiguration of existing or new resources, capabilities or structures (e.g. Kowalkowski et al., 2017; Prockl et al., 2012) by taking over an entire process at their customers. To this end, service lens towards logistics needs to adopt a multi-dimensional and multi-actor perspective.

Finally, this study complements the current logistics literature on provider-centric classifications where asset ownership (Sheffi, 1990), service orientations (Prockl et al., 2012) or capabilities (Lirn et al., 2014) determine how to classify LSPs. Since "the service environment may not allow completely separating the outsourced services" (Prockl et al., 2012, p. 557) classification based upon provider type is difficult; the same provider, despite having a basic orientation, might offer multiple types of services that capture the properties of multiple provider types. The results illustrate that global providers offer both productized and servitized versions of SSPs, SSCs, SSNs and SSUs to their markets. In particular, SSCs support their transition to servitization and there are many opportunities in terms of SSNs and SSUs for the logistics industry. Furthermore, such servitization

mechanism in logistics industry supports service-led growth in supply chains. Today's competitive global markets continue facing strong service-led growth, but logistics services are still treated with a product-based mindset by mainstream service literature. Therefore, mapping logistics services with a service-based mindset provides the new vocabulary that both scholars and practitioners need.

Conclusion

The dynamics of service-led growth that is taking place in global markets must be understood by providers offering logistics services to their customers supply chains. Whilst servitization has influenced in particular the manufacturing industry for over three decades, the explanatory power of that concept is not limited to that sector. This study shows that the offering of LSPs can be understood in these terms, both with respect to diversifying their offerings and for providing value to their servitizing customers, global supply chains. This study initiates a discussion on the servitization journey of logistics services, however, such an approach has its limitations. More knowledge is needed through in-depth studies of servitization as a process, revealing servitization mechanisms, drivers and challenges of LSPs. In addition, knowledge on resource acquisition, resource generation for servitized logistics offerings is expected to provide evidence on new actors in logistics service supply chains and valuable skills and capabilities that are required for successful servitization. Finally, whilst this study argues for a supply chain level of analysis, further studies at the levels of dyads, triads and network-level would aid understanding of how such servitization strategies are structured, what types of capabilities and resources are needed, how do servitization with logistics services enable competitive advantage for supply chains and how does value co-creation process take place in a servitized environment with logistics services could provide important insights to servitization research.

With respect to practical implications, the results enable managers in logistics industry to evaluate their service portfolios with a servitization perspective. During the analysis it was interesting to observe that LSPs label their market offerings as 'products' frequently. However, in an era where their customers are heavily servitizing, it is essential for LSPs to understand this service-based mindset and develop their business in an aligned manner with supply chain members that they target.

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[i] Only one example is illustrated in this version.

Managing proximity in a period of discontinuity: an opportunity for Industry 4.0

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Abstract

In this paper, we examine the impact of Brexit as a discontinuity in the logistics and physical distribution of products between EU member states and the UK. We propose that Industry 4.0 technologies have the capability to mitigate the impact of Brexit on supply chain coordination and proximity. Through secondary data analysis, we analyse logistics service providers and port operations. We find that elements of Industry 4.0 can restore or enhance proximity and impact on generic performance metrics.

Keywords: Industry 4.0, Brexit, Proximity, Operations Performance

Purpose
This paper explores the challenges to supply chain integration arising from Brexit as a discontinuity. The research question posed in this paper is as follows: how can the application of Industry 4.0 by firms dealing with Brexit foster de-territorialisation of closeness (Gertler, 2003) in logistics management and physical distribution? Said differently, how can firms and suppliers coordinate their actions by means of digitization and re-create a sense of proximity regarding major processes, routines and procedures in the context of Brexit?

Research motivation
Brexit represents a significant challenge for firms and individuals in Europe and in the UK. As of the time of writing, the shape of a withdrawal deal or the possibility of no deal is unclear. What is clear though is that the implications for the movement of goods and of people will be disruptive. The nature of that disruption will come from a need for increased border checks in the context of mis-alignment of standards and tariffs. The implications will be particularly evident in flows of goods and materials between the UK and other EU members, and also the flow of goods and materials between EU members which transit through the UK. The resulting challenges to manufacturers, logistics companies and customers will include additional shipping time and cost. These implications will be particularly severe in the case of time-sensitive goods such as food,

drink and pharmaceuticals. Nakamura et al (2019) demonstrate experimentally how new trading rules post-Brexit can critically disrupt existing global supply chain equilibrium.

Writing in 2003, Coughlan et al noted that the then recent slowdown in the global economy had been a trigger for discontinuous change, prompting many organisations to re-examine their collaborative strategies. The article focused on the management of collaborative relationships in a period of discontinuity and examined different choices faced by systems integrators in their management of collaborative relationships with their supply bases. In 2018, a new discontinuity has emerged – Brexit, which we explore in this paper.

Nadler describes two basic types of change, incremental and discontinuous (Nadler, 1998). Incremental or continuous change refers to the type of change which ought to go on all of the time. Such continuity helps in the generation of continuous improvement. In contrast, complex, wide-ranging changes brought about by fundamental shifts in the external environment lead to radical or discontinuous change. Here, there is a complete break with the past and a major reconstruction required of the organisation. An important element of leadership activity is whether it anticipates change or reacts to it (Nadler, 1998). In this respect, anticipatory changes are made early in the disequilibrium cycle and often before a period of industry upheaval has even begun. Reactive changes come either in response to some strategic initiative by a competitor, or when the organisation has its back against the wall. Combining these dimensions of scope and timing of change, Nadler (1998) presents a four-quadrant schema that plots anticipatory and reactive timing of change against incremental and discontinuous scope of change respectively and describes four responses to change:

- Tuning: the firm anticipates a change in conditions and takes incremental action
- Adapting: the firm reacts to a change in conditions and takes incremental action
- Redirecting: the firm anticipates a change in conditions and takes radical action
- Overhauling: the firm reacts to a change in conditions and takes radical action

Industry 4.0 represents the second conceptual strand of this research. In 2013, Acatech, the German National Academy of Science and Engineering, developed an initial description of Industry 4.0. Also referred to as "Industrie 4.0" in German, it was described as the technical integration of human-machine connections through Cyber Physical Systems (CPS), into manufacturing and logistics and the use of the Internet of Things (IOT) and Services (IOS) in industrial processes (Henning, 2013). This advanced digitalization of manufacturing facilities, incorporating internet technologies, smart machines and products was considered to be a new paradigm shift in industrial production, so much so that it would lead to a 4th industrial revolution, hence the term "Industry 4.0" (Lasi et al, 2014).

Tjahjono et al (2017) outline four principal features of Industry 4.0:

1) Vertical networking of smart production systems.
2) Horizontal integration via global value chain networks
3) Through-life engineering support across the entire value chain
4) Acceleration through exponential technologies

Industry 4.0 is a set of automated self-configuration, self-adjustment and self-optimization capabilities that allows for more agile and cost-efficient processes (Asdecker & Felch, 2018). While there is no conclusive definition of Industrie 4.0 or its features (Tjahjono et al 2017), Dallasega et al (2018) have categorised a range of elements as follows (Table 1).

Tjahjono et al (2017) assess the impact of specific digitalization and automation technologies on Key Performance Indicators (KPIs) for elements of the "Supply Chain 4.0", focusing on procurement ("buying"), production ("making"), warehousing

("storing"), transport logistics ("moving") and order fulfilment ("selling") functions. KPIs for each of these supply chain functions were identified, one of which was proximity. By analysing the impact of Industry 4.0 technologies on the KPIs, the implications for each supply chain function can be assessed.

Table 1 - Categorisation of elements of Industry 4.0 (Dallasega et al, 2018)

Category	**Elements**
Digitisation	MIS, Real-time SCM, Intelligent Transport Systems, Connected Vehicle Systems
Cloud Computing	Web service technology, mobile internet based SCM, Collaboration Technology
Information Management	Information integration and sharing, monitoring supply chains, supply chain performance improvement, decision support,
Tracking and Localisation	GIS, RFID, GPS
E-Supply Chain Management	Web portal, e-business, extranet

Dallasega et al (2018) explored challenges in Construction Supply Chains (CSCs) relating to distance between actors in the supply chain. Motivation, commitment and engagement were found to be influenced by proximity to the decision-making unit. Similarly, communication barriers, or exclusion from information flows, negatively impacted commitment and involvement in solution finding. They noted, however, that many concepts have emerged to bridge objective geographic distance since the advent of Industry 4.0 and digitization technologies. They include organizational, cognitive, social, cultural, institutional, and technological proximities. By drawing on proximity theory, Dallasega et al (2018) showed that Industry 4.0 concepts fostered what Gertler (2003) calls "de-territorialization of closeness" where construction firms and suppliers coordinated their actions by means of digitization, creating a sense of proximity regarding major processes, routines and procedures.

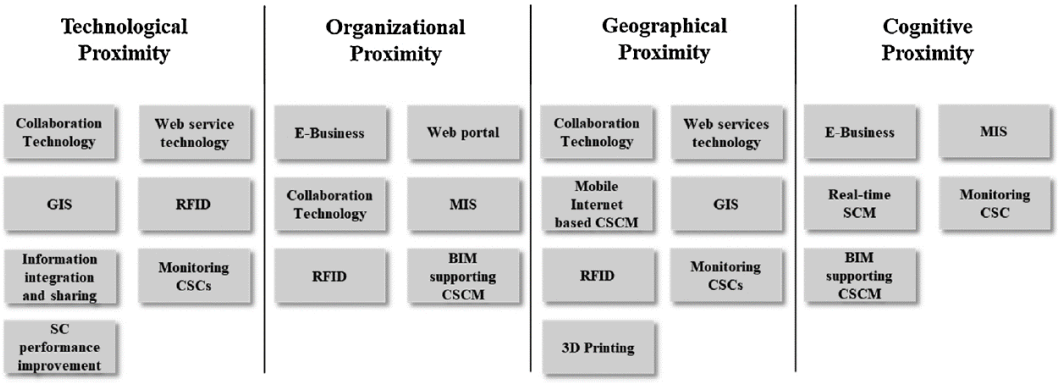

Figure 1 - Proximities and Industry 4.0 concepts (Dallasega et al, 2018)

Conceptual framework

Based on the literature, we outline the framework in Figure 2 to guide the analysis of our study. It reflects the research question and proposes that, in the context of Brexit as a discontinuity, firms and suppliers can coordinate their actions by means of digitization to re-create a sense of proximity regarding major processes, routines and procedures.

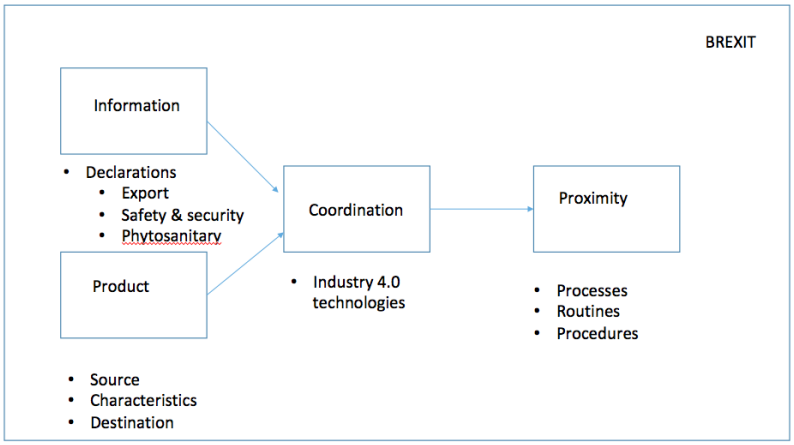

Figure 2 - Conceptual framework

Design/Methodology/Approach

This paper explores the challenges to supply chain integration arising from Brexit as a discontinuity. We develop a current case (Voss et al., 2016) focusing on the prospective experience of logistics services providers, exploring the operational context within which services are provided and the associated challenges to integration. We look specifically at two EU countries, Ireland and Spain, that trade with and through the UK. Applying the tests proposed by Miles and Huberman (1994) to the case selection: the case is relevant to the exploration of the research question, the phenomenon of interest is evident and, while generalisability is not of concern, it may be possible. Finally, the case is feasible with access to both archival and historical data.

We employ two data gathering methods to collect case narrative and historical and archival data. We are accessing the data by drawing from publicly available data sources, including published case histories, government agency guidance and commentary. Reflection on these data is undertaken from the authors' perspectives as operations and supply chain management researchers located in different member states of the EU. As such, we engaged in a shared reflection on the emerging challenges faced by logistics providers in the context of Brexit.

Findings

The findings are presented in terms of the nature of the logistics processes and physical distribution of goods through ports in Ireland and Spain, destined for the UK, or which pass through the UK to another EU country.

Ireland

Ireland has a particularly close trading relationship with the UK. A briefing for participants at the British Irish Chamber of Commerce Infrastructure Committee/ Welsh Government Roundtable with the First Minister of Wales, Mr Carwyn Jones AM, on Monday 12 February 2018 noted that 11% (€13.3bn) of all Irish goods exports went to the Great Britain in 2016 while a further 40% (€46.3bn) went to the EU. Similarly, 22% (€15.5bn) of goods imported came from Great Britain with the EU accounting for 38% (€26.5bn) of imports. Over 80% of Ireland's trade with mainland Europe transits as road freight through the UK. This is principally perishable or other time sensitive trade. Over 40% of Ireland's seaborne traffic is through UK ports while 36% of container movements to/from the island of Ireland go through Northern Ireland. 80% of freight trade into Ireland

enters via Dublin Port - 400,000 trucks use the Dublin-Holyhead route every year to transport exports to the UK and on to Europe.

The dominant mode for transporting goods is RoRo (roll on/roll off) and there is unlikely to be any realistic alternative for this trade other than the UK landbridge. After Brexit, this trade will have to exit and re-enter the EU with potential customs and border inspection implications which it does not face at present. Taking Diageo as a practical example, their trucks make approximately 13,000 border crossings each year. So, a customs check could potentially delay each truck by between 30 minutes to one hour resulting in additional costs of approximately €100 per journey or €1.3m per annum. Finally, should customs barriers be introduced for trade with the UK, an estimated 60,000 traders will be dealing with customs for the first time.

The Irish Government, through the state agency Enterprise Ireland has designed a Brexit Scorecard to assist Irish based firms prepare for Brexit and to develop a robust Brexit plan. This covers six key areas of business, one of which is "Operations", which assesses how prepared firms are for the delivery of products and services. Readiness questions focus on increasing efficiencies, reviewing supplier vulnerability, logistics processes and increased administrative resource requirement. A joint report by Chartered Accountants Ireland and The Institute of Chartered Accountants in England and Wales (2018) outlined the supply chain issues facing UK and Irish businesses. These issues include customs checks, new trade tariffs and laws, and increased lead times. It is suggested that border technology could play a role in mitigating some of these issues, including automated number plate recognition, barcode scanning, smart seals on containers, enhanced driver's licences and smartphone applications.

Spain

Spain is in a related but different position to Ireland in its exposure to Brexit. In anticipation, the Spanish authorities have developed a range of guidelines for all products and for specific categories including pharmaceutical, agri-food, and intellectual and industrial property. In the context of UK exit from EU with "no agreement", goods will be subject to customs supervision and control, which will entail:

- application of the corresponding tariffs
- prohibitions or restrictions on certain goods
- compliance with customs formalities
- customs authorisations issued by the United Kingdom shall cease to be valid in the EU.

In addition, non-customs controls may be applied for including agri-foodstuffs, cosmetics, pharmaceuticals, footwear or furniture. Such non-customs controls may be physical, depending on the risk assessment carried out by the different inspection services and the nature of the product. This physical control requires time spent at the border for the goods, which does not occur in the internal market.

Case Example

In November 2018, Simon Carswell of the Irish Times newspaper travelled with 1,400 kilos of high-value pharmaceuticals from Dublin to Wiesbaden, Germany. The resulting report illustrated how customs checks could impact upon Irish truckers in a post-Brexit context (Carswell, 2018). Carswell accompanied lorry driver John Carroll on his 41 hour, six-country journey to Germany, travelling by ferry from Dublin to Liverpool, driving 1100 kilometres across England to Dover and onto another ferry to Calais in France, through Belgium and The Netherlands to Germany. The pharmaceuticals he was carrying had to remain chilled until they reached their destination in a German factory at a pre-

defined delivery time slot. All this means that the refrigerated trailer, running on a diesel engine, had to be kept running and this could only be, for safety reasons, on the open top deck of the ferry where spaces are limited and in demand. This landbridge through the UK is currently the fastest route to Europe and is a preferred route for transport companies carrying loads like Carroll's because of the shorter transit times that minimise inventory costs and other working capital requirements. The industry anticipates that Brexit could put days onto journeys, putting logistics back to the 1980s.

Figure 3 illustrates the route taken by Carswell and associated timings. In a post-Brexit scenario with border checks, the M20 from London to Dover, a vital artery in the Ireland-to-continental Europe landbridge, may bring delays, the length of which will be unpredictable. This route connects the M25, 26 and M20 motorways to Dover. In anticipation of delays, the UK authorities are considering using this 16km M26 link road and 21km of the M20 as a temporary lorry park. This plan, called Operation Brock, would create up to 2,000 on-road lorry car parking spaces on the M20. In October 2018 and under no-deal Brexit contingency planning, the M26 in Kent was shut down overnight to assess how it could be used as a "parking lot" for lorries.

One way of guaranteeing Irish trucks fast passage through Dover would be to secure international transit paperwork known as TIR or "*Transports Internationaux Routiers*". This would allow approved hauliers traverse non-EU countries, as the UK will be, without stopping repeatedly for customs checks. However, this initiative could see tensions flaring as Irish lorry drivers drive by rows of parked-up UK lorries on the M20.

However, post-Brexit, the customer will still want a definite timeline and it may be that direct sailings become the only feasible option. There are alternative routes avoiding the UK by taking direct ro-ro ferries, from Rosslare to Le Havre or Cherbourg or "lo-lo" (lift-on-lift-off) freight routes such as the CLdN Cobelfret ferries from Dublin to Zeebrugge and Rotterdam where containers have to be loaded off and onto lorries. However, these direct sea routes to continental ports take longer, carry higher costs and have less capacity than the landbridge ferries. Ro-ro, drivers would still have long hours on the road to get to Benelux countries. As lo-lo ferries can take only a handful of drivers at a time, this creates another capacity problem.

Figure 3 – Journey from Dublin to Germany (Carswell, 2018)

In a subsequent article, Carswell (2019a) spent a day reviewing the operations and the preparations underway at Dublin Port (described as "Ireland's Ground Zero for Brexit") which will be the country's busiest location for customs checks and inspections. 90% of roll-on, roll-off ("ro-ro") freight arriving to and leaving from Ireland passes through Dublin port, with most containers leaving the port within minutes of arriving, including those carrying perishable foodstuffs such as sandwiches destined for the shelves of Marks & Spencer stores around Ireland. On average, there are 48 ship movements in the port each day. Four vessels arriving within one hour carry trucks adding up to thirteen lane-kilometres in length. The port is investing €10m for primary inspection posts and another

€20m for secondary inspection posts for state agencies including Department of Agriculture. It is expected to undertake up to five-fold increase in the number of inspections post-Brexit.

After Dublin port, Rosslare is the second busiest port in Ireland, handling 100,000 road freight units per year going to and arriving from Britain, mainly through two ports in Wales - Pembroke and Fishguard. Rosslare will be designated as a border inspection post. In anticipation of a no-deal Brexit, a set of virtual traffic lights has been developed 11km offshore Rosslare, at Tuskar Rock. Truck drivers boarding ferries in Wales will upload their cargo details to Irish Customs. As the ferry approaches Tuskar Rock approximately 3 hours later, a customs app (yet to be launched) will indicate if they are to go through a red, orange or green channel on arrival in Rosslare. Green means they can leave the port on arrival. Orange means their paperwork is not complete and they have to go to a newly opened trade facilitation counter in the port's terminal building to resolve any issues. A red light means they must proceed to the central control compound where their goods may be unloaded and inspected (Carswell, 2019b).

Analysis

The results show that, post-Brexit, there are critical vulnerabilities in the supply chain connecting EU states with each other. We return to the research question, how can the application of Industry 4.0 concepts by firms dealing with Brexit foster de-territorialisation of closeness in logistics management and physical distribution. Said differently, how can firms and suppliers coordinate their actions by means of digitization and re-create a sense of proximity regarding major processes, routines and procedures in the context of Brexit?

The basic argument that we wish to make is as follows: Brexit impacts on operations performance metrics – quality, speed, dependability, flexibility and cost. However, it is a fundamental challenge to proximity with implications for logistics and flow of goods. For example, because of Brexit, geographical proximity remains unchanged, while regulatory proximity disimproves. Then if the discontinuity of Brexit impacts negatively on operations performance, how can Industry 4.0 mitigate? Industry 4.0 offers generic potential for integration, data sharing and real-time control. Application may change and overcome some of the challenges to proximity. Attributes of Industry 4.0 may be linked directly to problems caused by Brexit and to proximity. Some of these metrics and dimensions of proximity may change for the better.

Three scenarios are explored: before Brexit, after Brexit, and after Brexit with the application of Industry 4.0:

Scenario 1

Before Brexit, the dominant proximity is geographical. In this single market and customs union context, technical proximity, though important, is predictable as regulatory standards are common within the EU. Institutional and organisational proximities are predictable.

Scenario 2

After Brexit, geographical proximity remains unchanged – the countries are still located where they were. However, technical and regulatory proximity have disimproved, given now separate regulatory regimes. Cognitive proximity has disimproved also as, from an EU perspective, the UK is seen as a 3rd party country.

Scenario 3

Underpinning scenario 3 is the proposition that, post-Brexit, Industry 4.0 can impact proximities. What can Industry 4.0 do to mitigate the negative impacts of Brexit, restore proximity and improve measures of operations performance? The attributes and

functionality of Industry 4.0 can combine to restore confidence in the supply chain and improve cognitive proximity – the UK is not so far and the barrier is not so high. To achieve this improvement in cognitive proximity requires that technical proximity through data sharing in real time improves to give a sense of physical progress of goods and materials through the logistics system. If it works, actors in the system have evidence-based choices where alternative routes, modes and delivery details are needed. With Industry 4.0, actors will deploy capabilities differently to locate a shipment through GIS, track it through RFID, integrate and share the information with other key actors to build/maintain confidence that a reliable performance is observable or latent.

Visualising these three scenarios in relation to the cases of the Dublin-Wiesbaden route, and the Dublin and Rosslare ports described earlier, we apply HACCP-like thinking to these operations. Here, the focus is on hazards to proximity and to each of the operations performance metrics at border crossings as Critical Control Points. So, post-Brexit, cognitive proximity has shifted due to UK barrier. Actors need to overcome that barrier. At the heart of the delay is the technological proximity. Previously what was an acceptable regulatory standard and tax regime no longer exists and, so, inspection is required resulting in delay. Application of Industry 4.0 can support electronic certification and speed up processing across critical control points. However, it requires data integration and access, elements of organisational proximity. So, in the context of Brexit as a discontinuity, there is a proposed hierarchy in the impact on dimensions of proximity and operations performance associated with an Industry 4.0 intervention. Post-Brexit (and before Industry 4.0), the hierarchy could be: geographical proximity remains unchanged, cognitive proximity disimproves, technological proximity disimproves, and organisational proximity is unchanged. With Industry 4.0, technological proximity is latent through existing systems but requires institutional and organisational proximity to improve. As a result, cognitive proximity improves back towards the original pre-Brexit level. Tables 2 and 3 reflect the argument:

Table 2 - Proximity chart - before, after, and with Industry 4.0.

Proximity	**Pre-Brexit**	**Post-Brexit (without Industry 4.0 interventions)**	***Industry 4.0 Interventions (e.g. GIS, RFID, Data Integration, Electronic Certification)***	**Post-Brexit with Industry 4.0 Interventions**
Technological	Close	Reduced	*Virtual traffic lights, Smart sensors, Automatic Number Plate Recognition (ANPR), Smart contracts*	Restored/Enhanced
Geographic	Close	Same	*No impact*	No impact
Organisational	Close	Reduced	*Systems integration Data access across organisational boundaries*	Established to enable a higher level of integration & supply chain coordination
Cognitive	Close	Reduced		Sense of closeness is newly enabled by Industry 4.0
Regulatory	Close	Reduced	*Virtual traffic lights, Smart sensors, ANPR Smart contracts*	Newly established

Table 3 – Generic operations performance objectives

Generic Performance Objectives	**Pre-Brexit**	**Post-Brexit**	**Industry 4.0 Intervention (post-Brexit)**
Quality	Competitive	Reduced	Restored
Speed			Restored
Dependability			Assured
Flexibility			Questionable
Cost			Reduced but not to previous levels

How can Industry 4.0 mitigate the impact of Brexit in support of both of these propositions? Tables 2 and 3 outline elements of Industry 4.0, linked to the each category of proximity and to the five generic performance objectives. Arising from Tables 2 and 3, three propositions emerge:

- There is a sense of hierarchy among the types of proximity.
- Brexit will impact proximity and Industry 4.0 can mitigate this.
- Brexit will impact on the generic performance objectives. Industry 4.0 can mitigate this impact

Conclusion

The research question posed in this paper asked how can firms and suppliers coordinate their actions by means of digitization and re-create a sense of proximity regarding major processes, routines and procedures in the context of the discontinuity that is Brexit.

Similar to Dallasega et al (2018), we find that that elements of Industry 4.0 foster "de-territorialization of closeness" where our this case, logistics firms, supported by port operators can coordinate their actions by means of digitization, creating a sense of proximity regarding major processes, routines and procedures. The expectation is that application of Industry 4.0 forms the basis for a technical proximity solution. "Control Tower" is an integration concept and implementation of Industry 4.0 requires institutional and organisational integration linking supply chain actors such as shippers, customers and customs bodies. Targeting the application of Industry 4.0, using HAACP-like thinking, can improve time losses and help to maintain quality. So, if that technological and organisational proximity can be improved in this way, then all dimensions of operational performance can be improved.

Based on our findings, we update our original conceptual framework from Figure 2. We now introduce a new category of proximity (i.e. regulatory proximity) and enable interplay between this and the pre-existing categories of proximity. Our overall conclusion is that Industry 4.0 technologies enable coordination of product and information, thereby restoring or enhancing categories of proximity, impacting on the generic performance metrics.

This Brexit situation is ongoing. Over the coming months (maybe years), the discontinuity will evolve, practice will be challenged and a research-rich environment will emerge. We plan to continue our analysis as the Brexit situation unfolds and through primary data collection via semi-structured interviews with key personnel in logistics providers as well as port and government agency bodies.

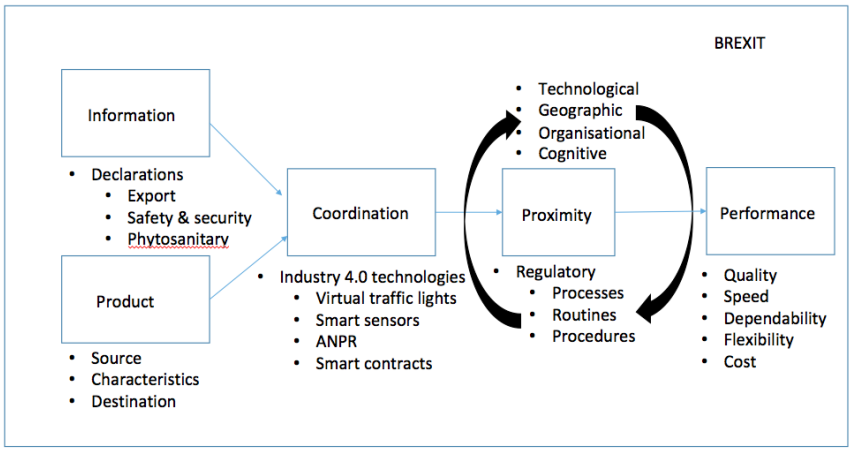

Figure 4 - Updated conceptual framework

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B2B approach for late delivery failures and the penalties imposed

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Abstract

In freight transportation, logistics service providers guarantee to deliver the orders of their industrial customers within specified time-windows. However, in some cases late deliveries occur resulting in an increase in overall costs, decrease in customer fill rate and bring penalties accordingly. In this study, we used interview technique by adopting a dyadic approach for examining late delivery problems from the perspectives of business buyers and logistics service providers. The research, herein, revolves around "on-time delivery" also by including penalties and recovery actions in case of delivery failures.

Keywords: Service failures, Late deliveries, B2B approach

Introduction

As service failure is an unavoidable reality due to the unique nature of the services (Hart et al., 1990), understanding service failures and developing effective recovery strategies are crucial both for service providers and business buyers. From the point of Exchange Theory, service failures and recoveries are part of special exchange processes. In this regard, customers who suffered from a service failure feel a certain degree of injustice and service providers offer service recoveries in order to compensate this feeling (Qin et al., 2012). In addition to this, Equity Theory posits that individuals in social exchange relationships benchmark the ratio of their inputs with the ratio of their outcomes within the exchange process. Inequity occurs when perceived inputs/outcomes are inconsistent with the actual

inputs/outcomes (Huppertz et al., 1978). In line with the these theories, recovery strategies in B2B environment come into prominence and they have been studied mainly in relation with customer satisfaction, timeliness, apology and compensation, e.g., discount, free products (Davidow, 2000; Hess and Ganesan, 2003; Hübner et al., 2018).

Delivery performance can be defined as the level up to which products and services supplied by an organization meet the customer expectation (Rao et al., 2011). In this regard, business buyers often attach particular importance to delivery performance. On the other hand, logistics service providers (LSPs) attempt to reduce transportation cost and to increase customer service level simultaneously. Herein, compatibility to time windows by providing "on-time delivery" is considered as the focus of our study. The purpose of this study is twofold. Firstly, we aim to figure out the attributes of on-time delivery. Secondly, we try to find out the penalties charged and recovery actions offered in late deliveries.

Although service failures and recoveries are well studied in B2C environment, more work is needed in B2B area. In this regard, the study reveals the importance of timely deliveries and it points out must-have on-time delivery attributes. In addition to this, the research demonstrates which penalties are particularly implemented for late deliveries on business buyers' side and which recovery strategies are offered by service providers in return.
This research addresses three broad research questions:

1. How service providers and buyers evaluate delivery performance attributes?
2. What kind of penalties charged by business buyers in case of late deliveries?
3. What kind of recovery strategies pursued by service providers for compensating on-time delivery failures?

Literature Review

In service failures literature, two types of service failures take place: outcome failures and process service failures. While outcome failure is realized when customer cannot receive the service which he/she pays for, process failure occurs when there is a disruption in the service received (Nyugen and McColl-Kenedy, 2003). In this regard, process failures are more likely to occur in B2C market while outcome failures are mostly experienced in B2B environments. Most of these outcome failures are related with the transfer of products to customers including late delivery, documentation failure, information/communication failure, operational or booking failure (Özaydın et al., 2015). In B2B markets, failures create domino effects by effecting multiple parties. When service providers cannot meet delivery deadline, the clients of the customers of service providers are also jeopardized and this cause dissatisfaction in a wider network (Zhu and Zolkiewski, 2015). Therefore, it can be seen that the timeliness of delivery has a direct effect on the customer relationship. If service providers cannot perform on-time, this puts business buyers into trouble in terms of lost sales or bureaucratic processes to correct it (Özaydın et al., 2015). Looking at the consequences of service failures in B2B, it causes reduction in repurchase intention and deterioration of long-term relationships (van Doorn and Verhoef, 2008; Harrison and Walker, 2012); complaints (Hübner et al., 2018); decline in trust (Tronvoll, 2011); and increase in costs (Komunda and Osarenkhoe, 2012). Customer dissatisfaction and negative word-of-mouth are other endemic reactions that are experienced in B2B marketplace (Zeithalm et al., 1996; Davidow, 2000; Hübner et al., 2018;). In literature, these consequences of service failures are defined in general. Therefore, we aim to shed light on how these penalties differentiate in the context of "late deliveries". As there are only a few studies on penalties and recoveries in B2B

context, we aim to investigate on-time delivery related penalties and recoveries more specifically.

Research Methodology

Data Collection

In this study, we used purposive sampling method. In purposeful sampling, sample members are selected based on their knowledge and expertise regarding the research subject (Palinkas et al., 2015). We selected companies from manufacturing and logistics sectors to address the late delivery problem in a more comprehensive way (Table 1). Through conducting face-to-face semi-structured interviews, we aimed to get a comprehensive insight in a dyadic way. All interviews were audio-recorded with permissions.

Themes of semi-structured interview are as follows: key attributes for on-time deliveries, consequences of late delivery, and recovery actions after late deliveries. Within this context, the participants of this study are representatives of 14 well-known companies. Due to confidentiality, company names are shown as "M" referring manufacturing firms, and "SP" for service providers.

Table 1- Sample of the study

Company	***Position***	***Duration/min***	***Company Operations***
M1	*Purchasing Engineer*	*48 min.*	*Commercial and military vehicle manufacturer*
M2	*Customer and Production Coordinator*	*50 min.*	*Fashion and textile manufacturer*
M3	*Order Management Specialist*	*40 min.*	*Wheel manufacturer*
M4	*Logistics Manager*	*31 min.*	*Food industry*
M5	*Logistics Specialist*	*35 min.*	*Construction equipment manufacturer*
M6	*Logistics Specialist*	*45 min.*	*Supplier of heating, ventilation, air conditioning*
M7	*Logistics Specialist*	*46 min.*	*Mining*
SP1	*İzmir Overland Freight Manager*	*43 min.*	*Global logistics solutions company*
SP2	*Road Operation Specialist*	*51 min.*	*Integrated logistics service provider*
SP3	*Sales Manager*	*38 min.*	*Transportation*
SP4	*Freight Operations Officer*	*60 min.*	*International cargo*
SP5	*Logistics Manager*	*62 min.*	*Logistics solutions*
SP6	*Sales Department*	*43 min.*	*Transportation*
SP7	*Land Freight Manager*	*50 min.*	*Supply chain consulting services*

Data Analysis

In order to develop a better understanding, we conducted a content analysis by basing on the methodology suggested by Strauss and Corbin (1998). We conducted open, axial and

selective coding in order to analyse the gathered data, and created main and sub categories accordingly.

Regarding open coding, company interviews were read line by line several times and divided into smaller discrete ideas, events or experienced moments. Then, tentative labels were created accordingly, which summarize the data extracted from the interview. Once some categories emerged, relationships among the open codes were identified and data were linked via a combination of inductive and deductive thinking through axial coding. Then, we identified the core variable that includes all of the data with selective coding, which involved integration of the categories in the axial coding model.

Regarding validity, a pilot preliminary test was done in order to ensure the clarity and accuracy of interview questions. In line with data saturation logic, process of gathering and analysing data lasted until the point where no new insights were observed in data.

In terms of reliability, we made meticulous record keeping through demonstrating a clear decision trail and ensuring that interpretations of data were consistent and transparent. After analyses completed, three authors conducted coding separately for ensuring inter-coder reliability.

Findings

Key Attributes in On-Time Delivery

The following attributes are seen as important indicators for on-time deliveries both for service providers and business buyers. Flexibility is defined as the ability of a system to change or react with little penalty in time, effort, cost or performance (Naim et al., 2006). Business buyers expect service providers to perform mode changes with flexibility in order to speed up the operations for being on time.

> *"Most forwarders do not want to deal with changing modes. I say that 'I want you to turn the mode to the air right now based on the mail that I received* from *my client!.' The forwarder needs to be able to change modes." (M6)*

Accessibility in delivery problems is another concern for both parties. This concept is defined by Litman (2017) as person's ability to reach services and opportunities as needed. Business buyers seek for authorized employees in delivery problems. Therefore, service providers should be reachable at all times to provide expected service level in delivery and they should inform their customers on timeliness.

> *"…in delays sometimes we cannot reach them for hours and we call thousands of people from the company." (M1)*
> *"Business buyers complain about logistics companies. They say that they cannot find any respondent and cannot get info about their product in case of late delivery."(S4)*

Consistency of service refers to a continuous operational process which is far from deviations (Knott et al., 2008). In this regard, consistency in delivery times is seen as a fundamental feature for business buyers. They expect service providers to set certain transit times and serve in certain standards.

"Most of service providers are certain in terms of transit time. However, their consistency is so important. In order to be consistent, they need to be serving in certain standards." (M6)
"Except weather conditions, being consistent is an important factor for customers. It also brings credibility." (S7)

Traceability of load and vehicle become more important in late deliveries both for service providers and business buyers because tracing enables a correct and up-to-date information transfer among business players.

"There are some companies that do not inform customers. In these companies, customers try to get information. These firms say 'I will call you in 3 hours' and they try to reach your truck." (S1)
"Nowadays, we can see what the driver is doing and where the truck is with the help of vehicle tracking systems." (S2)

Findings revealed that, trustability is an important indicator of customer satisfaction. If service providers do not meet the promised transit times, their image in their clients' eyes will be affected negatively. From the point of service providers, being reliable is important for satisfying their customers, maintaining their brand image and increasing profit.

"If providers give us incorrect transit times, their image get worse in our eyes." (M5)
"Customer chose us because of our delivery performance, if I did not give them the service that I promised before, and then I lost my credibility." (S3)

Delivery tolerance intervals refer to upper and lower bounds of delivery lead times. Both business buyers and service providers agree that business type and stock keeping strategy (make-to-order/make-to-stock) in which the business buyers engage affect delivery tolerance intervals. For instance in JIT based automobile industry, production plan is done based on zero inventory logic and the delivery must be on time. Similarly, in textile industry, due to fast changing trends or fashion seasons they have some lead-time obligations that service providers have to comply with it.

"As we are a fashion company, we race against time. There is no tolerance for late deliveries." (M2)
"There may be no tolerance if buyers' production band works as just in time." (S2)
"For example, even if we send some loads 10 days later, some companies do not say anything because they do not work on a JIT basis, and they already have enough material in their stock." (S4)

Herein, weight/value ratio is another important criterion for determining tolerance level for business buyers, if products are light in weight but heavy in value, tolerances are low.

"Our tolerances are low because we send loads that are light in weight but heavy in value." (M7)

Moreover, power relations among business players are important.

"Tolerances are related to the degree of the buyer's power on their customers." (S7)

Regarding lower and upper bounds of tolerances for late delivery, two days of delay are acceptable.

"You will tell one day delay in a certain way, but the second day the problem must be solved because customer cannot wait you anymore." (S5)
"We usually talk with their customer representative and ask them to solve this problem by 2 days because a delay of 2 days on road is a compensable delay." (M6)

Consequences of Late Delivery
When service providers breach the standards, business buyers employ a "stick approach" (Porteous et al., 2015). In this research, service providers are subjected to penalties in case upper bound for delivery is exceeded. However, these penalties vary by the consequences of delay. Reducing business volume seems to be the most frequent penalty employed by transferring a portion of business to other carriers in order to penalize them.

"We lowered the amount of load that we used to give to ABC provider after late deliveries. We were giving 350 tons of cargo monthly but it fell by 70-80 tons currently." (M4)

As a natural consequence of reducing the business volume, sales performance of the service providers is affected and it causes to lose their competitive advantage in the market.

"We started to fall to undesirable level and lost freight because the goods were not delivered on time." (S3)

Termination of business and being put into black list occur to be as the other penalties charged by business buyers.

"When we started our business, we were working with ABC Logistics. We worked with them in both partial and complete truckloads. After serious customer complaints came about late delivery, we terminated our relationship." (M4)

Switching service providers is another type of penalty implemented by business buyers.

"If you are constantly late, following the end of the contract customer says that he is going to try another firm and punish you with this way." (M2)

Apart from those, business buyers may reject the late shipment or keep late arrived vehicles waiting (vehicle retention) as a penalty.

"If you send the load after three days with delay, the customer may say I reject the load because it is useless." (S7)
"If our trucks do not go to Brand P's gate on time, they make us wait because they give a certain time to other vehicles, too." (S1)

Furthermore, if the subcontractors of service providers cause the delay situation, business buyers apply management intervention and use their influence to force service providers to work with their chosen carriers.

"Our sanction right is generally high in big companies. If subcontractors of service providers cause delay, we have the right to eliminate who we don't want to work with." (M3)

Initially, warnings and requests for official letters take place in case of late delivery.

"If the delay occurs, we apply pressure by asking official letters, warning them in the presence of a notary public." (M7)

Interestingly, similar to B2C context, negative word of mouth (NWOM) and complaints to third party mechanism are common penalty practices in B2B environment.

"In case of late deliveries, we absolutely transmit it to the central company in Germany. Their warning is more serious and sanctioning than ours." (M2)
"In the event of delay, end user complains to the business buyers and writes on internet blogs. This falls our score." (S4)
"In case when we do not send their orders on-time, they complain about us and spread NWOM" (S6)

Business buyers keep scorecard records to evaluate the performance of service providers. As on-time delivery is one of the most weighted performance indicators of service providers, they reduce the score as a punishment.

"Providers get a lower score on their score card because of late delivery. They are evaluated by such categories..." (M2)

In some cases, penalty fees charged. In case of band/production halts and extra labour costs, business buyers charge these fees to logistics service providers. Moreover, there may be some cost of reclamation and cost of unsold goods that arise from late deliveries. Herein, responsibility of paying these types of costs belongs to the service provider as a penalty.

"If we do not comply with the contract then we will be obliged to pay the worker's wage per hour. This is our liability." (S5)
"When you are late it means that the products are not going to be on-time in the stores. Then business buyers reflect the rate of loss to us as reclamation expenses." (S6)

Recovery Actions
Late deliveries occur inevitably and service providers attempt to compensate these failures. The recovery actions including distributive, interactional and procedural dimensions play a mediating role between prior satisfaction and satisfaction with recovery (Siu et al., 2013). Distributive justice actions are associated with the outcome of the recovery actions. It includes discounts, coupons, refund, free gift, repairs and replacement with the aim of compensating the service failure (Blotgett et al., 1997).

In order to compensate late delivery, service providers offer discounts or extend payment terms.

"*Certain concessions can be made for not losing the customer for example payment deadlines can be extended." (S2)*
"In case of late delivery, we make gesture to the customer. We offer 200 euros discount." (S1)

If delivery date exceeds the due date, service providers burden the cost of air cargo. In addition to this, service providers carry the loads of their customers free of charge due to being late. The aim of this action is to avoid losing customers and ensure continuity of good relations with their customers.

"If it is necessary, we send the load by air without demanding cost. We bear the cost and it is strongly related with the relationship with our customer." (S2)
"In case of late delivery, we do not take cost of freight to show that we are in good faith." (S6)

In some cases, service providers make unexpected service recovery offerings by providing a storage service to business buyers with the aim of improving their image in their customers' eyes.

"*Carrier provides us a storage service as a side service in order to fix their image." (M5)*

Interactional justice actions refers interpersonal treatments including explanation, politeness, honesty, effort, apology and empathy as the manner of the operation of the recovery process (Siu et al., 2013). In case of late deliveries, sending delay notice and providing timely information as well as providing explanation for delay become important for business buyers.

"Even if it was late, I could reach every time I called. Both sales and customer service shared delay details and reasons." (M2)
"We inform our customers every day. When the ship does not arrive to destination on time and we say that it will arrive tomorrow and after unloading, deadline info is shared with you immediately." (S1)
"It is very important to inform customers about late delivery because it allows the customer to foresee and take action accordingly." (S6)

Apologizing is another important thing to overcome consequences of late deliveries. In this sense, service providers organize customer visits and they look for the other ways to apologize as a constructive action.

"We tell the customer that we will be more careful in the future. We organize customer visits. We say that this was our fault, sorry." (S1)

Procedural justice actions concern the fairness of policies, procedures and criteria used by decision makers (Blotgett et al., 1997). It includes process and decision controls, accessibility, flexibility and speed. In some business relations, service providers are obliged to prepare process improvement report and proactive action plans after late deliveries. By this way, procedural improvements are achieved for ensuring on-time delivery.

"We prepare a CAPA (Corrective and Preventive Action) form after late deliveries. Then providers have to develop a project and heal themselves." (M1)

Conclusion

In this research, we addressed the key attributes of on-time delivery such as flexibility, accessibility, consistency, traceability, trustability, creating sustainable value, performance evaluation, tolerance levels, weight/value ratio and power relations. Accordingly, we aimed to find out the penalties charged as well as the other consequences when the upper limits were exceeded such as reducing business volume, termination of business, being put into black list, switching, rejection of shipment, vehicle retention, management intervention, warnings, negative word of mouth, complaints, reduction in scores, request of free freight, and handling variable costs.

In detail, the study examines the cases in which customers impose penalties and how these penalties are applied. Moreover, this study investigates the recovery options pursued by service providers for late delivery failures. We have found that also in B2B context, distributive, interactional and procedural recovery actions exist.

The scientific contribution of this research is to lay emphasis on the penalties and recovery actions within the framework of "on-time deliveries". We employed a dyadic approach embracing manufacturing companies and service providers. In practical sense, the study contributes for developing a deeper understanding for penalty and recovery actions in B2B context.

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Leveraging Emerging Technologies to Drive Logistics and Warehousing Transformation

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Abstract

In this study, we explore the factors that facilitate or hinder the deployment of emerging technologies in the logistics and warehousing industry in Australia. We conducted interviews with representatives of organisations in the logistics value chain in Australia. Based on our initial findings, interviewees generally agreed that there is greater pressure now to adopt newer technologies and alter their practices and business models or risk losing existing and new customers. Speed of change, cost and standardisation of data are three key considerations highlighted for the implementation of emerging technologies in logistics to facilitate efficiency and sustainability of supply chains.

Keywords: emerging technologies, logistics, warehousing.

Introduction

Emerging technologies such as Internet of Things (IoT), data analytics, artificial intelligence and machine learning, intelligent robotics, and blockchain have the capacity to transform industries offering substantial benefits to users (Fonseca, 2018; Posada et al., 2018). However, the factors that affect the deployment of these technologies are not well understood. Some of these include regulatory barriers and policy inconsistencies, cost, skills shortages and failure to understand the opportunities that new technologies offer (Schelechtendal et al., 2015; Fagnant and Kockelman, 2015).

In the context of Australian logistics, warehousing and supply chains, improving efficiencies and safety remains a high priority. Emerging technologies offer substantial improvements not only in productivity and safety but also in terms of flexibility,

transparency and interoperability (Tu, 2018). Hence, developing deployment strategies that address the needs of all types of businesses as well as large organisations and SMEs is essential.

The purpose of this study is to explore the factors that facilitate or hinder the deployment of emerging technologies in establishing world class logistics infrastructure in Australia and ultimately develop a decision-making framework that can be utilised for designing and operating logistics and warehousing infrastructure that meets the needs of the future.

Specifically, this study explores the following research questions: (1) What are organisational and industry level drivers for deploying emerging technologies in logistics and warehousing?; (2) What are the factors that affect deployment of emerging technologies and what impact do these have on outcomes?; and (3) What are the key actions necessary to be undertaken by organisations and industry for realising the capabilities of emerging technologies?

In order to address these research questions, this study will involve a review of the literature, logistics industry stakeholder interviews and qualitative case study analysis.

Literature Review & Theoretical Background

Drivers for deploying emerging technologies in logistics and warehousing

In order to understand the organisational and industry-level drivers for the implementation of emerging technologies in logistics, it is important to refer to the literature to understand the logistics function in supply chain management (SCM).

Logistics refers to "managing the flows of goods and information from a point of origin to a point of consumption" (Murphy and Wood, 2011). According to the Council of Supply Chain Management Professionals (CSCMP), "logistics management is that part of SCM that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements". Logistics management is usually divided into materials management and physical distribution management (Fernie and Sparks, 2014). Logistics-related activities within the firm may include the following: customer service; demand forecasting; facility location decisions; order management; inventory management; procurement; materials handling; packaging; transportation management; reverse logistics; international logistics; warehousing management. Any implementation of emerging technologies by the logistics operations of the firm may impact these other functional areas as well. In Australia, international technology start-ups are already disrupting the logistics industry by implementing emerging technologies in the areas of supply chain and logistics management. These include last-mile autonomous vehicle drones, trucking marketplace and fleet management and e-commerce logistics.

Warehousing is the storage of inventory or that part of a firm's logistics system that stores products (raw materials, parts, goods-in-process, finished goods) at and between points of origin and point of consumption" (Douglas et al., 1998). Warehousing management has an increasingly important role in logistics and supply chain systems due to the changes in other functional areas as a result of implementation of technologies and contemporary management strategies, such as lean inventories. (Murphy and Wood, 2011).

Warehousing has a significant relationship with transportation sometimes referred to as "transportation at zero miles per hour" (Murphy and Wood, 2001). There is a trade-off between warehousing and transportation, as the presence of a warehousing facility closer to a producer generates shorter-haul transportation routes, but this is more costly per mile than long-haul routes. However, this cost may be offset due to the possibility of transporting larger volumes of weight along the short-haul routes. The implementation of emerging technologies in warehousing management has been identified as having a major impact on logistics operations, particularly with regards to automated warehousing (Wang, McIntosh and Brian, 2010).

The implementation of emerging technologies within the logistics function facilitates the effective forward and reverse flow and storage of goods and services. There is an increasing need for logistics management to take into consideration the need for flexibility and real-time responses to the changes in market demands (Uckelmann, 2008). Customers of logistics service providers, such as manufacturers, have adopted new strategies such as agile manufacturing and mass customisation, which have transformed these organisations into integrated networks in which core competencies are aligned with those of other organisations in the supply chain. The development of new technologies, such as the Internet, has facilitated the virtualisation of inter and intra-company operations, which has enabled data, e.g., about production and products, to be exchanged autonomously with the embedding of systems throughout the entire value chain (Brettel et al., 2014). As a result, industrial production has globalised into an open supply chain network characterised by short-term business connections and cooperation between stakeholders. The technology required by this open supply chain network is made available by the concept of "Industry 4.0" (Vogel-Heuser and Hess, 2016), which is referred to as the 4th industrial revolution (Fonseca, 2018). Industry 4.0 is characterized by the advanced digitalisation and integration of industrial manufacturing and logistics processes, and the use of internet and "smart" objects (machines and products) and merging the physical and the virtual worlds by the adoption of information and communications technology (ICT) (Posada et al., 2015).

Barriers to the implementation of emerging technologies

In a partially-automated warehouse, emerging technologies are causing disruptive changes in warehousing strategies. For example, the development of advanced robotic systems which use digital add-on systems to transform forklifts. The brewing company, Carlsberg uses such forklifts to move up to 500 pallets per hour around one of its Swedish distribution centres. Even people are being displaced from the warehouse environment by emerging technologies, due to the speed and efficiency with which robotics and machines can pack goods. However, in a partially-automated warehouse, people still play a substantial role in its operations. In contrast, in a fully-automated warehouse, the implementation of emerging technologies means there is little need for people to conduct traditional warehousing tasks. For example, such a warehouse could house an automated storage and retrieval system (AS/RS), where the centre's Warehouse Management System (WMS) could be linked to cranes on rails, which move up and down aisles of racks that extend from the floor to the ceiling of the warehouse. Such a warehouse would offer high levels of productivity (due to the efficiency and being able to operate 24 x 7 365 days a year), and offsetting some of the power they use by operating in an unheated or un-cooled environment, with little if any need for artificial lighting, leading to savings on energy costs.

However, even a fully-automated warehouse requires people to manage it operations. Amazon, which has more than 100,000 robots inside its warehouses across the world, still has 500,000 human employees on its payroll worldwide. This is because the company claims that “robots do not have the 'common sense' or 'dexterity' needed for the job”. Also, while almost half of jobs in the transport, postal and warehousing sectors are within road transport, i.e., freight (Australian Industry Standards, 2017), presenting a huge opportunity for the implementation of autonomous vehicles, it would be hard to imagine replacing such a large number of workers right now. However, in future, this may be a possibility if the costs involved in using autonomous vehicles are reduced.

Theoretical Framework

The dominant theoretical approach to SCM and logistics research has been the systems approach (Lambert et al., 1998). This is because the systems approach recognises the interdependence of the major functional areas of the firm, including logistics (Murphy and Wood, 2011). It has been argued by academics that the systems can be used to understand SCM and logistics, which requires a holistic perspective, consideration of total cost and avoiding sub-optimisation (Grant et al., 2005; Bechtel and Jayaram, 1997). However, one logistics system does not fit all companies because goals and objectives vary from one firm to another (Murphy and Wood, 2011, p27). Although systems analysis is useful for describing and modelling the movement of goods, inventory data and demand patterns, there is an element of interaction between people in logistics management that is too complex for the systems approach to be applied (Rigby et al., 2000). Therefore, models and theories that are applicable to complex situations and contexts are more suitable for logistics management (Nilsson, 2006). The application of models and frameworks based on complexity theory has become more common given the increasing complexity of logistics management due to shortened product lifecycles, decreasing time to market, emerging technologies, etc. (Nilsson and Gammelgaard, 2012). Several studies apply complexity theory to SCM and logistics (e.g., Ellram et al., 2007; Wysick et al., 2008; Holweg and Pil 2008; and Svensson, 2010).

However, the theoretical approach that provides an organisational-level perspective, as opposed to a systems or complexity approach, is the resource-based view (RBV). This theory can be applied more simply to explain the drivers for and barriers to the deployment of emerging technologies in logistics and warehousing because it proposes that a firm’s performance is governed by its internal processes and management of resources (Wernerfelt and Karnani, 1987). One of the key underlying assumptions of the RBV is resources are distributed heterogeneously amongst competing firms, such that those firms with lower cost of resources and capabilities for implementing a certain strategy gain competitive advantage over their competitors. (Barney, 1991).

Overcoming barriers based on RBV

One of the key barriers to implementation of Industry 4.0 is the high costs involved (Schelechtendal et al., 2015). Despite the benefits of fully-automated warehouses, the costs of establishing such facilities is very high due to the need for customisation and specialised infrastructure. Consequently, smaller supply chain firms are not able to make use of such emerging technologies. However, since industry 4.0 will be like an ecosystem, collaboration will be a key determinant of a firm’s competitive advantage (Reinhard et al., 2016). This is because, within the ecosystem, there will be clusters of firms which are

active along common value chains, including manufacturers, service providers, suppliers, primary customers, research institutes, universities, etc., which can realise synergistic benefits from being in close proximity to one another by sharing resources, skills, knowledge, and costs which generally leads to accelerated innovation (KPMG, 2016). In this way, firms within the logistics and warehousing industry can compensate for a lack of resources and capabilities to implement emerging technologies for mutual benefit, including optimisation of the supply chain network.

Therefore, based on the RBV, we propose that resources such as emerging technologies provide firms in the logistics and warehousing industry with capabilities that provide them with a competitive advantage. However, as indicated by the literature review, firms struggle to gain access to the necessary resources (including both emerging technologies and human capital), infrastructure and services required at affordable prices. We expect to see this identified as a key barrier in our case studies. The purpose of this study is to explore the factors that facilitate or hinder the deployment of emerging technologies in establishing world class logistics infrastructure in Australia and ultimately develop a decision-making framework that can be utilised for designing and operating logistics and warehousing infrastructure that meets the needs of the future.

Research Methodology

This study employs a qualitative approach in addressing the research questions presented above. Interviews are more appropriate in cases where new/emerging issues are to be explored and the views of many different stakeholders are to be captured (Sofaer, 1999). Hence, we conducted a number of face-to-face interviews with senior executives and relevant mid-level managers working for different types of organisations providing logistics and warehousing services. Other interviewees included users of logistics and warehousing services, officers representing logistic and warehouse councils, regulatory bodies and policy making entities. The interviews were audio recorded and transcribed, with analysis conducted using the qualitative analysis software NVivo.

Results

Drivers for the implementation of emerging technologies

Customers are the drivers for the strategies of many companies now, as they demand certain products or services within certain short timeframes now. For example, a store manager at a local store wants a delivery to occur at a certain time of the day when they are not busy with customers. These technologies are enabling visibility to allow everyone along the supply chain to be efficient in what they do.

Companies need to understand the order, the customer, and then be flexible to meet demands of the customer. Companies need to recognise that their business models might be partly effective, e.g., regional distribution centres, but also recognise the need to create new models to achieve flexibility in supply chains. As the supply changes, companies need to know who they need to engage with to meet demand. This is a new trend in the industry. For example, a number of retailers or FMCGs are examining their supply chains and realising that the market is changing and that they may need to change their business models to perhaps take care of their own logistics, etc. Do they now remove the middle part of the supply chain and go direct to the end-user? However, these companies have never had any visibility of who these end users are in the past. Now that business models

are moving from a B2B to a B2C model, there may be a need to look at technologies that would support this shift.

Consideration of the "last mile" is crucial. For example, if a product is ordered at one location but delivery is required at another, it is possible to arrange for the delivery if a mobile truck has the stock and is close to that new location. Solutions are now emerging for this sort of demand. Toll was recently awarded a contract by Telstra for the provision of a last mile solution which is automated and has the ability to allow for moving delivery locations, real-time alerts, etc. In the past, Telstra used a solution called Brightstar for around 10 years to do this but it had no visibility of its customer base. The reason for this new tender was to provide Telstra with this visibility so it could market its products more effectively to the correct target markets with the most appropriate marketing materials, etc. This also facilitates packaging which is also targeted to specific customer segments. This sort of B2C activity is gaining momentum in the Australian industry. There is a need to develop a generic framework for the implementation of emerging technologies across the supply chains, driven by e-commerce. Apart from efficiency, sustainability also has to be considered. For example, companies, such as CC-Amatil are thinking about how to reduce the use of single-use plastic bottles.

Gaining access to resources and capabilities through collaboration

The case studies revealed that implementation of emerging technologies is driven by the need for network assurance (operational efficiency) and cost. In order to achieve supply chain network optimisation, CC-Amatil is looking outside its traditional network of partners and going outside of the industry to find potential non-competitive complimentary partners who have similar needs, such that they can share transport and warehousing, etc. On one hand, they could look to do consolidated loads, e.g., CC-Amatil could align itself with a chips company to transport both its drinks and chips to the same destination, e.g., vending machines location. This means customers would have to hold less inventory and it would be fresher. On the supplier side, CC-Amatil could be more responsive to changes in demand and make more frequent deliveries. CC-Amatil could also look at collaborating with non-competitive partners for reverse network distributions. CC-Amatil has spoken to Toll to identify other Toll customers and see where synergies exist, e.g., where the networks are shared such that trucks could be used to move stock from point A to B for one company and then B to A for the other. This is more efficient use of trucks hence reducing traffic congestion, emissions, etc.

For many 3PLs, short-term contracts mean that relationships are also short-term, so then 3PLs are not willing to invest in new solutions. 3PLs and also retailers have low margin gains, so they are in a different situation to the NBN, which focuses more on being able to provide spare parts to the network to ensure it operates no matter what the cost is. On the other hand, 3PLs and retailers are not able to spend as much to solutions. Therefore, the major 3PLs can play a key role in providing a platform for collaboration to implement new technologies and optimise the network. For example, they should be able to transport goods for various suppliers using the same trucks, in order to optimise the use of their fleet of trucks across the network. It shouldn't be an issue for these suppliers as long as their goods are segregated and data is not shared.

Further, the interviews revealed that collaboration can facilitate the implementation of emerging technologies, e.g., collaboration between industry partners facilitated by GS1 (under guidance of the Australian Logistics Council) to conduct pilots. This enables

businesses to understand their supply chains better. Pilots are important in proving to businesses that solutions can work in real-life. Apart from efficiencies, other advantages partners can reap include greater visibility, shared data, etc. When companies operate in silos, there is not enough volume to make it cost effective to implement these new solutions, but eventually, if these companies, e.g., a group of FMCGs, which are not competing on supply chain but rather product, collaborate to reduce costs of logistics.

Lack of capabilities for implementation of emerging technologies in the industry

The biggest challenge for the industry right now is that there are many areas of technological innovation, from block chain to Big Data to IoT, but there is not a great understanding of many of these technologies and how they can or can't be applied. Many companies do not know where to start, even though they might see IBM, for e.g., come and give presentations, they do not know how to implement the solution. This is the case with larger companies, such as NBN, which, despite having resources, are unsure of how to go about it. Digitisation is not a new concept, with some technologies being around for the last 30 years. The industry is on the verge of realising just how little it knows and how much potential there is for implementing emerging technologies. The industry has only touched on about 3% of Big Data, but there is potential for a much greater level of application of Big Data and IoT to supply chains. This is due to a changing market driven by consumers, e.g., customers want to receive more goods quicker.

Every organisation needs to understand its strategic landscape, i.e., what are the market forces that could lead to change or pose a threat are (SWOT). Businesses need to assess their current situation, where they want to be future, what path they need to take to get there, and what the potential forces (internal and external) that have to be overcome to achieve that. If they are focused on only one aspect of their operations, they will not be able to do this because they need to look at the bigger picture. It is important to realise that, although certain technologies can achieve certain results, not all businesses need to be looking to implement such complex technological solutions if they are not going to use them to their maximum capability because in reality on the ground, users are not able to use such sophisticated technology. The journey needs to be an evolution and different companies are at different stages of that evolution. For some organisations, current organisational structures and process are too deep-rooted to change and find solutions that can be implemented. If a technology provider can develop a platform that is simple enough to use, then this can be overcome. Organisations that have the design-thinking mentality are better positioned to be longer-term leaders in that field because they consider the end-user experience.

Role of government in facilitating access to resources and capabilities

The interviews reveal that Federal and State governments need to work together to link the various sea and inland ports together. They need to make inland ports stronger assets to reduce some of the pressure off the metropolitan routes by diverting traffic away from traditional seaports which are often located near growing metropolitan areas. Government can also play a role in protocol standardisation. In IT, standards are always sort after for interoperability. However, in terms of supply chains, there is massive fragmentation, and this is mainly driven by the fact that most supply chain systems require specialisation, or they are high proprietary. There have been attempts to implement this sort of

standardisation, such as supply chain-centric blockchains, etc. but a simple government-backed protocol would be very helpful.

Discussion

The landscape has changed such that 3PLs need to build assets with a view to the future, as B2C activity is gaining momentum in the industry. Some of these technologies will impact the way consumers order goods and their expectations of how quickly they will be able to receive them. Then there will need to be consideration given to how the supply chain will need to be flexible to meet this demand. This change is driven by consumer demand but also the underlying technology platforms that are being made available. One of the biggest barriers for large companies is that to add on other applications can be a complex process because it could impact a whole range of systems already being used which would need to be reconfigured. It is much harder to try a new technology and more expensive for larger companies for this reason. The other issue is that there is not a great deal of long-term thinking for e.g., in retail, there is a very short-term focus.

The industry in Australia is challenged by the high cost of labour and relatively expensive warehousing space (e.g., in Sydney). Within the area of automated warehouses, the major cost is labour. There are several relevant issues around labour that need to be considered: aging workforce, the need to attract a younger workforce, and the need to attract more females. Another challenge within the small Australian market is the current mindset. When a branded company sets up a solution, there is a thinking by competing companies that they should not share in the use of that solution. This is where universities could play a part in providing platforms to bring industry partners together to develop and apply new technological solutions for logistics. The major 3PLs could also play a key role in providing a platform for collaboration to implement new technologies and optimise the network. 3PLs could also lead the way in introducing new technologies and creating a culture of innovation.

Based on our initial findings, logistics and warehousing providers generally agreed that there is greater pressure now than before from users and customers on improving flexibility, timeliness and efficiencies. Providers are under great pressure to adopt newer technologies and alter their practices and business models or risk losing existing and new customers. For instance, a number of retailers in the FMCG sector are closely examining their supply chains and realising that the market is rapidly changing. Consequently, these retailers are considering the need to perhaps change their business models to the point of solely taking care of their own logistics. Speed of change, cost and standardisation of data are three key considerations highlighted for the implementation of emerging technologies in logistics to facilitate efficiency and sustainability of supply chains. The general consensus from stakeholders is that operating in silos does not enable companies to fully harness and nurture new technologies given that they lack sustainable volumes and that a joint effort amongst providers is perhaps more beneficial.

Providers and users also admit that even though digitization is not a new concept, there is still a lack of understanding of many of these technologies and its application. They assert that this void can be filled with greater awareness and support from government bodies and local logistics and warehousing councils. For instance, both parties need to work together to link the various sea and inland ports to reduce some of the pressure off the metropolitan routes by diverting traffic away from traditional seaports which are often

located near growing metropolitan areas and enforce protocol standardisation. in IT standards which are always sort after for interoperability.

Conclusion

In terms of contribution to literature, preliminary results of this study show how emerging technologies have the potential to create efficiencies. Providers of warehouse and logistics services including users admit that inefficiencies create unnecessary delays, affect service levels and unnecessary expenditures. However, all of these could be significantly avoided if stakeholders could embrace a more collaborative attitude rather than taking on a competitive disposition. The study brings to light a number of themes that suggest that emerging technologies needs to be consistently embraced and embedded within the company for sustainable growth. The findings of this study also allow the researchers to undertake a further in-depth inquiry to develop a decision framework that could be adopted by companies for the implementation of emerging technologies across the supply chains, driven by e-commerce. Despite the limitations of this study being conducted in the Australian context, the reasons highlighted and themes raised have been supported as important by other scholars (Koch et al., 2014) and with caution results can also be generalized to similar economies.

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‘The map is not the territory’: the subjective and purposive nature of supply chain mapping

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Abstract

Supply chain (SC) mapping is a stream of research as well as a managerial activity. It is also important in SCM teaching. Despite this importance, very little empirical research has addressed SC mapping and SC maps. Based on a qualitative case study in an industrial company, this paper gives evidence of the discrepancies between how managers define the outbound SC, the SC map they draw and what they say when mapping. It supports the underlying hypothesis about how individual mental representation of SC influences SC mapping. It opens avenues for further research about how using mapping and maps in SCM.

Keywords: Supply Chain Mapping, Outbound supply chain, Case study

Introduction

Since the 1990s, supply chain mapping has been a common practice and an important research topic (e.g. Lambert *et al*., 1998; Gardner and Cooper, 2003). Many different pictures of supply chains (SC) are made by companies, teachers and consulting firms. However, few studies question the role of these “pictures”, their use in companies and their usefulness for people involved in SC operations or management, as well as their influence on SCM concepts and practice. In line with Carter *et al*. (2015) or Fabbe-Costes (2017), we advocate that they are not neutral and could play a key role in SCM.

A supply chain map, like a geographical map, is supposed to represent the “territory”. Since no map can represent everything, people who map make choices, and, in particular when there is no mapping convention (Gardner and Cooper, 2003), often adopt personal representation codes, both of which reflect biases. Moreover, since a map is a “model”, it is “projective” (Le Moigne, 1990). Supply chain maps thus might reflect the viewpoint of the people drawing them, as well as their project or expectations related to SCM. Supply chain maps might also be influenced by people’s history, discipline, culture, experience of the territory, etc. They might also reflect the purpose of the mapping, being a sense-making activity (Henneberg *et al.*, 2006)…

The purpose of this paper/research is to study supply chain mapping as a managerial activity and to question the impact of SC maps on SCM. In the literature review, we combine perspectives from SCM and from the 'network pictures' literature in industrial marketing (e.g. Henneberg *et al.*, 2006) to ask the following: Do companies produce and use SC maps? Do managers' individual SC maps reveal different "viewpoints" of/in the supply chain that could reveal different mental representations of what a SC is? When managers map a SC, what are the differences between what they draw, how they explain their mapping, and how they define the SC? The research design section details our qualitative case study focusing on the outbound supply chain of an industrial company. After presenting the empirical results of the research, we discuss their managerial and academic contribution before concluding.

Literature review

Supply chain management and the "images/pictures" of supply chains

Since the early 1980s, the study of SCM has involved the drawing of pictures of supply chains. Some famous figures are commonly cited. They show different aspects of what supply chains are. Stevens (1989) focuses on internal *functions* that have to be integrated with a linear representation of what an integrated chain is. Harland's figure (1996) highlights the *structure* of the "chain" (from a line to a network) and the number of *echelons*. Mentzer *et al.* (2001) adds the types of *actors* participating in the chain. Some figures (e.g. Lambert *et al.,* 1998) are clearly "centred" around a *pivot* with an upstream SC (up to initial suppliers) and a downstream SC (to end customers). In their framework, Cooper *et al.* (1997, p.10) identify *actors*, *flows* (information and product), *business processes* and SCM *components*. With the influence of the network approach (Haakansson and Snehota, 1995), supply chains are also seen as networks (webs) evolving through interactions of *activity* links, *actor* bonds, and *resource* ties (e.g. in Skott-Larsen *et al.*, 2007). Consultants (e.g. Cohen and Roussel, 2005), who focus on the supply chain architecture, frame SCs around *entities* (actors), *processes*, *data*, *applications*, and *infrastructure* (IT and physical assets) referring to resources. The SCM literature review shows a variety of 'pictures' including different aspects depending on what message authors want to deliver about SCM. A cumulative list of categories of elements that figure on academic SC pictures can thus be established.

Supply chain mapping in SCM

SCM scholars have noted a "profusion of map styles", with a variety of categories of elements figuring in academic SC maps, and suggesting the need for a supply chain mapping convention (Gardner and Cooper (2003, p.37). Hines and Rich (1997), who studied 7 mapping tools, point out they are contingent and address different objectives, which suggest taking care of the context when choosing one. Probably the best-known source on mapping for SCM is Lambert et al. (2008), which groups maps in two categories. The *relationship-based* maps often take the perspective of a focal firm, thus they "will look different depending on a company's position in the supply chain" (ib., p.200). It points out the importance of the "viewpoint" and related "views". *Activity-based* maps include: time-based process mapping (TBPM), pipeline inventory process mapping focusing on physical flows and steps in the logistics-production-distribution process, and extended value stream maps. For these maps, "the determination of the unit of analysis is critical to any mapping effort" (ib., p.212). The chapter concludes with: "Many managers believe that supply chain maps, whether they are relationship-based or activity-based are not worth the effort to prepare. However, once management has these maps in hand, they often report that they cannot think of a better way to understand the

nature of their supply chain" (ib., p.216). Maps are useful tools to better understand the "SC territory" and could also be considered as decision tools. Since there is no convention or set of conventions by which to represent SCs, SC maps are influenced by personal mental representations, the SC being a social construct (New, 2004). It is thus worth studying the individuals' SC maps and the one(s) organizations provide to support SCM activities. It is also worth deconstructing SC mappings to unveil the implicit assumptions "behind" SC maps and the use of maps as tools of "power" in SCs.

Lessons from the network picture literature

Most contemporary SCs are named "networks" and SCM scholars refer to the IMP literature to better understand inter-organisational networks. Thus, the "network pictures" literature (in particular Henneberg *et al.,* 2006 and 2010; Geiger and Finch, 2010 or Leek and Mason, 2010) is relevant to deepen the study of SC maps. In line with this literature, individual SC maps are the managers' "theories-in-use about what the relevant business network looks like, and how it 'works' " (Henneberg *et al.,* 2010, p.356). Considering the variety of actors in a SC, these views could potentially be different, even between persons belonging to different functions in a company, and the mismatches could reveal important SCM issues.

To our knowledge, no empirical study has been done to question the making, use, usefulness of SC maps in companies and in SCs, as well as to question how mapping (as an activity) could reveal mismatch between mental representations of SCs and be useful for SCM. The research presented is an attempt to fill this gap.

Research design and methodology

We conducted a case study (Voss *et al.*, 2002) in the downstream (outbound) car supply chain of Renault Group (RG), collecting data from December 2018 until March 2019. We gathered existing maps of the distribution chain – from the manufacturing plants to the end dealers – and analyzed their purpose (why do they exist?) and use (how are they used?). We conducted facilitated mapping exercises, combined with semi-structured interviews, with 18 RG managers involved in the management of RG outbound SC. To gather as many different "visions" as possible of the RG outbound SC, we interviewed key informants from different RG functions (manufacturing, logistics/operations, Supply Chain, quality, informatics, commerce), at different hierarchical levels (among the 18 persons, 8 are *managers*). Table 1 summarises the 18 informants, in 4 main categories. We also gathered many relevant internal documents from RG.

Table 1 – Type of interviewees [n°of the interview]

Direction / Position	Managers	Others key informants	Total
Logistics and Supply chain Alliance	5 [1]; [6]; [10]; [15]; [16]	4 [2]; [4]; [5]; [13]	9
Quality, Informatics, Commerce	3 [11]; [12]; [14]	6 [3]; [7]; [8]; [9]; [17]; [18]	9
Total	8	10	18

The interview guide was structured around 4 themes, always asked in the same order:

1. Interviewee's profile (background, current position in RG, role in outbound SC);
2. Interviewee's definition of the outbound SC of RG (how he[she] represents him[her]self the "territory" of the outbound SC);

3. Does the interviewee have ready-made maps of the outbound SC? If yes, does he[she] use them in his [her] work? If no, would a map be a useful device in his[her] job?;
4. Can the interviewee draw a map of the outbound SC? The facilitated mapping exercise was done on a paper sheet A4 format that was scanned at the end of the interview (Figure 1 shows an example map).

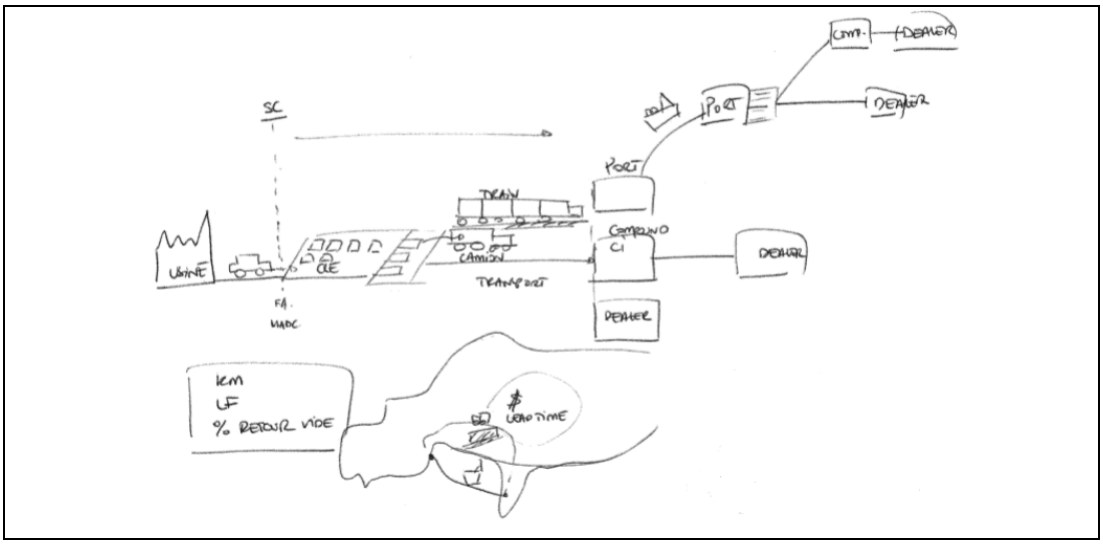

Figure 1 – Respondent's n° [1] map

After recording and transcription, two of the authors coded separately the data collected and discussed and resolved any difference of their coding. This was done in four steps using a cumulative open coding: i.e. adding new items at each step. First, the collected maps were coded (what is drawn by respondents). Every piece of the drawings were named (*items*) and characterised referring to the *categories* found in the literature review. Second, the discourse of the respondents during the mapping (what is said during drawing) was coded in the same way, including new items if any was found. Third, the outbound SC definition (territory) was coded. Finally, the answers concerning the existence/usefulness of maps were analysed.

We used presence-absence matrices to produce results. At each step, we identified core items in SC maps (sum per line) and difference between respondents (comparisons of the columns). Table 2 shows the coding of the 18 maps (step 1). We then compared the tables produced at each step of the coding process. Appendix 1 shows the items found at each step. We also collected significant verbatim to illustrate some of the results. The internal documents of RG helped us to interpret some results. We split the respondents in 4 groups (cf. table 1) to explore the potential influence of respondent's role in the management of RG outbound SC on mapping.

Findings

About the company maps. In fact, there are few maps of the outbound SC available in the company. There are two popular maps used in every presentation to sketch out the outbound SC. They are quite simplistic (linear and including few actors), mainly used for training new staff. They are so old that nobody can remember who drew them! They give a standardized representation of the SC from the moment cars leave the manufacturing plants, helping to develop a common vision and share objectives within

the company. In these maps, the *plant*, the customer (*dealer*) at an international level (*geography*), intermediary warehouses and *logistics points*, *operations* done on cars in warehouses, means of *transport* and the *physical flow* of *cars* are all represented. It is worth noting that, during the interviews, five participants (respondent [1], [5], [6], [15] and [16]) mentioned other maps. In the 2 extra maps provided, one is a geographical map of RG distribution; the other links the outbound SC with the overall SC of RG.

About the 18 outbound SC maps. The mapping exercise was not so easy for a lot of people, some respondents being at first reluctant to draw: "I am not good at drawing" (e.g. [E4], [E9], [E12], [E13]); "my picture is not clear" (e.g. [E11]), "have others made better pictures than mine?" ([8]). However, everyone produced a map. Table 2 gives the result of the analysis of the 18 maps. Thanks to the variety of respondents (different view points), we ended with **20 items** in total, referring to **8 categories** found in the literature.

Table 2 – Result of Step 1 (coding of the 18 maps)

Category of item	Items represented on respondents'maps	Respondent n° (total = 18 respondents)																			
		15	1	3	12	4	6	9	14	2	16	11	13	8	5	17	18	10	7	Total	%
Place	Manufacturing plant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	16	89%
Place	Warehouses (CLE), platforms (PDC), ports	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+/-	1	0	0	15	83%
Actor	Dealer Renault (customer)	1	1	1	1	1	1	+/-	1	1	1	1	1	1	1	1	+/-	0	0	14	78%
Tool/Ressource	Means of transport (trucks, boats, etc.)	1	1	+/-	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0	9	50%
Flow	Physical flow (1 if arrows)	1	1	1	1	+/-	+/-	+/-	+/-	+/-	1	1	+/-	1	+/-	+/-	+/-	1	+/-	8	44%
Place	Points of tracking	0	0	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	7	39%
Flow	Car	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	0	0	6	33%
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	1	1	0	1	1	0	0	+/-	0	1	0	0	0	0	0	0	0	0	5	28%
Flow	Time, leadtime…	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	5	28%
Activity	Operations done on cars (in logistics centres)	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	4	22%
Actor	Enduser (who buy the car)	1	0	0	1	0	0	+/-	1	0	0	0	1	0	0	0	+/-	0	0	4	22%
Actor	Organizational boundary (intra Renault group)	0	0	1	0	0	0	1	0	1	0	1	+/-	0	0	0	0	0	0	4	22%
Actor	Logistics suppliers + other suppliers	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	3	17%
Tool/Ressource	Information system (IS)	1	1	1	0	0	0	0	0	0	0	0	0	+/-	0	0	0	0	0	3	17%
Flow	Information flow	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3	17%
Tool/Ressource	Computer (IT)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	11%
Decision	Impacts on outbound of decisions taken before	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2	11%
Place	Geography (spatial)	+/-	1	0	0	+/-	0	+/-	+/-	+/-	0	0	0	0	1	0	+/-	0	0	2	11%
Decision	Planning (production, SCM…) in Renault	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	6%
Event	Hasards	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	6%
Total of represented items on respondents' maps (max = 20 items)		**11**	**10**	**9**	**9**	**8**	**8**	**8**	**8**	**7**	**7**	**6**	**6**	**5**	**4**	**4**	**3**	**1**	**0**	**114**	

Legend : (1) The items is represented on the respondent's map
(0) The items is not represented on the respondent's map
(+/-) The items is implicitly represented on the respondent's map

Three items are quite systematically represented (plant, warehouses, dealers) and four others are frequently present (means of transport, physical flow, points of tracking and the cars). Note that these items are the ones present in the official company map. The total per column shows a variety of richness of the maps. The individual maps confirm that every manager has his own supply chain vision. If the maps are not focused (centred) on the respondents' activity, they seem influenced by their experience (e.g. figure 1 has been drawn by a logistics person). Most of the 18 maps are much more complex than the company maps. The richer maps were done by respondents [15], [1] and [12], who have more experience in the company, a transverse role (interacting with many people and functions) and with operational field contacts.

About the 18 discourses during the outbound SC mapping exercise. First, the analysis of what the respondents say while drawing the maps confirms the importance of the 20 items found at step 1. Second, it shows (see Appendix 1) some differences between discourses and pictures: 7 new items mentioned by respondents were not in the maps. The new items did not lead to add any new category of items. Third the comparison of matrices done at step 1 and 2 (see Appendix 2) shows that all items are more cited (step 2) than drawn (step 1). The discourse during mapping is richer than the map for every respondent and every item (except for 2 items) and it confirms that respondent's experience of SCM influences his[her] way of mapping SC (e.g. [2] "since I am in the

export flow…"; [4] "you can have port or not, but since I like ports…"; [E17] "being in charge of quality, necessarily it is the vagaries that give us grain to grind"). Finally, like for maps, there is a difference in richness of the discourses of respondents (range from 17 to 4 items). The mapping exercise led some respondents to ask themselves some key questions regarding: SC *perimeter* (e.g. [E9] "does the outbound SC begin here or there? [...] for me it is a bit unclear"; [12] "the perimeter must go there [the dealer], but it should go further [the end customer]"), or how to *represent* some items ([E18] "there is also a kinematic part that seems to me to be missing from that representation. But on an A4 sheet I'm sure we can do better than that").

About the 18 definitions of what the outbound SC is (territory). In line with the previous results, the analysis of the definition of outbound SC given by the respondents confirms the importance of the 27 items found at step 1 and 2. 7 new items mentioned by respondents were not in the maps and the discourse during mapping (see Appendix 1). The new items did not lead to add any new category of items. Comparison of maps and definitions (see Appendix 3) shows that all items are more present in definition (step 3) than pictures (step 1). If most definitions clearly mention that the outbound SC begins "when the car comes out of the plant" ([E1]), it is less clear where it ends. In line with the company maps some persons mention the *dealer* as the end point of the outbound SC, while most (10 out of 18) clearly go up to the *end-user*. Most definitions (13 out of 18) mention the *performance objectives* related to the management of the outbound SC that were not much present in maps (5 out of 18). Some respondents go into detail in some aspects of the outbound SC, in line with their experience or their responsibility (e.g. [E3] insists on the SC information system giving visibility to the commerce). Some definitions clearly state that the outbound SC is "complex" and some point out a fuzzy difference between the SC in terms of "physical *operations*", "company *function*" and "company *department*" (e.g. [E14]).

About the use and usefulness of outbound SC maps. Appendix 4 sums up every point gathered in interviews concerning use, usefulness, existence of maps, experience of mapping… The need for having maps is clearly mentioned by a majority of respondents, even if most of them say that they don't use maps and do not map. Respondents express the need for mapping tools… Could this refer to the need for convention of Gardner and Cooper (2003)? Since SCs are complex (which is a problem for mapping them for a majority of respondents), maps are useful to visualise, represent and better understand the SCs. Respondents spontaneously mentioned 11 types of map usefulness and 7 sources of mapping difficulty. There is a controversy over whether a map should be as complete as possible or not. But some respondents insist on the need for maps to be as faithful as possible. [E13] states "I think for a long time the carmakers didn't take care of the downstream SC because they didn't really see the stakes". Could this explain why there are so few outbound SC maps in RG?

Difference between the 4 groups of respondents. The analysis of the differences between the maps, discourses and definitions of the four groups of respondents, even if subject to caution due to the low number of respondent per group, gives support to the importance of the experience of the territory (company, automotive sector, logistics operations and SCM, etc.) on mapping.

Discussion

In our case study, the alignment between organisational and individual maps is good. The organisational maps of RG, used for training, are simple and so old that they probably influence employees' representations. They include such basic and core elements of the outbound SC that it is not surprising they also figure in the individual

maps. The comparison of the individual maps reveals that there are mismatches (e.g. type of map, what is represented, perimeter…). All in all, the sum of what is represented on individual maps is not so different from what is represented in the collection of academic maps. The 18 maps (maid by RG key informants) tell us about managers' visible horizon (Carter *et al.*, 2015) of RG outbound SC.

The mapping of SC is not an easy task for managers who express the need to develop tool to map. None of the 18 maps refers to or looks like the mapping tools or maps found in the literature. However SC mapping is considered as useful for managers participating to the management of a SC. This encourages researchers to go on working on this aspect of SCM, and to better communicate their results to industry.

The comparison of the results obtained at each steps gives evidence of the varied and more or less complex SC maps, discourses and definitions. This variety confirms the subjective nature of mapping and probably reveals the variety of SC mental representation of managers. It suggests that sharing individual maps could be helpful to improve collaboration between SC actors and eventually to align representations.

The comparison of results from step 1 with step 2 as well as the comparison between the four groups of respondents supports the influence of individual experience and projects (and objectives) in the SC on the individual maps. It suggests, in case of dysfunctions in the management of the SC, that studying the mismatches between individual SC maps could help to better understand where problems come from and to solve them. In line with the network literature perspective, the interviewees' discourses also suggest that drawing maps made them understand things differently i.e. drawing doesn't just represent the world, it (re)constructs it.

The comparison of results from step 1+2 with step 3 attests that "the map is not the territory". The overall list of 33 items and 8 categories obtained at the end of step 3 is a valuable output to discuss and build SC diagnosis tool.

Conclusion

Our research questions the "neutrality" of supply chain mapping and helps to better understand the mapping process at the individual level. It also improves our understanding of the role/usage of maps in SCM. Philosophically speaking, it points to the importance of revealing the underlying ontological and epistemological vision of SC managers and researchers, respectively. Maps objectivize but are not objective pictures! Companies need to be fully conscious of the power of SC maps and to take greater care with their mapping activities.

The collected data did not permit us to unveil the implicit assumptions "behind" SC maps and the use of maps as a "powerful" tool in SCM. To go further on this understanding, a focus group with the respondents and other SC actors could be organized to discuss differences between maps and discuss the result of the research. The focus group could also discuss the following two questions. Does a better understanding of the differences between individual SC maps could help explain and solve SCM dysfunctions?

Our data did not permit us to study the potential influence of SC maps and mapping activity on SCM. This could be the aim of the continuing research collaboration with RG, with an action research approach. Can maps be considered (or serve) as intermediary or boundary objects in multi-function SCM teams (Carlile, 2002)?

Since the focus of our case study was the outbound SC of RG, adopting the point of view of the industrial company and studying first the internal actors' SC maps, further research could replicate the methodology to study the maps of 'external' actors such as suppliers (for transport, logistics and operations-on-car activities), dealers, etc.

Finally, the research questions the need for a company to spend time and resources to map its SC. It questions the kind of map to promote and the relevance to adopt a convention (Gardner and Cooper, 2003). Is it a good thing to standardize maps? It also questions the use of maps and mapping in industry as well as in academia. Can maps influence managers', students' and researchers' mental representations of SCs? Do persons' mental representations of SC influence their mapping of SCs? More generally, how can maps be used in SCM?

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Appendix 1 – Items founds at each step of the coding process

Category of item	Step 1: Items found in maps	Step 2: new items from discourses	Step 3: new items from SC definitions
Place	Manufacturing plant	Perimeter of/in outbound SC	Points of control **quality** (car)
	Warehouses (CLE), platforms (PDC), ports		
	Points of tracking (traceability)		
	Geography (spatial, countries...)		
Actor	Logistics suppliers + other suppliers		Role/importance of **contracts**
	Dealer Renault (customer)		**Politcal/relational** aspects in the SC
	Enduser (who buys the car)		**Transversality between actors** in the SC
	Organizational boundary (intra RG)		
Tool / Ressource	Means of transport (trucks, boats, etc.)		Importance of **standards**
	Computer (IT)		
	Information system (IS)		
Flow	Car	**Link** information/physical flow	**Link** physical flow/finance
	Physical flow		
	Information flow		
	Time		
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	On time delivery, leadtime…	
Activity	Operations done on cars (in logistics centres)	Transfer (of responsibility)	**Animation** of suppliers
		Process (related to outbound SC)	
Decision	Planning (production, SCM, logistics…) in RG	Dynamic piloting (thanks to traceability)	
	Impacts on outbound of decisions taken before		
Event	Hasards (in transport or logistics)	Security (IS hacking)	
Total	*20 items represented in maps*	*7 new items in discourses (total 27 items mentioned)*	*7 new items in SC definitions (total 34 items mentioned)*

Appendix 2 – Difference between maps (step 1) and discourses during drawing (step 2)

2.1. Difference per item

Difference between maps (step 1) and the discourse during mapping (step 2)				
Items found at step 1 of the coding process		Step 1	Step 2	Difference
Place	Manufacturing plant	16	16	**0**
Actor	Logistics suppliers + other suppliers	3	10	**7**
Decision	Planning (production, SCM, logistics…) in Renault	1	7	**6**
Tool/Ressource	Means of transport (trucks, boats, etc.)	9	14	**5**
Place	Warehouses (CLE), platforms (PDC), ports	15	17	**2**
Activity	Operations done on cars (in logistics centres)	4	6	**2**
Actor	Dealer Renault (customer)	14	15	**1**
Actor	End-user (who buys the car)	4	8	**4**
Flow	Car	6	16	**10**
Tool/Ressource	Computer (IT)	2	3	**1**
Tool/Ressource	Information system (IS)	3	6	**3**
Event	Hasards	1	6	**5**
Decision	Impacts on outbound of decisions taken before	2	3	**1**
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	5	10	**5**
Flow/objective	Time, leadtime…	5	12	**7**
Flow	Physical flow	8	8	**0**
Flow	Information flow	3	2	**-1**
Place	Points of tracking, traceability	7	6	**-1**
Actor	Organizational boundary (intra RG)	4	6	**2**
Place	Geography (spatial)	2	13	**11**
	Total	**114**	**184**	**70**

2.2. Difference for total of items per respondents

Total number of items mentioned per respondent																			
Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Total**
Nb of items step 1	10	7	9	8	4	8	0	5	8	1	6	9	6	8	11	7	4	3	114
Nb of items step 2	10	12	10	9	4	11	14	5	13	4	7	11	9	11	17	16	11	10	184
Difference	**0**	**5**	**1**	**1**	**0**	**3**	**14**	**0**	**5**	**3**	**1**	**2**	**3**	**3**	**6**	**9**	**7**	**7**	**70**

Appendix 3 – Difference between maps (step 1) and definition of SC (step 3)

Difference between maps (step 1) and the definitions of what the outbound SC is (step 3)				
Category	**Items found at step 1 of the coding process**	**Step 1**	**Step 3**	**Difference**
Place	Manufacturing plant	16	17	1
Actor	Logistics suppliers + other suppliers	3	15	12
Decision	Planning (production, SCM…) in Renault	1	11	10
Tool/Ressource	Means of transport (trucks, boats, etc.)	9	16	7
Place	Warehouses (CLE), platforms (PDC), ports	15	16	1
Activity	Operations done on cars (in logistics centres)	4	10	6
Actor	Dealer Renault (customer)	14	15	1
Actor	End-user (who buys the car)	4	10	6
Flow	Car	6	18	12
Tool/Ressource	Computer (IT)	2	9	7
Tool/Ressource	Information system (IS)	3	9	6
Event	Hasards	1	11	10
Decision	Impacts on outbound of decisions taken before	2	4	2
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	5	13	8
Flow	Time, leadtime…	5	13	8
Flow	Physical flow	8	11	3
Flow	Information flow	3	6	3
Place	Points of tracking, traceability	7	9	2
Actor	Organizational boundary (intra RG)	4	16	12
Place	Geography (spatial)	2	13	11
	Total	**114**	**242**	**128**

Appendix 4 – Results concerning use, usefulness of SC maps

		Respondents [n°]																		
Topic related to research question	**Coding**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Total**
Need of map	The respondant feels a **lack/need of map**	1	1		1	0	0		1	1	1		1	1	1	1	1	0,5	1	**12,5**
	The respondant express the need of a **tool to map**				1				1		1					1	1	1		**6**
Usefullness of maps	Maps provide **visual** documents, **visualise**	1	1		1					1	1		1	1	1	1	1	1	1	**12**
	Maps help to **represent** things (flows, plants, actors…)		1		1	1			1			1	1		1	1	1	1	1	**11**
	Maps help (new) staff of new interns to **understand**		1							1	1		1		1				1	**6**
	Maps help to **question** about SCM										1		1			1				**3**
	Maps open avenue to find potential **improvements**												1			1		1		**3**
	Maps help to **communicate (identifie** people in RG)								1						1					**2**
	Maps help to **share** information, knowledge									1				1						**2**
	Maps are usefull to (SC) **design** (before development)											1				1				**2**
	Maps represent a **memory**																	1	1	**2**
	Maps avoid **misunderstandings** between people													1						**1**
	Maps can help to take **decision**															1				**1**
	11 usefulness	**1**	**3**	**0**	**2**	**1**	**0**	**0**	**2**	**3**	**3**	**2**	**5**	**3**	**4**	**6**	**2**	**4**	**4**	
Difficulties of mapping activity	**Complexity** of SCs => difficult to map SCs		1		1				1		1				1		1	1	1	**8**
	The representation must be as **faithful** as possible		1										1			1	1	1		**5**
	Need to/must represent **everything** (but difficult)		1		1						1		0					0		**3**
	Need to **update** maps (operations change!)		1															1		**2**
	Difficult to have a **real-time (dynamic)** mapping																1	1		**2**
	Difficult to **simplify** complex SC				1															**1**
	Mapping consumes **time**																		1	**1**
	7 difficulties	**0**	**4**	**0**	**3**	**0**	**0**	**0**	**1**	**0**	**2**	**0**	**1**	**0**	**1**	**1**	**3**	**4**	**2**	
Existence of maps in the company	Does the respondant has/use a map of the SC outbound?	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0,5	1	1	0,5	**5**
	Are there SC maps in the company?	1				1	1									1	1			**5**
	Does the respondant has/use other type of "maps"?							1				1					1			**3**
Doing maps	The respondant tells he/she did a SC mapping		1		1										1	1				**4**
Effective use of maps in RG	Maps are used during staff training	1					1										1			**3**
	Maps are use to illustrate document					1														**1**

Legend of codes	0= NO	1= YES	= not discussed in the interview	= indirect answer

Managing Change in Operations

Digital Strategy and Transformation: a Systematic Literature Review

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Abstract

Nowadays, manufacturing companies have been facing a complex phenomenon of technological advance, often named Industry 4.0, that is reshaping companies' strategy and organization, products and services, supply chains and operations. At the best of our knowledge, the academical panorama lacks an exhaustive literature review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems. Accordingly, this paper carries out a systematic literature review with the aim of mapping the publications and systematizing the often-fragmented literature on this field to propose directions of future inquire that could inspire scholars and support practitioners.

Keywords: Digital Strategy, Digital Transformation, Literature Review, Industry 4.0

Introduction

Nowadays technologies progress like a dense avalanche of advancements pouring into the environment (Brynjolfsson and McAfee, 2014). The rhythm of growth has been exponentially hastening in recent times indeed, and this has been provoking shocks in the realm of management (Westerman et al., 2014; Brynjolfsson and McAfee, 2017; Venkatraman, 2017). This complex phenomenon, often named Fourth Industrial Revolution or Industry 4.0, is reshaping companies' strategy and organization, products and services, supply chains and operations (Porter & Heppelmann, 2014). The concept of Industry 4.0 (I4.0) was initially introduced in Germany in 2011 (Lu, 2017), referring to the integration of physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries, with the aim of realizing a system in which all the processes are integrated and information is shared in real time (Hozdić, 2015).

This wave poses an important challenge to companies that more and more are required to deal with the opportunities offered by the digital technologies which are at the core of

the Fourth Industrial Revolution. Aware of both the limited financial resources as well as of their level of digital readiness, companies need to make some strategic choices, selecting and exploiting the set of digital technologies that better fit with their own context (Hess, 2016).

In other words, to remain competitive companies are called to strategically govern the digital change by formulating and executing a clear strategy to keep pace with the new digital reality (Matt et al. 2014).

Since the beginning of the 2010s, a large proliferation of papers on this subject matter has been observed, but often in a quite fragmented fashion and using an ample variety of terminology. At the best of our knowledge, the academic panorama lacks a complete and exhaustive literature review on how companies can strategically govern the digital change provoked by technology advancements and occurring in business systems. To date indeed, the newness of the topic and the wideness of the combined domains blur the knowledge on the company ground and torment researchers and experts across their affairs by creating overlaps between words and meanings, constructs and definitions, and by fostering unuseful varieties of vocabulary, and diverse perspectives on the same objects and phenomena.

Accordingly, this paper carries out a systematic literature review (SLR) on this field, with the aim of charting the map of the publications and systematizing the often-fragmented literature on this field into a comprehensive body of organized knowledge, underlining the different perspectives and proposing some directions of future inquire that could inspire scholars and support practitioners.

In pursuance of these targeted objectives, the SLR has been guided by the following research questions:

- RQ1: Which are the perimeter and the current state of the art in the field of research?
- RQ2: Is there a way to frame and organize the knowledge belonging to this field?
- RQ3: Which are guidelines to drive future researches on this field?

Findings of the research contribute to systematize the often-snipped literature on how to govern the change provoked in companies by digital technology advancements. Results of the literature review show that the field under investigation may be framed into four blocks, namely: Digital Transformation Strategy; Digital Transformation Execution; Leadership & Culture; and Models. Hence, our review will depict the nature and the main contents of these blocks, to what extent they are intertwined, and which are the leverages managers may employ to govern the change. Along this line, in the final part of the paper, a discussion on the current detected gaps is carried out, and some avenues of future researches are spelt out.

Methodology

Towards achieving our aim and answering the research questions, a systematic literature review on how to strategically govern the digital change provoked by technology advancements occurring in companies has been carried out. The field under investigation, which concerns the process followed by companies to strategically select the most prominent digital technologies and then drive their implementation within the companies, revolves around two main key areas. From one side the opportunities offered to the companies by the set of digital technologies and the Fourth Industrial Revolution, and, from the other side, the strategic process they have to follow to govern within the company this change. Accordingly, two different groups of keywords have been selected to carry out the literature review on the ISI Web of Science Database (core collection):

- Group 1: it contains the keywords to intercept the papers referring to the Fourth Industrial Revolution (i.e. "Industry 4.0"; "Industrial Revolution"; "Smart Factory"; "Smart Manufacturing") and the ones referring to Digitalization or Digital Transformation (i.e. "Digital*").
- Group 2: it contains the keywords related to the investigation of how firms can strategically cope and manage these digital technology advancements which is the baseline of the studied field. The focus has been given to the governance of this kind of transformation ("Strateg*"; "Transformation*"; "Change"; "Roadmap"; "Cultur*").

We combined a) the terms belonging to group 1 and group 2; and b) the terms belonging to group 1 with each combination of two terms belonging to group 2. a) and b) where searched respectively in titles and topic (i.e. abstract, title and keywords). In this way, we were able to capture most of the papers covering the field under investigation.

The queries that were accomplished on the 12th of March 2019, returned 10.114 results at first, reduced to 508 by applying some basic filtering options proposed by ISI as the research area (i.e. Management, Business, Operations Research Management Science), the English language, and the document type. Duplicates have been subsequently removed. The application of these criteria provides us with 459 papers, that were subsequently analyzed by the authors.

Consequently, in order to check the pertinence of these papers with the field under investigation (e.g. how to strategically govern the digital change provoked by technology advancements occurring in companies), we read the abstracts of these articles and we excluded those articles that were not pertinent, and 168 relevant articles remain. The reading of the full articles made it possible to identify the 59 most pertinent articles.

At the end, after 16 papers and 8 books have been added via a snowball process, the final dataset was composed by 83 contributions. It may be argued that the final database is made up in most part by ISI ranked journals (i.e. the queries searched on ISI-WoS Database), while the snowball process added mostly practitioners' articles. We believe that this balance is valuable, bearing in mind the topicality and the hype of the theme discussed.

Finally, all the selected articles have been carefully mapped in a structured spreadsheet with different dimensions, namely: - the field, - the topic and the purpose of the article, - the construct/s under investigation and its definition (when provided), - the description of the theoretical ground, - the methodology, - the main findings. The analysis of this spreadsheet made it possible to develop a framework that organizes the contributions of the literature on the field and sheds some light on the state of the art on the theme as well as on gaps and avenues for further researches.

Field of research

Giving a general overview of the papers, the overall counter of publications per year on the field has been growing exponentially and the curve has just reared in the last three years (max[1996-2015]: 5; 2016: 8; 2017: 10; 2018: 28). The mounting interest around the topic witnesses its relevance and renews the necessity of this work.

The large part of the publications empirically test their arguments on real cases (Figure 1), interviews and surveys, secondary data analysis or action research, but the analysis of the papers also shows the presence of a consistent set of papers (i.e. "Opinions") which expound findings without the backing of a proper scientific methodology – and this principally happens with the articles dealing with strategical matters.

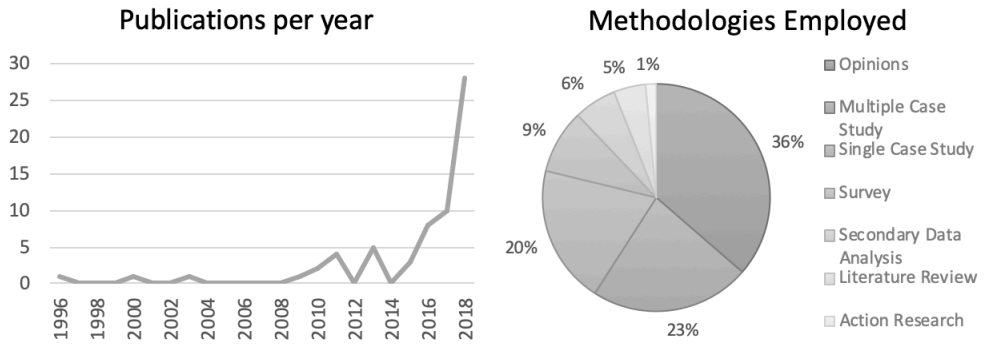

Figure 1 Publications per year and methodologies employed

The deep analysis of the papers shows that the articles on the field are quite fragmented and they deal with different aspects of the phenomenon, thus making it difficult to get a clear picture of it. To try to systematize the variety of these contributions, we develop a framework meant to integrate the different dimensions that shape the research field on how to govern the transformation provoked in companies by digital technology advancements. This framework (see Figure 2) is composed of four blocks.

The first two blocks – Digital Transformation Strategy (DTS) and Digital Transformation Execution (DTE) - constitute the backbone of the field and describe the process of digital transformation process (DT) triggered by the injection of digital technologies into companies. The second two blocks instead revolve respectively around the technical skills, Leadership and Culture companies need to be equipped with to be successful in the change process, and the Models literature supplies to comprehend these kinds of transformations. In this view, these latter two blocks sustain the field's backbone providing knowledge and tools to the people enlisted in the digital transformation process.

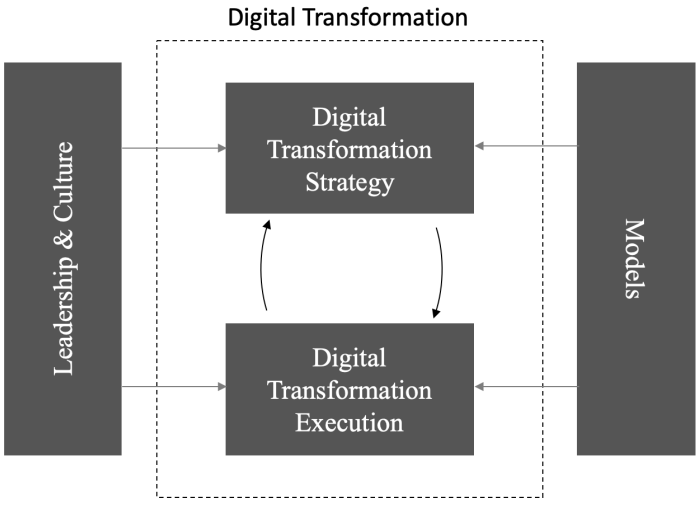

Figure 2 The architecture of a Digital Transformation Process

The Digital Transformation

The backbone of the field describes the process of governing the transformation of the company triggered by the injection of digital technologies. This process may be broken down into two diverse blocks, referring respectively to its strategical conception (i.e. Digital Transformation Strategy) and its execution (i.e. Digital Transformation Execution). More neatly, inside the concept of Digital Transformation there is one set of papers that concern Digital Transformation Strategy (DTS), where a company needs to explore the opportunities offered by technology (Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Konlechner et al., 2018) to select which to invest on (Mithas et al., 2010; Ardolino et al., 2018; Ghobakhloo, 2018; Pappas et al., 2018; Ross et al., 2018) and how to organize and control the strategical change (Tichy, 1983; Bharadwaj et al., 2013; Andriole, 2017; Davenport & Westerman, 2018). DTS papers conceptualize the path to be executed, argued in the second group of papers, which instead deal with the practical deployment of strategy into actions to transform the business model (Ross et al., 2016; Gobble, 2018) or with the management of the business-system-technology integration (Woodard et al., 2013; Agarwal & Brem, 2015; Teubner, 2018; Gastaldi et al., 2018). Consequently, as Digital Transformation Strategy lies in abstraction by the very nature of strategies, as its operations are made in the land of representations and models of reality (Gavetti and Levinthal, 2000), it has concrete effects on reality only through the Digital Transformation Execution (DTE) block (Gavetti and Rivkin, 2007). The proposed distinction comes out by the analysis of the aim and main constructs presented in the analyzed papers and will be clearly described in the subsequent sections.

Digital Transformation Strategy

Papers within this block deal with how to strategically address the opportunities and risks that originate from digital technologies, planning the company journey towards being digitally transformed (Singh &Hess, 2017). In order to refer to this concept, authors often employ different labels (i.e. digital transformation strategy, digital strategy, digital business strategy). A part from the different labels, the common features, which delimitate the boundary of the concept, relay on the fact that it governs the digital transformation: a) by defining objectives and priorities to provide directions (Mithas et al., 2010; Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Ardolino et al., 2018; Ghobakhloo, 2018; Konlechner et al., 2018; Pappas et al., 2018; Ross et al., 2018); b) by organizing the structure to enable the execution of digital initiatives (Agarwal & Brem, 2015; Hess et al., 2016; Sia et al., 2016); and c) by gauging progress to reroute efforts or investments when required (Sebastian et al., 2017).

Moreover, authors who use the label digital business strategy (Mithas, 2010; Kettinger, 2011; Bharadwaj et al., 2013; Grover and Kohli, 2013; Markus and Loebbecke, 2013; Mithas et al., 2013; Woodard et al., 2013; Sia et al., 2016) emphasize the integration between information technology (IT) function strategy and business strategy, which has its root in the need to achieve a peaceful and effective co-existence between IT and business strategy, thus suggesting a juxtaposition of their purposes and plans (Henderson & Venkatraman, 1992).

Beyond the definition of the concept of DTS, papers show that firms might craft their digital strategy to achieve two main objectives:

Value Propositions. A company can transform its value proposition to elevate "the performance implications of IT strategy beyond efficiency and productivity metrics to those that drive competitive advantage and strategic differentiation" (Bharadwaj et al., 2013). Ross et al. (2017) draw how companies use to pursue either a Customer

Engagement Strategy, whether they decide to focus on boosting their customer experience (Lanzolla & Giudici, 2017; Haenninen et al., 2018; Kotarba, 2018; Subramaniam et al., 2019), or a Digitalized Solution Strategy, if they bet on R&D chances to innovate their value proposition by combining products, services and available data (e.g. new smart and connected product, platform, analytics service-based) (Woodard et al., 2013; Porter and Heppelman, 2014; Echterfeld and Gausmeier, 2018).

Processeses. A company, pursuing an Operational Excellence Strategy (Ross et al., 2017) may decide to transform its processes. The matter is how to invest on the redesign of the way activities to deliver value propositions are performed, taking advantage of technology to generate more outputs employing less inputs (Zuehlke, 2010; Erol et al., 2016; Dremel et al., 2017; Sanders, et al., 2016; Szozda, 2017; Gastaldi et al., 2018; Kaidalova et al., 2018; Mittal et al., 2018). Moreover, authors sustain companies are required to consider adapting their processes whenever a change in their value propositions occur (Benner, 2009; Ross et al., 2016; Dremel et al., 2017; Lanzolla and Giudici, 2017; Ross et al., 2017).

Digital Transformation Execution

Digital Transformation is the product of the execution of a Digital Transformation Strategy (i.e. Digital Transformation Execution - DTE), where strategies transform the reality towards their exploitation by mean of actions (Gavetti and Rivkin, 2007; Ross et al., 2016). Accordingly, the overall subject matter of the second block is how to exploit the strategical transformations of value propositions and/or processes by leveraging on technologies (Day-Yang, L. et al., 2011; Gastaldi et al., 2018; Wagner et al. 2018; Weill and Woerner, 2018). Comparing to the previous block, here the knowledge is much more fragmented due to the absence of a referential theory and also because researches mostly and simply describe use cases of technology and how they have just been implemented (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018). Despite the complexity in navigating the knowledge of this block, the analysis on the research aims and the findings of each paper contained into the dataset allowed us to identify three patterns on DTE, regarding Industry 4.0, Lean Management and Project Management.

DTE & Industry 4.0. As salient detail, the contributions referring to the construct Industry 4.0 (i.e. The Fourth Industrial Revolution) mainly focus and prioritize the digital transformations of manufacturing operations and supply chains, and the way an Operational Effectiveness strategy (Ross et al. 2017) may be executed. (Hozdić, 2015; Lee, et al., 2015; Lu, 2017; Bienhaus & Haddud, 2018; Yin et al. 2018).

DTE & Lean Management. Going inside the contributions referring to the digital transformation of Supply chains and Operations, we notice a niche of contributions inquiring the relationship between Lean Management (LM) (Womack and Jones, 1997) and Digital Transformation, and we can outline two outlooks. On one side, Bortolotti et al. (2014) claim the effective execution of a Digital Transformation cannot avoid laying on already efficient and streamlined processes. This is the reason why tracking LM may lead to an operational readiness to change (Sanders et al., 2015; Mrugalska and Wyrwicka, 2017; Besser Freitag et al., 2018). On the other side, Kolberg and Zühlke (2015) overturn the concept, arguing that LM is enabled by Digital Transformation, because technology is broadening the chances for manufacturing and service companies to reinforce their efficiency by solving problems in ways afore unthinkable.

DTE & Project Management. Indeed Digital Transformation Executions are often described as a package of digital coordinated projects, (Erol et al., 2016; Goelzer and

Fritzsche, 2017; Dremel et al., 2017; Singh & Hess, 2017; Bertoncel, 2018), and this opens a question on the role of Project Management in the Digital Transformation process, although few publication refers explicitly to the issue (Schüritz et al., 2017; Teubner, 2018).

Leadership & Culture

The third block considers the academical interest on the impact of the organizational and cultural variables into a Digital Transformation (i.e. DTS and DTE). Compared to the rest of the papers, this block presents a dissonant peculiarity on the methodologies employed by scholars, that is the preponderance of hypotheses tested by surveys and statistic techniques, while case studies are the rule in the other papers. In this niche of knowledge results figure out two main topics discussed by scholars: technical skills, leadership, and cultural background requirements.

From the analysis, these requirements seem a prerogative to make a Digital Transformation effective, mainly for two reasons: first, they must to be fostered whatever the DT will be (Ross et al. 2016; Sia et al., 2016; Westerman, 2016; Dremel et al., 2017); second, it is "difficult, rather impossible, for a network of typical manufactures to achieve them in a short run" (Ghobakhloo, 2018)

Technical skills. Some publications claim that a Digital Transformation to survive in time without having a negative impact on performances need people to be equipped with some technical skills (Weizi et al., 2016). These are required to understand, deploy and manage the opportunities offered by technologies and the dynamics of the change their introduction involves Sia et al., 2016; Davison and Ou, 2017; Ross et al. 2017). Such skills are hybrid skills (Weizi et al., 2016; Schwarzmueller et al., 2018), for example, the ability to perceive week signals of disruption (Bertoncel, 2018) or to handle the analysis and conversion of big amount of data to make decisions above valuable information (Davenport and Patil. 2012; McAfee, Andrew, et al., 2012; Schallmo et al., 2017).

Leadership. Literature maintains the central role leadership plays in the Digital Transformation process, and in particular the interaction between leadership and technology advancements that is baptized as e-leadership (Avolio et al. 2014). Weizi et al. (2016) divide the construct of e-leadership in two layers, where at micro level it deals with the abovementioned skills requirements, and, at a macro level, e-leadership challenges the redesign of company's governance to allocate responsibilities to tackle a DT. On this account, the analysis on the dataset pinpoints a stream of research on the relationship between Chief Information Officers and Chief Executive Officers (Weizi et al., 2016; Hansen et al., 2011; Oberer & Erkollar, 2018), and the opportunity/possibility of introducing a new referential profile the Chief Digital Officer – CDO to supervise the DT (Singh & Hess, 2017).

Cultural Background. Some contributions address the theme of which kind of organizational culture is more suited to engage a Digital Transformation. From the analysis, two significant features emerge: agility and innovation (Ross et al., 2017; Dremel et al., 2017). In particular, Schwarzmueller et al., (2018) state "organizational culture should be transformed to a culture of involvement, in which decisions are taken together, a culture of innovation, that ensures agility based on the acceptance of suggestions, and a culture of training, in which staff is constantly developed (Patterson et al., 2005)." Furthermore, other authors hint companies need to pursue openness to change (Ghobakhloo, 2018) to adapt more quickly and shorten adaptation time to new working habits (Weizi et al., 2016), and, eventually, create a culture of decision making based on data instead of experience and intuition (McAfee et al., 2012; Dremel et al., 2017).

Models

The Models block collects the contributions which provide knowledge on the opportunities offered by technology advancements and on guidelines companies may follow to implement a Digital Transformation They are divided into three different groups: Frameworks, Roadmaps and Methodologies, and Assessment Tools.

Frameworks. As defined in the introduction of the paper, Digital Transformation is a consequence of the technological evolution which companies wrestle along their journey. Literature maintain diverse publications that try to build knowledge around this phenomenon (Porter & Heppelmann, 2014; Rometty, 2016; Westerman et al., 2014), inquiring how technologies progress, and/or their social impact, and/or the types of mutations they are provoking on companies (Brynjolfsson and McAfee, 2014; Porter & Heppelmann, 2015; Weill and Woerner, 2015; Brynjolfsson and McAfee, 2017; Venkatraman, 2017).

Roadmaps and methodologies. In this group are contained all the contribution referring to methods (i.e. standards and steps) (Bibby & Dehe, 2018; Mittal et al., 2018), guidelines, roadmaps and tools (Westerman, 2016; Andriole, 2017; Gobble, 2018) which a company could use for architecting and standardizing its Digital Transformation (Liu, Day-Yang et al., 2011; Porter & Heppelmann, 2015; Matt et al., 2015; Erol et al., 2016; Parviainen et al., 2017; Dremel et al., 2017; Ghobakhloo, 2018; Weill and Woerner, 2018). Methodologies can be applied to any type of digital transformation, and their focus ranges from the entire company to a specific project. Literature is rich of anecdotal cases of successful integration of technologies towards a digital transformation (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018), but a thorough reference methodology to handle the problem of Digital Transformation still lacks (Nwaiwu, 2018).

Assessment tools. This stream of papers provides contributions on instruments which support managers or companies in measuring and evaluating the degree of technological integration into company's processes. This results in a seminal provision to position companies into a reference system that can better drive the digital transformation process (Plomp and Batenburg, 2010; Bibby & Dehe, 2018; Heavin & Power, 2018; Kontic & Vidicki, 2018).

Conclusion

Although this is a preliminary review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems, some contributions to both research and practice have been provided. On the academic side, the paper systematizes the knowledge on the field and provides a framework to orient future researches. On the managerial side, our research offers some insights on the strategic aspects of the digital transformation that endeavour and supports organizations and managers that are tackling the challenges offered by the new digital era.

The paper has also some limitations, that can drive further developments. Results maintain that literature on the field is still in its infancy, suggesting that future research should go more in depth in comprehending how digital transformation can be developed and executed. The performed queries are more focused on the digital strategy conceptualization rather than its exploitation. So, additional research could be performed through a wider sample to validate and enrich the considerations addressed on Digital Transformation Execution subgroup.

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Managing digital innovation in manufacturing companies

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Abstract
The potential of digital innovations is clearly recognized. However, its implementation within manufacturing companies seems to be more difficult. Considering that digital innovation within manufacturing companies are a combination of digital and physical assets, it seems plausible that the consideration of information systems related governance mechanism may support the digital innovation management within manufacturing companies. We derive six propositions which give insights into which dimensions are relevant for digital innovation management in manufacturing companies.

Keywords: Digital Innovation Management, Digital Technologies

Introduction
The diffusion of digital technologies into the manufacturing industry creates new opportunities. These opportunities may arise from improvements in efficiency and effectiveness (i.e. smart factory) or through the offerings of new products, services or even business models. The combination of digital technologies such as sensors, actors and cloud computing with non-digital products and services provide significant opportunities but capturing the value of the digital transformation has proven to be challenging to firms in traditional industries (Henfridsson et al., 2018; Svahn and Henfridsson, 2012). Whereas the innovation potential of digital technologies is widely recognized, few studies address the management of digital innovations (Abrell et al., 2016). We aim to enhance the understanding of how to manage digital innovations in manufacturing companies. To do so, we relate to IS literature and derive insights from software development projects and compare these with the activities and challenges of eleven Industrial Internet of Things (IIoT) projects of three manufacturing companies.

Digital Transformation

Digital transformation describes how companies need to change their processes and the company's way to compete in the digital age. There exist different terms describing the changes, such as information age, industrial internet or industry 4.0. The information age started with the third industrial revolution, also known as the digital or ICT revolution, at the end of the twentieth century (e.g., Castells, 2011; Dosi and Galambos, 2013). The technologies, mainly

ICT, lay new foundations for companies, economies and societies. In addition, Musso (2013) concludes that the information age has sped up the transition from manufacturing to services, highlighting the influence of the technological changes on business models.

In industrial companies, these changes are labelled as industrial internet, industrial internet of things (IIoT) or Industry 4.0. The main approach of the industrial internet or industrial internet of things (IIoT) is to bring software and machines together (Bruner, 2013). The term stems from the US and was first introduced by General Electric. IIoT enfolds initiatives belonging to a higher degree of intelligence with the power of advanced computing, analytics, low-cost sensing, and new levels of Internet connectivity (Posada et al., 2015). Posada et al. (2015) highlight three key elements of IIoT: (1) intelligent machines, (2) advanced analytics and (3) people at work.

Industry 4.0 belongs to a similar initiative, mainly pushed from Germany. The core elements of Industry 4.0 are embedded systems, smart objects, cyber physical systems (CPS), the concept of a Smart Factory, robust networks, cloud computing, and IT-security (Bauer et al., 2014). The coexistence of the physical and virtual worlds, with the use of emerging ICT, opens possibilities such as "enhanced human-machine cooperation (including human interaction with robots and intelligent machines), connected machine networks that follow paradigms of Internet connectivity and social networks, improved human-in-the-loop interaction between the cyber and physical worlds, networked and decentralized value chain transnational scenarios, and emergence of product-service networks based in intelligent, smart products, and associated services" (Posada et al., 2015, p.27).

Whereas Industry 4.0, IoT, IIoT and digital manufacturing focus on the changes of digital technologies in industrial companies, the term digital transformation is industry independent and analysed based on the perspective of different research streams. Vial (2019) defines, based on a comprehensive literature review, digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies".

Although avoiding the term "digital technologies" in his definition, Vial (2019) highlights that that most of the digital technologies mentioned in the literature review fit with the popular SMACIT acronym, referring to technologies related to social, mobile, analytics, cloud, and the internet of things. Furthermore, it's the combination of technologies that are particularly relevant in the context of digital transformation (Bharadwaj et al., 2013). For example, the use of social media on the mobile phone may be the prerequisite for gathering and storing big data and to perform analytics.

Others, in addition, highlight the merge of the physical and digital world, enabled through IoT sensor and actuators and connectivity technologies (Fleisch et al., 2014; Yoo et al., 2010). Summarizing, the traditional processes of manufacturing companies focusing on physical products is challenged with the requirements to integrate digital aspects. How to cope with these new requirements is a challenging task for manufacturing companies. Hence, to get an understanding of the different requirements manufacturing companies are facing while developing digitally enhanced products, services or processes, we summarize the key aspects of the traditional innovation management and information systems (IS) related innovation management.

Traditional Innovation Management: Insights from Business Management

Managing innovation has traditionally focused on new product development (NPD) activities. Prerequisites for the development of products are the engagement in a bundle of activities that include the management and transformation of resources and information in order to create products that meet or create market demand (Wheelwright and Clark, 1992). Typically, in innovation management, four types of innovation exist: process, product, service and business model innovation (e.g., Teece, 2010). Considering key determinants of the traditional

innovation management, Damanpour (1991) highlights in his meta-analysis several factors that have a positive correlation with innovation: specialization, functional differentiation, professionalism, managerial attitude toward change, technical knowledge resources, administrative intensity, slack resources, and external and internal communication.

Johansson and Kullström (2018) argue that an innovation management, which has been dominated by structure and control, mirrors the circumstances where goals and objectives have been clear. Instead, innovation activities nowadays are increasingly confronted with fuzzy objectives and complex processes and traditional methods have been found lacking (Kapsali, 2013). Therefore, there is a need to find methods that suit more complex projects.

Innovation management: Insights from IS literature

Traditionally IS innovation research has focused on the adoption, diffusion, implementation, acceptance, and assimilation of IT in organizations (Fielt and Gregor, 2016). However, there is a growing interest on the paradoxes and dilemmas that digitization creates for organizations developing, deploying, and managing digital innovation (Nambisan et al., 2017). As Nambisan (2017) states: "This transition from innovation to digital innovation comes as a golden opportunity to be seized upon by information systems (IS) researchers. IS researchers have, for the last four decades, been at the forefront in observing the dawn and consecutive wakes of digitization in organizations and, broadly, in society, and explaining its repercussions." Similar to the definitions in business research, IS scholars define digital innovation as the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology. Stated differently, in digital innovation, digital technologies and associated digitizing processes form the base for new ideas. Thus, digital innovation management refers to the practices, processes, and principles that underlie the effective orchestration of digital innovation (Nambisan, 2017).

Svahn and Henfridsson (2012) conclude that product innovation and IT innovation literature provide a different outlook on innovation. While product innovation cultivates firm-centricity and exercise of formal control, IT innovation builds upon network-centricity and the creation of digital options. Network-centricity introduces uncertainty that counteracts the traditionally exercised formal control over the product innovation process. The authors conclude that more research is needed on these seemingly opposing logics (Svahn and Henfridsson, 2012).

Digital Innovation Management: Research Framework

Different researchers argue that there is a need for new theories in this age of digital innovation and digital transformation (Hinings et al., 2018; Svahn and Henfridsson, 2012; Yoo et al., 2012). More specifically, Nambisan et al. (2017) say that "[t]here is a critical need for novel theorizing on digital innovation management" that deals more adequately with the rapidly changing nature of innovation processes in a digital world. Although the innovation process itself is crucial to understand, the management is important as well.

As the proportion of software within innovations of manufacturing companies is rapidly growing, manufacturing companies can profit from understanding the requirements to successfully manage IT innovations. However, as Svahn and Henfridsson (2012) highlight, there are differences between the management of product and IT innovations and hence, there is a need to get an understanding on how to incorporate both aspects.

To do so, we rely on the concept on IT governance. As Leonhardt et al. (2018) summarizes, newer research on IT governance mainly enfolds the governance mechanisms related to structure, process and relational mechanisms.

One key aspect to IT governance is the decision-making structure, implemented to define the locus of authority for IT activities (Sambamurthy and Zmud, 1999). Choices range from centralized to decentralized or hybrid decision-making. More specifically, a central decision architecture grants all decision rights to the IT organization, a decentralized one delegates

decision-making authority to the business units (Brown and Magill, 1994). Thus, we conclude that the *locus of authority* and its role in digital innovation management needs further research attention.

Horizontal coordination mechanism enfold informal and formal designs that focus on the interaction of individuals and the coordination of activities across units (Mintzberg, 1979). The mechanism aim at facilitating interaction and problem-solving across different departments (Brown, 1999). The formal coordination mechanism refer to steering committees or cross-unit integrators. Examples of cross-unit integrators are Chief Digital Officers.

Since digital innovation requires the combination of diverse knowledge across different departments (Yoo et al., 2010), interdepartmental dynamics and the respective *horizontal coordination mechanism* may be at the core of digital innovation management.

Although Yoo et al. (2010) focus on the internal cooperation relevant to acquire knowledge, Hildebrandt et al. (2015) highlight the growing importance of cooperation with external partners. More specifically, acquiring and integrating complementary and heterogeneous external knowledge on digital technologies is an important prerequisite for digital innovation (Hildebrandt et al., 2015). Thus, we add *internal cooperation* and *external cooperation* as two further dimension as being potentially relevant to understand digital innovation management.

As it is our goal to understand digital innovation management, we focus on the analysis of the innovation process itself and the four governance mechanisms as summarized in Figure 1.

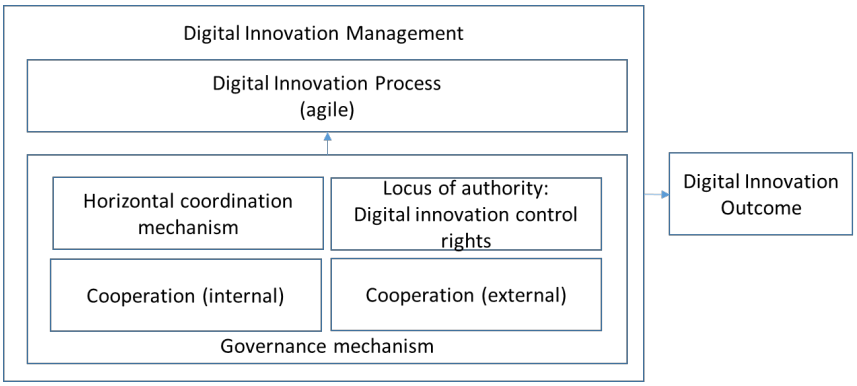

Figure 1 - Research Framework

Research methodology

We grounded our observations in data from a multi-case study with three multinational companies from the machine industry that face the diffusion of digital technologies. Each of the companies belong to a wider company network and reports to headquarters. In addition, company B acts as a national headquarter for further subsidiaries. Overall, we have analyzed eleven IIoT initiatives that are the unit of analysis for the study at hand. Because of the emergent nature of this topic, we apply an exploratory research approach. In addition, we analyze existing literature focusing on digital innovation and its management and derive a framework that guides our research (Eisenhardt, 1989). The goal is to match theory and reality in a nonlinear, path-dependent process that systematically combines empirical observations and insights from extant literature (Storbacka, 2011).

The exploratory research lasted from January 2016 to September 2017, with follow-up interviews in 2019. We accompanied the companies throughout the development process and conducted 12 to 16 meetings within each of the participating companies. The companies were part of a joint working group. Hence, there are activities that the companies conducted jointly (i.e. successful practice visits) or applied the same methods (i.e. evaluation of market trends). Other activities are company specific. The data gathering occurred through meetings within each of the three companies. During the meetings, we observed the activities and conducted

interviews. We wrote minutes for each meeting (observation and interviews), and compared them with literature.

We used Miles and Huberman's (1994) four-step approach to analyze the collected data. First, we developed a contact summary sheet in which the main themes of each interview were recorded. One researcher identified the main themes, while the other two researchers checked these themes using the interview minutes. The themes covered, for example, the content of different IIoT initiatives and the measures to implement them. Second, a complete theme list was developed based on the contact summary sheet. Third, all interviews were coded using selective coding (Strauss and Corbin, 1990) to categorize the answers into the main themes. One researcher was responsible for coding the interview minutes, while the other researcher checked the coding. In the event of disagreement, the point was discussed until agreement was reached. If no agreement was reached, the point was referred to the interviewees for clarification. This procedure ensured a high level of inter-rater reliability (Voss et al., 2002). Fourth, we wrote the case study and performed a final validity check, which was done by presenting the results to the interviewees and to the top management of the respective company.

Case study analysis

The three manufacturing companies developed nine IIoT ideas that focus on offering new services to the customers. Three initiatives focus on the digitalization of internal processes (i.e. digital working instructions, dynamic planning and production system (smart factory) and global service). Overall, the activities of the innovation process can be described according to the six generic dimensions: idea generation, idea selection (I), idea concretization, idea selection (II), development and dissemination. Table 1 and Table 2 summarize the main activities, separated into activities that each company conducted similar as well as company specific activities.

		Idea Generation		Idea Selection I		Idea Concretization	
		All companies	Specific	All companies	Specific	All companies	Specific
Case A1	**Guaranteed machine availability**	- Evaluation of market trends (general trends, customer trends) - Environmental scanning (competitors) - Generation of ideas based on creativity tools - Knowledge transfer from successful practices	- Collection of ideas from different sources within the company (meetings, informal discussions, documents)	- Visualization of ideas - Presentation of prioritised ideas (own choice) and open group discussion - Matching with strategy - Discussion based on portfolio analysis (impact and absorptive capacity) - Selection of 4 to 6 ideas	- Matching with digital transformation strategy	- Concretization based on I4.0 initiative analysis (value proposition, value chain, revenue mechanism, capabilities and technologies, connectivity) - Analysis of needed technologies and capabilities - Derivation of interdependencies between ideas	- Customer segmentation (i.e. personas) - Concretization of value offerings through service theater - Matching of value offerings with personas - Involvement of HQ
Case A2	**Pay per use**						
Case A3	**Smart Services**						
Case A4	**Smart factory of the customer**						
Case B1	**Guaranteed machine availability**		- Integration of projects from different subsidiaries (Swiss HQ perspective)		- Discussion based on functional strategies (sales, R&D, production)		- Comparison with ongoing projects and adaptation of ideas if needed
Case B2	**Digital working instructions**						
Case B3	**Smart Factory**						
Case C1	**Preventive/ predictive maintenance**		- Collection of ideas from different sources within and outside of company (e.g., meetings, informal discussions, presentations at trade shows, technical literature)		- Discussion based on functional strategies (sales, R&D, production)		- Customer segmentation (i.e. personas)
Case C2	**Global Service**						
Case C3	**Life-Cycle Management**						
Case C4	**System capability**						

Table 1: Insights from the innovation process of 11 IIoT initatives (I)

We conducted follow up interviews in 2019 to derive the level of diffusion. Whereas company A achieved to implement three pilot tests with customers (Case A1, A2 and A3), company B is also able to cooperate with pilot customers for case B1. Only company C had to stop all of its activities.

Based on the research framework derived, next to the process, we focused on the governance mechanism. Whereas in some cases, the governance mechanism have been similar for the studied company, other mechanism differed depending on the initiative. Table 3 highlights the insights of the governance mechanism.

		Idea Selection II	Development		Diffusion		Success
		Specific	All companies	Specific	All companies	Specific	
Case A1	**Guaranteed machine availability**	- Joint discussion and selection with HQ	- Setting up of roadmap and project management	- Stronger involvement of HQ and knowledge transfer with other business units and countries (A1-3) - Focus on technical requirements, data analysis and informations system (A1-3)	- Setting up roll-out activities	- cooperation with pilot customers (A1-3)	- Pilot tests
Case A2	**Pay per use**						- Pilot tests
Case A3	**Smart Services**						- Pilot tests
Case A4	**Smart factory of the customer**						- Stopped (not in the current strategic focus; 2017)
Case B1	**Guaranteed machine availability**			- Training of sales employees (selling software) (B1) - Focus on information system (incl. data and interfaces) (B1) - Joint development with external partners (all)		- Consideration of platforms and integration with complementary machine producers (B1) - Customer base: need to highlight the advantages of digitalisation (B1)	- Pilot tests
Case B2	**Digital working instructions**						- Stopped in 2018; restart in 2019
Case B3	**Smart Factory**						- Stopped in 2018; restart in 2019
Case C1	**Preventive/ predictive maintenance**	- Joint discussion and selection with HQ		- Evaluation of joint development with external partners (C2)			- Stopped from HQ (2017)
Case C2	**Global Service**						- Supplier evaluation, project ongoing
Case C3	**Life-Cycle Management**						- Stopped (not in the current strategic focus)
Case C4	**System capability**						- Stopped from HQ (2017)

Table 2: Insights from the innovation process of 11 IIoT initatives (II)

Discussion

The specific activities of company A and B at the beginning of the innovation process highlight the need to coordinate with other subsidiaries or activities conducted throughout the company. At company A, during the idea concretization phase, headquarters was involved to align the subsidiary activities with companywide initiatives. Although each of the four cases at company A was presented to headquarters, the “pay per use” initiative needed further alignment as the potential service offering influenced process steps covered from other subsidiaries and was clearly in the locus of authority of headquarters.

The interdisciplinary project team is a central part in traditional as well as digital innovation management and was present in each of the studied initiatives. Interdisciplinarity seems to be important, not only for the knowledge needed for the development of digital innovation but also for the strengthening of internal cooperation and thus the implementation of the digital innovation throughout the company. More specifically, the interdisciplinary teams helped to improve the attention throughout the company and, in addition, to integrate knowledge from other functions. In the case of company B, internal cooperation was strengthened through a mix of focused project developments and larger group meetings that involved up to forty employees from different functions and subsidiaries. Although company B’s project team consisted of internal members, there was a continuous possibility to take in additional knowledge from the network. Company A and B continuously harmonized their activities with other ongoing projects and hence, allowed to take in additional knowledge from the network. Thus, the insights suggest that besides the internal cooperation, digital innovation management is strengthened through collaboration with the company wide network.

P1: Internal cooperation through interdisciplinary project teams supports the knowledge intake from different functions and the knowledge diffusion throughout the company and hence, the digital innovation management.

P2: Cooperation throughout the company wide network supports the knowledge intake and hence, the digital innovation management.

Internal Cooperation
- Interdisciplinary project team, high attention of topic throughout the company
- Involvement of members of the company network where needed
- Interdisciplinary project team, various other initiatives on subsidiary level
- Mix between focused project teams of 4-6 members and bigger meetings (up to 40 people) to involve different functions and subsidiaries
- Interdisciplinary project team
External Cooperation
- Successful practice visits for idea generation
- Customer involvement happened late in the innovation process. Due to the strong internal competencies in the company wide network, no involvement of external cooperation partners.
- Idea concretization: collaboration with user experience specialists and software suppliers
- Continous integration of customers to understand the customer needs
- Smart Factory: supplier selection but supplier could not deliver the expected content. Own development activities but with to narrow focus. Stop of project (new start in 2019)
- External cooperation late in the innovation process and only for one initiative.
Horizontal coordination mechanism
- Assigment of a leader digital transformation, high involvement of CEO, decentralized approach (subsidiary decision authority), coordination between functions and with HQ, continous alignment between ongoing projects and digital transformation initiatives
- Digital transformation as part of the business development department (strategic projects), regular involvement of different employees of subsidiaries.
- Low involvement of Swiss COO, change of COO and stronger involvement and hence, re-start of smart factory project.
- Horizontal coordination through sounding board (CTO, COO, CEO)
- High involvement of CEO, no special assigments
Locus of authority
- In the beginning the locus of authority was within the Swiss subsidiary (decentralized approach). As one idea is within the competency of HQ, HQ involvement was needed.
- At the beginning: Authority of projects at Swiss HQ but parallel project developments at subsidiary level (hybrid solution with no clear regulations). Integration of projects into the Swiss HQ driven projects (involvement of key employees of different functions and subsidiaries).
- Development phase: global HQ started to intervene and stopped the initiatives in order to develop a global digital transformation strategy. After interdependency was achieved (buy out), re-start of projetcs with clear locus of authority at Swiss HQ (but involvement of subsidiary).
- In the beginning the locus of authority was within the Swiss subsidiary. HQ stopped further developments as it was unclear if subsidiary remained within the company.
Process
- Linear process with view iterations
- From early on application of agile development activities with a strong human centered approach (for guaranteed machine availability project), linear process activities for smart fabric project
- Linear process with view interations

Table 3: Insights from governance mechanism of 11 IIoT initiatives

With focus on external cooperation, the eleven initiatives differed. The development activities of the four initiatives of company A are conducted internally or in cooperation with the company wide network. Company C had an even stronger focus on the knowledge of internal members. Only company B did involve external partners, exemplifying the agile development philosophy through an early involvement of customers and suppliers. Based on the follow up interviews, the management of company B highlighted that the early collaboration with partners (customers and (technology) suppliers) helped for the internal and external focused innovations. The digital transformation representative of company A confirmed, as he states: “We should have integrated the customer right in the beginning”.

P3: External cooperation with partners (customer, supplier, experts) is important for digital innovation management.

The initiatives of company A have been orchestrated by a specifically assigned digital transformation leader. His role was to coordinate the different initiatives and to integrate the various activities throughout the company. In addition, the CEO had a central role, showing the

importance of the digital innovations and fostering its implementation activities. Company B assigned one initiative to the leader of strategic projects (guaranteed machine availability) and the internal focused projects to the COO. Whereas the leader of strategic projects continuously involved employees from different functions and subsidiaries and actively strengthened the informal knowledge transfer, the COO did not install similar coordination mechanisms. At company C, one initiative (Global Service) was assigned to the head of global services. Even though there was a high involvement of the CEO in company C, horizontal coordination mechanisms were missing for the other initiatives.

P4: Formal and informal coordination mechanism are important to consider for the digital innovation management.

The analysis of the locus of authority within the cases leads to different insights. In company A, the initiatives are highly linked to headquarters as the offerings of the services lies in the responsibility of headquarters. Being aware of this, the company tried to involve headquarters early and continuously. The locus of authority within company B changed during the innovation process. Whereas in the beginning, the company had the authority to decide, there was a development stop ordered from headquarters. Only after the company achieved a buy-out a re-start of the innovation processes were possible. After that, Swiss headquarters was officially assigned to be the locus of authority and, in the case of case B1, successfully continued the project. Similarly, based on headquarters orders, company C was not allowed to invest in the development of digital innovations as headquarters wanted to integrate the initiatives network. Since they were driven from the Swiss site alone, headquarters did not allow continuing with the initiatives before analyzing which other sites from the company wide network needs to be integrated into the development process.

Each of the analyzed initiatives had issues with the locus of authority. It seems that the primary prerequisite is to have it defined and second, to handle changing locus of authority and to adapt the management of digital innovation.

P5: The definition of the locus of authority is a requirement for digital innovation management. If new requirements lead to a change in the locus of authority, digital innovation management needs to be adapted.

Only one of the studied initiatives (B1) did integrate the agile development philosophy. The follow up interviews with the leader of the strategic development projects supported the importance of this philosophy, while contrasting the success of the digital innovation (B1) with the two other projects (B2 and B3). Similarly, company A highlights retrospectively that an earlier involvement of customer needs (and pains) and a more agile development process would have helped to speed up the development process.

P6: An agile innovation process with an early involvement of customers and suppliers as well as iterative phases supports digital innovation management.

Conclusion

The analysis of the management of eleven IoT initiatives exemplifies the difficulties of managing digital innovations within manufacturing companies. We add to literature as we compare the micro-level activities of the development of the IoT initiatives with the relevant dimensions derived from the IS literature on digital innovation and its management. First, we show that a linear development process, as implemented from the manufacturing companies, does not respect the complexity of digital innovations. As suggested from the IS literature on digital innovation, an iterative and agile approach helps to get a better understanding of the

underlying interdependencies. Another influencing factor is the interdisciplinary of teams, which need to be visible throughout the company and act as intermediaries between their functions and the project team (internal cooperation). Third, external cooperation is not only needed in the idea generation phase but during all the development stages. The development of digital innovations is complex and often, there is a lack of knowledge and experience which needs to be incorporated from external partners. Forth, in addition to internal and external cooperation, the cooperation within the company wide network is another important dimension for knowledge intake and diffusion. Fifth, changing locus of authority led to project stops and hence, exemplified its importance. The sixth dimension, horizontal coordination mechanism, shows the need to have defined responsibilities, which covers the interdisciplinary nature of digital innovations.

The exploratory research approach and the comparison with insights from IS literature allows to expand our understanding of digital innovation management. All derived dimensions need to be considered to successfully manage digital innovations within manufacturing companies. Limitations occurs as the development activities are still ongoing. In addition, more cases are needed in order to understand if one of the derived dimensions do have stronger impacts on digital innovation management than others.

Nevertheless, the derived proposition provide a starting point for further research. For example, the locus of authority needs further research attention as despite the clear finding of its importance, it remains open, how subsidiaries need to operate within the realm of headquarters.

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Managing change in operations: The case of the wire stripping machine in Agbogbloshie, Ghana

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Abstract

This paper investigates the cable processing in Agbogbloshie, Ghana, one of the best-known informal electronic waste management sites worldwide. Wire stripping machines have been installed on site, but are scarcely used. Instead, environmentally eroding and health hazard inducing, open-air burning continues in order to extract metals from the cables. To investigate the machines' lack of use, the theory of constraints is applied to empirical data collected in Agbogbloshie in 2017. Financial, policy, and market are identified as the system's constraints. The subsequent suggestions aim to increase the use of the machines, which would ultimately lead to environmental and socio-economic improvements.

Keywords: E-waste management system, Informal recycling, Theory of constraints.

Introduction

The electronic waste (e-waste) management in Ghana is a complex system comprised of a variety of processes and agents. Agbogbloshie – a scrap metal yard located in Accra – is an important part of such system, and is among the main sites for informal e-waste processing in the world (Akormedi et al., 2013; Daum et al., 2017; Oteng-Ababio et al., 2016). The scrap metal yard has drawn attention to many challenges that accompany such e-waste management within environmental, social and economic spheres (Akormedi et al., 2013; Grant and Oteng-Ababio, 2016).

Processes such as the manual dismantling of electric and electronic appliances, as well as the cable processing, are among the ones that are performed in Agbogbloshie. The cable processing, in particular, is responsible for one of the main environmental exposures in the area (Akormedi et al., 2013). This is conducted mainly through open-air burning, which causes substantial pollution in the region, and threatens both the environment and society (Tue et al., 2016). Different types of wire stripping machines have been installed on the site between 2014 and 2016, which are capable of processing a wide range of cable sizes. However, the burning of cables persists.

This paper investigates the reasons for the lack of use of the wire stripping machines. Qualitative approaches have been used to collect data, such as on-site observations, interviews, and photo documentation. The *Theory of Constraints* (TOC) is used in the analysis. The TOC has a systemic perspective and understands the system as a network of chains that is as strong as its weakest links – denoted the system's constraints

(Schragenheim and Dettmer, 2000). In order to be able to suggest improvements for the processing of cables, it is important to first identify the constraints of the system.

The case of cable processing is part of a larger research project that analyses e-waste management systems in different countries. Sustainability is the main guiding-lenses, with the basic understanding that these systems should aim to meet "the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 41).

The paper is structured as follows: the next section describes the data collection, followed by a brief discussion of the TOC. Next, I present the case of the cable processing by discussing the burning of cables, the implementation of the wire stripping machines, and the challenges regarding the change in operations. In the discussion section, I apply the TOC to the case of the wire stripping machines. In this context, the focus is on the two first focusing steps of the theory, namely to *identify the system's constraints* and to *decide how to exploit the constraints* (Goldratt, 1990). The last section concludes with remarks on the application of the TOC to the case.

Research design and situated context

The e-waste management in Ghana is understood as a complex system with several types of agents that interact with one another, each one performing different processes. This paper addresses two types of agents: the workers processing cables in Agbogbloshie, and the local non-governmental organization (NGO) that assisted in installing the wire stripping machines. The primary agents of interest are the workers who perform the cable processing.

Data were collected in Ghana during a period of two weeks in September of 2017. Several points of interest and organisations were visited in Accra and in adjacent cities. These visits enabled to better understand the challenges of e-waste management in the country. The Agbogbloshie site was visited seven times during the stay. Data were gathered through a mixed methods approach that combined observations, interviews, photography, and videos.

In Agbogbloshie, I engaged in conversations with 10-15 workers, while observing the activities performed by them and by other workers in the area. In addition, longer periods of observation on the e-waste processing, performed by different workers, have strengthened the data collection. Semi-structured interviews were conducted with the *Greater Accra Scrap Dealers Association* (GASDA) in Agbogbloshie, and with the NGO *Green Advocacy Ghana* (GreenAd) in Sakumono.

Theory of constraints

The TOC is a management theory, developed by Eliyahu Goldratt in the mid-1980s, that understands an organization or setting as a system (Rahman, 1998). This system takes inputs from the outside environment, acts on them through several processes, and produces outputs that go back to the outside environment (Schragenheim and Dettmer, 2000). The TOC defends the statement that "any efforts to improve a system's output must consider the effects of these efforts on the whole system (Schragenheim and Dettmer, 2000, p. 14)" due to the interdependent nature among variables in the system. Therefore, improvements should aim at optimizations to the whole system, instead of only individual processes.

The theory considers that the system's performance in achieving its goals is limited by one or more factor(s), referred to as the system's constraint(s) (Puche et al., 2016; Rahman, 1998). To improve performance, the TOC focuses on these constraints. Allocating efforts to improve processes that are not one of the system's constraints is

considered as a waste of resources since doing so would not affect the overall performance of the system.

The TOC has several tools that aim to understand and analyse a system, in order to provide suggestions for improvements. Tools include the *current reality tree* that is applied to identify the core problems and the *future reality tree* that aims to establish the future goals and ways of achieving them (Chou et al., 2012). Nevertheless, the TOC is more than a set of tools: "It is more fundamentally a paradigm shift which demands that we think about our problems, our goals and objectives, policies, procedures and measures, in a different way" (Mabin and Balderstone, 2000, p. 1).

According to Simatupang et al. (2013), the TOC comprises three different, yet interrelated, areas: logistics, performance measurement, and logical thinking; each one applying different methods. This paper focuses on the area of logical thinking, which primarily comprises the five focusing steps and the thinking process.

The five focusing steps

When seeking to make systemic improvements, Goldratt (1990) points out that it is fundamental to understand that every system was built for a certain purpose. Therefore, before any improvement is sought, it is necessary to first define the overall purpose of the system, and the factors that will be used to access the impact of any local decision on the global goal (Goldratt, 1990).

Once these are clearly defined, a series of steps may be used to aim for systemic improvements. Elaborated by Goldratt (1990), the five focusing steps are:

1. Identify the system's constraints.
2. Decide how to exploit these constraints.
3. Subordinate everything else to exploiting the constraints.
4. Elevate the constraints.
5. Return to step one, while preventing inertia to become a constraint.

Chou et al. (2012) explain the focusing steps in detail: *Step one* consists of identifying those processes in the system that have a capacity which is lower than the overall system's demand. *Step two* focuses on maximising the efficiency of such processes, based on the existing resources of the system. *Step three* comprehends the synchronization of the other processes in the system to the constraints. *Step four* targets on the acquisition of additional resources, in order to increase the constraints' capacity and eliminate them as constraints.

The five focusing steps are meant to be a cyclical process, and this is evidenced by *step five*. By exploiting and elevating the existing constraints, it is natural that other factor(s) – which previously had no impact on achieving the system's goal – become the new constraint(s). The search for improvements should be a continuous process because a system will always have at least one constraint.

Types of constraints

The factors restricting the achievement of goals within a system can vary substantially. Depending on the type, they might require different management approaches. For this reason, identifying the type of constraint enables a better understanding throughout the focusing steps. These constraints are categorized by Schragenheim and Dettmer (2000) as market, resources, material, vendors or suppliers, financial, knowledge or competence, and policy (cf. figure 1).

Resources and *material* are typically physical constraints. While the first comprehends internal sources (e.g. equipment, machines, people), the latter refers to external sources (e.g. raw materials, supplies), which are not enough to respond to the market's demand.

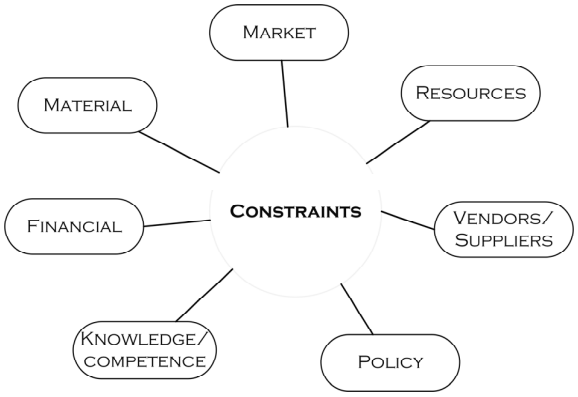

Figure 1: Types of constraints (built by the author based on Schragenheim and Dettmer, 2000)

The TOC recognizes that most constraints in a system are not physical, but managerial-policy related (Rahman, 1998). According to Schragenheim and Dettmer (2000), the reason for this is because almost all physical resources are dependent on some kind of policy. Managerial-policy constraints are often the most difficult to identify and require cooperation among functional areas (Rahman, 1998).

Market, financial, vendors/suppliers, knowledge/competence, and policy are all managerial-policy constraints. Schragenheim and Dettmer (2000) explain them in detail: The *market* constraint refers to the case in which the system's capacity is more than the demand. The *financial* constraint comprehends the lack of financial resources to meet the system's obligations. *Vendors/suppliers* refers to the case in which the lead-time of supplies is either too long or not reliable, to the extent that it affects the market demand. *Knowledge/competence* is a constraint when the lack of either hinders the achievement of goals in the system. Lastly, the policy constraint refers to cultural mores and ways of thinking: These appear either through explicit knowledge, such as written documents or through tacit knowledge, such as values.

The cable processing in Agbogbloshie

A multitude of processes is performed at the scrap metal yard of Agbogbloshie. The cable processing is one of these, and it has severe impacts in the area. In this section, I present my findings, focusing on the following points and their impact:

1. The burning of cables,
2. The implementation of the wire stripping machines, and
3. The challenges regarding the change in operations.

GASDA is the association of scrap dealers located in Agbogbloshie: It is responsible for organizing the activities, as well as granting permission to the ones who want to visit, or to work at the scrap metal yard. In an interview, the head of the association pointed out that the association has between 3000 and 4000 members and that everyone needs to become a member prior to working on the site. Amankwaa (2014) conducted a survey in Agbogbloshie, and the findings showed that the majority of workers are of young age – in the range from 15 to 30 years old – and that many have no formal education.

The e-waste that arrives in Agbogbloshie is first manually dismantled. The activity is often organized in groups, and the tasks are either performed in shelters or in the open air. Next, the cables are gathered in separate piles to be further treated (see figure 2). The most common practice to quickly remove the plastic insulation is to burn the cables. This process is assigned to a different group: often to the youngest men (Amuzu, 2018) as new members of the GASDA, to be accepted as workers on the site.

Figure 2: Gathering of cables

The burning of cables

For the burning activity, workers use an area further away from the dismantling area (see figure 3). They perform the activity primarily with shorts and t-shirts, leaving parts of their bodies directly exposed to the toxic emissions. Sandals are also more common than closed toe shoes, and the workers' feet often have direct contact with the polluted soil. Cables are transported in and out of the burning area with a wheelbarrow. The cables are fuelled with petrochemical products (e.g. insulation foam from refrigerators, old tires), and burnt with the help of long sticks. The e-waste activity is male-dominated (Amankwaa, 2014). Throughout this process, women go around the area – some accompanied by children – to sell food and water in plastic sacks.

Figure 3: Burning of cables (smoke plume in the left half) and dismantling shelters (right half in the background) at the border of the Odaw River (in the front)

The environmental NGO GreenAd conducts, among other activities, research on e-waste management in Ghana. During an interview, GreenAd mentioned that, on a health education campaign, they gave around 300 gloves and 300 masks to different workers in Agbogbloshie. The findings of this study revealed that workers did not want to use the Personal Protective Equipment (PPE) provided: Instead, they argued that the masks were uncomfortable and that it was easier to work with bare hands than wearing gloves.

The large amount of metal wires from the burning process is sold to intermediates – the scrap metal dealers – who then sell the material to smelting industries. Spread across Agbogbloshie are weighing scales, used to assess the value of the extracted metals.

The cable burning results in the emission of toxic gases and other dangerous species, which causes substantial pollution of the soil, water, and air in the region. The emissions can cause severe health problems; in particular, for the workers involved in the burning process and directly exposed to the toxins. Common health problems that have been observed include high concentrations of heavy metals in blood samples, and pulmonary issues (Daum et al., 2017). Even though a series of health initiatives have been implemented by NGOs trying to raise awareness among workers, many of the risks are not yet understood by them. As GreenAd explained in the interview:

"We've heard stories of people falling sick and they think it's malaria. They keep on taking medication, it doesn't work […]. It's all about education and people making an effort to help them out, to understand the various issues they are dealing with."

When talking with workers, some stated to know about the risks involved. However, they would emphasize that the e-waste is their business and a way of safeguarding their own families' livelihoods. This has been reinforced by GreenAd, which also pointed out to indirect risks unknown by workers:

"They feel they're making a living, that's the whole idea […]. But they don't know it's coming back to them […], cause these metals can also be found in the food chain. You have cattle eating there, people sell food […]. Before they eat it sometimes they don't even wash their hands. So they're earning money to buy medication, that's how it is."

Evidently, these overall negative impacts go beyond the workers who are directly involved with the e-waste processing. For instance, I could observe goats and cattle close to the cable burning area, which showed open wounds throughout their bodies. Food markets are focus points for further dissemination of the toxins to the greater community: For instance, the onion and yam market, located between Agbogbloshie and the urban slum of Old Fadama.

The implementation of the wire stripping machines

In 2014, the international organization Pure Earth opened the *Agbogbloshie Scrap Metal Recycling Center*. Funded by the *United Nations Industrial Development Organization* and the *Global Alliance on Health and Pollution*, this pilot project was implemented with the local partners GreenAd and GASDA (Pure Earth, 2016). The centre started its operation with four wire stripping machines (Pure Earth, 2014) capable to strip large coated cables of different thicknesses, down to a certain diameter. One of these machines is shown in figure 4.

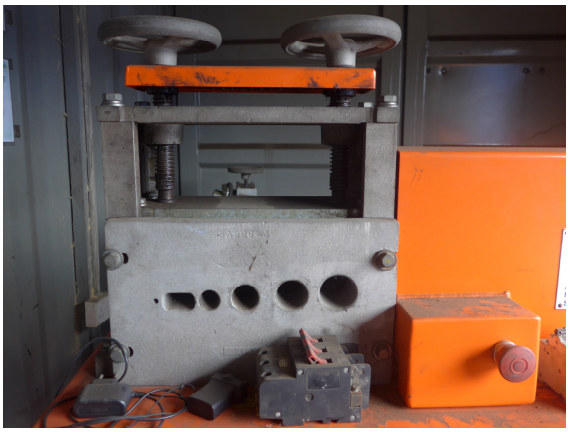

Figure 4: The automated machine to strip large cables

The machines are located inside a metal shed. Guidelines on usage and safety issues are provided by GreenAd and the *Global Alliance on Health and Pollution*, and are printed out on the wall of the shed. Safety guidelines include recommendations for wearing proper PPE, conducting regular maintenance, and safety measures prior, during and after the operation. Basic machine use guidelines include written information and figures to demonstrate the wire stripping process. These machines deliver long pieces of metal wires separated from the plastic. In front of the machines, it was possible to observe the remaining plastic from this process, which seemed to be there for long.

In 2016, another type of machine was installed due to the need for processing thinner cables (Pure Earth, 2016). This machine is a granulator/separator and chops the cables to separate the metals from the plastic. Therefore, it delivers the metals and plastic with a different shape than the automated machines for large cables.

The challenges regarding the change in operations

During all the on-site visits, I did not observe that any of the wire stripping machines were being used. Instead, the burning of cables was the common practice observed. The machines are located in a fenced area and access is only possible through the person that has the key.

In the specific case of the automated machine for thin cables, the difference in the shape of the material is one of the reasons for its lack of use. Workers pointed out about their mistrust in the amount of material delivered by this machine, which was also highlighted by GreenAd:

"They're used to burning the cables, getting it in one bowl and with the really small cables, you can't strip it […]. They want the good old way that they see it bent up and tied up into knots, which is not possible […] and they don't want it that way, they still want to see it together as one piece. If for the really big cables, then the equipment is good to get it in one long strip, […] but nobody has any equipment that can strip small cables to get it in strands […]. A lot of the boys there are not so educated. The way they see things, that's how they always want to see things. They feel when the machine chops it down and they get it in small pieces, that someone is stealing some."

Besides the above-mentioned challenges related to the use of the machine for thin cables, there are challenges regarding the resistance to using the machines for large cables as well. Two aspects were highlighted: cost and time. On the first, workers need to pay for the electricity consumed when using any of the machines, while there is no financial cost directly involved when burning. Some workers stated that they were aware of the fact that the burning leads to health consequences. Nevertheless, making the highest possible income on a day-to-day basis was pointed out to be the most important to them in order to maintain their livelihoods.

Concerning the other aspect, workers argued that it is time-consuming to perform the wire stripping process: the machines demand either that each large cable is stripped per time, or that small amounts of thin cables are chopped per time. On the contrary, workers can gather a large number of cables and burn them at once, which is considerably faster. So far, the burning activity continues to be the most appealing to them.

Discussion

In this section, I connect the main findings on the process of wire stripping in Agbogbloshie with the TOC. I focus here on the first two focusing steps proposed by Goldratt (1990): to identify the system's constraints, and to decide how to exploit them.

As presented in the TOC section, the first step when searching for systemic improvements is to define the purpose of the system, and the factors used to access the

impact of decisions. The discussion that follows considers that the main purpose of an e-waste management system should be to aim for sustainability. For this reason, the factors used to access the impact of decisions are the main pillars of sustainability; namely social, financial and environmental sustainability (Carter and Rogers, 2008).

From the description of the cable burning, several environmental and social challenges have been presented, including very poor working conditions, and the exposure to toxic gases and other dangerous species. From an environmental and social perspective, the wire stripping machines appear to be the most suited solution to achieve the system's purpose. As the first focusing step, I focus on identifying the constraints related to using the automated machines.

My investigations in Agbogbloshie have shown that the workers would rather burn the cables instead of using the provided machines. The conversations and interviews with the workers and with GreenAd provided insights into reasons that explain why the machines are not being used to their maximum capacity. These were:

1. The cost of electricity involved to operate the machines,
2. The long-time demanded to strip the cables, and
3. The lack of trust in the amount of copper delivered by the machines.

From the several types of constraints presented in the TOC, the ones identified in the case of the wire stripping machines are all managerial-policy related. The first two reasons identified are related to a *financial constraint* in the system. Regarding the first, workers are required to pay for the electricity when using the machines, while there is no direct financial cost involved in the cable burning process. Even though it may seem insignificant for some, such amount on a day-to-day basis makes a substantial difference for the ones living with extremely low income. Another crucial factor is that the machines require more time to perform the task of extracting the metals, compared to the burning. This is a financial constraint since workers retrieve fewer metals per time when using the machines than if burning the cables, which has a direct impact on their income.

The lack of trust in the amount of copper delivered by the machines is a *policy constraint*; this latter considered as the most pressing in this system. The lack of trust was pointed out both by GreenAd and by workers in Agbogbloshie. On this, some aspects deserve highlight: the first one is culture. A well-known cultural pattern is an intrinsic resistance to changes imposed from the outside. When changing the operation toward the use of the machines, the outcome for the workers was unknown to some extent. Another important aspect to highlight here, connected to the previous, is the level of education, which was low among workers processing e-waste in Agbogbloshie. It may seem clear that the input of metals in the form of wires and cables to the machines delivers the same amount of metals in its output. Nevertheless, if the basic functioning of the machine is not understood, misconceptions tend to appear.

Finally, there is a *market constraint*. According to Schragenheim and Dettmer (2000, p. 261), "market demand is always a constraint – usually to future profitability, sometimes to current profitability". In the setting of burning cables, the process delivers only the metals, while the setting of using the machines would yield both the metals and the plastic. However, since the market prices for plastic are insignificant compared to the metals, this additional yield is not considered profitable enough in order to make a difference in perception.

Next, I address the second focusing step: to exploit the constraints. For this, I suggest different options for further exploration, all focused on strengthening the machines' use. To tackle the financial constraint, for instance, an option would be to either improve or optimise the performance of the current machines towards faster processing. Another

would be to adapt them to strip several wires and cables at once. Such options would make the process more efficient, thus addressing the time concerns.

In order to address financial and market constraints combined, the electricity consumed by the machines could be offered free of charge for the workers performing the activity. In exchange, workers would have to forward the plastic removed from the cables to designated recycling companies. This could strengthen the use of the machines and, at the same time, it would ensure that the retrieved plastics were collected and handed at a designated destination.

Concerning policy, the reinforcement of regulations for the non-burning is an aspect that deserves consideration. In conjunction, it is important to address the aspects of culture and level of education. For this, education campaigns are required that aim to explain the functioning of the machines, as well as the health benefits of their use.

This study presents some limitations. First, it is important to make clear that the above discussion is based on data collected through a period of two weeks in Ghana. Even though I visited the Agbogbloshie site several times and, furthermore, collected data from different workers on the site, this considerably short time framework is a limitation. Further data collection would be complementary to this study (e.g. surveys with the workers on the site, and ethnographic research). In addition, the TOC has its own limitations: the most important one for this study being that the improvements are sought among identified constraints only.

Concluding remarks

The wire stripping machines implemented in Agbogbloshie have the potential to significantly influence several spheres, in particular, the social and environmental ones. The machines enable the processing of cables without the emission of toxic gases from the burning process, which is responsible for substantial pollution of air, soil, and water in the area. Consequently, this leads to an improvement in the health status of workers processing cables.

Evidence of the machines' use has been found on the site, such as some plastics resulting from the wire stripping process. However, I did not observe any of the machines being used during my investigations in Agbogbloshie. Instead, the burning of cables persisted, which demonstrates the opportunity for improvements. Particularly, to strengthen the machines' use.

In this paper, I have used the TOC to identify and investigate the constraints hindering the operational change from the burning process to the wire stripping. The main reasons identified have no connection with any physical constraint. Instead, they are all managerial-policy related: financial, policy and market have been identified as the system's constraints.

The application of the TOC to the case has enabled to consider the challenges of operational change from a systemic perspective. By looking at the e-waste management system in Ghana, cable processing was identified as one of the most challenging towards sustainable processes. The TOC has enabled to focus on the cable processing while perceiving this as part of a larger system.

The implementation of the machines in Agbogbloshie, although a sustainability-driven example, lacked a systemic perspective. It focused on the need for improvement as an individual process, contrary to the concepts of the TOC. Particularly, it did not focus on one of the most important elements in such operational change: the agents performing the operation. On this regard, it is essential to account for the workers' reality and needs when aiming for more sustainable processes and systems.

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Role of organizational motivation and coordination in continuous improvement implementations: An empirical research of improvement project success

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Abstract

This paper aims to elicit the understanding of improvement project success by researching the effects of organizational motivation and central coordination in continuous improvement (CI) implementations. The data analysed using structural equation modelling (SEM) comes from a sample of 387 respondents which are responsible for improvement project execution in the financial services sector. This research shows that a strong organizational motivation drives the embeddedness of improvement methodology in, and alignment to the CI implementation of, the organization and thereby affects project success. Next to that, central coordination is found to affect the alignment of the organization to CI implementation activities.

Keywords: Continuous improvement, Organizational motivation, Organizational coordination

Introduction

The organizational ability to continuously improve and optimize processes and products is commonly developed by the implementation of improvement methodologies such as Lean, Six Sigma and Lean Six Sigma. Despite the reported successes of such implementations there has also been criticism and these mixed results provide the motivation for this research.

The process of continuous improvement (CI) implementation is recognized as a multilevel initiative that consists of activities at the organizational- and the project level (McAdam and Lafferty 2004; Nair et al. 2011). On one hand there are the organizational

level activities, whereby senior management takes on pivotal challenges such as creating the motivation for change and subsequently coordinating the organizational change process, known as CI implementation. On the other hand CI implementation is commonly shaped in a project-by-project fashion. Organizations that commence with CI implementation form a portfolio of improvement projects that are initiated based upon their impact on corporate strategy realization (McAdam and Lafferty, 2004). The actual improvements are delivered at the project level where improvement project leaders are trained in CI methodologies and take up a leading role in delivering improvement projects.

The purpose of this research is to determine if and how the organizational level constructs of motivation and central coordination in the CI implementation process have a positive effect on improvement project success. To understand how both organizational level constructs affect improvement project success, mediating constructs that capture how an organization changes in the process of CI implementation and are hypothesized to affect improvement project success are designed.

Theoretical background

Continuous improvement (CI) implementation is a process of organizational transformation aiming for adoption of a "planned, organized and systematic process of focused and company-wide continuous incremental innovation and change of existing practices aimed at improving company performance" (Bessant and Francis, 1999). The reasons for CI implementation lay in the ever increasing complexity and pace of business environments and scholars have increasingly recognized CI as sound operations management practice (Jonsson and Johansson, 2011). Inconclusiveness on the bottom-line results that CI implementation yields however remains: prior studies have reported significant benefits (Bessant and Caffyn, 1997) and significant disappointments (Pay, 2008).

Determinants of continuous improvement implementation outcome

In order to better understand success or failure scholars have started to investigate CI implementation processes to explain their outcomes and systematic literature reviews have emerged in which critical success- and failure factors for CI implementation are summarized (Arumugam et al. 2014; Albliwi et al. 2014).Two interesting points stand out in these reviews. For one, the reviews confirm that organizational level constructs have an important effect on CI implementation outcome. Among others management commitment, customer focus and links to corporate strategy and human resource management strategies are named. The other interesting point is the acknowledgement of failure or success of factors at the project level as predominant determinant of CI implementation outcome, such as the rightful selection of projects, the adequacy of project leader skills and the structured approach of improvement projects (Arumugam et al. 2014; Albliwi et al. 2014). It is important to note that CI implementation is thus for one determined by organizational level success factors and secondly by the success or failure of factors at the project level. Hence CI implementation has a multilevel character, nevertheless most of the research on CI implementation adopts a single unit of analysis at either the organizational level (Shafer and Moeller 2012) or at the project level (Linderman et al., 2003). Our argument is that there is a causal relation whereby organizational level factors in the process of CI implementation affect the success of improvement projects. Improvement projects are a dominant operational manifestation of CI implementation in organizations and are therefore recognized as an important determinant of organization performance resulting from CI implementation.

Organizational motivation, coordination and improvement project success

The first organizational construct of interest is the organizational motivation, or sense of urgency, prior to and in the process of implementing CI. Prior CI research has highlighted the importance of making CI implementation core to business strategy realization and strong management commitment to the CI implementation as manifestations of organizational motivation (Arumugam et al. 2014; Albliwi, 2014). Although a strong and widely felt motivation is likely to influence how organizational actors will behave and affect improvement project outcomes (see Ajzen and Fishbein, 1980, for their Theory of Reasoned Action), the argument here is that strong and lasting organizational motivation for CI implementation principally drives the embedding of CI philosophies and principles in the organization. This line of reasoning is derived from research by McAdam and Lafferty (2004). In their research the authors have found that a holistic approach (inclusion of people and organizational criteria instead of a mere focus on tools) needs organization wide support and commitment for the implementation and enabled the embedding of improvement methodology in the organization. Embedding is the process whereby organizational staff is empowered and provisioned with the appropriate CI methods and tools to be used in an empowered manner. Thereby the organizations' CI implementation objectives were found to be achieved (McAdam and Lafferty, 2004). The positive effect of embedding (or adoption) of CI methodologies on organizational performance however is supported but also criticized by several researchers.

The primary interest here is in how embedding of CI methodology leads to improved performance, and research by Choo et al. (2007) on CI project execution revealed how learning and the creation of knowledge plays a pivotal role. Based on this finding it is argued that the gradual embedding or adoption of CI- philosophies, principles and routines drives a change from an "old way" of working, before CI methods were implemented to a "new way" of working where CI methods are part of everyday work at the process level. Thereby a growing number of organizational staff involved in, or subject to, the CI implementation has gone through multiple learning cycles of how to apply improvement methodology.

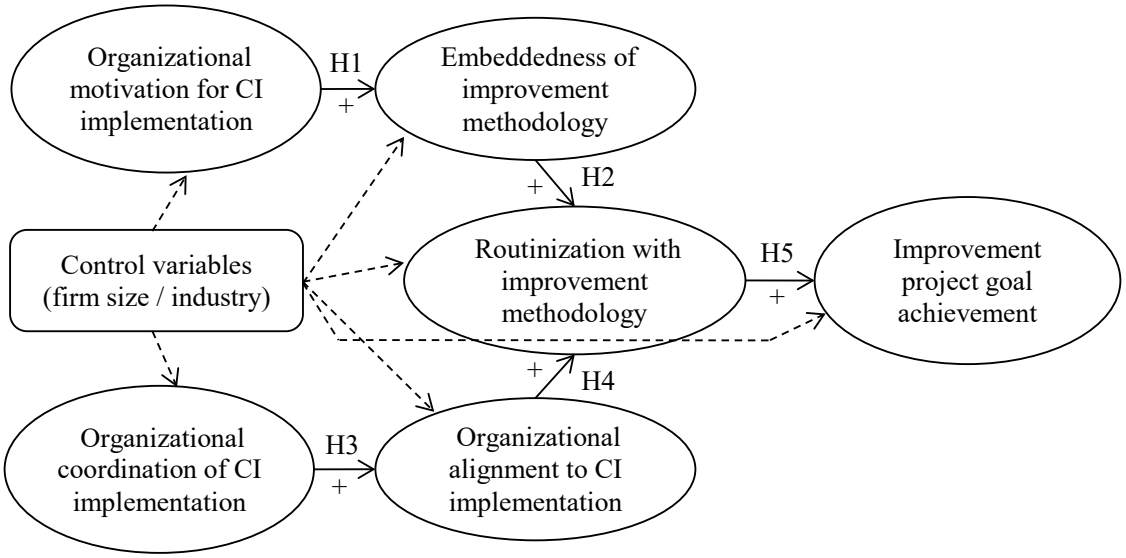

Figure 1: Conceptual model of the research

The application of improvement methodology to solve operational problems and improve process, product or service performance is performed more frequently and hence knowledge and routinization in the application of CI methodologies starts to grow. Therefore the following hypotheses are proposed (see Figure 1):

H1. Organizational motivation for CI implementation is positively related to the degree of embeddedness of improvement methodology in the organizational operations.

H2. Embeddedness of improvement methodology in the organizational operations is positively related to the degree of organizational routinization in improvement methodology application.

The second organizational construct of focus is the degree of coordination of the CI implementation process. Earlier research has emphasized the importance of coordinated selection and prioritization of improvement projects and training of improvement project leaders as a proxy for the degree of coordination of CI implementation activities (Arumugam et al. 2014; Albliwi, 2014). Prior research on improvement methodology implementation has recognized the importance of a parallel-meso CI management structure for the coordination of the implementation efforts (Schroeder et al. 2008). Such a CI management structure is parallel to, but outside of, the typical organizational structure and integrates multiple levels of seniority by the use of teams, improvement specialists, steering committees and other structures, roles and methods (Schroeder et al. 2008).

Here it is argued that the degree of orchestration of CI implementation efforts by means of a substantial central core-team positively impacts the degree of organizational alignment to the CI implementation. Organizational alignment boils down to the degree of improvement methodology dissemination throughout the organization in terms of business units involved, organizational staff trained and importance of CI for the success of the organization. The concept of organizational alignment or dissemination of improvement methodology based on organization specific characteristics has been previously studies by Ansari et al. (2010). In their research, Ansari et al. (2010) concluded that the fidelity to- and extensiveness of methodology adoption varies based on several organizational characteristics such as cultural fit, political fit and technical fit. Based on this research it is argued that central coordination by means of a core-team in CI implementation processes enables influence on the degree of organizational alignment. Vehicles to do so are among others central corporate training programs, communication strategies and leadership development. Subsequently it is argued that widespread organizational alignment and involvement of the organization in the CI implementation leads to more experience and acceptance of improvement methodology application throughout the organization, operationalized by the construct of routinization (Figure 1):

H3. Organizational coordination of the CI implementation is positively related to the degree of organizational alignment to the CI implementation.

H4. Organizational alignment to the CI implementation is positively related to the degree of organizational routinization in improvement methodology application.

The remainder of our arguments is that organizational routinization with improvement methodology application ultimately explains the likeliness of improvement project success. There are several empirical studies that have related routinization and improvement in ability over time (i.e., learning-by-doing) in a variety of business contexts. In a case research by Easton and Rosenzweig (2012) the effect of multiple types of routinization on improvement project success is researched. The authors find

that predominantly project leader routinization and organizational routinization (operationalized as the knowledge on improvement methodology application generated by other organizational members) are explaining the outcome of such projects.

Here it is argued that organizational routinization is determining project success, because the experience of an organization with the application of improvement methodology affects the ability and willingness of organizational staff to contribute, as project team- leads and members, to improvement projects. As more operational staff and selected CI specialist involved in improvement projects possess a degree accumulated learning, experience and knowledge on how to effectively execute improvement projects, the chances for success are expected to be higher. Additionally, the more improvement project stakeholders have knowledge of or have been involved in improvement projects, the more likely that improvement projects will be successful:

H5. Organizational routinization in improvement methodology application is positively related to the degree of improvement project success.

Data and research methodology

The sample is formed of improvement project leaders from financial service organizations in predominantly Europe comprising both banks and insurance firms. The respondents are selected via the authors' university alumni networks and professional social networks. Searches for discussion forums containing "Lean" or "Six Sigma" or "TQM" or "improvement" in combination with "deployment" or "implementation" or "implementing" in the title were performed. The unit of analysis is improvement projects in financial service organization and the questionnaire was developed based upon a review of the existing literature related to CI implementation and improvement project success and followed a two stage scale development procedure.

A total of 387 respondents showed interest and in the process of data preparation, incomplete responses were completely deleted and the imputation of missing values for less than 5% of the remaining sample by means of single regression imputation in IBM AMOS 25 was performed (Kline, 2011). A total sample of 198 usable cases for data analysis remained (descriptive statistics available as table).

Although sufficient research has addressed the topics of study and supported in construct definition, we concluded that to date no research could provide the scales needed for our study. Therefore, we have developed scales according to the sequence presented in a review of operations management studies that used scale development by Hensley (1999), comprising the stages of item generation, scale development and finally scale evaluation (process steps and outputs available as table).

The first step in item generation was creating focus groups stemming from the population, being CI leaders and practitioners from financial service organizations in Europe, Asia and North America comprising both banks and insurance firms. This first stage resulted in over 20 items per construct and additionally we have added control variables. After having established a first set of items per construct, subsequent content validity assessment was performed. This process revealed a high consistency of classification and items for which an incoherent classification remained after discussion were eliminated to mitigate multi interpretation risks. After the second round in between 7-18 items per construct remained.

After the data was gathered the stability of the scales was determined. Subsequently reliability of the proposed scales was assessed in IBM SPSS 24 by measuring the internal consistency of the items. Items that remained after principal component analysis were subjected to Cronbach's Alpha (α) assessment. The final step of construct validity assessment is performed in the model specification and optimization sequence where

both convergent and discriminant validity of the scales are assessed and optimized. Finally common method bias is assessed to exclude the possibility of bias due to the data gathering technique and we conclude that common method bias is not problematic in our sample.

Data analysis

Structural equation modelling was performed in a sequence of path model identification, optimization and finally structural regression model testing (Anderson and Gerbing, 1988). We follow Kline (2011) for reporting model fit indices. Reported and recommended values for model fit are presented in Table 1.

Table 1: Goodness of fit statistics of the model

Goodness of fit statistics	Recommended values	Final CFA model	Final SR model
Chi-square (χ^2):	-	164.529	180.638
Degrees of freedom (DF):	-	145	167
P-value:	> .05	.128	.223
RMSEA:	< .05	.027	.021
RMSEA LO:	< .05	.000	.000
RMSEA HI:	< .10	.046	.041
CFI:	> .90	.990	.993

Initial confirmatory factor analysis (CFA) model identification was performed in IBM AMOS 25 and convergence was achieved using maximum likelihood analysis after 11 iterations. To compensate for the risk of non-normality bootstrapping was performed (200 samples) and resulted in good final CFA model fit indices. Discriminant validity of the constructs was good (all constructs < .85 correlated) (Kline, 2011). Following sufficient CFA model fit, a structural regression (SR) model to test the hypothesized causal relations was developed and consecutive SR model identification and optimization was commenced.

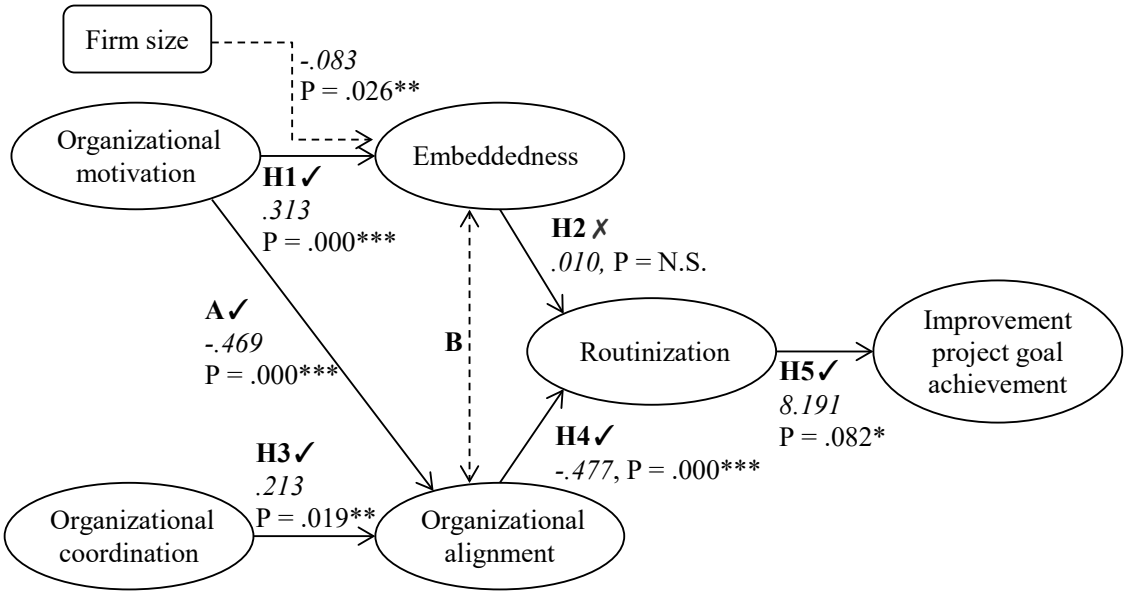

Figure 2: Final model with coefficients and significance (10% (*), 5% (**) and 1% (***) level)

The model modification indices signalled potential effects between embeddedness and organizational alignment, and between organizational motivation and organizational alignment. For the intermediate SR model we have followed the hypothesized relations and added the discovered direct effect of motivation on alignment ("A" in Figure 2) and ("B" in Figure 2) in the model, which resulted in good model fit. As presented in Figure 2, four of the five hypotheses are supported.

Firstly, we find that the degree organizational motivation to implement CI significantly and positively influences the degree embeddedness of improvement methodology in the organizations' operations (H1), which subsequently does not significantly influence routinization with improvement methodology application (H2). As discussed before embeddedness is, although not directly, related to organizational alignment.

Secondly, we find that coordination of the CI implementation significantly affects organizational alignment to the CI implementation (H3). This effect however only occurs when the discovered direct effect between organizational motivation and alignment ("A" in Figure 2) is added. Hence when the organizational motivation to implement CI and execute improvement projects is not present, coordination has no significant effect on the degree of organizational alignment to the CI implementation.

Additionally the effect of coordination on alignment slightly deteriorates (lower coefficient and slightly higher, still significant, P value) when the indirect relation with organizational embeddedness ("B" in Figure 2) is included. Hence when embeddedness of improvement methodology in the organization is lower, coordination combined with a strong motivation is positively affecting the degree of organizational alignment to the CI implementation and vice versa.

The degree of organizational alignment to the CI implementation is subsequently significantly affecting routinization (H4). The coefficient is negative, though this relation is positive as organizational alignment is a reversely scaled construct. Finally, routinization is found to significantly and positively affect improvement project goal achievement (H5).

Discussion and future research directions

The objective of this research is to study the effects of organizational motivation and coordination on improvement project success in CI implementations.

First our results show that strong and widely shared organizational motivation to engage in CI implementation positively influences the embedding of improvement methodology application and adoption in organizations. Organizational motivation is embodied by for instance the need to digitalize and innovate processes and embeddedness is manifested by practices such as continuous performance monitoring, ongoing communication and a degree of process-thinking in the organization. This implies that a strong and widely felt motivation to implement CI leads to greater adoption and embedding of CI methods by organizational staff in day-to-day operations. This effect is negatively related with the size of the firm, meaning that achieving higher degrees of embeddedness need more organizational motivation in larger firms (our findings suggest roughly above 2000 employees). Differences between larger and smaller organizations in organizational processes have long been recognized and researched, for instance for competitive behavior (Chen and Hambrick, 1995). However, confirming Bessant et al. (2001) it is concluded that little research on the effects of firm size and the CI implementation process is available to date.

The concept of motivation or sense of urgency as prerequisite for organizational transformation processes is widely acknowledged (Todnem By, 2005). For Lean Six

Sigma implementation specifically the need for change has been recognized as first implementation step by Kumar et al. (2011). Their findings are corroborated by this research and provide empirical insight into factors that might specifically create a compelling need for change. Hence we propose that future research should focus not so much on identifying if- but more on what- is most persuasive in creating the organizational motivation for CI implementation.

Evidence for the subsequent effect of embeddedness on routinization is not found. Greater embeddedness is however related to the degree of organizational alignment, manifested by greater management attention, an increasing demand for improvement projects and greater perceived importance of CI for the company's success. Hence acceptance and embedding of CI methods by organizational staff in day-to-day operations is related to the degree of perceived importance of the CI implementation by organizational staff. This finding complements the previous findings by McAdam and Lafferty (2004). In their research on Six Sigma implementation, the importance of embedding CI methods and tools in organizational staff their day-to-day operations is signalled. The authors report that by extending the scope of the implementation from just solving the problem or defect areas (the instrumentalist approach) to empowering organizational staff in resolving and preventing root causes of defect areas (joint people and process approach), Six Sigma objectives were achieved. This finding provides understanding of how the empowerment of organizational staff may contribute to improvement project goal achievement. Namely by first creating a degree of management attention and perceived importance (alignment), leading to acceptance and consecutive routinization or experience of organizational staff with improvement methodology.

Second, our results show a positive causal relation between coordination of the CI implementation and the degree of organizational alignment to the CI implementation. Alignment is embodied by greater management attention, an increasing demand for improvement projects and greater perceived importance of CI for the company's success. Our finding provides empirical support and corroborates prior predominantly case-based research that acknowledged the value of central selection, prioritization and coordination of improvement projects (Schroeder et al. 2008). Previous research proposed that having a parallel-meso hierarchal structure where business leaders initiate and review improvement projects and where more senior project leaders coach and support junior project leaders creates value in CI implementations (Schroeder et al. 2008). We find that the effects of central coordination however are only significant when strong motivation to implement CI is present. Conversely, when little motivation to implement CI is present, the effect of a central core-team leading the implementation is insignificant. Future research opportunities lay in understanding how the value of central coordination is created and should focus on the specific activities or roles that central coordination fulfils over time.

Third our results reveal that increasing organizational alignment affects the degree of routinization or experience with business improvement methodology application by organizational staff, and positively affects improvement project goal achievement. Goal achievement contains among others improved- customer satisfaction, process operations, quality levels and changes in the business culture. Hence increased organizational staff experience with improvement methodology and improvement projects is found to positively affect success of process improvement projects.

Routinization or experience in improvement project teams is found to positively influence success of process improvement projects. Research by Easton and Rosenzweig (2012) examined how various types of experience affect the success of

improvement projects and concluded that especially experience of the project leader and organizational experience is crucial. Our findings corroborate the importance of experience in the organization, though does not specify the type of experience and the exact workings. Prior case-based research did acknowledge that routinized process improvement methodology application is associated with knowledge creation and learning (Linderman et al. 2010). Future research opportunities lay in further empirical examination and understanding of how increased organizational routinization leads to success of process improvement projects.

Fourth is the relatedness between the constructs for organizational motivation, embeddedness and alignment. Together these three constructs capture how a strong need to implement CI, increasing levels of improvement methodology embedding in day-to-day operations and increasing attention and perceived importance seem to affect higher levels of routinization and project success. Prior research addressed the topic of CI infrastructure and thereby the creation of a dynamic capability (Anand et al. 2009). The authors found that characteristics of a CI infrastructure are among others a strong relatedness of the implementation to business strategy, a culture of constant change, standardized processes and improvement methods, and parallel participation structures that drive improvement project involvement. Several of these infrastructural components hold similarities with our second order construct identified in the process of model optimization. Hence, future research should further investigate and provide empirical support for the infrastructural components that jointly capture continuous improvement as dynamic capability.

Conclusions, implications and limitations

This study contributes to the empirical knowledge of process improvement project outcome in continuous improvement implementations in organizations. Specifically it revealed the positive effects of strong organizational motivation and central coordination on improvement project success via the creation of organizational alignment to- and experience with improvement methodology and principles.

Several implications for managing the CI implementation process and improvement project execution arise from this study. First CI implementation leaders are advised to ensure strong organizational motivation and support for the implementation. Second, the installation of a central core-team directing and overseeing the CI implementation process is advised. Finally, a focus on embedding improvement methodology adoption and application by organizational staff is influencing the levels of experience with improvement methodology application in the organization and thereby explains improvement project goal achievement.

Limitations of this research lay for one in the sample size as we were not able to adhere to the ideal sample size-to-free parameters ratio (Jackson, 2003). Although attention is paid to developing valid scales, the process of model identification revealed several items that displayed limited explanatory power for their respective constructs. Despite the fact that data from multiple continents was gathered, we were not able to make comparisons between different groups due to the dominancy of German and Dutch respondents. Hence the applicability of our findings for CI implementations outside of Western Europe remains uncertain.

Acknowledgements

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Curriculum internationalization in higher education as a resource-based change process

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Abstract

Based on a literature review, this study investigates to what extent and how changes with curriculum internationalization in higher education have been researched. This paper discusses 21 peer-reviewed articles, 9% of the total number published between 2011 and 2018. The main findings show that these articles are mostly about the process perspectives (441 references), and less so about the context (236) and content (77) of change. Curriculum internationalization is described as a mix of planned/rational and emergent/affective change processes, with many relevant content issues, highly contextual, and with human resources as a recurrent issue (115 references).

Keywords: change process, human resources, curriculum internationalization in higher education

Introduction

Since internationalization came to prominence in higher education around 1995 (Altbach & Knight, 2007), several literature reviews ((Kehm & Teichler 2007, Yemini & Sagie 2016) reported on the main topics and developments. Universities worldwide have recruited international students, built international networks and joint programs, facilitated student and staff mobility across borders, and translated many programs of study into English (Yemini & Sagie, 2016).

"Curriculum internationalization" is a more recent phenomenon, which first received attention in English-speaking countries like Canada (Bartell, 2003), UK (Caroll & Ryan, 2005), and Australia (Leask, 2009). In Europe, the relevance of curriculum internationalization, also known as "internationalization of the curriculum" (Leask, 2009, 2015), "internationalization at home" or the "international classroom" (Beelen, 2017) has only been acknowledged more recently.

In this paper, we use the term "curriculum internationalization". Recent studies reveal

that 78% of all students at universities in the Netherlands do not study abroad and can therefore only benefit from internationalization at their home university (van Gaalen & Gielesen, 2016). This percentage illustrates the relevance of curriculum internationalization (Leask 2009, 2015, Green & Whitsed, 2015). In a commonly accepted definition developed by Leask (2009), curriculum internationalization has been defined as:

"*the incorporation of international, intercultural and/or global dimensions into a program of study so that it will engage students with internationally informed research and cultural and linguistic diversity and purposefully develop their international and intercultural perspectives as global professionals and students"* (based on Leask 2009, pp. 209).

In short, curriculum internationalization is a process to make a program of study more international. This process can be undertaken in different ways at the individual, course, program and institutional level. It can involve changes in curriculum design, pedagogy, and in individual and collective beliefs (Leask 2015, Carroll 2015). As such, curriculum internationalization can be approached as a complex organizational change process (Smith & Graetz, 2011).

In educational practices in universities, it appears difficult to internationalize programs of study (Leask, 2015). Despite enthusiasm of individual academic staff, problems experienced are a lack of shared understandings, not knowing what to do, or how to do it to make it successful (Green & Whitsed, 2015).

Given the problems experienced in practice with a phenomenon which is increasingly relevant for all students, it seems interesting to take a closer look at what we can learn from change theories to overcome typical problems with the implementation of curriculum internationalization in higher education. Our research question is: '*to what extent and how has curriculum internationalization been researched as a change process?'*

Change theories

Theories of change ought to explain the balance between continuity and change through general patterns (Pettigrew et al, 2001). Studies on organizational change can be divided into three major themes: content, context and process (Armenakis & Bedeian, 1999). Pettigrew et al (2001) also depart from the assumption that content, context and process are interrelated and need to be consistent at different levels for a successful process.

Kuipers et al. (2014) signal a lack of change studies for public organizations. They observe that the specific nature of public organizations with values and services and a more political, juridical context with much bureaucracy (von Nordenflycht, 2010) requires different patterns of change. Universities, as regulated professional service organizations (von Nordenflycht, 2010), have complex, much informal structures and a highly professional workforce with unique knowledge and skills, high internal ownership and much informal power. Following increased globalization and competition (Altbach & Knight, 2007), universities have faced demands for urgent and radical institutional change (Trondal, 2010). Universities need to balance between instrumental design and the logic of hierarchy on the one hand, and academic autonomy and professional neutrality on the other (von Nordenflycht 2010, Trondal, 2010).

While the dynamics of the internal context have not yet been researched much with change theories, the external context for universities has been characterized by many different developments such as; changing demands, new technologies, financial crises, and for Europe; EU regulation, and particularly the Bologna process for higher education (Kuipers et al., 2014).

Theories of organizational change have focused primarily on planned, rational, top-down change (Kuipers et al., 2014), ignoring the complex and contradictory nature of professional service organizations and the diverse range of people working in them (Smith & Graetz, 2011). Armenakis & Bedeian (1999) signal that emergent change with non-intended, possibly negative affective outcomes such as stress or cynicism can seriously undermine or even defeat change.

For organizational change studies overall, the framework developed by Pettigrew et al., (2001) with the concepts of *content, context and process* has been widely applied in case study research, for example on the implementation of health care innovations (Boonstra et al., 2014). We now discuss each of these concepts.

Firstly, in theories of change the *content* issues related to successful or unsuccessful change have been defined rather broadly, at different levels (Kuipers et al., 2014), in terms of strategy, structures, management practices, policies and procedures, task requirements and individual abilities (Armenakis & Bedeian, 1999). Secondly, the *context* can be categorized in internal and external (Kuipers et al., 2014). Thirdly, the *process* of change in the literature can be divided into planned/rational versus emergent/affective change (Smith & Graetz 2011, Kuipers et al., 2014).

Further, Smith & Graetz (2011) advocate to combine these planned/rational and emergent/affective processes with different, interrelated process perspectives of change, to create a richer understanding. They distinguish the perspectives of; *rational/planned, biological/emergent, resource-based (*determined by access to resources*), institutional (*relevance of environment*), psychological (*individual impact*), systems* (interconnected with all aspects of the organization*), cultural (*values, beliefs and norms*), critical (*contradictions, conflict and power based*) and dualities (*dynamic, complex, managing tensions) (Smith & Graetz, 2011: 16-17).

The aim of this paper is to present a review of the recent literature about curriculum internationalization in higher education as a change process positioned within a conceptual framework of change. To our knowledge, there has been no systematic review of the literature concerning curriculum internationalization in higher education as a change process.

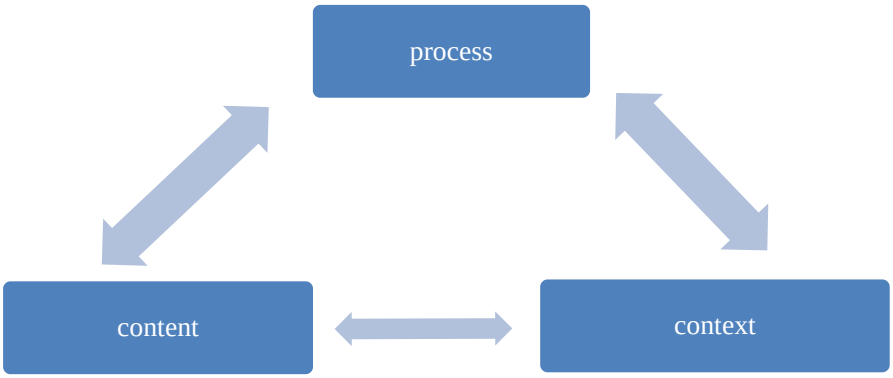

Figure 1. Conceptual framework of change, based on Pettigrew et al., (2001)

Conceptual framework

This paper draws on a conceptual framework of change (Pettigrew et al., 2001) with the concepts of *process, context and content* (see figure 1 above*).* This framework has been widely applied in research into organizational contexts, but has not been applied much in the public sector (Kuipers et al., 2014). Building on literature reviews of change until 2010 (Armenakis & Bedeian 1999, Pettigrew et al., 2001, Kuipers et al., 2014), we identified 21

articles in the period from 2011-2018. This is 9% of the total number of articles on curriculum internationalization in higher education for that period.

With the software of NVivo, we identified systematically how often the words of *process, context and content* appeared in these 21 articles. Next, we analyzed those sentences. First, we looked at the *process* with planned/rational, emergent/affective and the different, interrelated process perspectives of change (Smith & Graetz, 2011). Secondly, we screened for *context* with internal and external (Kuipers et al., 2014). Thirdly, we analyzed *content* including the curriculum, strategy and policies, structures and practices, task requirements and individual abilities (Armenakis & Bedeian, 1999).

Method

For this literature review, we searched the databases of SCOPUS, Web of Science and Pro quest. Only peer-reviewed articles in English were included. The search terms were: *internationalization of the curriculum, curriculum internationalization, internationalization at home, change process, and variants.* Articles were excluded from the set where these did not directly relate to higher education. Duplicates were also removed. Decisions about inclusion and exclusion were frequently discussed between the researchers (Karlsson, 2016).

With our conceptual framework of change (figure 1, page 3), we analyzed the concepts of *process, context, and content.* After our analysis, we come back to our research question: '*To what extent and how has curriculum internationalization been researched as a change process?'.*

Article	process(es)	content	context(s)	resources
Agnew (2012)	12	1	20	2
Bajada & Trayler (2013)	14	14	10	1
Bradford et al (2017)	93	0	9	48
Chang (2015)	10	0	11	4
Green & Mertova (2016)	11	2	20	2
Haigh (2014)	15	1	2	3
Kahn & Agnew (2017)	11	0	10	2
Lamberton & Ashton-Hay (2015)	12	10	5	2
Leask (2013)	52	2	15	6
Lumby & Foskett (2016)	16	0	13	3
Mak et al (2014)	10	2	3	6
Maringe & Sing (2014)	10	6	22	6
Mertkan et al (2016)	31	2	7	3
Quershi et al (2014)	30	0	2	1
Robson (2011)	9	5	11	0
Saarinen & Taalas (2017)	10	3	15	1
Said et al (2015)	19	0	2	9
Siska et al (2013)	14	5	24	1
Takagi (2015)	33	7	12	2
Tsuruta (2013)	8	0	4	12
Whitsed & Green (2014)	15	0	19	1
total per concept	441	77	236	115

Figure 2 – Overview of concepts per article

Analysis

Overall, most references are on process or processes (441), followed by context(s) (236), and content (77). The process is the dominant concept of change in 14 articles, followed by context as the main concept in 7 articles, and content in 2 articles. The resources (115) also received frequent attention (see figure 2 above). We will now discuss each concept.

Process

All 21 articles discuss curriculum internationalization as a process or processes of change. The references vary from 93 (Bradford et al., 2017) to 8 (Tsuruta, 2013). Following our conceptual framework (page 3), we discuss planned/rational and emergent/affective change, and the other, interrelated process perspectives.

Overall, curriculum internationalization is described as a dynamic, deeper, transformative process (Leask 2013, Qureshi et al., 2014, Mertkan et al., 2016). The transformative character implies both planned/rational and emergent/affective change, at multiple levels, with a combination of process perspectives. In all 21 articles, change is represented as a *planned/rational* process. In total there are 349 references to

rational/planned change, with a maximum of 80 in one article (Bradford et al., 2017). Planned/rational change is described in different ways. For example with plans, strategies, rationales, goals, models, stages, steps, patterns, blockers and enablers. The qualifications used are: active, iterative, adopting, adjusting, rational, cognitive, defined, designing, predictive, leading, managing, directing, controlling, evaluating, improving (Bradford et al. 2017., Leask 2013, Qureshi et al., 2014, Takagi 2015).

Despite this dominancy of planned/rational change, *emergent/affective* change is also present in 20 articles, varying from 1 to 16 references in an article (Mertkan et al., 2016), adding up to 127 references in total. Mertkan et al., (2016) picture emergent change as a "*rolling snowball, getting larger and undergoing a metamorphosis*". Leask (2013) incorporates emergent change with planned change through reflection and imagination, while stressing the overall complexity and sometimes chaotic character of the process. Tsuruta (2013) describes the complexity of curriculum internationalization with vulnerability, uncertain factors, ambiguity and competing priorities.

The most dominant process perspective is the systems perspective (145), followed by the institutional (112), the psychological (78), the cultural (64), the resource-based (53), the critical (9) and the dualities (9) perspectives. We will now discuss each perspective.

The systems perspective is present in 19 articles, most frequently with 40 references in Bradford et al., (2017). Bradford et al., (2017) draw on theories from the business domain, with a resource-based, multi-process perspective with a focus on systems and institutional elements, and financial and human resources. In other articles, the systems perspective is described as "*a complex range of interacting factors with the challenge to make the tacit explicit within informal university structures*" (Leask, 2013). In the context of quality assurance and accreditation, the systems perspective is illustrated with techniques and mechanisms (Qureshi et al., 2014). Further, the systems perspective often associates with successful implementation (Bajada & Trayler 2013, Siska et al., 2013), described as interactive (Robson 2011, Mak et al., 2014), integrative and coherent processes (Whitsed & Green, 2014), with indicators and dimensions for monitoring (Chang, 2015).

The systems perspective is closely related with the institutional process perspective (Smith & Graetz, 2011). The institutional process perspective is worded in globalization (Green & Mertova, 2016), in competitive processes (Bajada & Trayler 2013, Takagi 2015), or with the global versus the local (Said et al., 2015, Lumby & Foskett 2016). There are frequent references to the European Bologna process (Bajada & Trayler 2013, Haigh 2014, Lumby & Foskett 2016, Saarinen & Taalas 2017), or to accreditation (Qureshi et al., 2014). Other studies refer to national reforms and co-operation with partner institutions (Siska et al., 2013), external politics (Tsuruta, 2013), or historical processes and legitimacy (Lumby & Foskett, 2016).

The psychological and cultural process perspective are also closely related. The discussed transformative process character (Mertkan et al., 2016) implies both the psychological and cultural perspective. The differences are in the individual learning experience (Leask 2013, Mertkan et al. 2016, Takagi 2015) versus cultural processes in disciplines, programs, teams and communities (Agnew 2012, Lamberton & Ashton-Hay 2015, Leask, 2013, Mertkan et al. 2016). The individual process is characterized through interpretation (Takagi, 2015), reflection, imagination, engagement (Leask, 2013), with disorienting dilemmas (Kahn & Agnew, 2017), ethics and specific behavior (Haigh, 2014). The cultural process incorporates values, beliefs and attitudes beyond individuals (Green & Mertova, 2016), with inclusion and exclusion mechanisms (Lumby & Foskett, 2016), and disciplinary and institutional identities (Robson 2011, Lamberton & Ashton-

Hay, 2015).

The resource-based process perspective (53 references) is less present. Yet, resources as such are frequently discussed (115). The key resources noted are knowledge, leadership, staff and students (Leask 2013, Tsuruta 2013, Said et al. 2015, Bradford et al. 2017). Leask (2013) positions resources as essential to support the staff, the process of curriculum internationalization, and relevant policies. Financial resources are a separate category (Leask, 2013). Only Bradford et al., (2017) draw on resource-based theory, while they discuss resources in terms of essential, sustainable, scant and superior, creating advantages for a specific organization. Bradford et al., (2017) use the distinctions of human and non-human, internal and external, and the terms firm-specific, financial and superior.

Lastly, a critical (9) or dualities process perspective (9) is present in only 8 articles. Often, both perspectives are represented together. The critical process perspective is described through consultation, collaboration, empowerment and challenging dominant paradigms (Agnew, 2012), maintaining power and previous truths (Whitsed & Green, 2014), through contradictions (Haigh, 2014) and in the power to block or resist (Green & Mertova, 2016). The dualities perspectives is depicted as dynamic (Whitsed & Green 2014, Mak et al. (2014), and with points of tension (Leask, 2013).

Context

All articles discuss context or contexts (236 references in total) but much less than process(es) (441). In 7 articles, context or contexts is the dominant concept, with references varying from 24 (Siska et al., 2013) to two (Haigh 2014, Mak et al., 2014, Qureshi et al., 2014). We found almost the same number of references for the internal (147) as for the external context(s) (155).

For the internal context(s), we found different levels; the individual, course, program, conceptual and institutional level. The individual level includes subjects, agents, individual differences, skills and the academics (Green & Mertova, 2016). The course level includes classes, teaching, practices and the classroom (Bajada & Trayler, 2013), while the program level notes pedagogy, assessment and interdisciplinary (Mak et al., 2014). At the conceptual level, we found quality, equity, inclusion, efficiency, effectiveness and human resources (Maringe & Sing, 2014). Lastly, the institutional level frequently reports culture and policies (Saarinen & Taalas, 2016), and to a lesser extent, methodology, philosophies and research (Tsuruta, 2013).

For the external context, we found that the references can be categorized in cultural, ideological, historical, economic, political, financial, educational, reputational, ethical, social, and academic (Green & Mertova 2016, Chang 2015).

Content

Only 13 articles discuss content, with maximum 14 references in an article (Bayada & Trayler, 2013). The focus is clearly on the curriculum (50/77), with the sub categories of program, course and discipline (Bajada & Trayler 2013, Lamberton & Ashton-Hay 2015, Siska et al. 2013). The content is also discussed with the curriculum in relation with ethics, sustainability, graduate attributes, design, culture, skills (Bajada & Trayler 2013, Leask 2013), and strategy and policies (Robson 2011, Saarinen & Taalas 2017). There is an overlap between content and context.

Conclusions and discussion

What we can learn from this literature review is that curriculum internationalization can only be fully understood as a mix of planned/rational and emergent/affective processes of change, with interrelated process perspectives incorporating different levels (Smith & Graetz, 2011). The content of what to change involves the curriculum with many different issues, highly depending on the context. In line with Pettigrew et al. (2001), we found similar levels with each concept of change, including the individual level and several organizational levels, with deeper levels situated in informal and hidden structures and power (von Nordenflycht, 2010). Adequate facilitation through particularly human resources is needed to support and improve this change process (Leask 2013, Tsuruta 2013, Bradford et al. 2017).

Coming back to our research question, '*to what extent and how has curriculum internationalization been researched as a change process',* we conclude that with 9% of all articles selected for the period 2011-2018, curriculum internationalization has not yet been investigated much as a change process. Theories from organizational change studies have not yet been employed much with curriculum internationalization. Further, the focus is on the process, while the context, content and levels overlap.

Many of these articles (66%) concern conceptual studies. More empirical research is needed to research how the process, context and content of change are interrelated with different levels for the implementation of curriculum internationalization in higher education. Further research with these interrelated process perspectives needs to be done to find patterns of change and investigate how the process can be undertaken most successfully. A focus on human resources seems to be required. For practitioners, further research into change processes and resources can help to overcome typical problems in the implementation of curriculum internationalization. For change management, the application of change theories in the different context of higher education could provide new insights. Additionally, this study fits with the increasing interest in operations management with change, internationalization and intercultural issues (Karlsson, 2016).

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PRIvacy Management Responsibility On a Scrutinized Environment (PRIMROSE) - A management method to address privacy challenges

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Abstract

This paper's theoretical contribution is in reporting an innovative privacy management method designated as PRIMROSE - PRIvacy Management Responsibility On a Scrutinized Environment. Research contribution is in introducing a supported process concerning the effective efficient management of privacy requirements occurring in organizations. PRIMROSE was the outcome of deductive reasoning subjected to a focus group and eight DPO interviewees scrutiny. Practical contribution is in setting the missing link regarding a generally recognized privacy management method to guide practitioners in which the elements originate from the qualitative research supporting root definitions semantics, considering, among others, principles, stages, processes, enablers and composite requirements.

Keywords: PRIMROSE, privacy management method, data protection.

Introduction

The European Union's General Data Protection Regulation (GDPR) was enforced on 25 May 2018 and demands that organizations, i.e. data controllers and processors "implement appropriate technical and organizational measures" to safeguard the "ongoing confidentiality, integrity, availability and resilience of processing systems and services" (Regulation EU, 2016), regarding the management of personal information of EU citizens (Costa et al., 2018).

In this context, the research sponsor, i.e. the DATASHIELD DPBCS is a company that provides consultancy services and solutions for data protection. It supports the investigation of a holistic privacy management method, designated as PRIMROSE. As trained facilitators of strategic privacy thinking, the research sponsor follows a predetermined process and uses predesigned techniques and practices to keep organizations on track regarding the privacy forum and brings in objectivity to clients and to the discussion of legal and regulatory issues and concerns of data protection.

If we consider the analysis and implementation of privacy and data protection solutions alone, the issue itself is complex in nature. Combined with the legal imperative, the challenge is increased. For example, the US approach to privacy is sectoral, different from the approach of the European Union (EU) countries, which has a comprehensive Regulation for member states. Another jurisdictional example, the General Law of Protection of Personal Data from Brazil, inspired in the GDPR also imposes a set of rules that have to be fulfilled. If we take the example of an organization that performs in these three geographical areas, the management of privacy and data protection include a specific and demanding use of resources that must be managed effectively and efficiently. In addition, organizations have different forms and configurations of management.

So, what organizations want is a method that involves the strategic thinking of their own people that are part of the overall privacy solution (Robert, 1998). Moreover, the terms of reference coming from the Regulation to set what should be done, designated as the "permanent enablers" (Costa et al., 2017), are thoroughly examined in order to address the needed requirements. Depending on their timescales, organisations are either permanent or temporary. Thus, projects are temporary.

Therefore, this investigation presents a summary of the PRIvacy Management Responsibility On a Scrutinized Environment (PRIMROSE), a privacy management method for addressing the following research questions: [RQ1] *What are the high-level requirements of the permanent organization to be GDPR compliant?* and [RQ2] *How should the GDPR requirements be managed in the permanent organisation?* PRIMROSE is expected to keep the data protection requirements on track, to bring objectivity to privacy work and, simultaneously, to involve all relevant interested parties to the discussion. Moreover, PRIMROSE principles, strategy, stages, processes, enablers, composite requirements and continuous service improvement, developed as a function of the privacy environment, are described in this paper.

The required organizational changes will not occur overnight. This qualitative investigation revealed that, for organizations to be effective and efficient in the matter of data protection throughout time, specifically in what concerns the Regulation requirements, its variables should be managed through a privacy method to ease the achievement of their planned benefits. Thus, the following section describes PRIMROSE, a holistic and multidisciplinary method for privacy management. The elements of the method are detailed and described. Finally, the theoretical, practical and managerial implications of the model are examined.

Proposal of a method for privacy management

PRIMROSE is a rival approach of *OASIS Privacy Management Reference Model and Methodology* that has not become enough widespread and popular. Rival approaches compete to explain the same phenomenon and cannot be mixed.

Privacy and data protection issues are complex to deal with. Therefore, PRIMROSE's first goal is to make the complex and irreducible privacy elements as simple as possible, by: (i) contributing to support privacy by design and by default (Cavoukian, 2013), (ii) addressing organizational privacy factors and mechanisms with effectiveness and

efficiency, and (iii) considering the respect for user privacy and utility as quality components.

By doing so, PRIMROSE contributes to privacy management holistically, supported by the reasoning that privacy has multiple dimensions.

Moreover, these multiple dimensions exhibit cross-impacts that may require an interrelated analysis. For example, the dimension of privacy concerning "behaviour and action" (ISACA, 2016), put together with the dimension of privacy concerning "data and image" (ISACA, 2016) may enable the identification of someone' specific lifestyle pattern. So, an increasing number of commercial apps might be used to register and disclose a broad variety of their users' individual behaviours.

Thus, these dimensions can be used to classify privacy issues, concerns and problems, according to shared qualities or characteristics, e.g. of behaviour and action, of communication, of data and image (i.e. information), of thoughts and feelings, of location and space, and of association (ISACA, 2016).

Privacy dimensions are therefore examined as a synergetic interaction that intend to prevent harm to individuals by investigating the relations of two or more privacy dimensions, to produce a combined privacy solution greater than the sum of their separate parts. This interpretation recognizes that dimensions are multivalent in their nature and complex in their dynamics. Moreover, PRIMROSE considers processing, i.e. "any operation or set of operations which is performed on personal data or on sets of personal data" (Regulation EU, 2016), as well as the impact of that processing on individuals that use any "service" (Vargo and Lusch, 2004) provided by the organisation. So, organisations role and accountability in protecting people, processes, and technology are strengthen by rationalizing and managing privacy and data protection requirements.

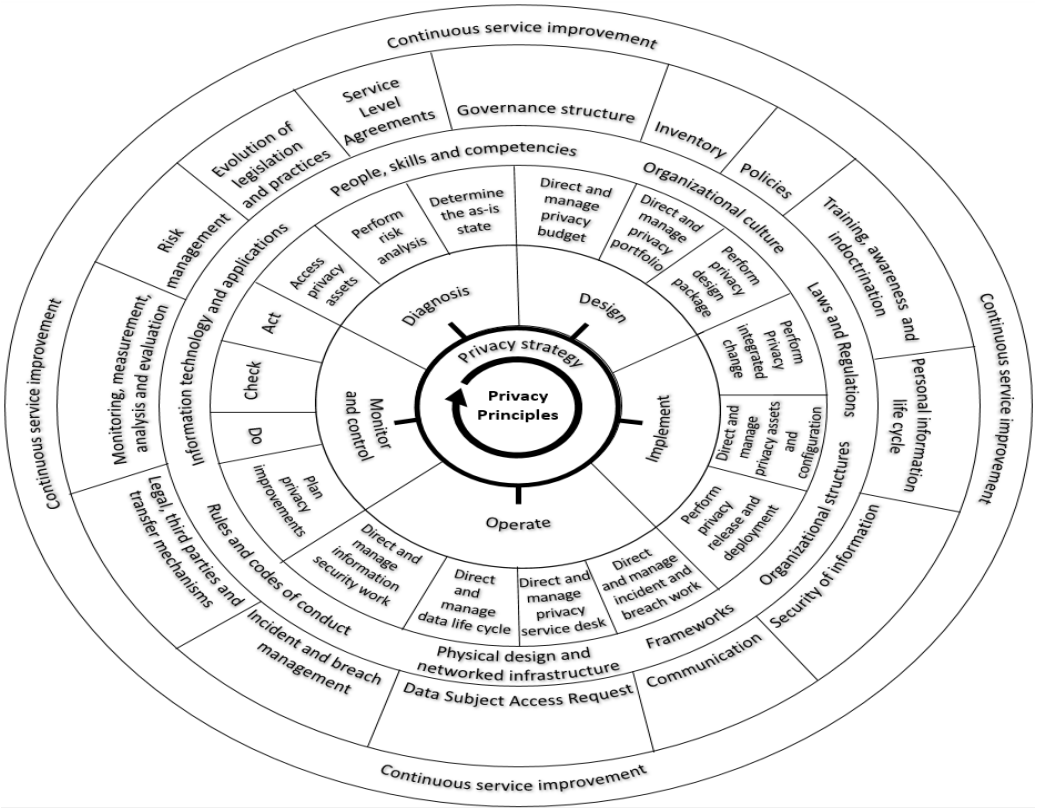

Figure 1 – PRIvacy Management Responsibility On a Scrutinized Environment (PRIMROSE)

Therefore, scrutinizing, examining or inspecting privacy issues and concerns, closely and thoroughly, in a complex privacy environment characterized by a diversity of laws and regulations, in different social-cultural and organizational configurations that are challenged every day, is of paramount importance.

For the reasons mentioned above, PRIMROSE considers relevant interested parties, internal and external, and encompass in a holistically, integrated and multidisciplinary way, principles, strategy, stages, processes, permanent and temporary enablers, composite (Ohnishi and Agusa, 1993) requirements, and continuous service improvement, in order to support organizational privacy strategic objectives, risk appetite and tolerance (*vide* Figure 1).

Principles

The first integrated layer of the method encompasses the fourteen PRIMROSE core principles. Together, they are the "strategic heartbeat" of the method and act as a "driving force or strategic drive" (Robert, 1998) that pushes or propels the organization toward certain privacy results, maturity level or profile. Moreover, they form the foundation base that the rest of the method adheres to.

These privacy principles have existing standards and principles as a foundation support. Therefore, the privacy principles are described in Table 1. Moreover, the standards and principles that supported the PRIMROSE principles were obtained from the BS10012:2017, GDPR, ISACA privacy principles, OECD 2013, ISO/IEC 29100:2011 (last reviewed and confirmed in 2017), APEC and GAPP (in Table 1).

Table 1 – Detail and source of the PRIMROSE privacy principles

PRIMROSE Privacy Principles	BS 10012	GDPR	ISACA	OECD 2013	ISO 29100	APEC	GAPP
1. Choice, decision and consent	N/A	N/A	✓	N/A	✓	✓	✓
2. Openness, lawfulness, fairness and transparency of processing	✓	✓	✓	✓	✓	N/A	N/A
3. Purpose limitation	✓	✓	✓	✓	✓	✓	✓
4. Personal information lifecycle	✓	✓	✓	✓	✓	✓	✓
5. Accuracy and quality	✓	✓	✓	✓	✓	✓	✓
6. Participation on individual rights and capabilities	N/A	N/A	✓	✓	✓	✓	✓
7. Accountability	✓	✓	✓	✓	✓	✓	✓
8. Security safeguards	✓	✓	✓	✓	✓	✓	✓
9. Preventing harm	N/A	N/A	✓	N/A	N/A	✓	N/A
10. Privacy by design	N/A	N/A	✓	N/A	N/A	N/A	N/A
11. Privacy by default	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12. Free flow of personal information	N/A	N/A	✓	✓	N/A	N/A	N/A
13. Interoperability	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14. Trust	N/A	N/A	N/A	N/A	N/A	N/A	N/A

It is important to underline that certain privacy principles, for example, regarding the ISACA privacy principles, namely monitoring, measuring and reporting, third-party/vendor management, and breach management were not considered principles in its true sense. Instead, the aforementioned principles are reasoned and described as management work. Therefore, they are organized in one of a reasoned set of composite requirements of the PRIMROSE method, and, among which, all variables having a determined number of characteristics might be distributed and put together.

In short, the PRIMROSE privacy principles set the tone and provide orientation towards the privacy goals, and indicate what your organization should do to protect personal information.

Privacy strategy

According to Mintzberg (1979) strategy may be viewed as a mediating strength between two dynamic variables; the organization and its environment. The conception of strategy, includes the "interpretation of the environment and the development of consistent patterns in streams of organizational decisions ("strategies") to deal with it" (Mintzberg, 1979). The fundamental question has to do with "strategic thinking" (Robert, 1998) and it boils down to elicit from peoples thoughts and reasoning's, who lead or manage the business, their finest rational judgment regarding what is indeed happening in the organization; what conditions, events or circumstances are taking place or occurring in the organization external environment, and "what should be the position of the business in view of highly qualitative variables" in order to "produce a vision, a profile, of what an organization wants to become" (Robert, 1998). Thus, PRIMROSE provides a method for privacy professionals interfacing with the organisation, as well as aligning its culture, processes, methods and strategic orientation with privacy and data protection requirements.

Stages

PRIMROSE stages ensure interested parties commitment and organizational assets, as well as authority to apply organizational resources and capabilities. Moreover, stages provide a significant way to help the privacy steering committee monitor privacy work at C-Level. At the end of each PRIMROSE stage, the privacy board can review the organizational privacy work and decide whether to commit assets to the next stage. Two benefits are highlighted: first benefit is planning, because there is, at all times, a planning horizon; secondly, there is no need for the c-level executives that are taking on roles in the privacy steering committee to get involved with the everyday's management of the stages, however, they can maintain the power to influence or direct people's behavior or the course of events of privacy work, by giving official permission for or approval to progress. PRIMROSE stages can be described as follows (in Table 2):

Table 2 – PRIMROSE privacy stages

Stages	Description
Diagnosis	To "move forward, it is crucial that we understand the current state" (Kerzner, 2017). Therefore, this stage provides a formal examination and reasoning, e.g. through privacy impact assessments, regarding privacy assets, i.e. "any resource or capability" (TSO, 2012) to determine where the organization is at, i.e. to ascertain the privacy maturity level.
Design	It is the stage in the PRIMROSE lifecycle that turns a privacy "strategy into a plan for delivering the business objectives" (TSO, 2012).

Implement	It is the stage where all approved privacy assets change requests are implemented, e.g. may be through privacy programs and projects to address privacy requirements, issues and concerns.
Operate	Privacy objectives are lastly fulfilled through the "operate stage", calling for an effective and efficient support of the organizational services to simultaneously ensure privacy and business practices.
Monitor and control	The "monitor and control stage" enables "tracking, reviewing, and reporting the progress to meet the [privacy] performance objectives defined" (PMI, 2017) in the business case and in the privacy management plan.

Each stage logically selects and organizes the privacy processes that concur to achieve the fulfillment of one or multiple objectives and requirements.

Processes

PRIMROSE processes comprise an organized set of inputs, practices, activities, techniques, that concur for the achievement of certain privacy requirements and objectives (ISACA, 2016). Moreover, they are undertaken to produce a set of required outputs, e.g. products, services, results (PMI, 2017). Therefore, circumstances that form the setting for a specific privacy commitment, and in which permanent or temporary organization they occur, aim at obtaining privacy requirements that provide value for the organization. Thus, privacy requirements should be fully understood, assessed, and clearly defined from the outset. However, they may be subject to change, but this variation must be formally controlled and managed.

Processes cover distinct needs and responsibilities which may co-exist simultaneously in any organization. Since, "becoming privacy compliant is a journey" (AICPA/CICA, 2009), they are iterative and may or may not occur in different timescales in which the organizations are required to whether diagnosis, design, implement, operate, and continuously improve their privacy requirements, as well as their intrinsic challenges.
In addition, these processes are meant to construct a more manageable and increasingly optimized organizational privacy environment. The seventeen PRIMROSE processes can be described as follows (in Table 3):

Table 3 – PRIMROSE privacy processes

Stage	Processes	Description
Diagnosis	Access privacy assets	Assess privacy gaps and vulnerabilities in the organization assets as compared to corporate strategy and policies, applicable laws and regulations, and data impacted.
	Perform risk analysis	Risk analysis is the "process to comprehend the nature of risk and to determine the level of risk" (ISO31000, 2009).
	Determine the "as-is" state	The "as-is" state has to be determined in order to represent the current situation that might need to be changed according to laws and regulations requirements.
Design	Direct and manage privacy budget	Budget concerns must be examined. Contingency and management reserves must be scrutinized and decisions about including them in the cost baseline should be made.
	Direct and manage privacy portfolio	This process describes the solutions currently being considered and being developed by the organization, along with its present contractual commitments, and retired solutions (TSO, 2012).
	Perform privacy design package	Defines all aspects of a privacy product, service, or result and its requirements through each stage of its lifecycle. A privacy design package is produced for each new privacy

		product, service, or result, major change, or privacy solutions retirement (TSO, 2012).
Implement	Perform privacy integrated change	It is the process where all approved privacy assets change requests are implemented and communicated (PMI, 2017).
	Direct and manage privacy assets and configuration	The purpose is to guarantee that the assets required to deliver products, services, or results are controlled in a truthful and correct way, "and that accurate and reliable information about those assets is available when and where it is needed" (TSO, 2012).
	Perform privacy release and deployment	The purpose is to "plan, schedule and control the build, test and deployment of releases, and to deliver new functionalities required by the business while protecting the integrity of existing" (TSO, 2012) products, services, or results.
Operate	Direct and manage incident and breach work	The purpose is to decrease the harmful impact on individuals and, on organization reputation, image and its assets, satisfy communication requirements to interested parties, and reinstate normal service operation as swiftly as possible (TSO, 2012).
	Direct and manage privacy service desk	As the single point of contact for Data Subject Access Requests (DSARs) both for employees as for customers on a daily basis, the purpose is to direct and manage this organizational interface.
	Direct and manage data life cycle	It is the process that organizations use to direct and manage the flow of data and information throughout its life cycle, i.e. from collection, use, share, retention, and deletion.
	Direct and manage information security work	This process is focal for all information security controls. It ensures that the information security policy is communicated and enforced, enabling an adequate management of the organization's data and information regarding its confidentiality, availability and integrity (TSO, 2012).
Monitor and control	Plan privacy improvements	Provides guidance and instructions regarding intended privacy improvements.
	Do	This process deals with the execution of the plan.
	Check	This process works toward the monitoring and measurement of progress against the privacy improvement plan.
	Act	The purpose is to identify deviations against the plan and act in accordance with its prevention or correctness definition.

Each stage and process address risks and opportunities and may have internal and external interested parties, which are shown in a responsibility assignment matrix (RAM), e.g. the use of a RACI (responsible, accountable, consult and inform) chart may be useful to ensure explicit and unequivocal assignment of roles and their essential responsibilities. Moreover, "RAMs can be developed at various levels" (PMI, 2017).

Enablers

Organizational "enablers are all that [singly or jointly] contribute and seek to construct the purpose in a positive-sum manner" (Costa et al., 2018). Thus, it includes "any [assets, i.e.] resources or capabilities" (TSO, 2012) that could contribute to the achievement of privacy requirements. The literature review has showed that there is a commonly agreed-upon definition and categorization of organizational enablers, e.g. Müller et al. (2016);

ISACA (2016); Costa et al. (2017); leading us to adopt and adjust existing categories for PRIMROSE use. Therefore, privacy enablers are grouped into eight categories: (i) people, skills and competencies, (ii) organizational culture, (iii) laws and regulations, (iv) organizational structures, (v) frameworks, (vi) physical design and networked infrastructure, (vii) rules and codes of conduct, (viii) information technology and applications. These privacy enablers can be organized into two parts: process facilitators and discursive abilities (in Table 4).

Table 4 – Privacy enablers (After Costa et al., 2017; Müller et al., 2016)

	Privacy Enablers	
	Process Facilitators	Discursive Abilities
Factors	Touchable characteristics, conditions, and variables that directly impact the effectiveness, efficiency, and viability, e.g., laws, regulations, standards	Effective communication and interpersonal skills that influence the mindset and behaviors of individuals, e.g., people, skills and competencies
Mechanisms	Trigger or accumulate actions in organizations to increase the likelihood of a certain output, outcome and benefits, e.g., structures, rules and codes of conduct	Structures that support effective communication (discourse), e.g., synchronized communication structures, dedicated network structures, e.g., shared beliefs, corporate culture

According to Costa et al. (2018), whilst effectiveness is defined as the expected organizational satisfaction of the privacy requirements (permanent enablers), efficiency has to do with the employees and collaborators of the organization, seeing that if they are educated and trained in privacy, data protection and security of processing, to what extent can they rapidly perform activities towards the resolution of privacy issues, concerns and problems, i.e. to be effective (temporary enablers).

Composite requirements

Composite requirements, i.e. high-level requirements "does not have its own testable fit criteria, but it rather "summarizes" a number of other individually testable requirements" (Robertson and Robertson, 2006). Therefore, the privacy composite requirements or themes are, as follows: (i) Governance structure, (ii) Inventory, (iii) Policies, (iv) Training, awareness and indoctrination, (v) Personal information life cycle, (vi) Security of information, (vii) Communication, (viii) Data subject access request, (ix) Incident and breach management, (x) Legal, third parties and transfers mechanisms, (xi) Monitoring, measurement, analysis and evaluation, (xii) Risk management, (xiii) Evolution of legislation and practices, and (xiv) Service level agreements. Moreover, they should coherently group several fundamental and distinct requirements. There are controls associated with these requirements that can be obtained from the Regulation, the BS10012 and the ISO27001.

Continuous service improvement

The purpose of the service improvement layer of the PRIMROSE method is to align privacy related business services with variable environment requirements, e.g. new laws and regulations, making the bridge between the external environment and the organization and, its internal environment, by acknowledging and communicating legislation updates to interested parties. These alignment activities support the PRIMROSE lifecycle approach through diagnosis, design, implement, operate, monitor

and control, constantly searching for ways to improve the "effectiveness, process effectiveness and cost effectiveness" (TSO, 2012) of privacy related services.

Method

The pursued research purpose is exploratory mainly because the scope of the study focus on the situation under analysis and no concerns for generalization are made explicit at this stage.

In addition, the presented research questions were used to guide a literature review, which supported the definition of the questions to be asked in two exploratory qualitative data collection situations, as follows: (i) one focus group made up by four participants and one moderator, one of the researchers. All participants are part of the sponsor company, i.e. the DATASHIELD DPBCS, and they act professionally as Data Protection Officers (DPO); (ii) eight semi-structured interviews led by the same researcher made to DPO working within the Portuguese context. DPO are individuals designated by the organization on the basis of professional competencies and, in particular, of expert knowledge on data protection law and practices (Regulation EU, 2016).

Data treatment and analysis was positioned under an interpretivist stance. It was supported by the use of the Vivo12 Plus software. In addition, visual representations were used adding more meaning to the findings. Moreover, the data analysis process occurred in the following steps: to produce audio transcriptions and to become familiar with the data, coding, and searching for themes, patterns and relationships. Chosen themes will be strongly justified by extant research. Finally, the themes were refined in order to be able to progress towards valid and firm foundation conclusions regarding the initial research questions.

Illustrative results and conclusions

This research addresses the [RQ1] *What are the high-level requirements of the permanent organization to be GDPR compliant? and* [RQ2] *How should be the GDPR requirements managed in the permanent organisation?* Thus, a qualitative study was carried out. An interdisciplinary literature review on the General Data Protection Regulation (GDPR) recitals and articles, on the data protection and privacy body of knowledge, and on security of processing was pursued. The interdisciplinary approach resulted into the melding the aforementioned knowledge with the literature related to privacy management. Outcomes are, as follows: (i) privacy requirements are supported by privacy principles and by privacy strategy [RQ1], (ii) organizational enablers (permanent and temporary) contribute and seek to construct the privacy purpose in a positive-sum manner [RQ2], (iii) privacy maturity models are acknowledged as a means by which organizational privacy progress can be measured against their organizational and technical implemented measures [RQ2], (iv) there is a gap regarding a generally recognized privacy management method [RQ2], i.e. a means by which the elements of the method described are applicable to most organizations most of the time, and there is agreement about its value and utility. The authors argue for PRIMROSE as an organised way to decrease the probability of risk occurrence, as well as its negative impacts, that are associated with this privacy management gap [RQ2].

Moreover, the focus group that was put together and eight semi-structured interviews confirmed these findings from the literature review. In addition, interviewees added new perspectives, namely: (1) they referred the existence of a common set of requirements on a relevant number of organizations most of the time. However, they also raised the need for specific descriptions of sectoral sets of requirements, e.g. health, education, insurances and so on; it is recognised that this sectoral set of requirements should be developed as

extensions of PRIMROSE, by interpreting additional specific issues and risks and by expanding the precepts of privacy management defined in PRIMROSE to specific sector needs [RQ1]. (2) Interviewees confirmation also allowed to explore and develop the semantics of the method root definitions, e.g. the proposed principles, stages, processes, enablers and high-level requirements elaborated as a function of the privacy environment [RQ1;RQ2]. (3) *Multidisciplinarity* [RQ2] was required to face the challenges that privacy and data protection demands. However, findings from the focus group brought forward for reflection *interdisciplinarity* instead [RQ2], in order to draw a bridge between disciplines and to become a truly integrated and coherent whole. Further research reflections also suggest *transdisciplinarity* as a required configuration of knowledge in the privacy and data protection curriculum to be analysed. (4) At the time of this investigation, the lack of national legislation, i.e. in Portugal, both in the public and private sectors, is often highlighted as an argument for the organizational leaders and executives postpone and not allocate the necessary resources to satisfy the privacy requirements in their business. (5) Interviewees clearly expressed that the State should give the example. (6) Careful consideration should be made regarding the primacy of the European Union law, as it functions as a principle aiming to assure uniform appliance of European Union legislation within the Member States.

As recommendation for further work, this investigation suggests that the pursued paths should be improved and further extended. The method should be progressively more elaborated, as far as optimizations and adjustments might occur, and as details and relationships become clearer. Moreover, it is expected that the presented descriptive model should generate several analytical ones with more limited scopes.

Finally, the meaning of what constitutes the success of data protection or privacy measures should be further investigated from the perceptions of the relevant interested parties, i.e. the stakeholders (Costa et al. 2017; Costa et al. 2018).

In summary, this assignment operationalised an exploratory research to address the general high-level requirements for organizational privacy resilience by proposing an innovative privacy management method positioned within the scope of an original conceptual model previously introduced by the authors (please *vide* Costa et al., 2017; Costa et al., 2018). It is believed that this might suggest a relevant contribution to the practitioner, because guidance to a more systematic diagnosis, design, implementation, operation, monitoring and controlling procedure concerning privacy management might come out. This method is also considered as an advancement to data privacy theory due to its originality. In addition, research as a path to avoid abusive prescriptions to real world problem-situations has also been valued through the outlined investigation.

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Exploring the integration process of new practices for knowledge sharing

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Abstract

The aim of this paper is to provide new perspectives on the implementation of new operations management practices by applying three different but interrelated frameworks: Human Interaction Dynamics, Normalization Process Theory, and Professional competence as ways of being. The empirical material in this paper is based on a case study within a global manufacturing company, and more specific the development and implementation of a new OM practice for knowledge sharing at one of the sites in Sweden. A mixed-method approach is used, and the empirical material is collected through analysis of a database, two group interviews, and a survey.

Keywords: Knowledge sharing, Human Interaction Dynamics, Normalization Process Theory, Professional competence

Introduction

In the pursuit of maintaining competitive production systems, manufacturing companies make great efforts to develop and implement new operations management (OM) practices that actually make a difference. In this draft paper, we explore an implementation of a system for knowledge sharing, intended to increase the level and quality of knowledge sharing within a global manufacturing organization. All staff, in all parts of the organization, can ubiquitously both share what they have experienced as good practices, and retrieve information that have been shared by others.

However, the reality of many companies indicates that there are major challenges when trying to implement new OM practices as an integrated part of the established

production system, which also is the situation in the case used in this paper. Thus, finding the keys to an agile integration of new OM practices then becomes an essential capability for companies to possess. Following this, the aim of this paper is to provide new perspectives on the implementation of new OM practices by applying three different but interrelated frameworks: Human Interaction Dynamics (Hazy and Backström 2013), Normalization Process Theory (May et al 2009, May et al 2016), and Professional competence as ways of being (Sandberg 2000, Sandberg and Pinnington 2009). The following research question is addressed: To what extent and how are the new OM practice for knowledge sharing integrated in the current production system?

Theoretical framework

In this section, the three perspectives that constitutes the theoretical framework are introduced. A common ground for all three perspectives is that they address different aspects of how human action and interactions in organizations can be explained. However, what differentiates the frameworks is the level of analysis and its primary unit of analysis.

Human Interaction Dynamics

Implementation of new OM practices usually occurs as a mean to bring change into an established production system. A production system is constituted by a web of OM practices, which together creates an organizational whole that emerge over time (Hazy and Backström 2013, Backström 2017). From a human interaction dynamics perspective, An OM practice – such as a system for knowledge sharing – are based on three structural elements (Fundin et al 2019): a) External structures, which refers to structures external to the specific situation. In a company, the external structures are embodied as formal work descriptions, SOP's, tools (e,g,. machines or IT-systems), laws and other national or international regulations. b) Internal group structures, which refers to the structures that emerge from the interaction between group members in terms of norms and values, and c) Cognitive structures, which refers to the individual actors internal dispositions in terms of knowledge, skills, and attitudes. All three level of structures are of a temporal character, and, as indicated in figure 1, social interaction is the key for both modifications and emergence of new structures, and, reinforcement and continuation of established structures. Thus, implementation of new OM practices requires modifications of structures on all three levels.

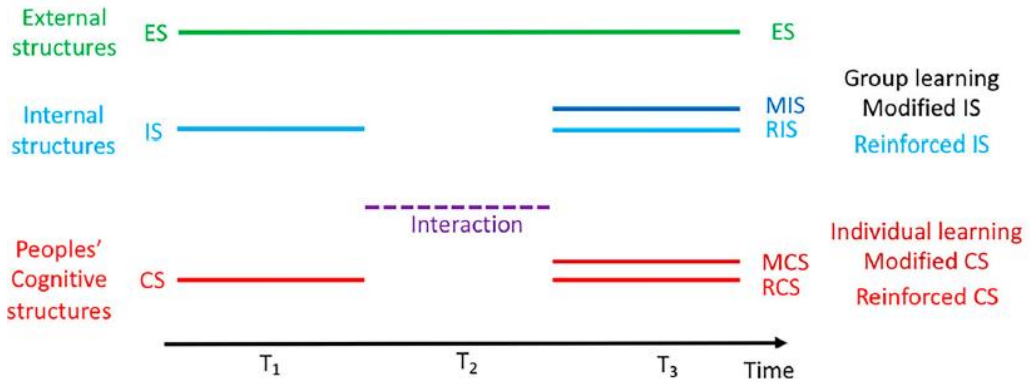

Figure 1. Basic building blocks in human interaction dynamics (Fundin et al. 2019)

Normalization process theory

How new OM practices actually affects a company and make a difference, depends on if and how it becomes an integrated part of the already established production systems (cf. May and Finch 2009, May et al. 2016). From a Normalization process theory (NPT) perspective, a successful implementation is a normalization process in which a new practice becomes 1) *Embedded*, that is routinely incorporated in everyday work i.e. in the cognitive and internal group structures, and over time becomes 2) *Integrated*, that is reproduced and sustained among the external structures of an organization. According to May and Finch (2009), implementation is operationalized through four generative mechanisms: *Coherence:* The sense-making work that people do individually and collectively when faced with the problem of operationalizing some set of practices. *Cognitive participation:* The relational work that build and sustain a community of practice around a new technology. *Collective Action*: The operational work that people do to enact a set of practices, whether these represent a new technology. *Reflexive Monitoring*: The appraisal work that people do to assess and understand the ways that a new set of practices affect them and others around them.

However, from an organizational perspective, a core issue is to achieve a fast and smooth implementation where new OM practices rapidly becomes an integrated and functional part of the production system, without losing the benefits of already established practices. In this respect, the current NPT does not provide sufficient empirical based knowledge on agile integration of new OM practices in manufacturing organizations. A proposition in this paper is that an important feature of agile integration is the plasticity of OM practices and the elasticity of the production system (May et al 2016). Thus, agile integration emerge in the interaction between the new and existing OM practices.

Professional competence as ways of being

Furthermore, to understand the implementation of new OM practices from an individual point of view, Sandberg and Pinnington's (2009) theory on professional competence as ways of being provides a pertinent perspective. Sandberg (2000, p. 20) concludes that: "'workers' knowledge, skills, and other attributes used in accomplishing work are preceded by and based upon their conceptions of work." (Sandberg 2000, p. 20). That is, professional competence implies they ways knowledge and skills are used in the particular situation. However, in Sandberg and Pinnington (2009, p. 1162), the authors also conclude that individual attributes – such as knowledge and skills – only constitute one aspect of competence, used to perform a certain work. Instead, professional competence emerges in any given situation as ways of being, based on the individual's self-understanding (e.g., identity as an operator), his or her understanding of work, relations to other people, and different tools that are accessible.

Research Design

The empirical material in this paper is based on a case study within a global manufacturing company, and more specific the development and implementation of a new OM practice for knowledge sharing at one of the sites in Sweden. A mixed-method approach (Merriam & Tisdell 2015) was used, and the empirical material was collected through content analysis of the database, two group interviews, and a survey.

First, to understand how the new OM practice for knowledge sharing was used, we conducted a qualitative database-analysis of what was shared in the database. The database-analysis was conducted in collaboration with one employee at the case company, working at the department of Operational Excellence.

Second, two semi-structured group interviews was conducted. As respondents in the two interviews, we invited the top ten contributors of good practices shared in the database. Seven of the invited accepted, and at the first interview four of the respondents participated, and at the second interview, the last three respondents participated. The interviews covered three main topics: General thoughts about the new OM practice; Their own experiences of using the OM practice; and, Other arenas for knowledge sharing.

Third, to understand to what degree the new practice for knowledge sharing has been embedded and integrated in the production system the NoMad survey (Finch et al 2015) was used, for measuring the implementation processes from the perspective of the managers and employees who are the potential users of the knowledge sharing system. The survey was distributed to 100 respondents (managers and staff) within one Swedish operations unit, with a response rate of 40 %.

Findings

In this section, we provide some tentative findings related to our RQ: To what extent and how are the new OM practice for knowledge sharing integrated in the current production system?

A new system for knowledge sharing

Since a couple of years, a new OM practice for knowledge sharing is used in the case organization. The OM practice is based on an open database to which all staff, in all parts of the organization, can both share what they have experienced as good practices, and retrieve information that have been shared by others.

According to one of the process owners, an overall intention with the new OM practice for knowledge sharing is to lower the threshold to share ideas and good practices among different sites and units. To avoid "inventing the wheel" again, is also used as an expression to describe the purpose of the OM practice, based on the idea of re-using knowledge and good practices developed throughout the organization. Since the introduction of the OM practice, global level SOP's are in place and the technical system is functional, although there are some reports on being slow and hard to find on the internal web. The system contains already over 15000 contributions shared worldwide, and almost 1700 good practices are shared from staff at the Swedish sites to due date.

Each month the global process owners of the new OM practice has a meeting were one or more of the new good practices are promoted, which means that it becomes highlighted and easier to find in the database. Further, when a good practice is 'used' or 'adopted' by anyone in the organization, he or she notes that in the database, which later has been measured and used as a KPI.

Distribution of power through an open and accessible system for knowledge sharing

Both the responses from the survey and the group interviews indicates that the basic idea of the OM practice for knowledge sharing seems to be well received in the organization. During the group interviews there are a lot of positive assertions about what the system brings in terms of added value. For example, the system is open and accessible to everyone in the organization, which can be described as contributing to a distribution of power. Everyone is allowed to share his or her good practices to anyone in the organization. However, when it comes to the practice of using the system for knowledge sharing in the Swedish organization, a different picture appears in the empirical material.

A brief look at the good practices shared in the system

To get an overview of what kind of practices that has been shared in the system, a content analysis on a number of practices was conducted. As the number of good practices shared was relatively high, we selected the shared practices that were most frequently 'used' or 'adopted' by anyone in the organization.

To understand what type of benefits the good practices served, we divided them into four themes: Inspiration, Improve process, New process, and, Transform system. The analysis indicates that the two themes in which most of the practices can be placed was 'Inspiration' followed by 'Improve process'. Further, we also analysed to what degree 'evidence of value' was provided as information when describing the good practices. The results indicates that very few of the shared practices provided any evidence of potential value (2 out of 21). However, information about 'evidence of value' was not requested from the system when the good practices was entered into the database.

Constraints for using the system for knowledge sharing

The results from the NoMad-survey indicates that the use of the OM practice for knowledge sharing is relatively low. Only a few individuals seems to be continuous contributors of good practices. Over 70 % of the respondents had never contributed to the database, and the rest responded positive to the statement that they had contributed to the database only "a couple of times a year". In terms of searching information in the system, over 50 % responded that they never had used the database, 47,5 % responded that they had searched for good practices "a couple of times a year", and only 2,5 % had searched "a couple of times a month".

This picture of how frequently the OM practice for knowledge sharing is used is supported by the group interviews, both when it comes to contributing to the system, and retrieving information from the system. Although people seems to be positive to the basic idea of the system for knowledge sharing, a number of reasons why the system is not used as intended emerge in the group interviews. First, *technical constraints*, are identified both in the survey and the group interviews as one problematic issue. The system is lagging and experienced as slow when entering new good practices into the database. Also, it is not obvious how to label the things that are entered into the database, which becomes an obstacle that might scare people of. That is, the system is not intuitive enough for people to use without having proper knowledge about how it works. Second, t*ime constraints,* are experienced, which means not having the proper time to use the system. Partly, this can be explained due to the technical issues in terms of delays when entering good practices into the system, but also due to not having the time to prioritize the sharing. Third, *management constrains*, in the sense that in the group interviews it becomes obvious that the use of the system is mainly driven by the fact that they are measured on it by senior management, and not due to experienced benefits from using it. One of the respondents concludes that "Unless it is not requested it will die, if it is not really good". Another aspect of managerial constraints, is that there is an insecurity of what is acceptable to share, that is, what are the requirements on the good practices entered into the database? According to one of the respondents, there seems to be different views of when something is mature enough to share, while some share things that still is work in progress, others seems to wait until they have a proof of concepts.

Other mediums for knowledge sharing

In the group interviews, the respondents were also asked what other mediums for knowledge sharing they are using. A recurring answer on the question was the relational networks in which the respondents are a part. The relational networks refers both to

personal networks – colleagues and friends at work –, and different professional networks, which frequently were used when the respondents needed to find a solution to a problem they had encountered. Through the interaction with different colleagues, they many times manage to solve the encountered problems and gain new knowledge in the area.

Conclusion

The aim of this draft paper is to provide new perspectives on the implementation of a new operations management practice by applying three different but interrelated frameworks: Human Interaction Dynamics, Normalization Process Theory, and Professional competence as ways of being.

Previous research using Normalization process theory has mainly been conducted in the healthcare sector, which makes it interesting to see how it can be used and adapted to a manufacturing context. Although there are differences between implementing evidence-based methods in healthcare compared to implementing new OM practices in manufacturing industry, there are also many similarities. One such similarity is the top-down initiative for most of its potential users. In both contexts it is possible that the implementation has been preceded by a pilot study, which in one way or another has proven to be successful. Followed by a decision that the new practice should be rolled out and serve as a new standard operating procedure in its domain.

As stated earlier, a successful implementation implies a process of normalization (May and Finch 2009), that is, when a new practice becomes integrated in the production system as a part of the routines of how work is done. A key to integration then is sustained behavioural changes. From the perspective of NPT, it is reasonable to conclude that the new OM practice presented in the paper has not become normalized. How then can this be further explained?

From a human interaction dynamics perspective (Fundin et al. 2019), the top-down decision made to use the new OM practice for knowledge sharing render modified formal structures – a globally dispersed digitalized tool and new SOP's –, which set the context for the staff in all parts of the organization. However, in terms of internal structures – norms and values – and cognitive structures – knowledge and skills –, the new OM practice still imply an additional set of tasks to conduct, and is not perceived as a tool that supports and help solve different problems that are encountered. Using the words of Sandberg (2000), the general understanding of work does not include the new OM practice for knowledge sharing as a mean to solve problems. This can be compared to the relational networks, which are frequently used as a mean to gain new perspectives on a problem, and not seen as a task in itself.

Finally, to become a functional OM practice for knowledge sharing, the new OM practice needs to be embedded into the routines of everyday work, which not seems to be the case now. Previous implementation research have provided knowledge on whether or not organizational interventions are effective, but less focus have been on *how*, *when* or *why* interventions have a positive impact on organizations (Biron and Karinka-Murray 2014). Thus, there is a need for further empirical research that address the role of process and contextual variables, and how it influences the implementation of new OM practices.

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Manufacturing network coordination in the digital age

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Abstract

Changes related to the information age or Industrial Internet of Things (IIoT) have led to new opportunities, which influence the internationally distributed manufacturing networks. The derived results show that IIoT initiatives are based on five dimensions (digital technologies, connectivity, data, capabilities and management), which are highly interrelated. The analysis reveals that if the level of standardisation in products, processes and systems is high and headquarters takes the responsibility to centrally manage the network and give little autonomy to the plants, a company can unravel the potential of its IIoT initiatives more than without taking the manufacturing network coordination into account.

Keywords: Industrial internet of things, manufacturing network coordination

Introduction

The pace of change in information and communication technologies (ICT) is still accelerating and influences every industry (Alcácer et al., 2016). International business literature defines these changes as the information and communication age and discusses influences on the geographical distribution of the international business activities

(Freeman and Louçã, 2001). Alcácer et al. (2016) highlight that the changes go beyond location and enfold, for example, organisational decentralisation or modularisation. Innovations in ICT heavily influences the MNEs international production processes (Chen and Kamal, 2016). Researchers and practitioners agree that ICT influences multinational enterprises (MNEs) and that the transformation is still ongoing.

As many medium and large manufacturing companies have gone from producing at single sites to having multiple production plants spread around the globe, ICT not only influences a single site but the manufacturing network. Manufacturing networks enfold multiple plants of one organisational company, most often, scattered around the globe in order to gain access to new skills or low-cost resources . If a company is not satisfied with the manufacturing performance, a variety of improvement suggestions is available. These improvement programs are usually on the site level, concentrating on optimising single sites in isolation. The improvement programs seldom take into account that today's companies are often composed of multiple manufacturing sites, which are connected and affect one another (Manyika et al., 2012). Subsequently, there is a need to jointly manage and optimise these sites as a network (Feldmann et al., 2013). Hence, manufacturing network coordination remains one of the key challenges (Scherrer and Deflorin, 2017).

One of the improvement areas for manufacturing companies results from innovations in ICT. Whereas in international business (IB) the changes related to ICT is widely known as the information age, operations management (OM) summarises similar changes as industrial internet of things (IIoT), digital manufacturing or Industry 4.0. Despite differences in the exact definition, two commonalities are the internet enabled information and communication technologies and the achieved connectivity. Many researchers have analysed the influence of ICT on a single manufacturing site (e.g., Kang et al., 2016). Others analysed the influence of new technologies, such as additive manufacturing, on the global supply chain (Laplume et al., 2016, Vereecke, 2017). Despite some research on the supply chain level, the influence of ICT or IIoT on manufacturing network coordination is unclear. Hence, we focus on the influence of IIoT on the coordination of internationally distributed plants and shed light into how manufacturing network coordination is influenced. Thus, we answer the following research question: "How does IIoT influence manufacturing network coordination?".

Literature review

Information Age, Industrial Internet of Things, Industry 4.0, Digital Manufacturing

New technologies influence the way industrial companies compete. The changes are labelled information age (e.g., Alcácer et al., 2016) (Alcácer et al., 2016), industrial internet (Posada et al., 2015), digital manufacturing (Wang and Wang, 2016) or industry 4.0 (Posada et al., 2015).

One commonality of the concepts is the internet of things (IoT) (Annunziata and Evans, 2012). Although there is not yet a common definition, the core concept is "that everyday objects can be equipped with identifying, sensing, networking and processing capabilities that will allow them to communicate with one another and with other devices and services over the internet to achieve some useful objective" (Whitmore et al., 2015, p.261). Hence, central to this perspective is the connectivity or interconnection (Hermann et al., 2016).

Analysing the key components relevant to the information age, industry 4.0, industrial internet of things and digital manufacturing highlights similarities, which can be grouped into (1) technology, (2) data and (3) people (e.g., Whitmore et al., 2015). Technology enfolds the hard- and software needed (i.e. sensors and actors) and the connectivity (i.e. interfaces, WLAN and protocols). The digital technologies combined with the

connectivity allows the generation of data which are the key driver of the information age. The combination of digital technologies, connectivity and data build the basis for visual analytics, augmented reality or simulation/visualisation (Posada et al., 2015). Besides the similarities in technologies and connectivity, another cross-cutting theme is the people at work, enfolding the changes in capabilities or human-machine cooperation (Hermann et al., 2016, Posada et al., 2015, Whitmore et al., 2015). In addition to the capability perspective, the people dimension covers the management perspective. Westerman et al. (2014) highlight that in order to turn technology into business transformation, four dimensions need to be covered from the management: (1) framing the digital challenge, (2) focusing investments, (3) mobilising the organisation, (4) sustaining the digital transition. Whereas the discussion of capabilities (i.e. data analytics) is present in all the described concepts, the management perspective did not receive the same attention. We determine that in order to successfully coordinate new potentials based on IIoT, the management perspective should be included.

Hence, we conclude that although the main vision of the concepts differs, the underlying factors related to digital technologies, connectivity, data, capabilities and management are similar. Hereafter, we use the term Industrial Internet of Things (IIoT) to summarise the dimensions, which serve as triggers for changes in companies.

Manufacturing Networks

Many studies have demonstrated the importance of understanding business networks (e.g. Andersson and Forsgren, 2000). Business networks are composed of subsidiaries that enfold different functions (e.g. R&D, manufacturing, sales). In this, manufacturing networks are dedicated to manufacturing plants and emphasises operations. In both network forms, the coordination of the subsidiaries or plants is important and especially, how the coordination of multiple subsidiaries/plants influences performance.

To analyse this, the study at hand does not employ measures of performance such as innovation or growth in sales, but focuses on operational performance as defined by Flynn et al. (2010), Vereecke et al. (2006) and Szász et al. (2016). We refer to two classes of operational performance: efficiency (cost and lead time) and effectiveness (quality, delivery, flexibility). These categories are also found in the OM literature (Szász et al., 2016).

Manufacturing Network Coordination

Coordination defines how to link, integrate, and organise manufacturing plants in order to reach strategic business objectives (Cheng et al., 2011). In their literature review on manufacturing networks, Scherrer and Deflorin (2017) distinguish between two main research areas of manufacturing network coordination: (a) how the physical and non-physical flows between sites in the network are designed and managed and (b) how rules and mechanisms for interaction between the sites, the sites and headquarters, or the sites and central network management are designed and established.

The study at hand emphasizes on coordination mechanisms of plant interactions, operationalised through the level of operational and strategic autonomy (Kawai and Strange, 2014) and parental control (Van Dut, 2013), the level of standardisation of R&D, production processes, and quality control (Maritan et al., 2004), coopetition and target setting and incentives (Luo, 2005).

Industrial Internet of Things and Manufacturing Network Coordination

The literature review on IIoT and the related concepts (information age, digital manufacturing, Industry 4.0) highlights the relevant underlying dimensions. In order to

be able to gather and distribute information, there is a need of digital technologies such as sensors and actors, image transmission, software and data storage (Porter and Heppelmann, 2014). In addition, there is the need to connect the devices, products or processes. Connectivity enfolds the ports, antennae and protocols which enable wired or wireless connections (Porter and Heppelmann, 2014, Hermann et al., 2016, Whitmore et al., 2015). The generation, storage and analysis of data builds another relevant cornerstone.

Finally, every transformation has a people side. There is a need to develop new capabilities such as data analytics or the human-machine cooperation (Hermann et al., 2016, Posada et al., 2015, Whitmore et al., 2015). In addition to the new set of capabilities needed, the new possibilities need to be steered and pushed from top management (Westerman et al., 2014).

Our aim is to understand how the IIoT enabler influence manufacturing network coordination. Thus, based on the above-described dimensions, we derive the research model as demonstrated in Figure 1.

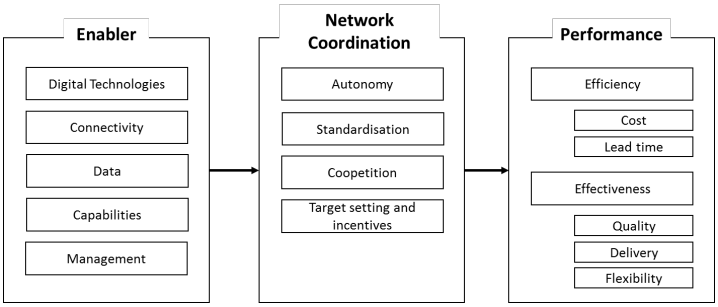

Figure 1 – Research model

Methodology

As we aim at understanding how IIoT influences manufacturing network coordination, we need to gain profound understanding of the relevant elements of IIoT and the manufacturing coordination mechanism. Subsequently, we follow a qualitative research approach (Eisenhardt, 1989). The advantage of gaining deep insight into IIoT ideas of one company was more important than having a broad but superficial data set. In doing so, the company, and more specifically, the manufacturing network level, serves as unit of analysis. The company chosen for analysis is a leading European manufacturer with eight business units, which occupy 2.000 employees in production sites and sales offices around the world. The company was chosen because of its qualification to generate usable results rather than because of its representativeness (Miles and Huberman, 1994). Eisenhardt and Graebner (2007) recommend that the case study approach is particularly suitable for topic areas not well documented and rather unknown, which suits our topic of interest. We have conducted an explanatory research approach (Eisenhardt, 1989, Eisenhardt and Graebner, 2007) that started in March 2016 and finished in July 2017. It involved eleven semi-structured group interviews with seven employees of the general management board. All interviews were attended by three researchers of the field of operations management to gain as much objectivity in result interpretation as possible. The interviews lasted between two and four hours. In addition to the interview data, we used multiple data sources such as archival data, industry publications, manuals, and company documentation. To analyse the collected data, we used Miles and Huberman's (1994) four-step approach.

Case Analysis

IIoT initiative "digital workflow and digital product"

The company under investigation faced two challenges, which they want to overcome. First, the assembly process was time-consuming because of missing information, poor quality and search for information. Second, there was a lack of customer specific information. This contained lack of information about the production history of the product, or lack of information about installed software updates since the product was handed over to the customer. Especially, technical and service engineers complained time-consuming information seeking, since customer-specific information was not available across all divisions (R&D, manufacturing, assembly, sales, customer service, etc.). To overcome these issues, the company decided to launch the IIoT initiative *"digital workflow and digital product"*.

The core idea of the initiative "digital workflow and digital product" (see Figure 2) is to develop and engineer the product virtually and to collect all information of each product of the company's portfolio digitally. Based on this digital product, a digital workflow is derived. The digital workflow serves as guideline throughout each supply chain step. It steers and monitors the activities as, for example, the assembly employees digitally confirm each process step and save additional data about the production process, if necessary. These data are saved in the customer's history of the produced product in the product life cycle management (PLM) system. Thus, the company has a virtual dataset of the delivered machine. After installation at the customer's site, additional data, such as software updates or maintenance that the customer conducted, are also saved in the customer history of the product. Thus, the initiative "digital workflow and digital product" not only gathers data from production, assembly and customer service but also provides information about the digital product (customer neutral) and the customer specific data. Both data (customer specific and neutral) are saved in the PLM system. The issue-tracking systems guarantees the backflow of information from the customer or customer service to the company. This supports the continuous improvement of the processes. However, there is no continuous monitoring of the product's condition at the customer's site and thus, the company cannot exploit the full potential of a digital twin.

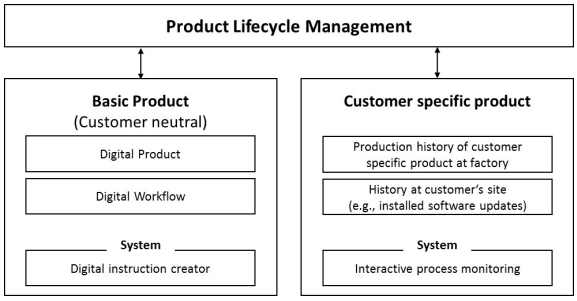

Figure 2 – Initiative "digital workflow and digital product"

Headquarters is responsible for the implementation of the "digital workflow and digital product" within each production site. Thus, headquarters is responsible for the definition of the IT-system and its implementation at the sites. In addition, each process step has an assigned owner, responsible for the provision of the needed data and the continuous improvement of the digital workflow and the digital product. The process owner is also responsible to coordinate the operating activities at each production site of the company's network. Thus, headquarters is able to transfer production capacity between their internationally distributed production sites.

Enablers of the IIoT initiative

The following section summarises the enablers for the IIoT initiative "digital workflow and digital product" according to the five dimensions of the research model: (1) digital technologies, (2) connectivity, (3) data, (4) capabilities and (5) management.

(1) From the technological point of view, the product-lifecycle-management system (PLM) is the backbone of the "digital workflow and digital product", in which all information is accumulated and the product data including the customer specific production, maintenance and service data are stored. It is extended by the "digital instruction creator" and an "interactive process monitoring" software, all based on

web-technologies, dashboards and interfaces to e.g. virtual reality technologies.

(2) Connectivity over-spanning the complete manufacturing network is one of the key elements of the "digital workflow and digital product".

(3) The technologies and the achieved connectivity between systems, processes and functions allows gathering data. The digitally available data, stored in the PLM-system, allows having up-to-date information on products and processes. In addition, the data from the issue-tracking systems allows, based on data-analysis, to derive improvements for processes and products. In the long run, the data allows the derivation of patterns of customer preferences, suppliers or cost structures which provide new insights for the company's development.

(4) On the human side, requirements on capabilities and management have to be distinguished. The initiative needs a change in the mind-sets of the company's employees. The new initiative "digital workflow and digital product" is based on three underlying philosophies. (a) The digital assembly philosophy, consists of a paperless workflow. (b) Cross-functional information- and knowledge-exchange. (c) The third philosophy takes all phases of the product-lifecycle into account, from the first ideas up to the disposal of the product.

The capability of data analysis is inevitable. Especially the capability to analyse and structure all gathered data to generate useful knowledge is key. This capability is central in order to learn from the issue-tracking system and to enhance the knowledge base further. Additional capabilities enclose software and hardware (i.e. sensors) capabilities.

(5) A key task of the management is the definition of responsibilities. Therefore, system- and process-owners have to be defined and project management has to be set up. Likewise, the management has to picture a clear vision of the three underlying philosophies and to communicate its importance. Finally, a concept of human resource development is established in order to ensure the development of the needed capabilities.

Another change encountered concerns the project management activities. The stage-gate-related project management (i.e., Cooper et al., 2002) or the very detailed planning requirements of six-sigma or lean management is adapted to an agile project management philosophy. Due to the fact, that many technologies are still new and the cause-effect-relation unclear, the company changed its project-management philosophy to a step-by-step and trial-error approach.

Network Coordination and the "digital workflow and digital product"

The initiative "digital workflow and digital product" is centrally developed (i.e., headquarters) and implemented at each production site. Thus, the initiative influences not only the production site but also the international manufacturing network. The following section covers the manufacturing network coordination mechanism and analyses the influence of the "digital workflow and digital product".

Autonomy vs. parent control

Headquarters drives the initiative and, in cooperation with the production sites, defines the (software) systems and processes. Thus, strategic decisions are all done centrally (high level of parental control). Although the process owner is located at a production site, the responsibility is clearly defined and thus, the level of operational autonomy is low.

Standardisation

The initiative "digital workflow and digital products" needs a high level of standardisation in processes, products and systems.

Coopetition (degree of cooperation and competition)

In former times, some of the business units that belong today to the company under investigation were competitors in similar fields. Thus, the transfer of knowledge and information was difficult. Different initiatives concerning the level of standardisation have led to a higher level of cooperation between the plants (i.e., product modularisation). The initiative "digital workflow and digital products" asks and enables a high level of cooperation as the products should be transferred easily between the production sites. In addition, the continuous improvement based on the data gathered (e.g., issue-tracking-system) allows every plant to improve. Thus, each plant has an incentive to cooperate.

Target setting and incentives

As described above, the level of standardisation in processes, products and systems is high. To achieve that plant managers accept the high level of standardisation and the low level of strategic and operative autonomy, the target setting and incentive systems need to include network level goals (i.e., improvements of the overall network).

Performance

We discuss the performance effect of the IIoT-initiative based on the two dimensions efficiency (cost and lead time) and effectiveness (quality, delivery, flexibility). The main interest is on performance improvements on a network level as we are interested to know how IIoT initiative influence manufacturing network coordination and performance.

Efficiency

The globally available data allows accessing information wherever needed without searching costs. In addition, the high level of standardisation in processes, products and systems should ensure that the level of quality is high and hence, accessed data can be used without further re-work. Compared to the previous system, product transfer costs between production plants can be neglected due to the digital workflow.

From a manufacturing network perspective, the flexible allocation of production capacity may also improve lead time. The company is an equipment manufacturer of large machines. Hence, the possibility to choose a production site, which is nearest to the customer, allows saving transportation costs and lead time. Furthermore, as the company already produced products in batch size one, there is no loss of economy of scale-benefits after the implementation of the initiative "digital workflow and digital product", as the batch size is still one.

Effectiveness

One of the key changes from a manufacturing network perspective concerns manufacturing network flexibility. The high level of standardisation and parental control allows to allocate capacity where needed. Although, the flexible allocation of production capacity is possible without a digital workflow, the main improvement is that this flexibility does not negatively influence quality and delivery. In point of fact, the quality at each plan can be increased as the digital instructions and the available technologies enable the employees of each site to produce a high-quality product even without extended training. The key enablers are the new technologies, connectivity, capabilities and management activities of the initiative "digital workflow and digital product".

Discussion

The IIoT initiative "digital workflow and digital product" highlights the composition of the five IIoT dimensions digital technologies, connectivity, data, capability and management. The digital technologies are needed to feed the product lifecycle management system, the digital instruction creator and the interactive process monitoring.

Connectivity reveals itself in technological solutions (platforms, interfaces, WIFI, protocols) as well as in the process level. The connectivity of processes exists between different functions of the company and between the company and the customer. However, without the underlying technological solutions, the connectivity would not be possible. Hence, we conclude that connectivity is one of the most important enablers of IIoT.

To gather data, technology and connectivity are needed. Within the case study, the data is collected throughout every process step. In addition, the data are crucial for the lifecycle management of the products and the transparency of the installed machinery base. One of the most important aspect is the data from the issue-tracking system, which collects incidents within the company (throughout assembly, production, installation) or at the customers site (maintenance, service). The analysis of this data helps to understand how to improve products and processes. The analysis of the supply chain related data (suppliers, product cost structure, customer preferences) may lead to additional insights. Hence, data is another central dimension of IIoT.

In order to successfully implement the initiative, new capabilities are needed. First of all, data analysis is an IIoT specific capability, which in the case of the analysed company needs to be build up. In addition, there are challenges which are more philosophical in nature and thus, need longer time to adapt. Change needs to be supported from top management. In addition, the need to apply a agile project management philosophy with its trial-and-error culture (Conforto et al., 2014) is another important learning.

The analysis exemplifies that the IIoT enabler are interrelated and hence, need to be taken into account jointly. Thus, an isolated analysis of the new technologies needed is not enough.

The main influence of the IIoT initiative on manufacturing network coordination stems from the digital technologies and connectivity. More specifically, investments in the systems ask for a high level of standardisation. This is mirrored in the level of plant autonomy which, compared to the beginnings of the initiative, is lower. The higher level of parental control is needed to achieve the high level of standardisation in product, processes and systems and with this to being able to exploit the potential of the IIoT enablers.

The higher level of parental control is also needed when it comes to knowledge exchange. The initiative allows to link different production sites. Due to the high level of standardisation in processes and products, headquarters has a high flexibility in deciding where to produce and assemble the products. Accordingly, headquarter can set targets for the collaboration between these plants.

Without cooperation, the joint collaboration on the digital workflow and digital product is not possible, as the initiative aims to implement a company wide system with a high level of standardisation. The cooperative behaviour needs incentives as the high level of standardisation does not always fit to the plant management goals.

The analysis reveals that the enablers and the respective measures in manufacturing network coordination positively influences performance. However, without adapting the manufacturing coordination mechanism, the full potential of the IIoT initiative may not be exploited.

Conclusion

Even though there exists literature that states that headquarters is a relative outsider of the manufacturing network and with this, not able to know which plants should, for example, exchange knowledge with each other (e.g., Van Dut, 2013), later results show differently (e.g., Golini et al., 2016). Their results show that a low level of autonomy is beneficial if the company aims at profiting from the manufacturing network (Golini et al., 2016). The analysed IIoT initiative reveals a similar relationship as a low level of plant autonomy seems to be needed to exploit the initiatives potential.

The results of Golini et al.'s (2016) study also refer to cooperation. The more a plant embeds itself in its manufacturing network, the more effectiveness benefits such as increased flexibility, quality and dependability can be achieved. Nevertheless, the company's management needs to pay attention who suitable exchange partners are.

From a managerial perspective, the analysis provides interesting insights. In combination with digital technologies, connectivity is needed to gather and store the needed data. Managers need to decide which processes, functions and supply chain steps to connect. Another decision to be made covers the open versus closed system.

Data is one of the key enablers of an IIoT initiative and reveals an interesting insight as there is a shift from documents to data. The two systems (interactive process monitoring and digital instruction creator) create and transfer data to the PLM system. In order to visualize the data, the two systems pull the data which are stored in the PLM system. This is only possible if data is gathered and stored and not documents. Thus, in order to implement IIoT initiatives, software providers are needed which are aware of this philosophy shift.

Another understanding reveals itself in the project management philosophy. The shift from stage-gate project to an agile project management supports the successful implementation of an IIoT initiative.

The study at hand has its limitations, as it is case study based and the company under investigation is still in the process of implementation and hence, the performance effects need to be evaluated after the manufacturing network coordination mechanism are adapted to the IIoT's need. Furthermore, the decisions on the manufacturing coordination mechanism are done based on a single IIoT initiative. Further research should consider multiple IIoT initiatives in order to get insights into possible trade-offs.

Overall, the paper at hand shows that companies with internationally dispersed plants can gain benefits from IIoT. It is important to take all dimensions into consideration and to know how to coordinate the manufacturing network. If the level of standardisation in products, processes and systems is high and if headquarters takes the responsibility to centrally manage the network and give little autonomy to the plants, a company can unravel the potential of its IIoT initiatives more than without taking the manufacturing network coordination into account.

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Comparing the key success factors affecting change operations between state-owned enterprises and private organisations

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Abstract

Due to business uncertainty, both public and private organisations need to adapt to change. Therefore, this study analyses the differences in change operations and proposes key success factors for organisational operation in the case of mergers and acquisitions. In-depth interviews and content analysis are used to collect and analyse data from one state-owned enterprise, and two private organisations. The performance measurement system, equal treatment, employee attitudes, and communications were found to be the success factors supporting operational change but all four factors differ among organisational type and employee level.

Keywords: Change operations, State-owned enterprise, Private organisations

Purpose

Due to instability and uncertainty in the current business environment, such as political, economic, social, and technological development, both public and private organisations have continuously attempted to align their operations with changing situations (Al-Haddad and Kotnour, 2015). The main reasons for organisational change originate from mergers and acquisitions (M&As), government legislation, and strategic reorganisation (Edmonds, 2011). However, M&As have the most impact on organisational change (Brakman et al., 2013). Most organisations tend to fail at managing change (Hodges and Gill, 2015). Moreover, the failure rates are higher than 70% for change initiatives (Erwin and Garman, 2010; Isern and Pung, 2007), which is the same as the failure rate for the post-integration stage of M&A deals (Brakman et al., 2013; Muehlfeld et al., 2012). The majority of these failures are employee-related (Kotter, 1995). Therefore, active operational support for employees is crucial during the change implementation process (Self et al., 2007).

Previous studies have also demonstrated that the particular characteristics of an organisation, including public sector organisations, state-owned enterprises (SOEs), and

private organisations have led to differences in the way organisational change is managed (MacLeod, 2009; Van der Voet, 2015). These differences depend on factors such as organisational goals (social responsibility and profit expectations), culture, structure, and systems. However, most studies related to organisational change focus on the private sector only (Coram and Burnes, 2001), excluding the public sector. In addition, literature on change management in SOEs is limited compared to that available on private sector operations, particularly regarding M&A situations. This study aims to identify the differences between SOEs and private organisations in relation to change situations, as well as analysing the key factors for successful change in both SOEs and private organisations.

Change operations

Skalik (2016) mentioned that change operations are related to organisational policies and general strategies. A company's policy demonstrates its global vision in relation to operational conditions and guidelines as to how it should behave when undergoing a major change. The strategic principles for change relate to effective employee management, and how the change is designed and implemented depending on the organisational situation (Skalik, 2016). Many researchers have studied successful change operations. These studies reveal that the operational factors to consider during change include an identified vision and goal for the direction of change, stated roles for all employees involved, leadership guidance for those directly involved, employee training, and the implementation of a strong performance measurement system (Ackerman et al., 2001; Bridges, 2003; Kenny, 2006).

Holbeche (2006) stated that a successful change operation is defined by a variety of stakeholder needs. The success of a change operation is measured by short-term financial goals, but there are other considerations for a successful outcome which can be classified into six areas: improvement of business performance in the industry market, positive financial performance with sustained growth, improvement of customer notice for services or products, customer happiness and loyalty, benefits gained from continuous innovation and an increase in industry knowledge, and a better brand image with a good market position.

Key success factors for change

First, organisational performance measurement is an increasingly important issue in many areas such as international business and change management (Larimo, Nguyen and Ali, 2016). The most important decision when facing change involves defining and setting performance measurement goals (Al-Haddad and Kotnour, 2015). Performance measurement helps organisations to evaluate their general progress towards objectives and the management of operations by providing the necessary information to make key decisions (Gunasekaran and Kobu, 2007). Performance measurement systems are also essential for analysing the current development of organisational activities (Schmid and Kretschmer, 2010). Many researchers mention the benefits of performance measurement in relation to three main areas: first, formulation, implementation, and review of an organisational strategy; second, communication of the results achieved to stakeholders; and third, employee motivation at all levels to create a performance improvement culture (Micheli and Mari, 2014).

Second, based on the equity theory (Adams, 1965), employees are concerned not only with the treatment they receive during a change situation, but also that received by others. When employees are forced to change, they compare the effect on their daily

work with that of their colleagues. This can affect employee morale and work behaviour (Williamson and Williams, 2011). Moreover, equity theory also relates to employee motivation and the perception of their input and output ratio in comparison to that of others (Ryan, 2016). When an employee perceives their input and output ratio to be the same as that of others, the perception of equity remains. On the other hand, if an employee feels there to be a difference between themselves and other employees, the perception of equity declines (Taylor, Kluemper, and Sauley, 2009). Employees will try to adjust their input, output, or employee comparisons to justify any effect on their working behaviour (Adams, 1965).

Third, recent study by Fernandez and Rainey (2006) found that change agents should consider eight factors during a change situation: analysis on the need for change, creating a plan, building internal support systems and overcoming resistance, ensuring the support and commitment of top management, building external support systems, providing resources, institutionalising change, and pursuing comprehensive change. Luecke (2003) stressed the significance of accepting the necessity for urgent change, as well as the importance of strong leadership to support change and encouraging employees to accept change. He proposed that change operations should start with joint identification of existing problems and their solutions, followed by the development of a shared vision, identification of leaders, implementation of the change, and finally the monitoring and adjustment of strategies to cope with any problems that occur during the change operation (see also Al-Haddad and Kotnour, 2015).

Fourth, a number of scholars found communication to be the key to organisational success in a change situation. Alas (2008) emphasised that a willingness to change is strongly related to the information received by employees. Additionally, Lewis (2006) suggested that the provision of better quality information to employees leads to more willingness for change. Erwin and Garman (2010) also found that communication throughout the change process influences any resistance to change. They suggested that an organisation should provide ample, clear, and quality communications regarding change initiatives, associated implications, and implementation actions. Husain (2013) suggested seven key factors for an effective communication model in relation to change management: tackling queries, community spirit, trust, employee commitment, employee participation, lessening uncertainty, job security, and feedback.

Although these operational factors are crucial, their level of importance may differ for various types of SOEs. This leads to the main research question:

RQ: Do the key success factors for change differ between SOEs and private organisations?

Methodology

This study adopts a qualitative research approach, focusing on M&A situations in large organisations. The most impactful change issue for organisations involves M&A situations, creating complications in obtaining research contributions for this study from large companies. In-depth interviews were used to answer the research questions with data collected from one SOE and two private organisations which have recently experienced an M&A in Thailand. According to Dion et al. (2007), the effect of an

M&A should be studied within three years of the event. The organisations selected for this case study passed this criterion.

The SOE used in this study is the agricultural support organisation; the result of a merger with three previously established entities: a commercial organisation, a public support organisation, and a research institution. This M&A primarily occurred to comply with government policy, resulting in a company with approximately 2,400 employees: 84% from public support SOEs, 13% from commercial SOEs, and 3% from research institutional SOEs.

The first private organisation in this study merged with two transportation companies related to the provision of expressway and metro services including commercial development. This M&A primarily occurred to extend the company to make it more competitive with other fast-growing businesses, and increase returns. The merger involved a total of approximately 2,500 employees: 31% from motorway services and 69% from the underground.

The second private organisation, in the food production industry, was a merger between two companies: a tapioca products manufacturer and a vermicelli and noodle products manufacturer for local and international distribution. This organisation currently employs over 1,400 employees: 50% from each original company. These employees are from both production and support departments. The primary reason for the M&A was to expand the company to improve competitive advantage.

The participants selected for interview held senior management, middle management, and operational positions in one SOE and two private organisations (transportation and food production) affected by M&A. A total of 19 employees from these three organisations were interviewed for this study (8 men and 11 women). Nine employees were selected from the SOE and ten from the private organisations. Table 1 illustrates the position of each employee in the three categories.

Table 1 – Interviewees by employee level from SOEs and private organisations

Organisational type	Employee level			Total
	Top	Middle	Operational	
SOEs				
1. Commercial	1	1	1	9
2. Public Support	1	1	1	
3. Research Institution	1	1	1	
Private I (Transportation)				
1. Expressway	1	1	1	6
2. Metro	1	1	1	
Private II (Food Production)				
1. Tapioca	-	1	1	4
2. Vermicelli	-	1	1	
				19

The interview questions were created based on the literature review with two experts confirming the content validity. The main questions for this research were divided into three parts. The first group of questions related to participant information such as position, work experience, and job responsibility. The second group of questions involved the change situation and impact of change. An example of a question from this

section is "What is the effect of M&A on your organisation?" Finally, the third group of questions on operational factors during change situations, consisting of four main parts, are adopted from Fernandez and Rainey's (2006) study. These four parts included questions about an effective performance measurement system, equal treatment for all employees, the encouragement of employee attitudes towards change, and communication. An example of a question from this section is "What are the important operational factors for a successful change situation in your organisation?"

After revising the interview questions and requesting permission from the organisation, appointments were made with the employees. The participants were briefed about the objectives of the interview prior to commencement, and each interview lasted approximately 30 to 45 minutes. All audio interview recordings were transcribed and the transcriptions carefully checked by the interviewer. This study adopts the qualitative data analysis approach with content analysis performed to answer the research questions. The process of analysing the interview transcripts began with condensing all the raw data into code, categorising this into themes, and finally verifying the central themes into categories and sub-categories. The data obtained in this research was discussed and validated to ensure inter-coder reliability (Kurasaki, 2000). In addition, experts reviewed and discussed all processes before proposing the final results.

Findings and Discussion

Upon analysing the research interviews, it was discovered that the factors supporting the operations of SOEs and private organisations in change situations include having an effective performance measurement system, equal treatment for all employees, encouraging employee attitudes towards change, and communications within all levels of the organisation. All four factors differ between organisational type and employee level. Table 2 summarises the interview results:

Table 2 – Operational factors by employee level for SOEs and private organisations

Operational Factors	SOEs			Private organisations		
	Top	Middle	Operational	Top	Middle	Operational
1. Effective performance measurement system	√			√	√	
2. Equal treatment for all employees	√	√	√	√	√	
3. Encouragement of employees' attitudes towards change	√	√	√	√	√	√
4. Communication	√	√	√		√	

Employees from SOEs and private organisations suggested both similar and different operational success factors in a change situation.

Firstly, an effective performance measurement system was considered differently at employee level between SOEs and private organisations. Only top management in the SOE mentioned an effective performance measurement system as a key success factor, while both top and middle-level management in private organisations, mentioned it, with some respondents stating:

"*I think the performance measurement system and a promotion plan that reflects real employee performance and potential are the keys for us*…." (response from top management at an SOE)

"*Under the M&A situation in our company, we are revising the performance measurement system to align with all parts of the organisation. It will help considerably in driving the goal of the organisation to become a single company*…." (response from top management of a private organisation)

"*It's a clear performance measurement system. Our performance measurement system is quite clear now compared to the last system that did not link to employee performance*…." (response from middle management of a private organisation).

These results indicate that both SOEs and private organisations mentioned an effective performance management system but differed according to employee level. Top management recognised that a performance measurement system provides a link between employee performance and rewards. It was an important factor in motivating high performers within organisations. On the other hand, employees at operational level working on daily tasks focused only on salary and rewards received after the change.

An effective performance management system is another tool for promoting change within an organisation. Furthermore, a performance measurement system should be linked to reward. Outstanding employees should be recognised and rewarded for promoting change. This practice will motivate employees to put additional effort into their tasks and overcome difficulties under change situation. Consequently, an effective performance measurement system is an important factor for promoting motivation in change situations.

Secondly, all interviewees from both SOEs and private organisations state that equal treatment for all employees is a key operational factor during change situations, with the exception of operational-level employees in private organisations, and some respondents stating:

"*The management principle under M&A, for me, is equal treatment for all employees because it will affect employee morale and commitment. If they think that it's not fair for them, they will not change*…." (response from top management of a private organisation)

"*I will change, if my boss and organisation treat me the same as my colleague, or everyone feels the same effects, not only me*...." (response from an operational-level employee at an SOE)

"*I think that fairness to all employees is the key. The organisation has to give us reasons why we have to change and everyone should be treated the same*…." (response from middle management at an SOE).

These findings follow the equity theory by Adams (1965), in that employees are concerned not only with the treatment they receive during a change situation, but also the treatment others receive. When change is forced on employees, they compare how it affects themselves compared to other employees. Thus, organisations must communicate the change message to their employees, and especially the reasons for

change, to increase their willingness towards it. Private organisations have more effective management systems, leading to equal treatment for all employees. Moreover, employees in SOEs suggest that the working environment is an important operational factor. They focus on colleagues, supervisors, and subordinates since the people around them have a greater effect on their opportunities for promotion and career growth.

Thirdly, all employee levels from both SOEs and private organisations mentioned employees' attitudes as an operational factor in change situation. However, top management-level employees in SOEs and middle-level managers in private organisations felt that they did not observe any encouragement in the attitude of employees towards change with some respondents stating:

"*The main factor is the employees. Their involvement and support will lead to a successful change. Without employee support, the change will not happen*…." (response from top management of an SOE)

"*Employee attitude is the key if we mention change as an advantage for both the employee and organisation, we will accept the change*…." (response from an operational-level employee of an SOE)

"*Employees have to accept that they must change with an organisation. If an employee accepts change, they will be willing to learn new ways of thinking and follow the organisational goals*…." (response from middle-level management of a private organisation)

These findings indicate that employee attitude and employee involvement are key to a smooth change operation. Employees who face a change situation must consequently alter their daily routines, develop new knowledge, and handle additional workloads (Tummers et al., 2015). Therefore, if employees do not possess a good attitude or think of change as a challenge to improve their skills, ability, and knowledge, they will be resistant to it. Organisations should encourage employees to change by giving them an opportunity to develop themselves, providing a coaching support system for challenging tasks, particularly the middle management of a private organisation.

Finally, all employee levels in SOEs and middle-level management in private organisations remarked that communication between management and all levels of the organisation regarding change is an essential operational factor, with some respondents stating:

"*Management teams have to clearly communicate change strategies, policies, and goals to all employees so they can show the direction of an organisation*…." (response from an operational-level employee of a private organisation)

"*Communicate to all employees why we have to change and what we can expect after the change. Employees have to know the real situation of an organisation*…." (response from top management of an SOE)

"*I think communication to all employees, unifying the whole organisation is important to organisational success*…." (response from an operational-level employee of an SOE)

These results indicate that comprehensive communication is a key success factor when handling change, in addition to perceived utility, the perception of personal gain, and a lack of resistance to change (Erwin and Garman, 2010; Sreekeessoon, 2010). The management team should communicate information about the benefits of change, efforts made during the change, and organisational direction to all employees.

Conclusion

Under a change situation, SOEs and private organisations mentioned the key factors affecting change management at employee level. Firstly, the effective performance measurement system was mentioned by the management team only. For SOEs, only top management focused on the performance measurement system, while in private organisations it was mentioned by both top and middle management. Due to private organisations experiencing a competitive business environment, the performance measurement system is an important tool for monitoring organisational performance. Secondly, all employees of both SOEs and private organisations state that equal treatment for all employees is a key operational factor during change situations, except for operational-level employees at private organisations. Private organisations use more effective management systems, leading to equal treatment for all employees. Thirdly, top management-level employees at SOEs and middle-level managers from private organisations felt that they did not observe any encouragement in employee attitudes towards change. It can be argued that organisations will succeed in change operations when employees have a positive attitude towards change. Finally, all employees at SOEs and middle management at private organisations remarked that communication between management and all levels of the organisation regarding change is an essential operational factor.

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Managing Inter-firm Relationships in Supply Chains

Managing Co-opetitive Relationships in Supply Chains: A Narrative Review

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Abstract

This paper aims to provide a review of the process and mechanisms of collaborating with competitors, i.e. 'co-opetition', in the supply chain management (SCM) context. For this reason, a narrative review of the literature on co-opetition in supply chain and logistics management fields is conducted. The paper identifies the process and mechanisms in three categories: initiating phase, management phase and facilitators of co-opetition. This research contributes to the body knowledge on inter-organisational relationships in SCM by filling the current gap on the process and mechanisms of co-opetition.

Keywords: Co-opetition, Logistics, Supply Chain.

Introduction

The growing intensity of market competition and the development of increasingly complex global supply chains make companies become more involved in cooperating with their competitors as a feasible way of coping with these challenges (Schmoltzi and Wallenburg, 2011). 'Co-opetition', coined by Brandenburger and Nalebuff (1996), is a phenomenon explaining the win-win situations which can be created when competitors with complementary resources and capabilities cooperate with each other. A well-known example of co-opetition has taken place in mobile phone industry, where a supplier as Samsung is also a direct competitor of Apple (Sodhi and Tang, 2013).

For more than two decades, co-opetition has been a topic of study in different fields of business including marketing, innovation and operations management (Ritala and Hurmelinna-Laukkanen, 2009; Meade et al., 2009). However, the potentials of co-opetition for improving supply chain performance of companies is increasingly recognized in recent years (e.g. Kovac and Spens, 2013; Hobson, 2014; Pathak et al., 2014). For contemporary firms, the level of vertical integration of actors across supply chains is usually already high and further improvements in their operational efficiency is possible only through horizontal collaboration with the companies which are outside their

firms' supply network, and even through co-operation with their direct competitors (Hobson, 2014).

According to Granata et al. (2018) there are several challenges for firms when managing co-opetition including: finding the right balance between competition and cooperation, asymmetric earnings resulting in more advantage for one firm in the alliance, separation of tasks between companies, and tensions created due to the emotional ambivalence of such a paradoxical relationship. However, despite extended literature in different fields of management and business addressing these issues (e.g. Fernandez and Chiambaretto, 2018; Fernandez and Chiambaretto, 2016; Le Roy and Czakon, 2016; Le Roy and Fernandez, 2015; Fernandez et al., 2014) the SCM literature still needs much further elaboration on finding suitable process and mechanisms for co-opetition to overcome these barriers.

Despite its theoretical and practical importance, in the SCM field there is still limited research (both in terms of number and depth of studies) on process and mechanisms of co-opetition (Pathak et al., 2014; Sodhi and Tang, 2013). This calls for a review to clarify the body of knowledge in this area so as to pave the way for more research in the future. Therefore, this paper aims to explore the existing processes and mechanisms of managing co-opetitive relationships and the factors impacting them in the SCM context through a narrative review of literature.

Methodology

In this paper, a narrative review of literature on co-opetition in SCM context is conducted. First, we carried out a comprehensive search for relevant published peer-reviewed journal papers in key business and management journal databases (including, Google Scholar, Science Direct, and Ebosco). This search included empirical studies, conceptual papers, and theoretical papers. We did not include conference papers, book chapters and working papers in consideration that inclusion of those may reduce the adequacy of search routines due to the fragmentation of data sources and increase the risk of including studies that have not met the required quality threshold. We adopted the definition of co-opetition of Brandenburger and Nalebuff (1996), to identify the search strings, which included: "co-opetition", "cooperation and competition", "collaborating with competitor", "co-opetitive".

Second, our search was supplemented by tracking citations, checking the reference lists of reviewed papers, personal enquiries with authors, and online searching in press. In total 103 articles were identified focusing co-opetition in management and business fields (including logistics and SCM).

Third, these papers were cross checked between two researchers on the title, keywords and abstract. As a result, 31 relevant articles were identified which focused on coopetition in logistics and SCM area, which are from established journals (such as Production and Operations Management, Journal of Operations Management, Industrial Marketing Management, Supply Chain Management: An International Journal, and European Journal of Operational Research). These articles are published over 18 years from 2000 to 2017.

The process of selecting papers is shown on Figure 1. The small number of published journal papers on co-opetition in logistics and SCM (N=31) does not allow a large-scale systematic review to be conducted (Tranfield et al., 2003), therefore, a rigorous narrative review process is applied (Seuring and Gold, 2012). This narrative review involved extracting, contrasting and synthesizing the focus and findings of the published journals, so as to provide a framework on processes and mechanisms of managing co-opetition in SCM. The review process of involved two researchers checking and then cross checking

the themes emerging from the articles, which ensures the consistency and reliability of the review (Haddaway et al., 2015; Belur et al., 2018). Although the 31 papers focusing on logistics and SCM are analysed in depth, other papers on co-opetition from other areas of management (among the total 103 identified papers) are used in our discussions through the paper especially when co-opetition in different contexts are discussed.

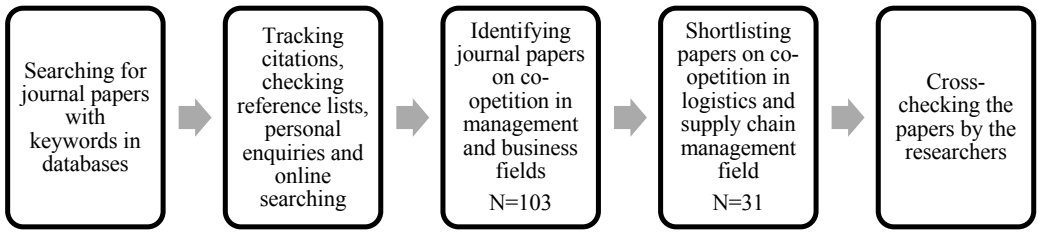

Figure 1- The process of paper selection and narrative review.

In the following sections, the main themes emerging from the reviewed articles are discussed in details.

Managing co-opetitive relationships in supply chains

According to Xu and Beamon (2006: p.4) "*A coordination mechanism is a set of methods used to manage interdependence between organizations. By definition, there are a number of different people, entities, and processes that interact in order to execute supply chain objectives. Coordination mechanisms, then, provide tools for effectively managing these interactions.*" In SCM literature, knowledge about the mechanism and process of managing co-opetition is fragmented, and lacks appropriate generalisation and elaboration. As one of the few studies addressing this topic, Cetindamar et al. (2005) identifies co-opetition mechanism in SCM by a number of aspects including: communication methods, aligned performance measures, common procedures, having collaborative teams, and inter-organisational trust. Through this study, the process and mechanism of co-opetition in SCM are categorised into three aspects including: initiating factors, management factors, and facilitators. These factors are introduced in the next sections.

Initiating phase

For studying the mechanism and process of managing co-opetition, first we need to identify the motivations and objectives of companies for becoming involved in such relationships and the degree to which competitors should collaborate. Almost always a strong business case leading to financial savings or enhanced profit is needed for initiating co-opetition. A suitable business case leading to co-opetition is presented by Kotzab and Teller (2003) where they show how through collaboration of companies in retail industry, e.g. by utilising standardised loading units, costs of transportation will decrease as a result of achieving economy of scale. In another case in farming industry, collaborative logistics, shared research projects, joint subsidy applications, and sales scheduling has led to financial advantages for firms (Galdeano-Gómez et al., 2015). A strong motivation for co-opetition could be outsourcing non-core business functions to a competitor, resulting in improving efficiency and reducing the costs of operations for a company (Zhang and Frazier, 2011). In some sectors, survival of an industrial community can be the reason for co-opetition, e.g. when clusters of regional rival wine manufacturers shared knowledge

in sales and production, enabling them to compete with wine manufacturers from other regions of the world (Dana et al., 2013).

Besides having strong motivations, companies should set reasonable and aligned objectives and well-defined scope or boundaries for their co-operation, considering their competing situation (Cetindamar et al., 2005). Co-opetition takes place at areas in supply chains which are not close to customers, because companies are competing in downstream of supply chains over a 'larger slice' of the market (Bengtsson and Kock, 2000). An example on this is joint return logistics operations by breweries on collecting empty bottles, while they compete on sales at bars' and supermarket's shelves (Bengtsson and Kock, 2000).

After having sufficiently strong motivations and reasonable objectives, companies decide to select a partner. The literature in SCM has provided limited elaboration on this aspect. Song et al. (2015) examined the important factors in partner selection in logistics co-opetition which include: size of partner companies, the level of their competition, operational synergies between them in terms of their logistics facilities, equipment and vehicles, location of their facilities, and similarities in their services.

Sometimes a non-partisan third-party can be a key facilitator to help initiating a co-opetitive relationship (Pathak et al., 2014). IGD, a British non-profit organisation, has played a key role in facilitating the co-opetition between Nestlé and Pladis (Mirzabeiki et al., 2017).

Management phase

Managing co-opetition is a sensitive task, given that collaboration between competitors are based on selected areas with functions and strategic priorities.

If managed well, co-opetition creates a co-learning process between partners (Peng et al., 2017). Higher levels of cooperation among companies lead to increased knowledge acquisition by firms which can make value for their customers (Song and Lee, 2012), e.g. when co-opetition enables companies to cover a geographically larger market. For achieving such positive results, strong top management support is needed to overcome the operational and psychological barriers which are existing by default when working with competitors (Kotzab and Teller, 2003). Joint decision making and governance by partners are widely used in supply chain co-opetitive partnerships (Pathak et al., 2014; Lejeune and Yakova, 2005). When managing co-opetition, it is important to separate the collaborating and competing parts of operations (Bengtsson and Kock, 2000; Shockley and Fetter, 2015). As an example, in logistics collaboration between leading rival UK food manufacturers the teams form both companies were advised and trained to protect sensitive information, e.g. on marketing and sales, when interacting with each other (Mirzabeiki et al., 2017). This leads to creation of a right balance between the cooperative and the competitive aspects of co-opetition which is necessary for success of such initiatives (Eriksson, 2008). Agreeing on using consistent standards, e.g. for transported load units, is a key for success of logistics co-opetition as well (Kotzab and Teller, 2003).

Configuration of inter-organisational relationships can also be a factor in determining the structure and complexity of co-opetitive relationships. Therefore, managing co-opetitive relationships in triadic settings can be different from dyadic relationships. Co-opetition in triadic supply chain relationships has been studied in more depth (compared to dyadic co-opetition) in SCM literature (e.g. see Wu and Choi, 2005; Choi and Wu, 2009; Wu et al., 2010). These studies indicate that a buyer can ask its two rival suppliers to collaborate on product development, however, it can play them against each other for

its own advantages (Wilhelm 2011). In such a situation when customer participation and customer value is high among suppliers, a higher level of knowledge sharing between the buyer and its suppliers takes place (Ho and Ganesan, 2013). In automotive industry, lack of influence of a buyer on the relationship between its suppliers, which are in rivalry situation with each other as well, can lead to reducing the understanding of the buyer from its suppliers, causing negative consequences including diminishing its bargaining power (Wu et al., 2010). Direct material exchange and communication between the two competing suppliers of the same buyer will lead to improving the efficiency and competitiveness of both of them (Choi et al. 2002).

The continuation and effectiveness of any co-opetitive relationships depends upon fair allocation of cost and profit between partner firms. Differentiation of product lines and segmentation of geographical markets between competitors is a mechanism leading to success of co-opetition (Peng et al., 2017). Joint investments by competing firms, e.g. on technology, is needed for overall supply chain benefits from co-opetition (Bakshi and Kleindorfer, 2009). Motivations for gaining high levels of reward and avoiding losses or punishments in joint innovative projects are also affecting success of co-opetitive relationships (Nasr et al., 2015).

Communication can be a barrier in any supply chain horizontal collaboration (Cruijssen et al. 2007). This can be a significant issue to overcome in co-opetition (Shockley and Fetter, 2015) because there are concerns regarding leakage of sensitive data to competitors in this form of relationship (Mirzabeiki et al., 2017).

From a legal perspective, co-opetitive relationships should not lead to breaching any anti-competition regulations including market manipulation or price fixing (Cullinane and Song 2003; Shockley and Fetter, 2015).

Facilitating factors

In general, mutuality and symmetry between partners are very important in facilitating co-opetition (Mirzabeiki et al., 2017). Networks or companies are suitable co-opetition matches which have compatible but different structures and resources; and second, can create separated fields of coopetition and competition (Peng and Bourne, 2009). Simplicity of relationship structures make co-opetition take place easier. An example is in food industry where competing farming companies can collaborate with less difficulties when they are directly selling their products to retailers, compared to when there is a wholesaler involved in their supply chains (Galdeano-Gómez et al., 2015). On the other hand, lack of common technology and shared performance measures among partners can hinder co-opetition (Cetindamar et al., 2005).

Personality of people representing companies can also facilitate co-opetition. Goodwill and trust are the key components needed to overcome the barriers set by default against working with competitors (Mirzabeiki et al., 2017). For co-opetition, informal arrangement between boundary spanners sometimes can play a more important role in creating trust rather than formal contractual relationships. In line with that, Kotzab and Teller (2003) suggest that social exchange is more important than economic exchange in co-opetition.

Special care and maintenance are needed in co-opetition because of preventing any potential conflicts or tensions in different organizational levels between the companies (Bengtsson and Kock, 2000). According to Peng et al. (2017) higher similarity in competitive actions by rivals in a competitive relationship is a major cause of conflict.

Socializing through group activities is effective in creating shared understanding and common values among partners (Eriksson, 2008). Niceness, i.e. cooperative behaviour, versus meanness, i.e. competitive behaviour, of partners towards each other are seen as strategies influencing success of co-opetitive innovation-led projects (Nasr et al., 2015).

Discussion

Among previous studies on co-opetition, the main focus has been on the business advantages gained, e.g. in terms of expanding the logistics networks of companies (Song et al., 2015), reducing the costs of reverse logistics (Bengtsson and Kock, 2000), lowering the load units' expenses (Kotzab and Teller, 2003), and improving supply chain security and risk management (Bakshi and Kleindorfer, 2009). However, the literature has not been paying enough attention to the development and management process of this challenging and paradoxical strategic form of relationship (Park et al., 2014) and the mechanisms involved in it (Kovac and Spens, 2013). Despite the small number of publications on this topic, there is generally a lack of systematic understanding of the associated management processes in co-opetition (Bengtsson & Raza-Ullad 2016).

The specific issues or gaps regarding the current research on co-opetition in SCM field and the areas which demand further exploration are presented below:

Lack of consistency in terminology

Literature review on co-opetition in the SCM context highlights a lack of clear and consistent definition of the phenomenon. This issue is not only limited to the SCM literature and other management and business fields suffer from it as well (Bengtsson and Kock, 2014; Peng et al., 2017). As an example, authors have used the term 'co-opetition' when explaining vertical relationships, e.g. between buyers and suppliers, which involves simultaneous competition and cooperation (Gurnani et al., 2007; Kim et al., 2013; Lacoste, 2012; Li et al., 2011; Nair et al., 2011). While this type of relationship is different from 'horizontal' co-petition, i.e. when two types of similar actors compete and cooperate at the same time, (Gnyawali and Madhavan, 2006; Peng et al., 2012), still the same terminology is used for studying both types of relationships. Furthermore, in a number of papers, the relationships studied under the title 'co-opetition' were not representing any of these two mentioned types of configuration (vertical or horizontal). This separation should be made in the SCM literature for clarifying the path of research in the area.

In some cases, authors have used the term co-opetition when they have studied cooperation and competition, however while they have not been occurring simultaneously (e.g. see Iida and Zipkin, 2010). Such a lack of consistency in terminology causes confusion and ambiguity when studying the phenomenon.

Co-opetition management in SCM compared to other business fields

Although the co-opetition literature in SCM still does not provide a clear picture of process and mechanisms of management of such a relationship (Bengtsson & Raza-Ullah 2016), this topic is discussed in much more depth in the other fields of business and management including marketing, product development and innovation management (e.g. see Granata et al., 2018; Fernandez et al., 2018; Pellegrin-Boucher et al., 2018).

Regarding the initiating phase, criteria for making appropriate partner selection in SCM literature demands further elaboration when we compare it to to the other business areas (e.g. see Gnyawali and Madhavan, 2006).

Another gap in the SCM field is on the dynamics of co-opetition, i.e. changes taking place in the relationship through time which is discussed in details in the marketing research (see Raza-Ullah et al., 2014). The impact of analytical capabilities for successful

execution of co-opetition is also a timely topic which is covered in the other areas of management much more than SCM (Gnyawali et al. 2016). Tensions in co-opetition and the factors influencing them are explored in business research through a relatively large number of publications (e.g. Fernandez et al., 2014; Le Roy and Fernandez, 2015). Among these researches, Dahl (2014) discusses the ways that confrontations and conflicts can change the nature and dynamics of co-opetition over time.

The importance of separation of collaborative and competitive sides of co-opetition in SCM also needs further exploration compared to the other business and management fields (e.g. see Bengtsson et al., 2010; Le Roy and Czakon, 2016). Co-management as a key factor in success of co-opetition and the mechanisms and process involved in that, as studied by Czakon and Czernek (2016), needs to be explored further in SCM. Information sharing as a facilitating factor for co-opetition also need further exploration in SCM field. Mention (2011) shows that how restricted information sharing in co-opetition can lead to generating outcomes with lower degree of novelty in innovation-related projects.

Areas for further research

On the organizational and managerial aspects, partner selection in co-opetition with focus on the types of resources, capabilities and areas of SC expertise among co-opetitors needs to be studied in much more depth. Setting or adjusting the aims and scopes of co-opetition is also an area with very limited research.

The mechanisms for balancing cooperative and competitive sides of the relationship in horizontal dyadic co-opetition and process and methods for co-management of co-opetitive partnerships is another area for future research.

There is little knowledge on the soft aspects of managing co-petition between companies, e.g. inter-personal interactions, which demand further research. Legal governance mechanisms, e.g. explaining how service level agreements or contracts should be written to make sure that companies can benefit from co-opetition and on the other hand can leave the relationship easily if necessary, is another avenue for research. Also, compliance with anti-trust regulations and checks and the ways this could be avoided needs to be explored much further.

Conclusion

Body of knowledge on co-opetition in SCM research is fragmented and limited. Among these literature, little attention is paid to the mechanisms and process of managing co-opetition. This paper, through a narrative study, provides a review of the current research on the initiating phase, the management phase and the facilitators of co-opetition in the context of SCM. The paper identifies the gaps in the current literature on co-opetition management in SCM by comparing the literature in this field with the publications in the other areas of business and management.

From a theoretical perspective, the paper fills a gap in SCM literature on inter-organisational relationship management. Also, it provides useful practical knowledge for supply chain managers about the specialities and challenges of initiating and managing co-opetition.

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Buyer involvement in supplier's HR practices as complimentary governance mechanism: two case studies in airport service triads

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Abstract

This working paper explores buyer involvement in managing supplier's personnel as a complimentary mechanism to assure supplier service delivery performance in service triads. We analyzed two service triads cases embedded in the setting of an international airport that outsources several services to third-party suppliers. Thirty in-depth interviews to informants both from the airport and the service suppliers, and review of relevant documents was conducted. Our analysis demonstrates that in a specific type of service triads (i.e., core service and a high degree of contact), buyer's involvement in supplier's HR practices is relevant to assure the supplier's service delivery performance.

Keywords: Service triads, HR practices, quality management

Introduction

Ensuring suppliers service performance is an essential concern for buyers in service triads (Sengupta, Niranjan and Krishnamoorthy, 2018). In this context, where a supplier serves a customer on the buyer's behalf, customers will perceive the quality of service delivered by the supplier as (part of) the buyer's performance (Li and Choi, 2009). Thus, the customer's ongoing satisfaction with the buyer company is mainly dependent upon the service supplier's performance. This state of relationship establishes an interdependency of the performance of different actors involved in service triads (Li and Choi, 2009; Wynstra, Spring and Schoenherr, 2015).

Several studies thus investigated the buyer's mechanisms/possibilities to assure and control supplier's service performance, with an emphasis on the use of contract and service level agreement (Van Iwaarden and Van der Valk, 2013), contract and monitoring activities (Van der Valk and Van Iwaarden, 2011), and combination of performance-oriented and behavioral-oriented contract terms (Broekhuis and Scholten, 2018). More recently, Bastl, Johnson and Finne (2019) propose to differentiate between

control and coordination mechanisms in managing the quality of service performance in service triads. In short, the current literature highlights the use of formal and informal governance mechanisms to ensure the supplier's service outcomes.

While without any doubt these approach are appropriate, for example, to mitigate the risk of supplier opportunistic behavior (Van Iwaarden and Van der Valk, 2013) and to influence the satisfaction of both buyer and suppliers in terms of meeting the needs of the customer (Broekhuis and Scholten, 2018), we argue that relying on these mechanisms sometimes is insufficient in a service triads. As services endure the inherent characteristics of inseparability and heterogeneity, customers define quality not only based on the outcome but also on their experiences during the service delivery process (Verhoef *et al.*, 2009; Jaakkola, Helkkula and Aarikka-stenroos, 2015). Moreover, suppliers' employees often embody the intangible nature of services in the eyes of the customers. Employee's attitude and behavior significantly impact the customer's view of the service (Schneider and Bowen, 1993; Zeithaml, Berry and Parasuraman, 1993). However, managing and controlling an employee's attitude and behavior by pre-defined rules and protocols is a very challenging process, and its effectiveness is questionable (Schepker *et al.*, 2014). Therefore, a complementary mechanism to induce appropriate behaviors from suppliers' employees through direct involvement in human resource (HR) practices might be relevant in assuring the quality of service delivery in service triads, because practices like selecting the right employees and providing them with training, will influence employee's performance and thus the service delivery (Fitzsimmons, Fitzsimmons and Bordoloi, 2013).

In organizational settings, HR practices are known to be positively related to - supply chain - performance (e.g., Foerstl, Hartmann, Wynstra, & Moser, 2013; Huo, Ye, Zhao, & Shou, 2016). However, although extending these approach to inter-organizational settings, such as supply chains and service triads, seems attractive, surprisingly, research into that direction has been almost absent (Yaqoub, Broekhuis and Van Donk, 2018). Consequently, this research aims to understand *when and how are buyers involved in the supplier's HR practices, and what is their impact on assuring the quality of service delivery in service triads?*

To investigate this question, we adopted a multiple case study research with service triads as the unit of analysis. Two service triads within the airport (service buyer), passenger (end-customers), and service providers (i.e., aviation security and airport cleaning service) were selected.

This paper seeks to contribute in two ways. First, to the development of literature in service operations by providing empirical evidence of the use of HR practices in managing and controlling the quality of service delivery in service triads. Second, to the literature of strategic human resource management. While previous work focused on the intra-organizational view of HR practices in affecting performance, this paper provides an empirical assessment whether HR practices are effective in assuring the supplier's service performance in an inter-organizational setting, i.e., service triads.

The remainder of this paper is organized as follows. We begin by reviewing the relevant literature that we use to build our arguments, followed by a comparative case study of the two different service triads within an airport setting to explore how different service triads characteristics can affect buyer's decision to involve in managing supplier's HR practices. This paper concludes with a discussion of the results and potential avenues for further research.

Literature review

Managing service quality in service triads

In this study service triads are business constellations where a service buyer relies on a service supplier to deliver service which requires maintaining an ongoing interface to buyer's end-customer (Hartmann and Herb, 2015). In line with this, we consider service triads as *transitive*, meaning that the three actors in the relationship (buyer, supplier, and end-customer) are connected to each other without the presence of structural hole. The interconnectedness of the three actors implies performance interdependency (Li and Choi, 2009).

In service triads, buyer dependence on the supplier is more substantial due to the presence of direct contact between supplier and customer (Li and Choi, 2009; Hartmann and Herb, 2015). This direct contact between supplier and customer is inevitable, since "*…the key characteristics that separate services operations from manufacturing operations are the direct contact between the services provider and the customer*" (Li and Choi, 2009 p.32). This ambiguity and dependency are stated as antecedents that increase the risk for supplier opportunism in service triads compared to dyadic relationships because a certain distance is created between the buyer and the end-customer.

In order to reduce this distance between buyer and end-customer, initiatives to affect supplier's internal processes can be undertaken. Supplier development initiatives arise from supplier deficiencies, or the buyer's wish to ensure service quality (Krause and Ellram, 1997). These initiatives that often also consist of supplier feedback, supplier incentives, and audits, but also (direct) investments by buyers in suppliers, have shown to increase buyer control over quality (Krause and Scannell, 2002). However, even though supplier development is applied to services, most of these do not form service triads, since the suppliers are upstream to the buyer. To control the downstream service in service triads, the buyer should try to control the moment of service delivery. Holmlund (2007, p. 853) states that customer contact employees hold a 'key position' because: *"They are able to influence how the customer perceives interaction with the company."* Direct involvement through, e.g. training supplier employees is an example of gaining control over the expected service delivery (Van Iwaarden and Van der Valk, 2013). Getting involved in the supplier's employee relations and HR practices could, therefore, be a promising way to influence service delivery. Because, especially in services that rely on human assets, HRM can provide a competitive advantage (Schneider and Bowen, 1993; Swart and Kinnie, 2003).

While the interaction of supplier's employee and end-customer are potentially present in all types of service triads, the intensity can be different from the type of service that is outsourced in a service triad. For example, in case high-contact services are outsourced to a supplier, supplier-customer interaction is more frequent and related to customer experiences than in case low-contact services are outsourced (Van Iwaarden and Van der Valk, 2013b). This variability might require or provide different forms of buyer's HR involvement to safeguard supplier's service quality.

Inter-organizational HR practices

We conceptualize HR practices as "*planned HR deployments and activities intended to enable [an organization] to achieve its goals*" (Boselie et al. 2005, p. 67). A considerable effort has been displayed to grasp conclusive evidence of the relationship between HR practices and performance. There is little disagreement about how HR practices affect organizational performance. Mainstream research found convincing evidence that strategies that influence organizational performance involve "*coherent*

sets of HR practices that enhance employee skills, participation in decisions, and motivation" (Batt 2002, p. 587). These practices may, for instance, include activities in the fields of job design, recruitment, training and performance management.

Even though not much has been written about inter-organizational HR and even less about the role of HR practices in service triad settings, some initiatives have been put forward to understand how HR practices can/might operate beyond organizational boundaries. Literature shows different configurations of inter-organizational (for instance buyer-supplier) relationships in which buyer involvement in supplier's HR practices is present. For example, (Kinnie, Swart and Purcell, 2005) report that an organization's choice of HR practices is frequently influenced, and sometimes controlled, by relationships in which that organization operates. In other words," networks *influence [HR] strategic choice*" (Kinnie, Swart and Purcell, 2005 p.1006).

Inter-organizational HR practices might be part of multiple practices conducted by a buyer company that aims to improve supplier performance (Handfield *et al.*, 2000). Supplier development activities are conducted in both production and service organizations and often encompass HR activities (Krause and Scannell, 2002; Nagati and Rebolledo, 2013). A buyer can either involved in direct or indirect in a supplier's HR. Specifying a supplier's employee competence and attitude as a requirement for business cooperation is one example of indirect intervention. Another example is by being involved in the development of supplier's HR programs and procedures (e.g., preparing manuals for employee selection and reviewing supplier's employee performance evaluation standard). Direct involvement might entail the provision of training to the suppliers' contact employees, giving performance incentives, and involving in employee recruitment (Handfield *et al.*, 2000). Direct buyer influence might also be in the form of funding specific types of training and dictating performance management in terms of employees that should stay or leave. Another option a buyer can choose is no involvement at all and relies on the supplier's expertise to manage its employees.

Methodology

Research setting and case selection

We adopted a multiple case study with service triads as the unit of analysis. Case-based research is pertinent when little is known about a phenomenon and when the existing perspective is insufficient and have frequently been used in service triads research (see for example Van Iwaarden and Van der Valk, 2013b; Karatzas, Johnson and Bastl, 2017). The case setting is an international airport in an emerging country that outsources several services to third-party suppliers, forming multiple service triads. Services in an airport are diverse in terms of relevance, complexity and degree of customer contact, ranging from a core (e.g., executive lounge, aviation security) to facilitating services (e.g., contact center, cleaning, passenger assistance). A single service triads structure comprises of the relationship between the airport (as service buyer), a service supplier, and passenger (as end-customer).

Among the various service triads structures in our case setting, we purposefully selected two cases to be analyzed in this study. The case selection criteria following the replication logic including both literal and theoretical replication-oriented criteria (Eisenhardt, 1989). In terms of theoretical replication, the following case selection criteria were applied:

1. *The presence of different buyer involvement in supplier's HR practices*. As the focus of our study is to understand buyer motivation to get involved in the

supplier's HR practices, we have chosen cases that have different variance in this characteristic.

2. *Different degree of customer contact*. Since theoretically buyer involvement in supplier's HR practices is influenced by the degree of customer contact (Van Iwaarden and Van der Valk, 2013b), we also maintain contrast in this characteristic of selected cases.

Regarding literal replication, we maintain the similarity of the selected cases in these following criteria:

1. Both have identical *transitive* structure, where the buyer, supplier and end customer are connected in a complete relationship, and there are no structural holes.
2. Both have an equal buyer-supplier relationship, measured by the length of the relationship between buyer and supplier.
3. Both services are part of the buyer's value-proposition to end-customers.

By using this case selection strategy, two cases were selected; they are aviation security (AvSec) and cleaning service (CleanServ) triads. The background information about the two cases is provided in table 1.

Table 1 - Background information about the cases

Characteristics	**AvSec**	**CleanServ**
Part of the value proposition to end-customer?	Yes	Yes
The degree of customer contact	High	Low
Length of relationship	Three years	Three years
Buyer's primary motivation to outsource	Cost and flexibility	Quality and flexibility
The intensity of buyer HR involvement	High	Low

Data collection

Data collection were conducted in two waves. The first wave was taken place in June-July 2018 with the main focus to explore service contexts, buyer's overall strategy to manage supplier's service quality, and buyer's involvement in supplier HR practices. The second data collection was carried out in February 2019 to the more selected key informants identified in the first data collection. The second wave aimed to validate the draft of analysis that has been prepared based on the data from the first wave. In total, this research involved 30 informants within the airport and the providers across different organizational levels (i.e., strategic, managerial and operational) and functions (i.e., service, human resource, and corporate strategy).

Interviews lasted around 60 minutes on average. In order to further increase triangulation, we also collected documents (contracts, service level agreements, training programs customer's quality reports, instructions for personnel) and observed buyer involvement in supplier's HR practices. We did not interview customers but relied on written documentation for information such as customer satisfaction reports.

After coding all materials, we combined within-case and cross-case analysis. In the next section, we present the findings from the within-case analysis which focuses on the service characteristics, buyer-supplier relationship, and the way the buyer involves in managing supplier's personnel.

Findings

Within case description: AvSec

Maintaining the safety and security of the passenger, worker, airport facility, and an airline is one of the core functions of an airport. Aviation security personnel delivers this function. Security checking in an airport involves multiple layers of integrated processes to detect and mitigate security risks. The smooth running of security examination plays a vital role in the passengers' overall airport experience. Therefore, aviation security personnel are not only responsible for ensuring the safety and security of the airport, but also contribute significantly to overall passenger experience.

Aviation security service is highly regulated. Although categorized as a routine service, it requires professional knowledge. Personnel working in this field needs to have a license which reflects their skills and competencies in recognizing potential security breaches and their understanding of aviation security regulations and laws. There are three levels of aviation security license, basic, junior, and senior. These three levels of license reflect the level of competencies of the holder. For example, in the case of passenger body screening, the junior and senior levels have the competence to operate an x-ray detector. While the basic level only capable of carrying out body screening by using a handheld detector.

Aviation security personnel and passengers have intensive contact during service provision. The value delivered by aviation security personnel to a passenger is depended on the way the service is performed, i.e., the speed of the security check, politeness, and courtesy of the personnel. Although the passengers' role is passive during service delivery, the quality of security checks is strongly influenced by their knowledge and behavior. For example, the speed of security checks is strongly dependent on the passenger's compliance not to carry items that are considered dangerous for flight safety. The ideal range of security check should be around 20-30 seconds per passenger. However, the extent of negotiations that take place between personnel and passenger is the leading cause of delays in the "ideal" throughput scenario. Figure 1 shows a complete value exchange in aviation security service triads.

The aviation security service in the airport was previously entirely carried out by the airport's internal employees. Driven by mostly the motivation of cost efficiency and regulation opportunity, a large proportion of the aviation security operation has been delegated to a third-party provider since 2013. "*The average cost of recruiting internal personnel is equivalent to three times of the cost of outsourcing personnel*" [Buyer Manager]. The current supplier has been performing the service since 2015 with the number of supplier's personnel that deployed in the airport's facility is around 1.800 persons, constituting more than 70 percent of total aviation security personnel in the airport. In this condition, one can say that the buyer and supplier are bound in an interdependent relationship. "*if the supplier's employee behave badly to the passenger, the effect will be damaging to us. Conversely, if we decide to switch suppliers, it will also bring much harm to them, because a large portion of their revenue came from our company*" [Buyer Strategic].

Despite delegating the operation of security service to the subcontractor, the airport still holds up control over the service delivery by involvement in the supplier's HR practices. For instance, the supervisory role is still managed by the airport's internal employees. Among the three levels of aviation security ranks, the airport outsources the basic and junior levels.

The recruitment process consists of four stages; initial screening (e.g., body mass index measurement and documents verification), psychological test, discipline test, and interviews. The airport gives a clear direction to the subcontractor about their desired

qualifications and competencies of the new hires. The subcontractor conducts most of the hiring process; however, the airport is involved in the final interview.

The airport conducts a daily briefing at the beginning of each working shifts to ensure the employees understand buyer service values. During the briefing, supplier employees are required to recite the airport's service pledge. The content of the pledge includes promises of the personnel to maintain behavior in accordance with the airport's corporate values. "

Every aviation security officer must periodically renew his/her license within five years. Typically, the renewal cost is paid by the supplier. Personnel training and development is also the responsibility of the supplier. However, the airport still involves in the development of personnel through what they called as "*local training*" which conducted after the night shifts. The local training materials include updates on aviation security technical knowledge. For example, update on customer handling methods, familiarization of dangerous goods, X-ray machine operation, body search techniques, explosive trace detection, narcotics trace detection, and baggage screening system.

In carrying out the daily jobs, the subcontractor employees wear the almost identical uniform as the internal airport employees. Therefore, the passenger can hardly differentiate between supplier and internal aviation security personnel.

The subcontractor pays the monthly salary and other benefits (for example holiday allowance). However, the minimum amount of the salary and the types of benefits are regulated in the buyer-supplier contract. Additionally, the airport also provides monthly financial incentives from their budget for outstanding employees regardless of the employment status (subcontractor or internal employees).

Within case description: CleanServ

Cleaning service in an airport can be categorized as non-core service but essential to achieving overall airport service performance. Cleanliness of the terminal area and restrooms is regarded as the most basic physiological airport needs. Many reports from customer satisfaction measurement have established a direct link between the cleanliness of an airport and overall customer experience (Airport Council International, 2016).

Managing a cleaning service in an airport is different from other industries, take a hotel as an example. Besides the fact that a general airport has a more extensive space than a typical hotel, an airport is also a public space. Consumers who use airport services, i.e., the passengers, have more various demographic backgrounds, for instance, in terms of the level of education, country of origin, and social, economic status. This wide range of customer profile has consequences to the range of broader spectrum of airport consumers' cleanliness expectations and hygiene standards.

Besides, there are not so many passengers who are very familiar with every corner of the airport facilities, which caused numerous passengers to have difficulties in finding their point of destination. As stated by the Terminal Manager, a lost passenger tends to be more confident of getting information from people in uniform. Cleaning service employees are not an exception. That is why in an airport, cleaning service officers also act as "touch points" of passengers who need information.

"*We train our employees to read passenger's gestures. When an employee sees a lost passenger, he/she must offer help… If the passenger asks for the employee's favor to send him/her off to a certain location, the employee must help him/her. If the employee at that moment holds a (cleaning) tool, he/she must put the tool down and help the passenger*" [Supplier Manager]

The selection of the existing cleaning service subcontractor is more motivated by the effort to improve cleanliness performance at the airport. The existing cleaning service supplier is a joint venture between the airport's subsidiary company and one of the leading multinational facility services providers. This multinational provider has an excellent reputation in facility service and operating in more than 40 countries worldwide.

The relationship between the airport and the existing subcontractor has been running for three years. The quality requirements and performance indicators are agreed upon in the service level agreement (SLA). The SLA also includes an agreement about penalties for non-achieved performance.

The subcontractor started providing this service at one of the airport's terminal. Within the past year, there has been an expansion of cooperation. All of the three airport's terminals are now using subcontractor's service. Overall, the number of the subcontractor's workers for the airport is more than 3000 persons who work 24 hours a day in three shifts.

The existing cleaning service employees were absorbed from the former supplier. The transition was taken place in 2016. The existing supplier trains and standardizes the employees to meet their standards. The supplier provides technical skill as well as attitude trainings for the employees. The airport does not involve in employee training. As for the performance monitoring practices, the buyer monitors the quality of service, not the performance of personnel. This performance monitoring is done through routine inspections conducted by buyer's designated personnel and establishes the customer evaluation system to assess the cleanliness of the facilities. Moreover, the buyer involves in a regular briefing at the beginning of each working shift to ensure the supplier's employee understand and implement company values. Supplier employees are also required to recite the service pledge prepared by the buyer.

Table 2 - Summary of buyer involvement in supplier's HR practices

Case	Hiring	Training and development	Performance monitoring	Incentive	Other
AvSec	- Detail input on qualification and competency criteria - In special cases, buyer involved in employee termination	- Provide service awareness training, and updates on new aviation security regulations	- Direct supervision of supplier's employee is carried out by buyer's personnel	Monthly financial incentive (bonus) for the outstanding employee	- Prescription of employee appearance - Daily recitation of service pledge
CleanServ	No involvement	No involvement	Establish customer survey system to evaluate performance	Monthly financial incentive (bonus) for the outstanding employee	- Prescription of employee appearance - Daily recitation of service pledge

Based on the within case description, buyer involvement in supplier's HR practices can be summarized in table 2. Our initial analysis reveals that the buyer involvement in managing the supplier's employees is more substantial when the degree of customer contact is higher, and buyer-supplier relational strength is stronger (the case of AvSec).

At this time, further analysis is being carried out and is expected to be presented during the EurOMA conference.

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Port supply network strategies: An ERBV perspective

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Abstract

Increasingly supply networks are recognised as the most meaningful level of analysis in many industries. Yet few studies examine the additional capabilities and revenue options generated by such alliancing. ERBV is one perspective that addresses how these alliancing related opportunities can create competitive advantage. The ERBV perspective and notion of relational rents is used empirically to understand three distinct port supply network strategies. Whilst this study is confirmatory regarding the basic tents of ERBV, beyond studying ERBV in a new context the study contributes to theory by reporting that, paradoxically, temporary relational rents can be generated without close partnerships.

Keywords: Extended resource base view, ERBV, logistics value added services

Introduction

Since the 1980s the growth of new inter-firm alliances has transformed the business environment; firms are now considered as parts of networks, engaged in *"social, professional and exchange relationships"* with other firms embedded in the same network (Gulati et al., 2000, p.203). More recently, hyper globalisation has created ever more complex supply networks and markets. These trends create a resource gap in organisations, particularly between the strategic goal of a firm and its idiosyncratic resources (Lewis et al., 2010). Consequently, in dynamic and fast cycle markets firms acting independently often cannot possess the resources and capabilities which would enable them to compete equally or seek competitive advantage (CA) (Park et al., 2017). Therefore, firms develop external relationships to acquire resources and develop capabilities (Squire et al., 2009).

Researchers acknowledge that superior performance derives from strategic partnerships between firms (Dyer and Singh, 1998). Dominant theoretical frameworks from organisational sciences, such as transaction cost economics (TCE) and the resource based view (RBV), which have frequently been utilised in operations and supply chain management research (Hitt et al., 2016), focus on the single firm and its control over proprietary resources. As such they do not consider the contribution of resources residing

outside of firm boundaries, and rent generating capabilities that emerge from inter-organisation partnerships (Squire et al., 2009; Spring and Araujo, 2013; Xu et al., 2014; Prajogo et al., 2016; Park et al., 2017). Therefore, a potential conceptual disconnection between those firm based frameworks and the view of firms as members of business networks is created (Lewis et al., 2010). This theoretical gap between the so called traditional theories of the firm is where the Extended Resource Based View (ERBV) sits, enabling research on the strategic behaviour and performance of allied firms (Lavie, 2006; Prajogo et al., 2016). Therefore, ERBV is considered the most appropriate theoretical framework to underpin this research, which aims to investigate the competitiveness of supply network strategies of interconnected organisations in an infrastructure network context. The literature review of this research reveals that ERBV studies are scarce in comparison to the predominant view of RBV and the predominant notion of rent generation derived by proprietary resources. Additionally, the analysis of the few studies that do apply ERBV reveals that ERBV has not been applied in research in the context of infrastructure networks such as ports. This creates a research opportunity considering the view of ports as business networks.

Literature review

ERBV is based on the concepts of complementary assets, the relational view, and network resources, and questions the origin of value generating resources. Complementary assets are additional resources that are needed in conjunction with existing know-how and capabilities for the achievement of innovation (Teece, 1986). The relational view emphasises dyad/network routines and processes which are considered as significant units of analysis for the explanation of CA (Prajogo et al., 2016). This aspect differentiates the relational view (and in extension ERBV) from theoretical frameworks, which explain CA in a single industry or company. CA in the case of the relational view is realised by the creation of relational/quasi rent; which is defined as *"supernormal profit jointly generated in an exchange relationship that cannot be generated by either firm in isolation and can only be created through joint idiosyncratic contributions of the specific alliance partners"* (Dyer and Singh, 1998, p.662). However, relational rents cannot be generated by adversarial commercial relationships, as these relationships are not rare or inimitable. Therefore, partnerships and inter-firm relationships are crucial for CA creation based on relational rents (Dyer and Singh, 1998; Hitt et al., 2016). Relational rents can only be created from resources that are intentionally committed and mutually possessed within the alliance. These resources would involve all shared idiosyncratic assets, knowledge, and capabilities of the firm and its alliance partners. Therefore, the value of the shared resources determines the contribution of relational rents to the outcomes of the alliance (Lavie, 2006). The employment of effective governance, and organisational centrality also affects the creation of relational rents (Dyer and Singh, 1998; Arya and Lin, 2007; Moxham and Kauppi, 2014).

In addition to relational rent, literature identifies three additional types of rent that can be realised by the firm from shared and non-shared resources. The first is the internal rent, which is the combination of Ricardian and quasi rents that can be realised by the proprietary resources of the company, and are exclusively retained by the firm (Moxham and Kauppi, 2014). The Ricardian rent will derive from the rare internal strategic resources of the company, and the quasi rent will derive from added value extracted from the company's strategic resources, given the possibility to access the complementary resources of the interconnect alliance firms (Lavie, 2006; Arya and Lin, 2007). The second rent type is inbound spillover rent, which is an additional type of rent private to the firm (Moxham and Kauppi, 2014). This rent relates to the unintended gains of the

firm, such as reputational and knowledge gains (Arya and Lin, 2007; Lewis et al., 2010; Moxham and Kauppi, 2014), derived from both the shared and unshared resources of the network partners. Thirdly, outbound spillover rent, refers to unintentional beneficial leakage from the firm that can be appropriated by its alliance partners for the creation of spillover rents (Lavie, 2006; Moxham and Kauppi, 2014). Together, under ERBV, these are the four types of rents that can be realised by the firm regarding shared (network) and non-shared resources within an alliance that determine the financial and strategic impact of the supply network strategy of the firm.

The third theoretical construct of ERBV is network resources. Network resources emerge from inter-firm networks that the firm belongs to, and are information rich resources that differ from internal resources (Gulati, 1999). Network resources can be considered as a specific form of a firm's resource, which can represent the strengths upon which a firm will realise and apply its strategy. Moreover, the unique historical experience and path dependency related with the frequency of past ties and partners' identity are crucial components which can result in the creation of network resources (Gulati, 1999). Grounded in the term network resources, Gulati et al. (2000, p.207) argue that the network a firm is part of *"can be thought of as creating inimitable and non-substitutable value (and constraint!) as an inimitable resource by itself, and to access inimitable resources and capabilities.* Therefore, organisations, which are members of network structures, can enjoy CA and benefits in comparison to organisations that are not members of such structures (Arya and Lin, 2007). Moreover, business-networks are idiosyncratic and path dependent. Thus, imitation or substitution of business-networks by competitors is difficult. Consequently, network resources are also idiosyncratic, because they are generated through the unique networks of the firm. Therefore, network resources are relatively inimitable and non-substitutable. Consequently, the combination of a firm's network and network resources leads to sustainable competitive advantage (SCA) (Gulati et al., 2000). From the above discussion it is evident that one of the main arguments of ERBV is that resources which exist outside the boundaries of the firm can be sources of CA. Additionally, it can be argued that alliances enable firms to develop a bundle of value creating resources which could not be developed by the firm in isolation and that these resources in combination with the path-dependent and idiosyncratic network of the company can potentially lead to SCA. Reviewing extant ERBV literature also reveals that ERBV has previously been applied in research in manufacturing, IT, non-profit organisations, petrochemical, and pharmaceutical contexts. As such ERBV has not been applied in research in an infrastructure network context such as ports. In an effort to re-establish their role within supply networks, ports implemented various supply chain integration practices and focused on provision of value added services (VAS) (Demirbas et al., 2014), facilitating a new view of ports as business (Van der Lugt et al., 2013) and infrastructure networks. For example, port operators realised that increased benefits could be derived by the on-site provision of logistics-VAS (e.g. container unloading, cross-docking, warehousing), in addition to their core offerings. This strategic shift of ports is defined as Port Centric Logistics (PCL). PCL literature does not investigate both *"why"* and *"how"* ports move beyond core offerings and implement strategies enabling them to co-create value with customers. Therefore, the present study by linking ERBV literature to PCL, and to infrastructure networks, combines research gaps in applying ERBV and the rent generating capabilities of inter-connected firms.

Methodology

An abductive research approach is employed (Ketokivi and Choi, 2014). A qualitative multiple case study research strategy was adopted to investigate the dynamic and complex

research phenomenon in-depth, and to provide clarification concerning the actors and mechanisms that create an augmented offering within a dynamic environment (Yin, 2011). Furthermore, a multiple case study design augments the external validity of the research and reduces the potential researcher's bias (Barratt et al., 2011). When following an abductive approach, Dubois and Araujo (2007) suggest that cases should emerge during data collection and analysis, permitting contextual idiosyncrasies to shape the unit of analysis, and facilitating a more pragmatic conceptualisation of the researched phenomenon. This novel approach within operations and SCM research is defined as casing (Spring and Santos, 2015). As such, the exact definition and number of cases of this research were not predetermined, but rather emerged during data collection and analysis, particularly at the point that the data collection reached theoretical saturation. Following a disciplined desk-based identification of companies that met the specified company selection criteria, 25 semi-structured interviews among 18 organisations were conducted. The semi-structured interviews ensured a systematic approach to data collection but did not preclude pursuing emerging threads. Additionally, observations within 4 organisations and extensive secondary data allowed for verification of informants' responses. The multiple data sources increase the reliability of the research by the achievement of data triangulation (Yin, 2011; Barratt et al., 2011). Combining interviews with observations and company documents is common in case study research in operations and SCM research (Barratt et al., 2011; Ketokivi and Choi, 2014). Finally, template analysis (King and Brooks, 2016) allowed for a rigid yet flexible data analysis method combining theoretical assumptions (a-priori codes) with empirical observations (emergent codes).

Data analysis

The data analysis, in accordance with the process of casing (Spring and Santos, 2015), allowed the development of three emerging cases studies. Each represents a distinct competitive supply network strategy for ports and intermediaries involved with the provision of on-port logistics-VAS. Each positively impacted on the competitiveness of the ports and intermediaries, however, the impact varied depending on the type of strategy. These supply network strategies are: leasing, operator, and lease and operate. Due to space constraints only the first two strategies are reported on here.

Case study 1: Leasing supply network strategy

Analysis of the data revealed two organisations with similar supply network strategies. Both organisations do not actively provide logistics-VAS, or manage port-centric warehousing facilities *per se*. Instead, their role is limited to *leasing* land and/or warehousing facilities to intermediaries that wish to provide on-port logistics-VAS. The leased land and facilities can either be within the premises of the port, or in logistics parks adjacent to- and owned by the port. Implementation of leasing supply network strategies is either path dependent, as it is inherited from the traditional functions of ports prior to containerisation or is a "*risk averse"* approach to meeting market demand.

Forms of leasing supply network strategy extend from the basic leasing of land to a tenant through to the construction of warehousing facilities by the port according to customer requirements, or the co-finance of facilities in joint ventures (JV). However, in no circumstance will the port be actively involved with the provision of logistics-VAS. Therefore, the leasing supply network strategy related revenue is only from leasing land and/or facilities to third parties, not from operation. There are marketing benefits: on the one hand the success of tenants' operations results in increased container throughput. On the other hand, successful operations lock-in tenants for longer leases.

Analysing the data also revealed that a leasing strategy gives the capability to offer a joint value proposition (i.e. bundle of port services and logistics VAS), which can confer CA, and that it enables the development of a network of interdependent organisations, which also enables the creation of network resources. These network resources are the bundles of services that comprise the joint value proposition of the port, and its network partners. The combination of those elements creates the conditions for the realisation of SCA. The Head of Commercial of Port4T reported that a lease strategy positively affects their competitiveness because it enables the offering of a joint value proposition to cargo owners tailored to the individual requirements of cargo owners, and the characteristics of the cargo itself. The Commercial Manager of Port5 argues *"…it definitely has enhanced the competitiveness of the port in the sense that our end to end product is so much better with the fact that these facilities are in the port and the companies that use them are able to drive efficiencies"*. Respondents reported that the combination of capabilities derived from the lease strategy, and other intrinsic strategies enable the ports to differentiate and achieve CA. The Head of Commercial explains how Port4T differentiates itself from competitors *"…where we safeguard our revenues is through the fact that we are able to be quite diverse, it is not just containers for us it's about what's in the container, and how it flows through the port"*. She further argued for a lease strategy with PCL enabling other forms of diversification into niche markets and how it helps to lock in either importers, end customers, distributors or LSPs; "*We like to lock them in so that they are obviously reducing their SC cost, but it also forces them to put their bill of lading at [Port4T]" ibid.* In addition to the financial and strategic benefits reported above, the data analysis also shows that a leasing supply network strategy allows ports to leverage marketing opportunities and yields two marketing benefits. The explicit marketing benefit is that a port can directly lease land and/or facilities to LSPs. The implicit marketing benefit; is that the existence of LSPs at port premises enhances the market proposition of the port, which leverages the organisational resources and capabilities of its tenants to promote a bundle of port and logistics-VAS.

Case study 2: Operator supply network strategy

Analysis identified that twelve organisations actively operate logistics-VAS, either as providers (external use: revenue from the charges for logistics-VAS), or as providers and consumers (internal use of logistics-VAS) or as organisers of logistics-VAS (i.e. the port/intermediary is the trading entity but subcontracts part or the entirety of the offering to counterparties). This strategy is labelled operator supply network strategy.

An operator supply network strategy is a response to market requirements, i.e. demand from cargo owners for logistics-VAS at points of import. Furthermore, organisations implemented an operator supply network strategy to enter new markets. Distinct examples are LSP8, LSP4 and LSP5 who entered the fresh fruit and frozen foods market, the wine bottling market, and e-commerce market respectively. All of these market segments were new to these organisations. Another reason for implementing an operator network strategy is the capability to extend control over the SC by incorporating another SC segment. These were organisations with existing national distribution networks whose investment in PCL enables them to extend SC control by capturing imported products at the point of import (e.g. LSP8, Retailer1 and Retailer2). Finally, implementation of an operator supply network strategy can be path dependent (e.g. LSP4 developed from a freight forwarder to an asset based LSP).

All twelve companies reported positive financial impacts from an operator strategy; broken down into two components. The *first component* regards the increased revenue opportunities; such organisations realise increased revenue from *higher charges for*

logistics-VAS, and *increased demand for logistics-VAS and enhanced marketing capability (*The Group Sales Director of LSP5; the Sales and Marketing Director of LSP8). The higher charges for logistics-VAS will increase the revenue of those who implement an operator strategy. The higher charges are justified by offering specialist services, and because a PCL solution can rationalise the SC of cargo owners and reduce inland distribution costs. Analysis of the data shows that these value-added capabilities can create CA. The Commercial Manager of LSP7 argues that an operator supply network strategy enables them to become more competitive by eliminating non-value-added distribution segments; the Sales and Marketing Director of LSP8 argues that the operator supply network strategy enables them *"to facilitate an end-to-end supply chain using a facility for goods coming in the SE of England";* the Commercial Director of LSP6 argues that the ability to handle products at *"the first point of landing"* increases visibility and control of cargo owner's pipeline inventory levels. That is because they *"have it on their stock system potentially 3 to 5 days earlier rather than if they have to send it to the middle of the country"*. Additionally he asserts that the possibility to handle products at *"the first point of landing"* gives the value-added capability to offer flexible SC solutions to customers. He comments: *"…with the model we've got here, we can delay containers on quay, we can fast track containers, we can put into holding areas, so we can help manage the flow of work at this point"*.

The *second component* of the positive financial impact regards the stability of the revenue derived from an operator supply network strategy. This revenue stream can be regarded as relatively stable due to the loyalty of cargo owners to the "port-centric" benefits, and the length of contracts between cargo owners, and ports and intermediaries. LSP6's Systems Project Analyst claims that the company differentiates itself from other LSPs that do not implement an operator strategy. He maintains: *"Having a port centric operation enables us to reduce some of the haulage charges. For example, for [wine importer], we save around £3,000,000 per year, by having a port centric operation that allows the use of [curtain-side trucks] for delivery of the stock and improves about 19% the efficiency because they use backloads to return"*. A view supported by the Commercial Director of LSP6 in terms of on port location and collaboration opportunities. The second differentiator lies in how the operator strategy investment in this resource enables LSP4 to focus on particular market segments, and thus, differentiate itself from other LSPs that implement an operator supply network strategy. In summary, the operator supply network strategy differentiates the LSP because it enables the LSP to provide product specific logistics-VAS within a port's environment, and because the particular investment enables LSP4 to differentiate itself from competitors in the PCL market.

Discussion

Case study 1: Leasing supply network strategy

Major revenue streams are associated with the leasing of warehousing facilities to intermediaries that have established operations at the port. The presence of those intermediaries at the port attracts more customers for the port. Subsequently, the leasing supply network strategy implicitly secures cargo owners for the core services of the port. The increased number of cargo owners enhances the revenue derived from core services in addition to the revenue derived from the leasing of land and/or facilities. Concerning the higher revenue that derives from increased demand for core services of the port, it can be argued that the port leverages its own idiosyncratic resources (port land) by accessing the complementary assets of its tenant. In this case complementary assets are regarded as the tangible and intangible resources of the tenant that are necessary for the innovation in question (i.e. logistics-VAS). According to Lavie (2006) and Moxham and Kaupi (2014),

if the firm leverages the value of its proprietary resources (i.e. port land, financial resources for development of the building and marketing capabilities), by accessing its partner's complementary assets, then the firm realises internal rent.

The joint value proposition identified in the leasing strategy above is a bundle of core services (offered by the port), and logistics-VAS (offered by the port's tenants), which positively affects the competitiveness of the ports that implement a leasing supply network strategy. The joint proposition of the port with its tenants is the outcome of the combination of the port's idiosyncratic resources (port land, and physical and human capital resources responsible for the accommodation of cargo from/to sea), and the organisational capabilities of the port's tenants (derived from the idiosyncratic resources of the tenant that enables them to offer logistics-VAS). This argument confirms the theoretical views of ERBV, in that value generating resources reside beyond the boundaries of the firm (Lavie, 2006; Spring and Araujo, 2013; Prajogo et al., 2016).

Furthermore, services are intangible resources of the firm; therefore the joint proposition of the port with its tenants is an intangible resource residing within the port's network. However, according to Gulati (1999), the resources that are emergent from inter-firm networks that firms belong to, are network resources. It can be argued that a leasing supply network strategy enables the establishment of a network around the firm; and within this network the development of network resources. The combination of the network that a firm belongs to, and the network resources, can lead to the realisation of SCA. That is, because networks are considered idiosyncratic to the firm, are relatively inimitable and non-substitutable, and their development is path dependent (Gulati, et al., 2000; Arya and Lin, 2007).

From case study one it appears that a leasing supply network strategy does not confer CA based on differentiation for the port *per se*; it is the combination of the capabilities derived from the leasing supply network strategy, and other intrinsic strategies that enable the port to differentiate. These intrinsic strategies enable the port to focus on specific market segments, select business partners, and develop networks, both for maritime and land transportation. These networks create differentiation. Thus, the leasing supply network strategy is only a fragment of a broader strategy that enables differentiation of the port based on the utilisation of the organisational capabilities of business partners. This argument complements the ERBV literature (Lavie, 2006; Lewis et al., 2010; Prajogo et al., 2016); in that the organisational capabilities of network partners assist the differentiation strategy of the port. The responses suggest that a leasing supply network strategy enhances the marketing capability of the port by implicitly or explicitly leveraging the environmental benefits that are associated with the organisational capabilities of its tenants. Capabilities are considered a particular form of organisational resources, and they can generate value on their own, or increase the value of a resource. It can be concluded that the organisational resources of intermediaries enhance the value of the marketing capabilities of landlords. This argument confirms the theoretical view of this research; that value generating resources can reside beyond the boundaries of the firm (Lavie, 2006; Spring and Araujo, 2013; Prajogo et al., 2016).

Case study 2: Operator supply network strategy

An operator supply network strategy creates a twofold positive strategic advantage for firms. Firstly for all the companies populating this case study, CA or SCA can be achieved by the value-added capabilities that derive from an operator network strategy. These value added capabilities, which can create CA, are associated with the underlying efficiencies of the port-centric warehousing and distribution model. However, this CA is also identified as dependent upon two non-exhaustive factors; the location of the intermediary,

and the level of collaboration (from close to arm's length) with the port. Interviews with participants from LSP8, LSP4, and Retailer 1, reveal that the combination of the location of port centric facilities, and the intrinsic processes and capabilities of intermediaries can result in CA. However, the interviews with participants from LSP5, and LSP3, highlight that such value-added capabilities can be attributed to intermediaries that are marketed as port-centric, but are not located on port land and have only an arm's length relationships with the ports.

This argument contradicts the ERBV literature (Lavie, 2006; Lewis et al., 2010; Prajogo et al., 2016); in that organisations can leverage resources of other organisations without formal collaborative agreements. Consequently, the possession of logistics-VAS provision capabilities, and the location of the intermediary are not exhaustive factors for the realisation of CA. An operator supply network strategy can confer CA even if one of those factors is fulfilled. Prior to any conclusive arguments the sustainability of such CA needs to be evaluated. Conditions for the realisation of SCA can be achieved by the inimitable and ambiguous nature of services due to their dependency on labour. However, only very niche logistics-VAS require highly skilled workers. In this case the complexity of interactions between the tacit knowledge that resides in the human resources, and the assets of the firm, will result in increased causal ambiguity, which is positively related with the imitability of a firm's CA. Inimitability of resources can contribute towards the sustainability of a firm's CA. It follows that human capital resources can contribute towards the realisation of SCA if their interactions with the assets of the firm are complex, because added complexity will impose higher imitation barriers. Services are also less imitable due to their ambiguous nature. In our context the provision of logistics-VAS is based on the bundle of the intermediary's idiosyncratic resources and the resources of network partners or counterparties. Considering the concept of network resources, it can be argued that the combination of the firm's network and the network resources can lead to SCA (Gulati et al., 2000). Thus, intermediaries who engage in collaboration with other network partners can realise SCA, because the logistics-VAS derive from a bundle of idiosyncratic and network resources and capabilities. Subsequently, the offerings of intermediaries that are not located within a port, or do not collaborate with network partners is more imitable, because they provide services based only on their idiosyncratic resources, and the exploitation of the marketing power of the PCL model.

The operator case study shows that intermediaries leverage marketing opportunities by the provision of on-port logistics-VAS which result from a combination of the idiosyncratic resources of the port, with the idiosyncratic resources of the LSP. This confirms the theoretical assumptions of ERBV (Lavie, 2006; Spring and Araujo, 2013; Prajogo et al., 2016). In this case the value generating resources are the idiosyncratic resources of the port that enable intermediaries to implement such a strategy to leverage marketing opportunities. However, intermediaries can not lease land from a port and instead, advertise themselves as port centric and compete in this market without being involved in a contractually defined collaborative agreement with a port. Consequently, the idiosyncratic resources of a company can confer value to another company without those two companies being engaged in a partnership. This argument complements the ERBV literature. In summary, it can be argued that an operator supply network strategy can confer SCA if the logistics-VAS derive from a bundle of idiosyncratic and network resources. Additionally, it can be argued that even though a port centric operation can result in a competitive edge based on differentiation, this edge is temporary, due to imitability of the offering. The competitive edge is more sustainable when the differentiation derives from a combination of factors, such as collaboration with the port for the development of services and processes, and/or focus on a niche product market.

The data presented above reveal that the marketing capabilities of intermediaries that implement an operator supply network strategy are positively affected. The logistics-VAS inherent in an operator supply network strategy enable firms to fulfil the demand of cargo owners for on-port logistics-VAS, and *enter new markets, attract more recognisable cargo owners, and quote to competitors' customers.*. Therefore, an operator supply network strategy enables intermediaries to leverage marketing opportunities. In a PCL context, the logistics-VAS are designed to facilitate the movement of product through the SC and are offered in combination with port services. Intermediaries combine the offering of two organisations to provide this bundle of services. The combined offerings can be bilateral (intended) (i.e. formal collaborative agreement between firms) or unilateral (opportunistic) (i.e. LSP exploits its proximity to the port). The development of logistics parks close to ports negates the entry barriers set by the limited availability of on port land. Additionally, LSPs not located on port land increase the level of imitability of this resource. Thus, even though the possession of a state-of-the-art facility could lead to CA based on differentiation, this CA is imitable. Consequently, LSPs that implement an operator supply network strategy should be located directly within the port and collaborate closely with it.

Conclusion

This research has used ERBV to understand the adoption of port centric strategies by UK ports, where new levels of service are offered at, or close to, the port. The use of ERBV theory mirrors the contemporary perspective of ports as parts of wider business networks (Van der Lugt et al., 2013), who now compete with rival supply networks (port networks) not standalone ports. Two of three strategies identified were reported on here. In case 1, ports that implement a leasing supply network strategy leverage the value of proprietary resources (i.e. port land, monetary resources for the development of facilities, and marketing capabilities) by accessing organisational resources of business partners (i.e. relationships with cargo owners) for the realisation of internal rents, CA, enhanced marketing proposition, and widened customer base. It was reported that the combination of the network that a firm belongs to, and the network resources, can lead to the realisation of SCA; because such networks are considered idiosyncratic to the firm, are relatively inimitable and non-substitutable, and their development is path dependent. In case 2 an operator supply network strategy will only generate SCA when there is a formal collaborative relationship between port and logistics intermediaries, which has developed their idiosyncratic resources and network resources. However, only one of the two factors influencing the capabilities of intermediaries is necessary for CA; if an intermediary is not located within the port's premises nor/(or does not) collaborate with a port for the provision of logistics-VAS, then its CA is prone to imitation by competitors. Thus, CA can be conferred if one of the two factors is achieved. However, the fulfilment of both factors can lead to the realisation of SCA. In summary, it can be argued that an operator supply network strategy can confer SCA if the logistics-VAS derives from a bundle of idiosyncratic and network resources. If intermediaries and ports share resources that result in the creation of a rent that cannot be realised by either firm in isolation, then conditions for the appropriation of relational rent, and SCA are created. This research confirmed the theoretical arguments of ERBV in a new context, by proposing that in an infrastructure network context value generating resources can reside beyond the boundaries of the firm. This study also identified that the organisational capabilities of network partners can assist the differentiation strategy of the firm. This finding contributes to extant ERBV literature by highlighting differentiation as an additional positive outcome of resources/capabilities sharing among network partners.

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Improving transparency in a supply chain: A case study of manufacturer-supplier collaboration

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Abstract

This paper addresses supply chain transparency improvement in a manufacturer-supplier relationship. It investigates the problem of improving transparency is using a set of interviews; then, a detailed problematization and a simulation model is formulated based on the results. There are two key issues: information systems issues related directly to transparency and capability issues related to utilizing transparency. The simulation supports developing capabilities by illustrating the effects of different options for coordinating material flow. While solutions to improve transparency are straightforward to implement, developing the capability to benefit from it can be more challenging, even in a well-established close partnership.

Keywords: supply chain management, transparency, responsiveness

Introduction

Issues, such as transparency, responsiveness, real-time transfer of demand data, and just-in-time (JIT) delivery, are all interrelated and remain topical in the research field of supply chain management (e.g., Prajogo et al., 2016; Singh, 2015; Yu et al., 2018; Zhu et al., 2018). In particular, transparency remains one of the main managerial challenges, even though information is ample and easier to share than ever before (Butner, 2010; Francis, 2008). However, scientific research on transparency still lacks a strong empirical basis (Egels-Zandén et al., 2015; Francis, 2008). Barriers to transparency have been recognized, suggesting that supply chains could be smarter through information technology (IT) solutions as well as processes (Butner, 2010). In this paper, we discuss this phenomenon through a detailed study of transparency improvement efforts in a selected manufacturer-supplier relationship.

The dyad under investigation consists of a leading machinery manufacturer and one of its key suppliers. The two companies are physically located near each other, enabling delivery in a short time span. It was found that improved transparency, with methods such as real-time availability of demand data, could further improve the timeliness of deliveries and reduce inventory levels in the supply chain.

We utilized a mixed methods study design to investigate this practical problem; first the situation was investigated in more depth through interviews with all the stakeholders and by analyzing the data related to supply chain operations. A simulation model was created based on this understanding to illustrate the effects of some possible improvement efforts. A case study design with multiple methods allows for the investigation of practical behaviors and their effects, addressing the methodological gap noted by Fayezi et al. (2017).

In the following sections, we first describe the case study situation and present the methods and materials we used. Next, the stakeholders' views of the situation are presented and some of the key differences are compared. This is followed by a discussion of the simulation results. In the conclusion, we discuss potential opportunities for improvement in the studied case, as well as the implications and limitations of our results.

The case study situation and research methods

The starting point for the study was the manufacturing company's interest in improving information transparency, and, consequently, the responsiveness and material flow in its supply chain. In initial discussions, it was also decided that choosing a local key supplier (Supplier A) as a pilot case would be a good way to begin these efforts. The choice was also influenced by experiences from earlier co-development projects, and by perceived open information sharing and mutual trust. During the initial analysis, another supplier (Supplier B) was included in the study, because it welds and paints some of Supplier A's products into sub-assemblies for the manufacturer. These three businesses are located within 1 km of each other. This relationship is illustrated in Figure 1.

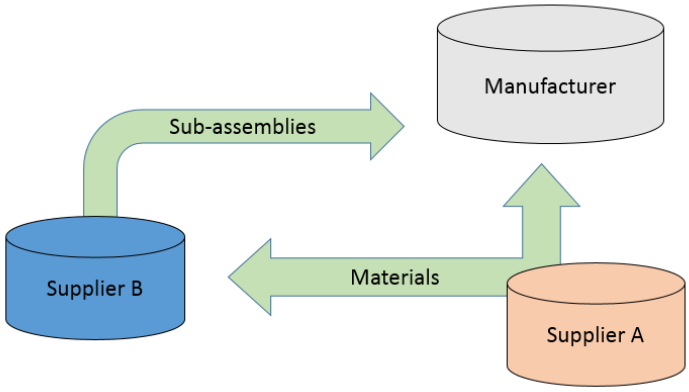

Figure 1 – The case environment

The manufacturer produces configured machines for customers worldwide; it is one of the market leaders in its niche with a turnover of around 500 M€. Its production and factory are built around JIT concepts. Roughly half of the materials used in production are sourced from local suppliers, a vast majority of which are from domestic suppliers.

Supplier A is a medium-sized subcontracting partner for machine building companies and other companies in the metal industry. It focuses on system and component deliveries as well as various cutting methods. Supplier A delivers different sheet metal parts and machined parts to the manufacturer.

Supplier B is a small short-run contract manufacturer of metal products and their sub-assemblies. It produces welded and painted sub-assemblies for the manufacturer's products.

To further understand the current situation from the viewpoint of these three companies, interviews were conducted in February 2019. Additionally, the courier responsible for the logistics between the three companies was interviewed. A summary of the interviewees is presented in Table 1.

Table 1 – The interviewees

Company	Role
Manufacturer	IT project manager; buyer; logistics engineer; director, supply chain; country director; production planner; development engineer
Supplier A	Development manager, production planner
Supplier B	Factory manager
The courier	Logistics operator

The interviewees received a short list of topics that will be discussed in this paper; these topics varied depending on the person's title/position/working area. The interviews lasted between 45 minutes and 1.5 hours. A total of 10 interviews were conducted with 13 participants. All the interviews were recorded, except for the telephone interview with the courier. The manufacturer and supplier A also shared supporting materials, such as inventory, order, and production data, via email.

A more detailed view of the problem was obtained based on that information, and it is presented after the description of the current situation. A simulation model was created, using the AnyLogic simulation software, to further analyze and illustrate the coordination of materials between the manufacturer and Supplier A. The assumptions for this model were based on the collected data.

The current situation from all perspectives

The manufacturer

The order-to-delivery process begins when a customer confirms the order and a bill of sale and the machine configuration chosen by the customer are sent to order processing. The order is entered into the factory's production system and scheduled according to the agreed upon delivery date. This information is also visible to the suppliers through the Extranet. After the sale, the customer can change the order up to three months before the shipping date. Typically, the 12-week production schedule is only subject to minor changes.

Fixed four-week production plans are generated based on the 12-week plan, and they include detailed production plans that are scheduled backwards using the target shipping dates. After an order is entered into the four-week plan, orders for the suppliers' parts are generated automatically. The four-week plan is changed only in special conditions, such as material shortages. For example, the production sequence can be changed to avoid idle time. Suppliers can view the 12-week and four-week production plans via the Extranet.

The manufacturer purchases components from Supplier A in two ways. Cut parts for welding form 80% of the quantitative order volume. These are ordered through the Extranet as automated orders, and the system provides shipping documents that the supplier attaches to an order. If the supplier meets the required quantity and delivery date, no further communication with the manufacturer is needed. The courier visits the suppliers' premises four times daily, so the suppliers do not have to order deliveries; they only prepare them for pick-up. Bulk items are ordered manually via the Extranet based on their re-order points; they have to be manually processed by the supplier's buyers. In

terms of order lines, the volume of these orders is very small in comparison to automatic orders.

The four-week production plan can fall behind the target date, for instance due to a sequence of particularly demanding machines, breakdowns, material shortages, or faulty materials. Weekend shifts are scheduled to catch up. This provides a significant temporary boost to the weekly capacity. These fluctuations are not visible in the Extranet, so suppliers are unaware of manufacturer's current demand; they follow the orders from the four-week plan. This problem is caused by the interface between the manufacturer's and the supplier's IT systems; schedule changes do not update existing requests; instead, they create new material requests without removing the now outdated ones. Deliveries arriving earlier than needed create extra inventory. This is particularly troublesome because the production facilities are designed for JIT deliveries, and there is no dedicated inventory space in all of the production line steps. Moreover, this requires extra manual work for coordinating production and communicating changes to the suppliers.

Supplier A

Supplier A reads the automated orders from the manufacturer seven workdays in advance from the Extranet using an automatic order-reading tool. The orders are scheduled in line with the logistics arrangement (date and time of delivery) between the manufacturer and Supplier A. A large percentage of A's parts are needed for early production stages, meaning that deliveries are scheduled for 1.5 weeks before a machine is finished. For the four-week plan, this means that Supplier A's effective planning window is 2.5 weeks. In practice, Supplier A has chosen to use the first week from that window because accuracy decreases as the number of weeks increases. The delivery capability is managed with safety stocks to allow timely delivery and reaction to fluctuations in demand. Because Supplier A's lead times, including order processing and production planning, vary from four to nine days, this is seen as a necessity. Safety stocks usually accommodate six days of estimated average demand.

Even in a one-week planning window, schedule or quantity changes in orders are sometimes needed. The more changes are required, the more challenging it is for a supplier to schedule production and manage inventories. Every day, Supplier A receives 400 to 500 new order lines. A line is a specific item for a specific machine, and the quantity varies depending on how many units is required for a product. The production planner relies on the automated order-reading system to determine if a line is not in stock or if it will drop the stock level below the re-order point. Consequently, roughly 50 to 80 lines need to be scheduled for production/day. The time required for the planner to process these orders is about one hour/day. The manual orders are handled by sales; these require a similar amount of work.

Supplier B

The manufacturer orders sub-assemblies from Supplier B via the Extranet; these orders are also processed using an automated order-reading tool. As with Supplier A, these are scheduled so the date and time of delivery are indicated. The materials that Supplier B needs to produce the sub-assemblies come from Supplier A. Their lead times can be up to 2.5 weeks, including Supplier A's lead times; however, Supplier A keeps safety stocks to expedite the lead times. Supplier A can see the manufacturer's demand for Supplier B's sub-assemblies in the Extranet. This view is offered by the manufacturer, but it does not include a bill of materials for Supplier A's parts. Consequently, Supplier B orders parts from Supplier A via e-mail, and the orders must be processed manually.

Logistics

Logistics between the manufacturer and the suppliers are handled by a local logistics operator. Deliveries to the manufacturer are made four times/day; deliveries between supplies are made twice daily. The courier picks up materials at Supplier A, then at Supplier B, before driving to the manufacturer's receiving dock.

When a supplier prints out the packing list to pack an automatically generated delivery, the manufacturer's buyer can see the status of the order as "Packing list generated". Once orders are packed, the courier picks them up during the supply runs. The delivery pick-up times are color-coded. Delivered orders are signed in at the manufacturer's receiving dock, and entered into the inventory system. However, this information is not visible to the buyer. If a delivery is missing from production, emails and phone calls are required to determine its location.

A more detailed problematization

Based on the interviews and auxiliary data, we were able to summarize the key issues affecting transparency, responsiveness, and material flow in this case. Some of the issues are not strictly about transparency; rather, they are about the prerequisites for extracting value out of improved transparency. A summary of these key points is presented in Table 2.

Table 2 — Key issues

	Issue
Manufacturer	Production falls behind schedule Limited room for inventory in the production facilities Buyers cannot access the delivery information from the IT systems
Supplier A	Cannot exploit medium- or long-term visibility of demand Safety stock ties up working capital Long production lead time
Manufacturer-Supplier A interface	Schedule status cannot be relayed due to IT system limitations Supplier A delivering according to the production plan causes excess inventory for the manufacturer
Supplier A-Supplier B interface	Demand for Supplier A's parts going through Supplier B is not automatically relayed, resulting in a need for manual order processing work

As seen from Table 2, the key issues are related to IT systems and production capabilities. The IT-related issues relate directly to transparency and indirectly to operations. The production capability issues hinder the utilization of transparency.

Simulation modelling

A simulation model was constructed to support additional analysis of the information and material flows between the manufacturer and Supplier A. The model was based on the available data and discussions with the manufacturer and Supplier A. It addresses several of the issues listed in Table 2: transfer of real-time production status, production rate variability, lead times, and stock levels. The simulation interface is presented in Figure 2.

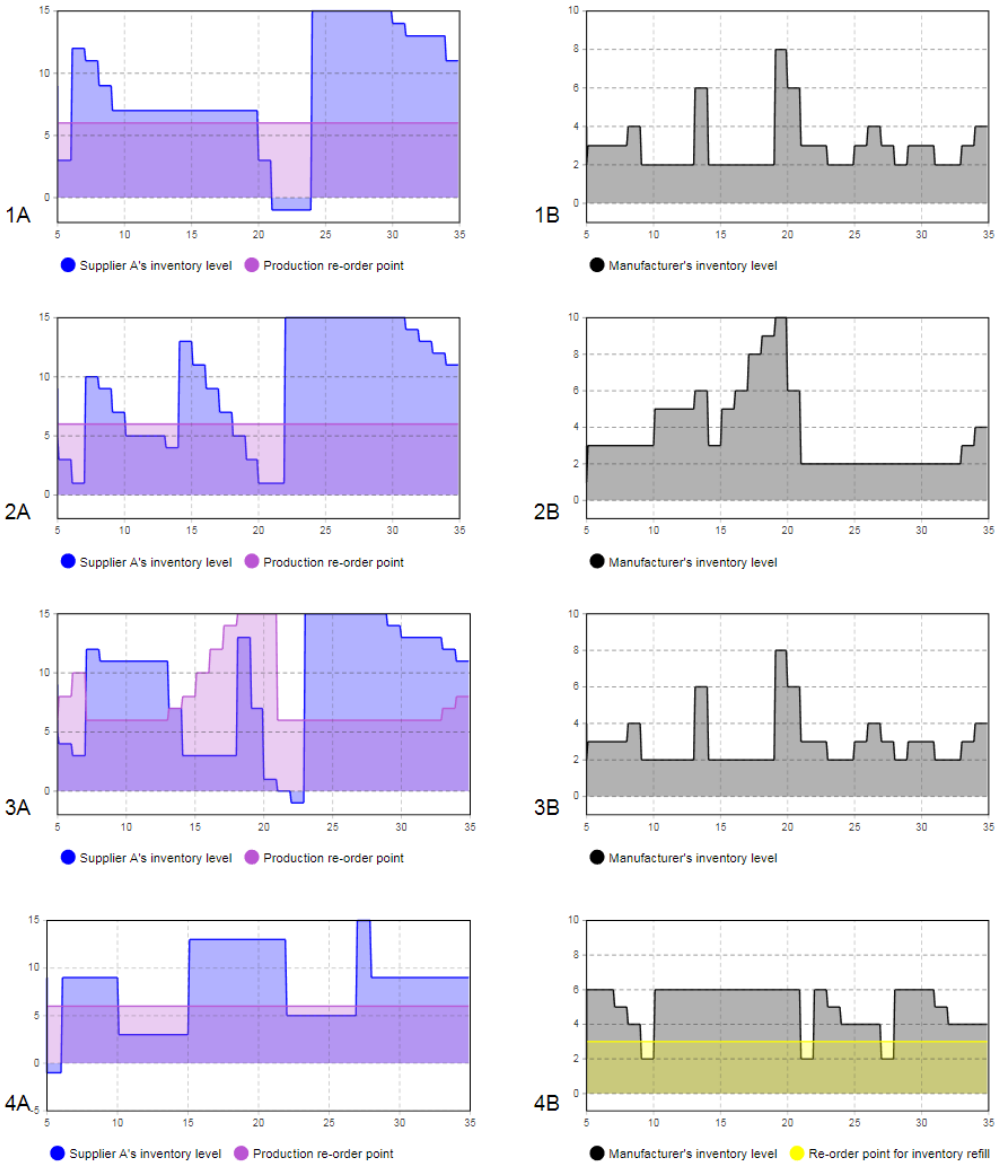

Figure 2 – The simulation interface

In the model, the manufacturer has a demand that is relayed to the supplier. The supplier's operations are defined by three parameters, production lead time, re-order point (ROP), and a re-order quantity, which can be interactively varied. The resulting view compares four different scenarios of how supply and demand is coordinated with the supplier's inventory levels on the left (xA) and the manufacturer's inventory levels on the right (xB).

Scenario 1 has the supplier delivering according to the manufacturer's next-day demand. The one-day delay is based on an actual situation; the time required for picking and packing makes it too challenging to pack and deliver on the same day.

Scenario 2 shows the supplier delivering according to the production plan, without knowing if the manufacturer is on schedule.

Scenario 3 is Scenario 1 with the addition of the supplier accounting for backlog in the manufacturer's production. If backlog exists, the supplier's ROP increases with the amount of backlog.

Scenario 4 features a ROP at the manufacturer's end; the supplier delivers an order with a one-day delay when the manufacturer's inventory falls below the ROP. The amount delivered will increase the manufacturer's inventory level to the target level. A comparison of these four scenarios is presented in Figure 3.

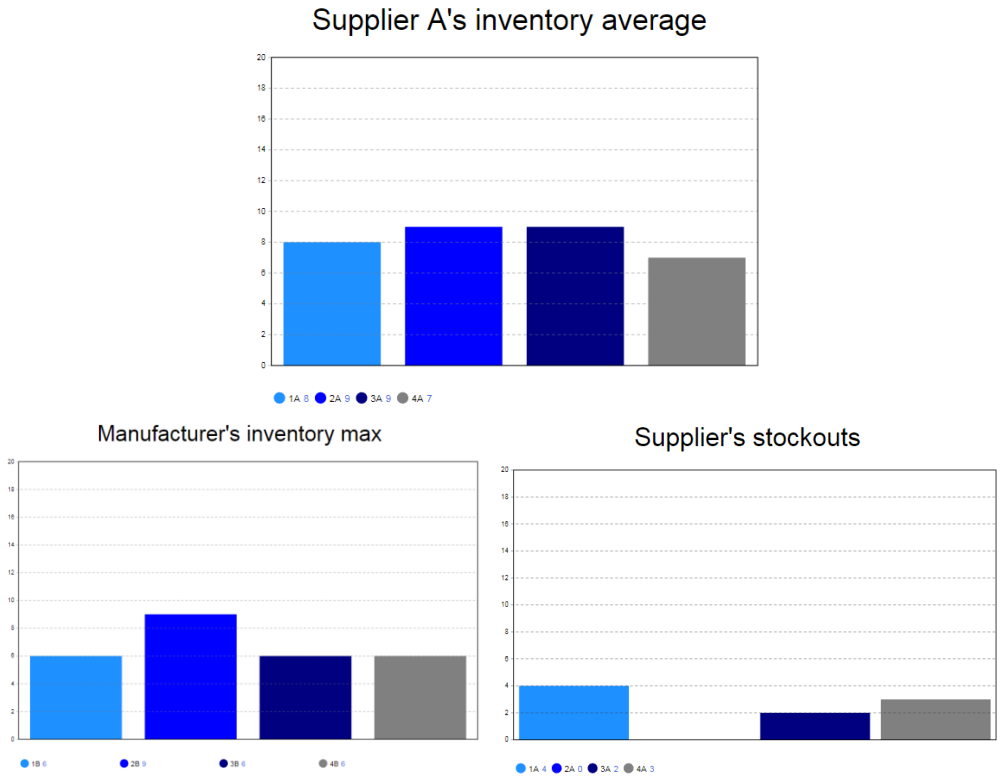

Figure 3 – Comparison of the four scenarios

When only the inventory levels are considered, Scenario 4 is optimal for both the supplier and the manufacturer. For the manufacturer, the maximum inventory level in Scenario 4 will be equal to the target level. Scenario 2 is the least optimal because it has the highest maximum and average inventories.

Considering stockouts, Scenario 2 is the best option with zero stockouts. Scenario 1 is the worst scenario with the highest stockout rate. Scenario 3 has four stockouts, but that is less than the stockouts in Scenario 1.

The simulation model results suggest that if the supplier delivers according to the manufacturer's estimated demand for the next day (Scenario 1 and Scenario 3), counting the backlog decreases the stockout risk at the supplier's end. Although this leads to increased inventory at the supplier's end, it is needed to respond to the demand peak that occurs when the manufacturer produces the machines in the backlog during an extra shift. If the supplier only follows the production plan and the manufacturer does not share its actual demand, this causes high inventories at the manufacturer's end if production is not on schedule (Scenario 2). Scenario 4 is the best solution; the supplier delivers based on real-time information about the manufacturer's inventory level. However, if the delivery delay increases from one to two days in Scenario 4, the supplier's stockouts decrease but

the manufacturer faces a stockout (Figure 4). It is also important to note that changes in the parameters will cause different outcomes. Moreover, it is easy to implement additional scenarios in the model, such as a hybrid of Scenario 3 and Scenario 4.

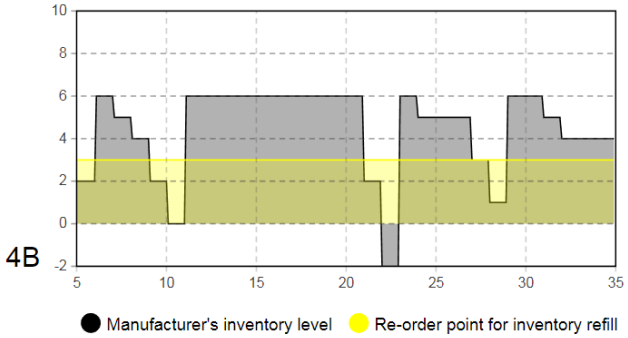

Figure 4 – Outcomes of longer delivery delay in Scenario 4

Discussion

Based on the results, actions can be proposed to improve transparency and the readiness to benefit from transparency. These proposals are presented in Table 3.

Table 3 – Development proposals and possible outcomes

	Action	Impact
Manufacturer	Decrease production variability	Deliveries arrive JIT Suppliers can rely on the production plan No need for extra shifts Reduces the need for manual coordination due to being behind schedule Decreases manufacturer's inventory issues
	Integrate warehouse inventory management with the buyers' IT system	Reduces the manual work of locating deliveries
Supplier A	Shorten production lead times	Increases responsiveness Safety stocks can be decreased
	Reduce safety stock	Frees up working capital Reduces risks of obsolete items (end-of-life parts)
Manufacturer-Supplier A interface	Create visibility for real-time inventory levels/demand	Enables pull Reduces the need of manual coordination due to being behind schedule
	Deliveries based on real-time production status	Decreases manufacturer's inventory issues
	Provide a clearer view of demand for the entire range of parts ordered	Eases medium- and long-term planning Supplier A can decrease safety stocks
Supplier A – supplier B interface	Create an IT solution between Supplier A and Supplier B to relay order information	Lead times are shortened Responsiveness is increased Supplier A can reduce safety stocks Decreases the amount of manual order processing work

As seen in the results and the proposed solutions, transparency is already at a reasonably good level in this case study, apart from some gaps in the systems. Transparency could be further improved by enabling the relay of the current production status, improving the visibility for Supplier A for the bills of materials required through Supplier B, and integrating the inventory system. Solving these issues would primarily be work related to systems; thus, it would not require major changes in policy or processes. Solving the IT-related issues would be the proverbial low hanging fruit, with some immediate effects related to reducing the amount of manual work.

However, moving towards better responsiveness and JIT deliveries is more complex. As the adage goes, inventories are used to cover up issues in the supply chain; this also applies to our case study, at least to some extent. The supply chain works very well as is, and the process is well established. However, Supplier A's inventory is an important link in the chain. It serves both the manufacturer and Supplier B, allowing them to keep little or no inventory, and it safeguards the supply chain from issues, such as not being able to respond to fluctuations in demand due to the lengths of the lead times.

To exploit the full potential of improved transparency, the responsiveness of the supply chain should be improved according to JIT and lean principles. This includes, for example, the reduction of production setup and lead times (e.g., Anand & Kodali, 2009). A key challenge is how to motivate the suppliers to improve their performance in this area. This issue is related to the larger concept of supplier development, which should be of interest to the manufacturer and the supplier if they want to invest in their collaboration. One practical approach would be to explore the utilization of comprehensive collaboration frameworks, such as collaborative, planning, forecasting, and replenishment (CPFR). However, using CPFR also requires supply chain members to have shared targets, interoperable IT systems, and mutual trust (Panahifar et al., 2015).

This study addresses a methodological gap indicated by Fayezi et al. (2017); it provides insight on how transparency and responsiveness issues manifest in a fairly mature supply chain partnership. It also contributes to the literature (e.g., Hilletofth et al., 2016; Sandhu et al., 2013) on using supply chain simulations as "a communicative means between the analyst between the analyst and stakeholders" (Van der Zee & Van der Vorst, 2005, p. 66). The results confirm some challenges related to taking advantage of transparency, such as IT system limitations, internal capabilities, and motivation. These are in line with previous findings (e.g., Akkermans et al., 2004; Butner, 2010; Morgan et al., 2018; Prajogo & Olhager, 2012).

In regards to managerial implications, the results are a good reminder that transparency has limited value. While it has some direct positive effects, such as a reduction in the amount of manual work, to maximize its benefits, the supply chain must be capable of transparency. Managerial tools to achieve this include strategic supplier development (e.g., Krause et al., 2007) and collaboration frameworks, such as CPFR (Panahifar et al., 2015). This is similar to the current hype around digitalization, Industry 4.0, and the Internet of Things: the fundamentals must be in place. The use of digital twins is a recurring topic in the Industry 4.0 discussion; a simulation model could be seen as a digital twin, albeit a simplified one. Simulation can be a powerful tool for analyzing the effects of different collaboration models, such as changes in inventory levels and stockout risks in different scenarios. This is applicable to short-term demand and supply management, as well as long-term planning in cases where significant changes in demand are expected over a longer period of time. The use of simulation can be an important stimulus to motivate improvement.

This paper presents a single case study utilizing mixed methods to investigate a practical supply chain problem. We discussed a set of practical issues related to

transparency, and we presented a case example using simulation models in development work. In a single-case study, the findings are naturally context-related, with limitations on generalizability. Further studies using a similar approach would allow for a comparison between cases and providing the ability to draw more generalized conclusions.

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CREATING AND CAPTURING VALUE IN ORIGIN AGRIFOOD SUPPLY CHAINS: A Multi-stakeholder Perspective

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Abstract

This study seeks to investigate the creation of value in the supply chain, primarily dealing with the Origin Segment. From this, a qualitative approach was carried out to understand how the inter-organizational relational structure contributes to the creation and appropriation of value in these supply chains. Thus, it was concluded that even in a similar relational configuration, the supply chains presented different mechanisms, that in essence facilitate or create barriers in the development of practices that create value, based mainly on two main categories of analysis, being: a) Relationships and b) Identity regional.

Keywords: Multistakeholder Governance, Value creation, and Agroalimentary Chains.

1. Introduction

In recent times, supply chains have allied with new technologies, that allowed them to expand their national boundaries, reaching global levels of production and distribution. However, despite recognizing advances allowed by technology and globalization, there are still a number of problems that persist in reports provided by NGOs such as: asymmetry of power in interorganisational relations, poor working conditions, child labor, among others (Lee, Gereffi, Beauvais, 2010, Oxfam, 2018 and Danwatch, 2016).

Global Value Chain (GVC) is used as a basis to understand the dynamics of supply chains in these markets, especially considering the changes in the field of organizations that have developed new configurations driven by globalization. A GVC consists of the activities by which a product goes through to its end use and thus the importance of interorganisational relationships with different configurations in global context (Lee, 2017 and Gereffi et al. al. 2005).

This study focuses on domestic supply chains which are also embedded in a global supply dynamic. They are supply chains in a specific segment, considering the standard such as Geographical Indication (GI) - denomination given to the products that have

reputation and quality linked directly to a region, that is, to its origin (National Institute of Industrial Property - INPI, 2018).

These agrifood supply chains involve different social actors, not exclusively from the private sector, but also from the local community, the public sector and the third sector, within a complex dynamic of exclusively local production that meets both a niche market of the origin segment and a commodity market, from this, a research question is: How does the interorganisational relations contribute in the value creation and capture in the GI agro-food chains?

Two Brazilian agrifood chains were investigated, the Coffee of Cerrado Mineiro and Cocoa of the Southern Region of Bahia. Specifically, these producing regions present different levels of maturity and are interwoven in different cultural and social contexts.

2. Value in relational structures of multi-stakeholder governance

Agricultural products in recent years have come to use a new approach to governance in their supply chains, mainly driven by addressing sustainability (Schouten & Glasbergen, 2012). A sustainable approach in agrifood chains accompanies a greater interest in the consumption of origin product, valuing certified products, of traceable origin and often with a narrative involved.

Thus, firms have adopted production standards aligned to sustainability, enforcing standards systems and other distinctive labels, often in partnership with NGOs and other local institutions. These collaborative alliances are defined as non-hierarchical and self-organized, in which they use the market as a coordination mechanism to achieve the agreed objectives (Glasbergen, 2007).

Governance from the GVC perspective looks at industries, and therefore can serve as an initial overview to extend the discussion of value creation to other stakeholders along the chain. Thus, in the face of the various organizational and societal challenges, one must go beyond the limits of business in isolation and understand the complexity of collaborative networks in a multistakeholder perspective of value co-creation (Reypens, Lievens & Blazevic, 2016).

Value creation can be proposed in different ways, in the literature the most common types are: a) Value in Exchange (VIE), in which value is the value in monetary and financial terms of a service or product that a company receives in exchange for what they pay for what the market offers (Anderson & Narus, 1998, 54); b) relationship value (RV), the sum of the benefits and the reduction of costs generated in the ongoing exchanges with partners (Lefaix-Duran et al., 2009; Ravald & Grönroos, 1996). As well as, c) Value in use (VIU), the result, purpose or objective reached by the partner from a service or product (Macdonald et al., 2011; Eggert et al., 2018). More recently other types of value have been discussed in the literature, being: a) value of innovation; b) value of knowledge; and c) relational value, among others (Reypens, Lievens and Blazevic, 2016).

The origin supply chain can be interesting to analyze the products related to quality such as GI, it is can be a way to understand these products with high specifications, closer to the fashion and luxury industries (Carvalho et al., 2016). These supply chains operate under a different logic of commodities or mass consumption; it is organized to specific segment of consumption market with price premium. This type of supply chain can create value from the tight relationships between the actors involved in this dynamic, it was showed in the organic segment (Vieira et al, 2013; Carvalho et al., 2016).

Geographical indication has been identified as a possible rural livelihood based on local resources, from the interaction between local knowledge (selection, production and processing) with environmental conditions such as climate and soil. However, the

value create in these products does not accrue for the producers, this can occur due to the lack of regulation and mechanisms of control, the GI can also serve as a tool to face this difficulty of appropriation of value by the producers, providing opportunities to rural communities in order to create and appropriate value, whether economic or other types of value (Pacciani et al., 2001; Bramley et al., 2009)

The structures involves in GI can be characterized as multistakholder. According Hemmati (2002), the term "Multistakeholder" describes a process aimed at bringing together key stakeholders in a new form of decision-making tackling wicked problems. There is a horizontal relationship of responsibility, dialogue and representativeness in this relationship, based on principles such as transparency, participation, partnerships, collaboration and networks of common interest. They may be associated with policies, consensus building, decision making or practical solutions, depending on the nature of the initiative as to the objectives, participants, scope, time and other associated factors. This type of initiative which there is a mobilization of several actors in obtaining and consolidating this distinctive seal, which can be an important catalyst in value creation.

They stand out as the main reasons for participation in value creation in multi-stakeholder initiatives: more reputation enhancement, experimentation and relationship building, and may be linked to innovative practices of resource integration and individual characteristics. It also highlights elements such as trust and social inclusion (Pera, Occhiocupo, Clarke, 2016).

3 Methodology

This study has a qualitative approach, with research design based on multiple case studies (Yin, 2014). From a researched question based on "how", this study can be classified as an explanatory approach. A combination of methodological resources that is capable of providing rigor and reliability to research has been used (Eisenhardt, 1989, Yin, 2014, Stuart et al., 2002, Eisenhardt, 2007 and Machado et al., 2018)

3.1 Selection of cases

The cases were selected from the criteria: products produced in regions protected by geographical indications, which showed growth in the segment of origin, and which are inserted in global value systems. For this, two cases were chosen for analysis, which according to Stuart et. al. (2002), depending on the objective of the study, up to three cases may be satisfactory for analysis.

It is also worth noting that the cases were chosen because they demonstrated different levels of maturity, or management of the geographic indication badge and differences in the type of GI protection, while the Cerrado Mineiro region protected their products through the type of IG "denomination of origin" in 2013, the Southern Bahia region only achieved the same achievement for the type of GI "indication of origin" in 2018. The choice of multiple cases may provide more basis for the construction of a theory, more grounded, accurate and generalizable. Moreover, the choice of polar cases may be an interesting type of structure of analysis (Yin, 2014).

The agrifood chains of origin chosen represent types of products that are part of the historical construction of Brazil, being: coffee and cocoa, located in different regions of the country, one in the southeast and another in the northeast Brazilian.

3.1.1 Case 1 - The Coffee by Cerrado Mineiro

Coffee has a strong historical heritage in Brazil, for a long time the first Brazilian republic had its policy based on the elite of the country concentrated in the southeast region, which controlled the country through an agreement known as "coffee latte policy", this aspect demonstrates the importance that this product had in the country.

The Cerrado Mineiro region is one of the pioneers among the regions protected by geographical indication in Brazil, having been recognized in 2005 as an indication of origin and in 2013 as a designation of origin. The Cerrado Mineiro region encompasses 55 municipalities and involves 4,500 producers and partners, with production reaching 5 million bags with the quality seal of origin, representing 12.7% of the national coffee production. The structure of the Federation of Coffee Growers of the Cerrado has 6 associations of producers, 9 cooperatives and 1 foundation.

The coffee produced in the region is Arabica type, with characteristic marked as coffee of altitude, produced in areas that vary between 800 and 1,300 meters that attributes a very typical flavor of the region. To determine the quality of the drink, it is necessary to achieve a minimum score of 75 quality points in the sensorial analysis. (SEBRAE, 2018, INPI, 2018, Federation of Coffee Growers of the Cerrado, 2019).

3.1.2 Case 2 - Southern Bahia Cocoa

Cocoa has considerable relevance for Brazil, being the fifth largest producer in the world, a large part of its production (90%) is for export (CEPLAC, 2018). For many years' cocoa was a symbol of prosperity for Bahia, where its climate and soil had a good adaptation. Despite this, in the 1980s the region was hit by a disease known as "which broom", which decimated the plantation in the region, however, recently the region has consolidated as a producer of quality almonds.

The southern region of Bahia is made up of 83 municipalities. In addition, it has 14 associations, cooperatives and sectoral institutions, representing more than 3,000 producers in the region. is of humid tropical climate, characterized by the Atlantic forest, with latitudes of 20 degrees to the line of the equator, highly favorable to the production of cacao. The species of cocoa produced is Theobroma cacao. The product of the region has characteristics such as: fermentation index of 65%, and moisture content less than 8% (SEBRAE, 2018; INPI, 2018; Association of Southern Bahia Cocoa, 2019).

3.2 Data collection

The data collection followed a research protocol. We used semi-structured interviews with the main stakeholders involved in the products of origin, being carried out locally in the two regions of analysis (Barratt et al., 2011). In addition, secondary data such as public reports, products of the segment of origin documents, sectors reports and from organizations as a way of triangulating the data were used (Stuart et al., 2002). Thirteen interviews were conducted in Cerrado Mineiro and twelve interviews in the South of Bahia, with an average of 40 minutes, conducted face to face with different local stakeholders, such as producers, cooperatives, government and associations. As can be seen in Table 1.

Table 1 - Interviews conducted in the field

The Coffee by Cerrado Mineiro		
Stakeholder	**Interviews**	**Hours**
Producer	03	46 min
Cooperative	05	125 min

Producer association	01	38 min
Companies	04	115 min
Southern Bahia Cocoa		
Producer	07	217 min
Cooperative	01	42 min
Producer association	01	57 min
Companies	02	258 min
Public agencies	01	71 min
Total	25	969 min (16h15min)

Source: The author.

3.3 Data analysis

Data analysis was done using content analysis and case analysis (Eisenhardt, 1989; Duriau et al., 2007). And, therefore, the following steps were followed: a) transcription of the interviews; b) organization and renaming of interviews; c) data coding; d) interpretation of the data through categories.

From the interviews, governance and value issues were grouped, and thus, they initially formed the subcategories, later they were grouped into larger dimensions, forming the categories of analysis.

4 Results

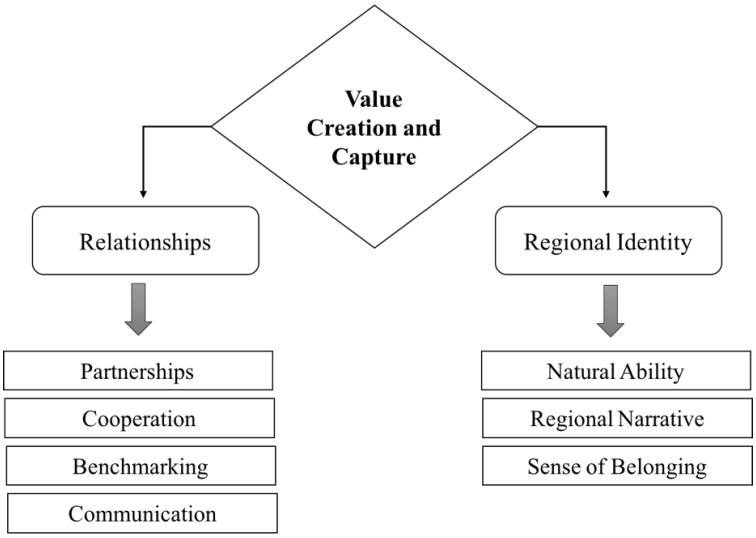
Value chain literature has been based on relational value, the relationship through the integration and cooperation between several players can create more value (Miguel et al., 2014). The interorganisational relationships found were between producers, between regions (benchmarking) and between public and private institutions (in the form of local partnerships). The research data evidenced the importance of relationships and regional identity in the supply chain for value creation and capture, highlighting four constructs that influenced in the value from relationships: partnerships, cooperation, benchmarking and communication, and three constructs that influenced in the value from regional identity: natural ability, regional narrative, sense of belonging.

In the ***Relationships*** category, each subcategory represent base to understand how occurs these relations in producer region for value, such as: cooperation is fundamental objective of supporting the other members of the supply chain, characterized as interaction, collective marketing and legitimation from standards. Benchmarking is used in relationships between individuals in the supply chain, in this category the observation and replication of other stakeholders or other agrifood chains about experience and maturity. Communication is the ability to articulate either by conducting training or events in the region that stakeholders have the opportunity to learn from the exchange of information, these spaces of dialogue facilitate the capture of value, through the exchange of knowledge and experience that these environments provide.

In the ***Regional identity*** category was an attribute highlighted by interviews in the process of creation and capture of value as these agrifood chains have high dependence on regional and natural factors, such as climate, soil and other factors, they have been categorized as a natural ability. The second subcategory observed in the interviews was the capacity of narrative through regional history, an asymmetry in the capture of value in these chains was perceived, as a basic characteristic of the geographical indication to communicate the history of the region. The third subcategory is about sense of belonging,

the importance of this feelings is to involves the local actors in the same main questions, it can be important for the regional narrative. In the Figure 1 is possible to observe the organize of categories of analysis.

Figure 1 – Categories of analysis



Source: The authors.

4.1 Inside the categories

4.1.1 Relationships

The importance of interorganisational relationships is already highlighted in the literature through relationships and interfirm with different configurations (Lee, 2017; Gereffi et al., 2005). This means that the value generated by the relationship between the companies can not be obtained individually by the agents; they are the result of the combined resources of the agents. Developing relationships, alliances with vendors that have the key features, or even additional features that will be added, are essential in the competitive landscape (Dyer & Singh, 1998).

The importance of the relationship in the supply chain for generation and capture of value was highlighted through cooperation, partnership development, benchmarking and training in an integrated and formalized way.

In the cocoa chain relationships are not yet structured to capture value, there are benchmarking initiatives and cooperation with purpose to create value. However, in general the perception of value creation in relationship structures such as cooperation, partnerships and benchmarking are not sources of value capture, the main reason is highlighted as the disarticulation between members with greater technological capacity and know-how.

"A lot of people from here sell from there ... not can I get there" (RC).

The relationships in the coffee chain are structured with the purpose of creating and capturing value, the links are engaged and articulated so that the practices are disseminated to the links. This value created through relationships enables a strengthening in operations, bargaining power and is mainly perceived as an improvement in quality.

> *"That alone will never be too, much more difficult to achieve as well. So if we unite, we, the union makes the force, the union makes us strong" (SPSH producer).*

In these regions, the presence of the universities, innovation centers and public agencies are important to share the knowledge through events and others initiatives to mobilize the local stakeholders to exchange information's, experiences, best practices, these dynamics can be explained by knowledge value in this type of network (Reypens et al., 2016). It is can reinforce the sense of belonging and helps in the construction of narratives.

Benchmarking was captured in the interviews to demonstrate the importance of the other cases in the same structure from GI, but in the other maturity level. The coffee chain used the practices from wine chain - *Vale dos Vinhedos*, the first GI recognized in Brazil as example of structure in interorganisational cooperation, technical infrastructure and local narrative. The cocoa chain has been inspired by practices from the *Cerrado Mineiro* to strengthen the communication about the region.

4.1.2 Regional Identity

For agrifood chains, regional identity has a specific character, based on the interaction between local know-how (including selection, production and processing) and specific environmental conditions such as soil and climate (World Bank Report 2004). The value of traditional products has increasingly been associated with products that can be associated with a particular location and / or special means of production (Ilbery and Kneafsey (1998)).

A process of crisis of regional identity in the cocoa chain has been identified, local actors have highlighted challenges to better structuring the standardization and communication in the region. The cocoa chain, although historically well-defined is still little explored by the actors as a reputational differential, the crises that marked the sector are present in the discourse of the interviewees as a negative attribute to the region, increasing the insecurity and credibility. The reputation is indicated by the quality of the product, however the process proposed by the geographical indication, corroborates for a formalization of the relationship between the product and the region and / or tradition, in this process the use of legal instruments guarantees the capture of due value (Arora , 2009).

> "*And that was historic, a long time ago it was very bad, but no one ever proved that it had already changed." (University)*

> *"It's a region that has suffered a lot from the past" (Company 1).*

However, it was noted that there is a process of reformulation in the value proposition in the region with private initiatives, for example the tree-to-bar proposal in which the producers themselves manufacture chocolate, the events also as a way to attract visibility to the region and strengthen relationships in the chain.

An influence of the natural vocation of the chain was verified as an important and determinant factor for the quality of the product, however this character is little explored in the creation of value for the region.

The issue of belonging is associated with the reputation that the chain has, the ability to recognize itself as an actor in the chain causes a greater disarticulation between the actors. According to the interviewees' discourse, this is one of the main factors hindering the capture of value in the region.

In the coffee chain, this scenario is the opposite, regional identity has been highlighted by the positioning of value capture, the region has a greater structure of communication focused on the specifics, as well as narrative to create a value for the product to the external public, less focused in the regional social aspect, but in the quality of its product.

5 Conclusion

On supply chain relationships literature from Lee (2017) and Gereffi et al. (2005), that can be extended to the dynamics of supply chains in the origin segment, more specifically the geographic indications, is possible to observe that do not have partnerships in the cocoa chain through projects between cooperatives and leader's companies in the industry (Considering the presence of these companies in the region such as Barry Callebaut, Cargill and ADM). The relationships are not integrated along the supply chain, there is a greater need for presence and performance of public institutions. Likewise, governance is guided by the incentive of public institutions to strengthen the generation of value through natural resources and the narrative of the region.

On the other side, in the coffee chain occurs predominantly through investments, innovations and a variety of standards (public and private) categorized by a value enhancement. Some multinational companies have projects in partnerships with local stakeholders such as cooperatives and producer's association. The Governance is driven by the performance of private companies, promoted and the most presence of leader players.

According to Pacciani et al. (2001) and Bramley et al. (2009), it can be concluded that in the case of origin coffee and cocoa, the GI is mechanisms to protect the local producer, it is can facilitate the development of practices that create value, the formalization of the geographic indication standard can be considered as a first step value-oriented. It must be considered that all the local effort in obtaining the geographical indication seal presents a first avenue in the creation of value at the network level, mainly because it is linked to issues such as quality, reputation, traceability and sustainability, however, only the seal does not ensure that the value is perceived and that larger financial gains have been made on a large scale.

However, about the GI and value appropriation as proposed by the authors Bramley et al. (2016), in the cocoa chain the producers do not appropriate for value added along the supply chain, it is different in the coffee chain, here the producers have more presence, and can be observe more organization to add economic value in the origin products.

The Relationships within this type of supply chain are essential if local organizations are to take ownership of the value that is created, so these points become clearer when looking at issues such as cooperation, partnerships, and information sharing. Cerrado's coffee has performed better in creating partnerships with multinational companies, especially in projects related to sustainability and environmental recovery, as well as private seals that are also adhered to by cooperatives and producers, according to Carvalho et. al (2016), these seals are as high specification guarantees for the market.

It is possible that the result of this study contributes to the understanding of the interorganisational relationships in the value proposition in configurations as in the agro-food chains in the segment of origin. Thus, each category found from this study has an explanatory character about the local dynamics, considering the global circuit from which these chains are inserted.

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Sharing knowledge for customization: a triadic perspective

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Abstract

For customizations where individual customers are involved as early as in design stages, referred to as engineer-to-order (ETO), the ability to effectively share knowledge across organizational boundaries is a necessity. This concerns knowledge shared both in the customer interface and the supplier interface. Different situations may however require different processes for knowledge to be effectively shared. This research proposes a framework for analysing knowledge sharing complexity in ETO scenarios from a triadic perspective. Combined with empirical illustrations, the analytical framework supports in describing scenarios and their implications for effective knowledge sharing.

Keywords: Customization, Knowledge Sharing, Engineer-to-Order

Introduction

Many efforts have been made to understand how knowledge can be created, shared and utilised which has been manifested by the emergence of knowledge management research. Generally, knowledge management research is focused on knowledge itself e.g. its creation or conversion (Nonaka, 1994; Nonaka and Von Krogh, 2009) and/or on the activities involved in creating and managing knowledge to gain competitive advantage (Alavi and Leidner, 2001; Martelo-Landroguez and Cepeda-Carrión, 2016). The ability to create new knowledge enables companies to innovate and it has been suggested that knowledge creation is reliant on the personnel's collective ability to share and combine knowledge (Nahapiet and Ghoshal, 1998; Del Giudice *et al.*, 2013). Furthermore, a shared interpretation of knowledge among personnel supports unified responses that improves operational performance (Fugate *et al.*, 2009). Thus, it can be argued that knowledge sharing is essential for a company's innovativeness (Nonaka, 1994; Del Giudice and Della Peruta, 2016) and ultimately its competitiveness (Crossan and Apaydin, 2010).

To be competitive, a company's governing premise should be to primarily focus on the customers rather than on maximizing shareholder value (Martin, 2010). In embracing the principle of being customer driven, many companies offer customizations and this can be done in various ways and to varying degrees (Lampel and Mintzberg, 1996; Wortmann *et al.*, 1997). When customizing, the specific needs of individual customers must be considered for some of the production-related activities that is to be performed (Wikner and Rudberg, 2005). As the desired outcome is to provide a product that is

satisfactory to the customer, it is of importance that the needs of the customer are clearly understood (Du *et al.*, 2003). If the product is engineered-to-order (ETO), individual customers are involved as early as in the design stage (Gosling and Naim, 2009) and the novelty of these circumstances requires knowledge to be shared across organizational boundaries, but there is limited research into knowledge sharing in the ETO sector.

In ETO settings, knowledge is shared with customers to, for example, reveal flawed reasoning and challenge preconceived ideas about the product requested (Engström and Käkelä, 2019). Conversely, customers share details of their knowledge that must be accounted for, but the importance of knowledge sharing does not only apply to the customer interface. Knowledge must also be shared with suppliers as some procurement activities are performed in line with the individual customer's needs and as engineering decisions made in agreement with customers may be dependent on supply (Tate *et al.*, 2015). If knowledge is not shared effectively in these interfaces, costly errors can be made that has a negative impact on customer satisfaction and this can ultimately deteriorate competitiveness.

To get a holistic view of knowledge sharing in ETO scenarios, and due to the interdependency between knowledge shared in the customer interface and the supplier interface, this research takes the analytic perspective of the supply chain as a triad (See Figure 1). With the triadic perspective on the supply chain, the analysis is focused on the *focal actor* (FA). The focal actor functions as a supplier to the customer actor (CA) but as a customer to the supplier actor (SA). From the FA's perspective, consideration need to be taken both to the customer interface and supplier interface.

Figure 1 – A triadic inter-actor perspective

In ETO scenarios, knowledge sharing is an everyday, practical concern. The products are often 'one-of-a-kind' which means that different customer requirements must be met for the fulfilment of each customer order. In novel circumstances such as these, the complexity and effort required to effectively share knowledge across boundaries increases (Carlile, 2004) but the actors in the triad may have different views on what knowledge that is difficult to share. The purpose of this research is to develop a framework for analysing knowledge sharing complexity in ETO scenarios from a triadic, inter-actor, perspective. Empirical illustrations are made to demonstrate how knowledge sharing complexity can manifest itself in practice. Two research questions have been formulated to respond to this purpose:

RQ1: How can inter-actor knowledge sharing complexity in ETO scenarios be differentiated?

RQ2: How can inter-actor knowledge sharing complexity manifest itself in practice in ETO scenarios?

Combined, the analytical framework and the empirical illustrations supports in differentiating ETO scenarios, suggesting that an important skill for ETO companies is the ability to recognize what is required for effective sharing of knowledge across organizational boundaries in different situations. To be able to promptly identify circumstances that impacts knowledge sharing complexity can be critical for a company's ability to provide products that satisfies customer's needs.

Methodology

This research has been carried out in two main segments; the first adopting an analytical conceptual approach for theory development (Wacker, 1998), resulting in the development of an analytical framework, and the second relying on empirical data to check the validity of the framework. The research therefore has a deductive approach, where the analysis of empirical data has been based on the analytical framework.

In the first segment, the analytical framework (see Figure 3) was developed to describe the phenomenon of interest. The framework was based on current literature on knowledge sharing complexity and integrated with a triadic, inter-actor perspective on ETO scenarios. With the intention to not only accurately describe the phenomenon as such but also to explain how it works, the second segment of the research included empirical illustrations from four ETO companies. The empirical illustrations act as examples of how different scenarios discerned in the analytical framework may manifest themselves in practical embodiment. The empirical data used for these illustrations are of qualitative character and have been collected from two workshops where representatives from the four companies have jointly discussed issues related to knowledge sharing in their customization practices. In the workshops, the researchers and company representatives shared experiences and jointly discussed the problem at hand. As illustrated in Figure 2, the first workshop consisted of general discussions about sharing knowledge across organizational boundaries. After the first workshop, the company representatives were given an assignment to prepare and present at the second workshop. The assignment was based on the critical incident technique (see e.g. Flanagan, 1954; Davis, 2006). The participants were instructed to select and describe customer order incidents or scenarios they had perceived as challenging in terms knowledge sharing with customers and suppliers. In this way, the discussions in the second workshop revolved around concrete descriptions of situations where the complexity of knowledge sharing became apparent.

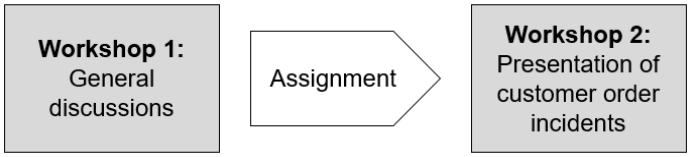

Figure 2 – Data collection procedure

The four companies represented in the workshops are all industrial business-to-business companies of which large parts of the business is comprised of ETO deliveries. The companies are however quite different in other respects, such as number of employees and type of product, as seen in Table 1. Each company had one or two representatives participating the workshops, all with managerial roles with a holistic understanding of their customer order fulfilment process.

Table 1 – Participating companies

Company	Type of product	Employees (approx.)	Role of representative(s)
Company Beta	Doors and gates	25	CEO and Sales
Company Gamma	Network equipment	100.000	Materials manager
Company Delta	Industrial equipment	400	Quality Manager and Business Manager
Company Epsilon	Heat exchangers	150	Customer support manager and customer support

Theoretical framework

Knowledge sharing complexity

Knowledge sharing is a knowledge management-related issue. As the centrality of knowledge in organizational practices have been more evidently recognized, knowledge management research has gained interest in a variety of scholarly domains (Paulin and Suneson, 2015). Efforts to manage knowledge are taken by organizations with the intention to leverage between differentiated knowledge held by employees, to integrate knowledge that exists outside the organization, to develop new knowledge, or to put knowledge into use in ways that advance organizational goals (Davenport and Prusak, 1998; Barley *et al.*, 2018). In other words, the essence of organizational capability relies not simply on the possession of unique knowledge, but rather on the ability to integrate individuals' specialized knowledge to achieve capabilities that other firms do not possess (Nonaka, 1994; Grant, 1996). Accordingly, to understand how knowledge can be effectively shared is of utmost importance.

Knowledge sharing is a frequently used term in knowledge management research but there are some sources of confusion regarding its precise meaning (Paulin and Suneson, 2015). One issue concern how knowledge sharing relates to knowledge transfer. These terms are sometimes discussed interchangeably (see e.g. Jonsson, 2008; Liyanage *et al.*, 2009) but they can also be seen as having different meanings based on the view and understanding of knowledge (Paulin and Suneson, 2015). A distinction can be made between the view of knowledge as an object and the view of knowledge as a subjective contextual construction. When knowledge is viewed as a subjective contextual construction, researchers tend to be more drawn to the term knowledge sharing (Sveiby, 2007), resulting in a clearer emphasis on e.g. sensemaking of situations and creation of shared meaning in this stream of research. Another important distinction made is between knowledge sharing and information transfer. While information transfer explicitly refers to the relay of codifiable information or knowledge, knowledge sharing also includes the contextual understanding required to effectively interpret the information and make sense of it.

Activities that supports sensemaking is critical in contexts where there is a need to create and maintain coherent understandings for collective action (Weick, 1993; Weick *et al.*, 2005). Working across functional or organizational boundaries is a key source for innovation but it also implicates that actors with different specializations or interests join in a common task. To effectively share knowledge across boundaries can be challenging as the heterogeneity among the involved actors may require an integration of incompatible perspectives for a shared meaning to be attained (Bechky, 2003). The complexity of the processes required to share knowledge across boundaries is relative to the difference, dependency and novelty of the circumstances around the boundary (Carlile and Rebentisch, 2003). Carlile (2004) suggested three progressively complex processes for sharing knowledge across boundaries; to *transfer*, to *translate* and to *transform* knowledge. When it is insufficient to just *transfer* knowledge, interpretative differences as to what for example a word or a customer requirement means calls for processes or mechanisms that help *translate* the differences to create shared meanings (Dougherty, 1992). If there are substantial discrepancies between the different interests that hinders the development of shared meaning, the involved actors must negotiate, make trade-offs, adapt and *transform* their knowledge to define a common interest (Brown and Duguid, 2001). Such discrepancies can for example occur when knowledge developed in one domain are incompatible or have a negative impact on knowledge developed in another

domain. To understand what consequences domain-specific knowledge can have on the task at large is thus crucial as it allows for the knowledge to be transformed accordingly (Carlile, 2004).

Differentiating ETO

To offer customizations can contribute to companies' competitiveness as customer get the opportunity to influence the form of the product they procure. Customers can get involved at different stages of the production and if they are involved as early as in design stages, it is commonly referred to as a ETO scenario (Giesberts and Tang, 1992; Hoekstra and Romme, 1992). In ETO scenarios, products are tailored according to the needs of individual customers which means that design, engineering and production activities are performed in response to a customer commitment. The operating environment is therefore to a large extent characterized by the uncertainty of not knowing what to produce in advance (Bertrand and Muntslag, 1993; Gosling *et al.*, 2013; Gosling *et al.*, 2015).

While there are similarities between individual ETO scenarios, there are also factors that distinguish them. ETO does not only concern cases where completely new designs are developed for the individual customer but also when modifications are made to existing designs (Wikner and Rudberg, 2005; Gosling and Naim, 2009). Distinctions between ETO scenarios have also been made based on the degree of vertical integration, source of competitive advantage and core competencies (Hicks *et al.*, 2001). Product complexity and level of detail in specifications from customers are also aspects that differ (Bertrand and Muntslag, 1993). For example, functional specifications that merely describe what the product should do enables the supplier to propose innovative solutions and their own design. On the other hand, detailed specifications also describe how the product should do it, which may limit the suppliers influence on design (Hicks *et al.*, 2000). The information available for the product may also vary in commonality, some being only applicable for the specific customer order, some being applicable to a certain customer and some that is independent on the customer or customer order (Wikner and Bäckstrand, 2012). There are also differences in terms of relationships with suppliers, varying degrees of customization for purchased components, extent of collaborative measures, balance of power and the importance or value of particular components (McGovern *et al.*, 1999).

Sharing knowledge for customization: an analytical framework

The triadic perspective of this research is adopted to account for that knowledge shared in one of the FA's interfaces sometimes need to be considered in the other interface. Knowledge shared by the SA may for example have a major impact on the product at large and can sometimes force the FA to involve the CA in redesigning the product and vice versa. To fulfil the customer order and provide a product that is satisfactory to the customer, the FA must together with the SA and CA take initiatives to make differentiated knowledge (e.g. domain-specific knowledge) integrated knowledge (knowledge held in common). However, the efforts required to effectively share knowledge across boundaries differ. In Figure 3, a triadic perspective of knowledge sharing is considered with regard to Carlile (2004) three levels of complexity for sharing knowledge across boundaries.

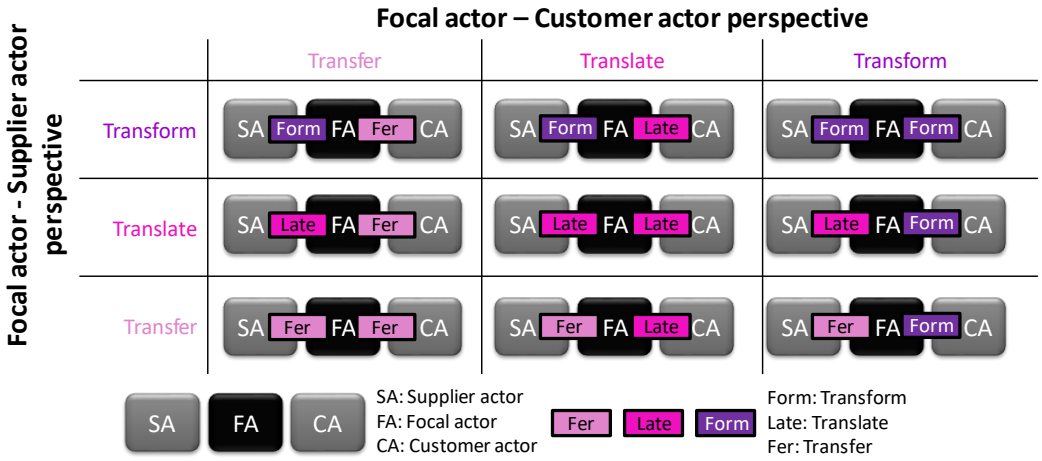

Figure 3 – Triadic perspective of knowledge sharing complexity

Empirical illustrations

The empirical illustrations in this section serves as support for the applicability of the analytical framework. All illustrations are based on the customer order incidents the companies described in Workshop 2. Relating to Figure 3, they are presented from bottom left to top right with the sub-headings indicating that the SA-interface is followed by the CA-interface as logical in the down-stream materials flow direction. However, the actual illustrations are described in the opposite order to better represent the sequence of events, as logical in the up-stream information flow direction.

Transfer - transfer:

This is a situation that can occur in ETO settings when the FA's relation to both customer and supplier is established and stable. The organizational routes for knowledge sharing are known and knowledge that are specific for the customer order can be shared in codifiable form. For Company Beta, this is a typical scenario when they sell doors to end-customers through one of the qualified carpenters they collaborate with. They have long-term relationships to the carpenters that shares a common understanding of the product to the degree that they can discern what knowledge that needs extra attention when shared. The level of novelty and difference is hence low. In the supplier interface Company Beta purchases standard wooden raw materials and only need to transfer what they need, when they need it and how much they need. In the supplier interface it is hence usually sufficient for Company Beta to transfer knowledge.

Transfer - translate

Company Beta have another type of relationship with customers that purchases doors as a representative of a tenant owner cooperation. These customers are usually novice when it comes to knowledge about the product and the relation to the customer is usually new. Company Beta's ability to translate knowledge about the product to the customer that can support the customer's decisions about product requirements is of critical importance for this customer segment. When the customer expresses their needs, there is usually a process of translation as the explanations sometimes leave room for interpretative differences. As stated in the previous paragraph, the knowledge shared in Company Beta's supplier interface can simply be transferred as there are no considerable novelty in terms of supply.

Transfer - transform

Once again Company Beta will be used as an illustration, which emphasizes that it is sometimes beneficial for a company to have different approaches to knowledge sharing depending on the circumstances of the boundary, in Company Beta's case dependent on

the customer segment. Company Beta's third customer segment is large construction firms and although these relationships are rarely entirely new, these firms usually have several liaisons which complicates knowledge sharing. Additionally, the liaisons are often changed during the order fulfillment process. The customer requirements are received from architects and they generally call for a high degree of customization which sometimes conflicts with the construction firm's emphasis on timed deliveries that are to be coordinated with other deliveries to the construction site. Company Beta is hence dependent on their customer to be able to deliver. Neither the large construction firm nor the architect is novice per se, but their knowledge can sometimes be incompatible with each other but also with the product specific knowledge held by Company Beta. This requires negotiation and trade-offs, often in terms of product design, cost and delivery time. This is demanding and since there are several liaisons involved with different interests, there is usually someone who is not entirely satisfied. As stated previously, the knowledge shared in Company Beta's supplier interface can simply be transferred as there are no considerable novelty in terms of supply.

Translate - transfer

For Company Epsilon, this situation occurs when orders received are just slightly different from existing designs. It is therefore sufficient for the customer to transfer their knowledge about their needs as long as Company Epsilon is familiar with the context of which the product is to serve in. The novelty in the customer interface is therefore not significant and the adaptations to the existing designs is relatively easy for Company Epsilon to understand. However, if the customer demands for example a material certificate for the product, Company Epsilon must make efforts to translate knowledge about what this implies for the specific customer order to its suppliers. Requirements that are seldom demanded, such as a material certificate, implies a novelty and Company Epsilon cannot assume that the suppliers are knowledgeable about why the material certificate is of great importance in some cases, but not always. For this reason, Company Epsilon makes effort to translate knowledge about the customer's context so that the supplier shares an understanding of its importance for the delivery.

Translate - translate:

The following example is a case of knowledge sharing gone bad due to misrecognition of complexity. Company Delta often develop completely new designs for customers they have not dealt with before and they are known for being able to deliver high quality and conform to strict standards. In this case, a customer from a business segment they had no previous knowledge about requested a seemingly simple product. However, it turned out that products for this business segment were required to follow specific laws and regulations that were unlike those standards Company Delta had experience of. This knowledge was not shared or requested until it was too late, as the novelty of the circumstances were not recognized by either Company Delta or the customer. Consequently, this knowledge was not shared to Company Delta's suppliers either, who delivered parts that did not comply with the regulations for this specific customer order.

Translate - transform

Company Delta also has a recurring customer that have particularly high demands on quality and documentation. The products ordered are complex, and the customer usually have a lot of knowledge about it. Due to their high demands on quality, this customer tends to be persistent in adhering to requirements established early in the process. As knowledge have been developed at Company Delta during the order fulfillment process, these requirements may however not be compatible. This force Company Delta and their customer to resolve their different interests and transform their respective knowledge

accordingly. In the supplier interface, Company Delta had to translate this knowledge so that the suppliers could adapt.

Transform - transfer

In this scenario, Company Gamma were to provide a relatively simple product which was a view initially shared by the customer and Company Gamma. Company Gamma had developed similar products before, and the customer order were for this reason taken somewhat lightly. During the process it did however become clear that several conflicting interests from the suppliers had to be resolved which was not anticipated from start. One of the main reasons as to why these issues were not anticipated was because the standards of the encompassing systems that the product were to be integrated to were quite different from what Company Gamma had experienced before. There was this a high degree of dependency between this product and its interfaces. While Company Gamma had to engage in negotiations with suppliers, the customer was still under the impression that there were no significant complexities that Company Gamma would have to confront. Company Gamma knew that the customer had high quality requirements and that they were not willing to settle for less than was agreed to from start. Rather than approaching the customer to explain or negotiate, Company Gamma put a lot of pressure on their suppliers to solve problems which was possible due to the power balance between the actors.

Transform - translate

For this scenario we did not identify an illustration through the critical incidents presented by the companies in Workshop 2 but will instead present a scenario based on logical reasoning. This scenario can occur when the FA has an established relation with the customer. The customer has high demands and is requiring something novel to the extent that knowledge must be translated in the customer interface. Let's now assume that this specific customer order requires a new supplier to be included. The knowledge from the customer about the novel product must be shared to the new supplier who may have knowledge that does not comply. This would require transformation of the knowledge shared by the customer and the knowledge shared by the supplier.

Transform - transform

In this case, Company Delta were awarded the business to develop a customer's prototype to a manufacturable product, to find and establish supplier relationships and to develop Company Delta's own manufacturing so that it could ramp up to full production volume. There was considerable novelty both in terms of the relationships with customer and suppliers but also for the product itself. Along the process, Company Delta encountered several issues that required negotiation between the actors to be settled, both with the customer and supplier respectively but also all three parties jointly due to the dependence between the different actors.

Conclusions

The purpose of this research was to develop a framework for analysing knowledge sharing complexity in ETO scenarios from a triadic perspective. This framework was presented in Figure 3 and complemented with empirical illustrations to demonstrate how knowledge sharing complexity can manifest itself in practice in ETO scenarios. A contribution has been made in terms of further differentiating ETO, demonstrating that different ETO scenarios have diverse implications for how knowledge is to be effectively shared across organizational boundaries. A first step towards efficient knowledge sharing for customization in both customer and supplier interface is awareness from the focal actor regarding the current situation. As can be seen from the empirical illustrations, problems occur when an actor underestimates or misjudges the complexity of sharing knowledge

across a boundary. Companies providing ETO products can thus benefit from improving their ability to promptly and effectively identify circumstances in specific customer order scenarios, or for specific customer segments, which impacts the measures required for effective knowledge sharing. This way, the company can plan resources and competences accordingly and build structures for a variety of modes for communication. By being responsive and adaptive to the circumstances, the ability to provide products that satisfies the needs of different kinds of customers can be improved, which is an important factor for the company's competitiveness.

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An Alternative Explanation of Inter-Organizational Management Control: The Psychological Contract

1. Purpose

The construct of the psychological contract has been developed in an attempt to explain why BPO arrangements that resemble each other in terms of the promissory contract between client and supplier can display important differences in relational methods of coordination, conflict resolution, commitment, communication behaviour and cultural adaptation. Recent research (Lioliou et al (2014) into relational governance has used the concept of the psychological contract.to provide a more in depth assessment of the phenomenon. Koh et al (2004) noted that research on managing outsourcing relationships had concentrated either on contractual control methods or on promoting partnership-type arrangements; albeit with later research arguing for a compliment of the two approaches. Lahiri (2016) highlighted that the work of Koh et al (2004) suggests that partners' obligations and their fulfillment predict outsourcing success in a significant way. Lahiri (2016) emphasised that how outsourcing affects the client–provider partnership has not been adequately examined. Koh et al (2004) felt that the body of knowledge overplayed the role of the client i.e. that the supplier was obligated to satisfy the client. Rather, they argued, the client-supplier relationship was an arrangement with mutual obligations. This displays similarity with social exchange theory. However, Koh et al (2004) adopted the theory of the psychological contract as espoused by Rousseau (1989) from the organization behaviour field to support their argument. Contrary to the legally stipulated obligations in the written contract,

the psychological contract focuses on individuals' beliefs concerning mutual obligations resulting from a contractual relationship. Whilst social exchange theory overlaps with the concept of trust as a sociological construct, the psychological contract has more similarity with trust as a psychological construct. Three principles of psychological contract theory are fundamental: (1) a concentration on mutual obligations; (2) emphasis on the psychological interpretation of obligations rather than legal ones; (3) a focus on individual-level analysis rather than at the organization or inter-organization levels. Therefore if the concept of the psychological contract is to be relevant to providing better understanding of outsourcing relationships, these three principles must hold. The purpose of this study is to investigate if such expectations are valid.

2. Design/methodology/approach

A multiple case study approach using several units of analysis was deployed in this study. The unit of analysis was the operational BPO arrangement. This dyadic relationship was studied from the perspectives of the client recipient and the service provider. The case studies were: (1) National Broadcaster – BPO1, 10 year contract worth £100 M to provide HR administration, EU; (2) Healthcare Provider – BPO 2, 7 year contract worth £48 M to provide HR administration, USA; (3) Investment Bank – BPO 3, 10 year contract worth £63 M to provide HR administration, USA; Oil Company – BPO 4, 5 year contract (value undisclosed) to provide F&A, HR and C&P administration, India. From the client perspective, the sub-units of analysis were the managers responsible for managing the outsourcing contract and its implementation; generally HR personnel. From the service provider perspective, the sub-units of analysis were

front line management and staff; team leaders and team members who had the greatest levels of interaction with the client across a range of management layers. The case study protocol resulted in the same interview schedule being used throughout the research study. To enhance the validity of the information collected in this research study, multiple sources were used. The perspectives of at least two managers from each of the client and supplier organizations were collected; in the case of the supplier organization, at least one of the managers would be a first line Team Leader with greatest levels of interaction with the client. Data was collected from at least two client-facing team members involved with service delivery in the supplier organization. In addition, each participant was offered the opportunity to read and comment on their interview transcription and the researcher's field notes in an attempt to reinforce the internal validity of the data collected. Some informants did make additional comments after the initial interview and this helped to clarify their opinions.

3. Findings

It had been the expectation at the commencement of the data collection process that an investigation of four similar transactional BPO arrangements with comparable outsourcing objectives would have exhibited similar methods of management control by the client and supplier firms if not necessarily similar levels of performance. However, the results reveal significant differences in how both clients and suppliers went about achieving management control in this context. The results revealed both positive and negative evidence relating to coordination. The findings support the view that increased coordination improves performance against contractual metrics and general satisfaction with the BPO arrangement. The findings indicated a spectrum of coordination with

very little coordination at one end through coordination on specific projects to extensive coordination combining joint problem solving and team working. At the team working end of the coordination spectrum, the evidence was supportive of cooperation in terms of process design and quality practices.

The results also revealed very interesting results with regard to conflict; the largest source of conflict being due to poor supplier performance against contracted measures and at times of such conflict hostage penalties were generally imposed by the client firm. The results of the multiple case study indicate that conflict between exchange partners is a common aspect of on-going transactional BPO arrangements. With the exception of the Investment Bank-BPO 3 case study, suppliers tried to smooth over problems to avoid them escalating in the client firm. By contrast, the clients' approach depended on the seniority of the person experiencing the problem. More senior personnel tended to report problems loudly and formally where more junior personnel could often be influenced by suppliers' staff to keep the issue informal to generate more time for the issue to be resolved without penalty. Even when issues of conflict were highlighted to client contract management staff, there were differences observed in how it would be handled; this hinged to a large extent on the presence or absence of joint problem solving. The general supplier perspective revealed a hope that clients would engage in joint problem solving. That said, only Investment Bank in their arrangement was motivated to do so. They felt that it helped avoid on-going conflict and improved performance generally. There was a mutual desire to avoid unnecessary contact, to practice clarity of behaviour and to avoid provocation. That said, Investment Bank generally, but

not always, imposed hostage penalties despite their use of joint problem solving. Such behaviour needs to be explained.

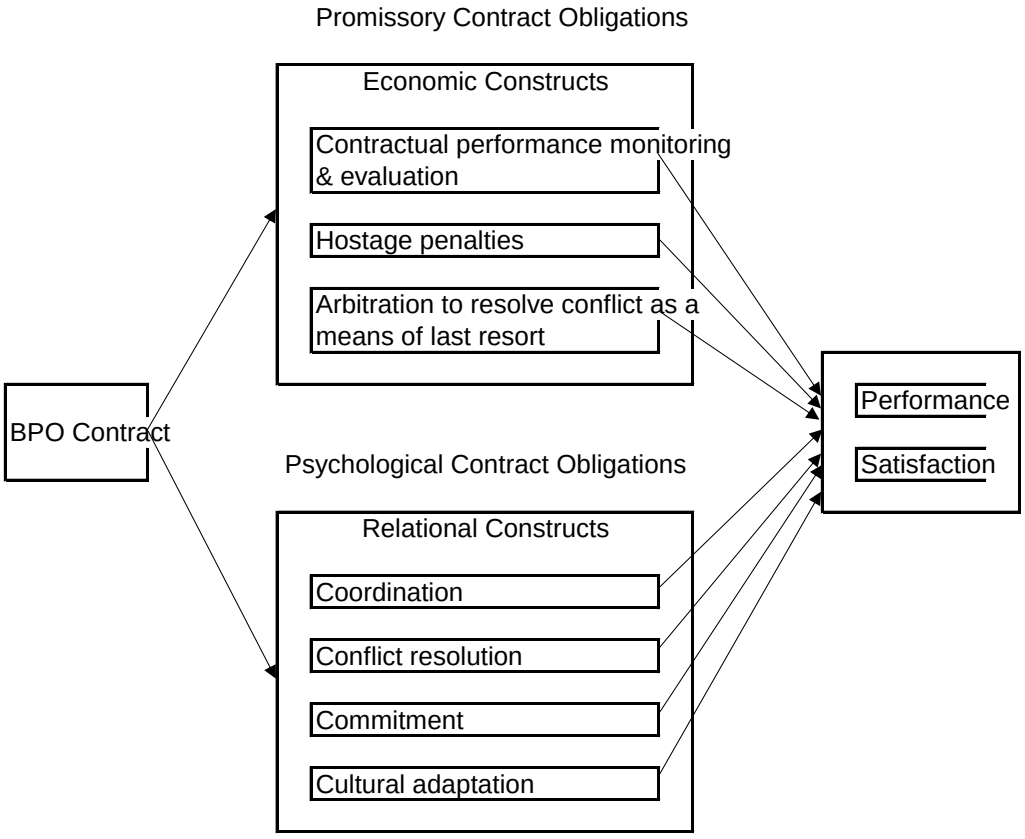
4. Relevance/contribution

This work has been influenced by the small body of extant studies (Koh et al, 2004; Miranda and Kavan, 2005; Hill et al, 2009; Kingshott and Pecotich, 2007; Kingshott, 2006; Blancero and Ellram, 1997) that have attempted to integrate the concept of the psychological contract into outsourcing and other inter-organisational contexts. As stated earlier, Guest (1998) argued that the concept of the psychological contract was unreliable in terms of validity and parsimony. Both Guest (1998) and Koh et al (2004) argued that no definite list of dimensions had been determined for the psychological contract thus limiting the potential for theory development. It is hope that this research can go some way to addressing this gap in existing knowledge and to developing a theory of the psychological contract as an inter-organisational construct.

The belief that inter-organisational relationships are controlled by more than legal arrangements has been long argued (MacNeil, 1980; Macaulay, 1963) often with reference to the notional and unwritten “spirit” of the contract. Rousseau and McClean-Parks (1994) argued that the working of a contractual relationship was influenced by subjective interpretation by individuals involved in its implementation. Koh et al (2004) went as far as to argue that:

> “Ultimately, it is the individual’s beliefs and perceptions of these obligations (i.e., the psychological contract), rather than the actual written contract, that drive her behaviour”
>
> (Koh et al, 2004, p 358)

This is potentially an argument stretched too far; it is arguable that both the written contract and unwritten interpretations of it will influence behaviours. For example, specified performance metrics will influence behaviour to achieve the required outcomes. In fairness, Koh et al (2004) did propose that the psychological contract was a broad concept that incorporated beliefs about explicit and implicit contractual terms. However, by doing so there is a risk that the probable importance of the legal promissory contract gets downplayed.



The theoretical model presented above assigns primary and direct impact on outsourcing performance to the use of the explicit promissory contract but also proposes a secondary and direct impact on performance from the use of the implicit psychological contract. This work builds on the recent work of Lioliou et

al (2014) which demonstrated that the psychologically binding nature of the psychological contract makes it a particularly forceful substitute to formal governance while its links with other relationship aspects make it a forceful complement.

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Improving manufacturing performance by developing innovative capabilities: the importance of supply chain relationships

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Abstract

This research investigates the relationships between supply chain relationships/integration, innovative capabilities and manufacturing performance. Data was collected from 171 organisations based in three rapidly developing countries – Brazil, India, China. Data was collected as part of the International Manufacturing Strategy Survey (IMSS VI) and analysed using Structural Equation Modelling. The findings indicated that supply chain relationships and integration relate positively to both product and process innovative capabilities. The study also found that there were positive relationships between both product and process innovative capabilities and manufacturing performance. Finally, there was a positive relationship between product innovative capabilities and process innovative capabilities**.**

Keywords: Innovative capabilities, Supply chain management, Developing countries

Introduction

This study investigates the relationships between supply chain relationships and integration, innovative capabilities and manufacturing performance within the context of three rapidly developing countries - Brazil, India and China. Previous studies including those by Back, Parboteeah, and Nam (2014) and Ren, Eisingerich, and Tsai (2015) have highlighted the necessity for more research on innovative capabilities and product development in developing countries. Developing countries such as Brazil, China and

India are increasingly seeking to improve their global economic presence and influence. To this extent, many organisations in these countries focus extensively on the development and exploitation of innovative capabilities. This study seeks to investigate if the supply chain relationships that manufacturers in these countries develop encourage them to develop their innovative capabilities. In addition, the study investigates if the development of these innovative capabilities result in improved manufacturing performance. Hence, the key questions that motivate this research are as follows:

Within the context of manufacturers in rapidly developing countries, do supply chain relationships and integration relate with the development of product and process innovative capabilities?

Do product and process innovative capabilities drive manufacturing performance in these rapidly developing countries?

Literature Review and Hypotheses

According to Tsai and Hung (2016), supply chain performance can be improved by developing a well-integrated supply chain. In essence, organisations that become more integrated or which develop better relationships with their suppliers and customers improve co-dependency and can develop an innovative advantage (Day, 2000; Souitaris, 2001). However, despite increasing evidence that manufacturers are under increasing pressure by their customers to adopt innovative practices and improve their innovative capabilities (Laosirihongthong, Punnakitikashem, and Adebanjo 2013), the relationship between customer relationship and integration and the development of innovative capabilities of manufacturers remains largely unexplored. The key hypotheses investigated in this research are now presented.

The study by Ren, Eisingerich, and Tsai (2015) suggested that within the context of developing countries like China, organisations tend to lag in technology development and are under the control of their western customers. The impact of the control of western customers is that the manufacturers in developing countries are necessitated to tailor their innovation-related activities to meet the needs of their customers (Bullinger, Auernhammer, and Gomeringer 2004). Increasingly, these customer needs include the ability to develop their innovative capabilities (Mishra, Chandrasekaran, and MacCormack 2015). Such innovative capabilities can be either product-related or process-related. Hence the following are hypothesised:

H1. Improvement in supply chain relationship and integration will relate positively with improvement in product innovative capabilities in manufacturing organisations in developing countries.

H2. Improvement in supply chain relationship and integration will relate positively with improvement in process innovative capabilities in manufacturing organisations in developing countries.

Product innovation is important to organisations because it has the potential to deliver new streams of income (Kleinschmidt and Cooper 1991; Teece 2010). However, Martínez-Ros and Labeaga (2009) and Ballot et al. (2015) noted that while product

innovation and process innovation are different, they could have a complementary relationship and could lead to each other. Linton (2015) also suggested that that product innovation is likely to result in process innovation. Therefore, the following hypotheses are proposed:

H3a. Improvement in product innovative capabilities will relate positively with improvement in process innovative capabilities in manufacturing organisations in developing countries.

H3b. Improvement in product innovative capabilities will partially mediate the relationship between supply chain relationship and integration and Improvement in process innovative capabilities.

The main reason why organisations focus on the development of product innovative capabilities is the need for organisations to maintain a competitive edge in the market place (Leskovar-Spacapan and Bastic 2007). This relationship between product innovative capabilities and organisational performance has been explored in previous studies. The study by Yang et al. (2015) concluded that supply chain performance is influenced by innovation capability. This argument also extends to process innovative capability. The potential impact of developing process innovation on the performance of an organisation was investigated by Oke and Kach (2012) and they found that the benefits included improvements in the production process, efficiency and cost. Hence the following are hypothesised.

H4. Improvement in product innovative capabilities will relate positively with improvement in manufacturing performance in developing countries.

H5. Improvement in process innovative capabilities will relate positively with improvement in manufacturing performance in developing countries.

Methodology

The study collected data from Brazil, India and China through the International Manufacturing Strategy Survey (IMSS) version VI between June 2013 and June 2014. For this study, manufacturing performance was measured using a combination of quality and flexibility because these two dimensions of performance should be of major concern for all organisations that are focussed on product and process innovation. The responses for manufacturing performance were assessed using a five-point Likert scale that compared organisational performance to the main competitor. The measures for all other constructs were developed from established scales and were measured on a five-point Likert scale as well. The study collected 171 valid survey responses which were used to test the hypotheses presented above. The dataset comprised of 28 (16.4%) responses from Brazil, 56 (32.7%) from India and 87 (50.9%) from China.

The study performed a principal-component exploratory factor analysis for each survey item to check for the specified constructs. The results showed that all the items of each construct had factor loadings between 0.725 and 0.896, exceeding the recommended coefficient of 0.50 (Hair et al. 2010). The constructs were also examined for internal consistency and the results showed that every construct had Cronbach's Alpha ranging from 0.840 to 0.900, meeting the desirable value of 0.70 (Hair et al. 2010). In addition, the study also checked the composite reliability of all constructs and the results showed

that the values of composite reliability for all the constructs ranged between 0.894 and 0.928, which are above the recommended value of 0.60 (Bagozzi and Yi 1988). The values of average variance extracted (AVE) for each construct were above 0.50, indicating convergent validity. To address the problem of multicollinearity, the study evaluated multicollinearity through the variance inflation factors (VIF) and the values of all variables were between 1.287 and 1.942, lower than the recommended thresholds of 3 (Hair et al. 2010), thereby confirming there was no multicollinearity problem in this study.

The study then used structural equation modelling to test the hypothesized relationships. The SEM results showed a good model fit with normed chi square (χ^2) = 1.114, GFI = 0.923, AGFI = 0.893, RMSEA = 0.026, RMR = 0.053, NFI = 0.928, TLI = 0.990, and CFI = 0.992

Findings

The study found that supply chain relationship and integration had a significant and positive relationship with product innovative capabilities (β=0.682; p-value < 0.001). Supply chain relationship and integration was positively related to process innovative capabilities (β=0.294; p-value < 0.01). There was a positive relationship between product innovative capabilities and process innovative capabilities (β=0.475; p-value < 0.001). Product innovative capabilities was positively related to supply chain relationship and integration (β=0.270; p-value < 0.05). Process innovative capabilities (β=0.305; p-value < 0.05) was found to have a significant and positive relationship with manufacturing performance. The results provided evidence to support hypotheses H1, H2, H3a, H4 and H5. These results are shown in table 1.

The significant positive relationship between product innovative capabilities and process innovative capabilities resulted in the testing of a mediating effect for product innovative capabilities. The bootstrap approach (Preacher and Hayes, 2004) was adopted to test the mediation hypotheses. The indirect effect of product innovative capabilities on process innovative capabilities was calculated as the product of the path coefficients between supply chain relationships and integration and product innovative capabilities (β = 0.682) and between product innovative capabilities and process innovative capabilities (β = 0.475). This indirect effect coefficient was equal to 0.324, which can be validated for significance using a bootstrap approach. The indirect effects were significant given that the lower confidence interval of the bias-corrected bootstrap does not contain zero. As both direct and indirect effects were significant, the partial mediating effect (H3b) was supported for product innovative capabilities.

Conclusion

The study shows that for manufacturers in Brazil, China and India, the ability to develop supply chain relationship and integration will significantly and positively impact on their ability to develop their product innovative and process innovative capabilities. The study also found that, product innovative capabilities have a strong positive relationship with process innovative capabilities. The implication of this finding is that organisations that develop strong product innovative capabilities are also likely to develop process innovative capabilities thereby improving the overall level of innovativeness in the

organisation. Finally, the study found that both product and process innovative capabilities have significant positive relationships with manufacturing performance.
From a theoretical perspective, the findings suggest that institutional pressures that affect manufacturers such as pressure from supply chain customers can lead them to develop new capabilities with respect to product and process innovative capabilities. From a competitive perspective, the findings show that that manufacturers in the countries that were studied are increasingly beginning to focus on product and process innovative capabilities. If and when they develop such capabilities to an advanced level, the impact on global manufacturing and trading relationships could become very significant.

Table 1. Results of Hypotheses testing

Hypo-theses	Causal Path	Standard Path Coefficients	Standard Errors	Critical Ratios	*p*-value
H1	Supply chain relationships and integration → Product innovative capabilities	0.682	0.062	7.876	0.000***
H2	Supply chain relationships and integration → Process innovative capabilities	0.294	0.088	3.034	0.002**
H3a	Product innovative capabilities → Process innovative capabilities	0.475	0.137	4.384	0.000***
H4	Product innovative capabilities → Manufacturing performance	0.270	0.113	2.230	0.026*
H5	Process innovative capabilities → Manufacturing performance	0.305	0.088	2.568	0.010*

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Value dimensions and value capture in B2B relationships: A general framework with moderation effects

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Abstract

This research investigates how value creation and moderating factors can be combined to increase value capture**.** Based on a dyadic case study and qualitative comparative analysis (QCA) with a firm in financial payments and five suppliers, it recognizes the existence of core and non-core dimensions of value creation and demonstrates the principle of equifinality through six combinations that increase value capture. Limitations are the use of only three theories and constraints when QCA is based on judgement. It brings practical understanding of mechanisms and options available to increase value capture and shows how to apply QCA method in qualitative settings.

Keywords: Value creation and capture, buyer-supplier relationships, QCA analysis

Introduction

Value creation and capture are central concepts of business-to-business (B2B) relationships in the marketing and operations management (OM) disciplines (Pinnington, Meehan, & Scanlon, 2016). Over the past decades research has proposed several definitions for the dimensions (or sources) of value creation (Ulaga & Chacour, 2001), investigated different forms of value capture (Bowman & Ambrosini, 2000), the factors that moderate these relationships (Anderson & Narus, 1990) and the interdependency between price and volume (Lindgreen & Wynstra, 2005). However, these streams have mostly run independently without much interaction (Su & Yang, 2017) and further empirical investigation is needed to better understand how the components of value creation interact to increase value capture.

This study brings several theoretical, empirical, methodological and managerial contributions. Based on grand theories, it recognizes the existence of core and non-core dimensions of value creation. It advances the knowledge about how contextual variables identified in previous models influence value capture and demonstrates the principle of equifinality through six different combinations that increase value capture. From a methodological perspective, it fulfills Su & Yang (2017) need to move towards QCA to study complex B2B relationships, a method that has been accepted in important journals (Schneider & Eggert, 2014). It also shows how to conduct QCA when starting with a

qualitative approach using interviews (Russo, 2019), a method rarely found in the literature. For buyers and suppliers it brings more practical understanding of the value capture mechanisms, how business is divided among suppliers, and options available to increase value capture (Ellegaard, Medlin, & Geersbro, 2014).

The research was conducted in two phases, an embedded case study and QCA, to clarify how the dimensions of value creation and moderating factors can be combined to increase value capture in B2B relationships. The analysis was based on a focal firm in the financial payments industry and five key suppliers responsible for supplying specialized services.

Theoretical background

In this study, value creation was defined based on three theories commonly used in OM research. TCE (Williamson, 1981) brings an economic approach to predict exchange governance structures and performance of an exchange. Exchanges are conducted by transactions that have a cost associated to them and firms will conduct an activity internally as long as the transaction costs are lower than conducting the same activity in the market. Examples of value dimensions are operational efficiency, asset efficiency and financial efficiency. RBT (Barney, 2001) focuses on internal or outsourced heterogeneous resources. Organizations that own, access or control valuable, rare, costly to imitate and imperfectly substitutable resources can sustain a competitive advantage. Examples of value creation are capabilities, innovation and time reduction. In the SET (Granovetter, 1985) actors enter and maintain relationships with the expectation that value will be exchanged through cost or social reputation and prestige. As the duration and intensity of interactions between actors increase, it is expected that opportunism and malfeasance decrease and lead to more informal governance and lower transaction costs. Examples of value creation include the quality of relationships, access to information and access to market.

Value capture is the portion or share of the value created which is held by each focal firm and is independent of value creation. Buyers and suppliers can capture value based on three distinct forms: (i) by getting a larger share of the transaction value at expense of the relationship partner through price negotiation (Bowman & Ambrosini, 2000; Lindgreen & Wynstra, 2005); (ii) by shifting volume at expense of other competing firms inside the supply network (Ellegaard et al., 2014) or (iii) by increasing the total value in the relationship through collaborative efforts at no one´s expense because new value is created (Ellegaard et al., 2014).

Four factors moderate value capture. Power and dependence have been recognized as a primary source of value capture and are particular to the individual dyad because the powerful party tends to appropriate a larger share of the created value at the expense of the weaker through price negotiations, direct reinforcements or indirect manipulative ways (Bowman & Ambrosini, 2000; Ellegaard et al., 2014). Attraction (or attractiveness) is the force that pushes a buyer and a supplier closer in a dyadic relationship and is an opposing mechanisms to power because a firm that is attractive in the eyes of another also has power within the dyad (Hald, Cordón, & Vollmann, 2009). PSM practices are defined as “activities that [directly or indirectly] relate to the purchasing–supply base interface”. They are crucial to achieve effects on buying firm performance, have a significant role in cutting the total costs (Narasimhan & Das, 2001) and mediate the effect of relational practices (Foerstl, Franke, & Zimmermann, 2016). Changes in the supply strategy are inevitable and the most prominent reasons why an organization initiates change are tensions caused by the external environment (i.e. cost competition), customer´s demands (i.e. a new channel strategy), performance issues, or internal changes at the individual or

organizational levels (i.e. a new manager) (Flint & Woodruff, 2001). Although client-specific knowledge suggests that the buyer requirements are likely to be fulfilled by suppliers that already provide and can adapt their services and not new suppliers (Chatain, 2010), cases like that are often followed by a new bidding process that impact both volume and price.

Methodology – Phase 1: dyadic case study

The objective of Phase I was to identify the cases and consisted of a dyadic case study (Miles, Huberman, & Saldaña, 2014) because there are hardly theoretical frameworks that explain the relationship among value creation, value capture and moderating factors within B2B relationships. The unit of analysis was the buyer-supplier relationship.

The focal firm (FIN) was a leading Brazilian company in the financial payments industry and the six dyads supplies strategic services. The suppliers consisted of two Software Factories (SW- and SW-B), two Independent Sales Organization (ISO-C and ISO-D) and two Logistics Service Providers (LSP-A and LSP-B). At least a procurement (buyer), commercial (supplier) and operations representatives (buyer and supplier) were interviewed. A total of 27 interviews with 32 participants were conducted based on a mirrored interview protocol, leading to 28 hours of recording. Interviews were transcribed and managed with the CAQDAS software AtlasTI. All interviews were read in detail and the passages coded based on a provisional list that was revisited and refined during the analysis (Saldaña, 2015) until a final list containing 41 codes was assembled.

The specific dimensions of value creation used in this study were identified based on the count of how many times they appeared in each interview and total mentions. Three dimensions were repeatedly identified across all interviews and dyads and defined as "core". Each one was grounded on a theory: operational efficiency (TCE), quality of relationship (SET) and capabilities (RBT). Other seven dimensions were mentioned less often or only in specific interviews or dyads and were defined as non-core. They are based on TCE (asset efficiency, financial efficiency and risk management), SET (access to information) and RBT (firm reputation, innovation and time reduction).

The next step was to define the cases. A case was composed of three elements: a condition related to the outcome (value capture), the variables associated to the condition (dimensions of value creation or moderating factors) and the outcome. A specific case was considered when the coded text could clearly identify the specific condition, describe in an open-ended manner one or more variables associated to that condition, and be associated to a positive or negative outcome (Farrell & Marsh, 2016; Russo, Confente, Gligor, & Cobelli, 2019). A qualitative interpretation of all quotes coded as context information and value capture was performed and different conditions were associated to generic price/volume decisions, a specific supplier increasing/ decreasing price or volume, new supply strategies and collaborative projects. Then, all quotes related to each specific case were connected into one unique string that represented the case, independently of the person interviewed. Finally, each case was copied and represented a line in an MS-Excel spreadsheet for further analysis.

Thirty different cases were identified and were fairly distributed across the dyads and outcomes, and therefore considered satisfactory. However, four cases related to collaborative efforts were not considered for further analysis because the sample was too small to obtain a meaningful conclusion and in all cases the value created was totally captured by the buyer. Therefore, the final samples consisted of 24 cases.

Phase II – QCA analysis

Based on the results of Phase I, a QCA was conducted to identify the causal conditions that lead to value capture (Fiss, Peer, 2011). Unlike traditional regressions or correlations, QCA uses set relations and formal Boolean logic to find commonalities between different cases with the same outcome (equifinality) and determine which conditions are necessary and sufficient for the outcome (Rihoux & Ragin, 2009). A sufficient condition ensures that the outcome will occur when present, although it may be one of many conditions that produce the outcome. QCA is traditionally considered appropriate for small samples in the range of 10 to 50 cases (Schneider & Eggert, 2014) and has been used to evaluate complex supply chain phenomena (Russo et al., 2019). The crisp-set methodology (Rihoux & Ragin, 2009) was used because the variables had only two possible values (0 and 1), and the model was analyzed with the Fuzzy Set Qualitative Comparative Analysis (fs/QCA) software.

Assembling a truth table containing the cases was the first step. In the truth table each attribute is composed of binary variables coded 1 for "present" (high score) and 0 for "absent" (low score) (Rihoux & Ragin, 2009), and it was necessary to transform the text into "1" or "0" because the variables were based on verbal reasoning. The outcome was considered "present" when the case pointed to an increase in volume or to an increase in price. For the other variables, a "present" condition was considered when the quote had a positive relationship with the outcome.

Validity of the truth table was based on frequency and consistency. The cut-off criteria for frequency for samples between 10–50 cases was 1 and considered acceptable. The consistency measure should be above acceptable levels of 0.8 (Rihoux & Ragin, 2009) and two cases showed measures of 0,5. The first was a contradictory price configuration and was removed because it was only a conjectural (not real) situation mentioned by a supplier, and the second was adjusted after reexamining all quotes and interviews associated in more detail.

The existence of a necessary condition that could simplify the model was tested and not found. A necessary condition implies that when you observe the outcome you will always observe the condition (Schneider & Eggert, 2014). A sufficiency analysis was performed and results were below 0.83, less than the conventionally accepted threshold of 0.9 (Rönnberg, Parida, & Kohtamäki, 2016). Two variables were excluded from the conditions tested. The moderating factor PSM was excluded because no heterogeneity was found on the different cases and the non-core SET dimensions was excluded because it was not mentioned in any of the cases.

At the end of this process two truth tables were built (one for each outcome - price and volume) with a total of 23 cases, 12 for volume and 11 for price. Outcomes were analyzed for the presence or absence of eight conditions: three core value dimensions (Core-TCE, Core-RBT and Core-SET), two non-core value dimensions (Non-core-TCT and non-core-RBT), and three moderators (attraction, power and change).

QCA Results

Findings are presented using the notation method found in the literature (Russo et al., 2019). The presence of a condition is marked by a filled circle (•), the absence of a condition is noted by a circle with an "x" (⊗) and there is no notation if a condition is not involved in a solution. For the configurations, the symbol * represents the logical operation AND, the symbol ~ represents the absence of the condition.

Interpreting the results requires a dialogue between the QCA results, the theoretical background and concrete examples of the solutions at work (Farrell & Marsh, 2016).

Eight combinations (I to VIII) of conditions associated with change in volume were identified and demonstrate the principle of equifinality (Table 1). The solution had overall consistency and coverage scores of 1, meaning that they are sufficient to produce the outcome, and the coverage of the sample was adequate (Rihoux & Ragin, 2009). A logical simplification was conducted to reduce the eight configurations presented by the QCA (Rihoux & Ragin, 2009) and resulted in three business situations that lead to a change in volume (A, B and C).

Table 1: Configurations associated to change in volume

Business situation	A					B		C
Configuration	I	II	III	IV	V	VI	VII	VIII
Core TCE-Performance	●	●	●	●	●	⊗	⊗	⊗
Core RBT-Capability	●	●		●	●	●	⊗	●
Core SET-Relationship		⊗	●	●	●	⊗	⊗	●
Non-core- TCE	⊗		⊗	●	●	⊗	⊗	⊗
Non-core-RBT	⊗	⊗	⊗	⊗		⊗	⊗	⊗
Power	⊗	⊗	⊗		●	⊗	●	●
Attraction	⊗	⊗	⊗	●	●	⊗	●	⊗
Change		⊗	⊗	⊗	⊗	●	●	⊗
Consistency	1	1	1	1	1	1	1	1
Raw coverage	0,33	0,17	0,17	0,17	0,17	0,08	0,08	0,08
Unique coverage	0,17	0,08	0,08	0,08	0,08	0,08	0,08	0,08

Circles "●" indicate the presence of conditions, and circles "⊗" indicate absence.

Situation A contains configurations I to V and indicate that a combination of high operational performance and capabilities is sufficient for increasing or decreasing volume. Although only configuration III showed that capabilities do not necessarily need to be present, it was included because all other situations were absent of operational performance and results would remain the same. In specific situations, other core dimensions (quality of relationship), the non-core dimensions and moderators (attraction, power and change) had high or low levels depending, and therefore they do not need to be present in all situations to capture volume. In the absence of operational performance (situation B) change was a sufficient condition to impact volume capture since higher or lower scores of the other core and non-core value dimensions and moderator factors were not always present. Situation C shows that when both operational performance and change are absent, an increase or decrease in volume depends on the presence of high capabilities, relationship and power. Again, the non-core dimensions were not relevant for volume capture.

Eight combinations (I to VIII) of conditions associated with change in price were also identified (Table 2). The overall consistency and solution coverage was 1, implying that they are sufficient for the outcome. The logical simplification showed that these eight configurations can be combined in three main business situations that lead to a change in price (A, B and C). Situation A contains configurations I to IV and indicate that high levels of operational performance alone is sufficient for increasing or decreasing price. The other core dimensions (capability and quality of relationship), non-core dimensions and moderators (attraction, power and change) do not need to be always present since they showed high or low levels in specific configurations. In the absence of operational

performance, high levels of change are sufficient to impact price (situation B), since higher or lower scores of the other core and non-core value dimensions and moderators were present. When both operational performance and change are absent (situation C), high levels of power are sufficient to affect price. In that case, high levels of core and high levels of non-core value dimensions or other moderators (attraction and power) do not need to be present.

Table 2: Configurations associated to change in price

Business situation	A				B		C	
Configuration	I	II	III	IV	V	VI	VI	VIII
Core TCE-Performance	●	●	●	●	⊗	⊗	⊗	⊗
Core RBT-Capability		●	⊗	⊗	●	⊗	⊗	●
Core SET-Relationship	⊗	●	⊗	●	⊗	⊗	⊗	●
Non-core- TCE	●	⊗		●	●	⊗	⊗	⊗
Non-core-RBT	⊗	⊗	⊗	●	●	●	⊗	●
Power	⊗	⊗	⊗	⊗	⊗	●	●	●
Attraction	⊗	⊗	⊗	⊗	⊗	●	⊗	⊗
Change	⊗		⊗	⊗	●	●	⊗	⊗
Consistency	1	1	1	1	1	1	1	1
Raw coverage	0,33	0,17	0,17	0,08	0,08	0,08	0,08	0,08
Unique coverage	0,25	0,17	0,08	0,08	0,08	0,08	0,08	0,08

Circles "●" indicate the presence of conditions, and circles "⊗" indicate absence.

In summary, the results (Table 3) show that high levels of operational performance, change or power are a sufficient condition to capture value through price. In other words, there is no need for a combination of factors to capture price, but only one of these. Value capture through volume follows a slightly different combination. Although high levels of change is also a sufficient condition, volume is captured by combining operational performance and capabilities, or by combining capabilities, relationship and power. Non-core dimensions of value creation (TCE, RBT or SET) and attractiveness were not relevant in any combination.

Table 3: Configurations associated to value capture

Value capture	**Price**			**Volume**		
Configuration	**I**	**II**	**III**	**I**	**II**	**III**
Core TCE-Operational performance	●			●		
Core RBT- Capabilities				●		●
Core SET-Relationship						●
Power			●			●
Change		●			●	

Circles "●" indicate the presence of conditions

.

Discussion: Operational performance and value capture

High levels of Operational Performance is a sufficient condition to capture value through price and bring more light to the contrasting views on value: while some authors provide a common and simplistic conceptualization of value-for-money as the ratio

between quality and price, others suggest that viewing value as a trade-off between only quality and price is too simplistic (Sweeney & Soutar, 2001). Different theoretical explanations support the simplistic view. For the past three decades buyer-supplier relationships were driven by operational performance (Terpend, Tyler, Krause, & Handfield, 2008) and supplier's quality performance of service activities were used to choose a particular vendor (Gassenheimer, Sterling, & Robicheaux, 1996). High levels of other dimensions do not affect price because they seem to be antecedents to performance, relevant only in specific situations or too subjective. For example, the quality of relationships is a social and subjective mechanism and capabilities that a partner brings to the relationship have already been linked with the ability of an organization to achieve superior performance (Barney, 2001).

These arguments were found in the software factory, ISO and logistics cases. Prices were based either on commoditized umbrella contracts with standard rates or specialized services with specific and higher rates. In these cases, high levels of operation efficiency acted as a certification that the partner already had the capabilities, and therefore prices were not driven by them. According to the managers:

> "*If a supplier has better quality and delivers [the service] with fewer errors, I would not be uncomfortable in paying a little more";*
> *"I could pay a little more to have a better quality"*

Value capture through volume requires high levels of operational performance and capabilities. While operational performance is a necessary condition for assigning volume to a supplier due to the same reasons explained in the price discussion above, the reason why capabilities must be present can be explained by TCE and RBT. Resources are assets, processes, information or knowledge of a firm that enable development and implementation of strategies to improve efficiency and effectiveness (Barney, 2001). As the buyer shifts more volume to a certain supplier, he increases his dependency and need to secure the supply (or reduce risk) in case the supplier fails to deliver (Aminoff & Tanskanen, 2013). Therefore, before shifting volume it is expected that the buyer will assure that the supplier has the specific capabilities, can deliver the additional volume without affecting operational performance and not increasing risk.

High levels of operational performance and capabilities increased or decreased volume in the software, logistics and ISO services cases. In the day-to-day business, suppliers that performed also had a pre-defined scope that could be a geographical region, a technology platform or a technical expertise. In these cases, additional demand was automatically given to that specific supplier. According to the ISO managers:

> *"we really want suppliers that can allocate a larger number of sales representatives. However, it does not help bring a very large supplier if I´m not sure that his team knows how to do my door-to-door sales"*

Although it would be expected that suppliers with good relationships would also be able to capture more volume (Anderson & Narus, 1990; Granovetter, 1985), it was not a necessary condition to capture volume and the reason was found in the cases. Quality of relationships seems to be an antecedent to performance, since the suppliers that increased volume had good relationship with the buyer while the ones that lost volume not. According to the buyers, suppliers that lost volume had a "*relationship sickness*" and were "*bureaucratic and had a lot of friction*".

Discussion: Change in supply strategy and value capture

In the absence of operational performance, a change in supply strategy is a sufficient condition for capturing value for both price and volume. Changes in buyer–supplier relationships can be initiated due to the external environment, new customer´s demands,

performance issues, or internal organization changes (Flint & Woodruff, 2001). The reason for a having only change in supply strategy as a condition seems to be because it tends to involve a new bidding process that may lead to positive or negative effects on price and volume depending on the situation. Although in a bidding process the buyer requirements are more likely to be fulfilled by exiting suppliers (Chatain, 2010), it is also an opportunity for new suppliers to invest and get additional business..

These situations were found in different cases. When the ISO managers decided to implement a new supply strategy due to changes in FIN´s channel strategy, they first reduced the number of suppliers to keep the best performers and then planned to conduct a new bidding that would change the operational and remuneration model and attract new suppliers to reduce dependency on the fewer suppliers that remained. According to a buyer:

> *"The request for proposal will be new because we will quote everything since the beginning, starting from zero".*

A situation of volume decrease occurred in the software factory after the implementation of a disruptive strategy. In that case, a new large supplier that had global reputation for managing strategic projects in technology and other small software boutiques was contracted based on his specific capabilities and as a consequence the remaining suppliers decreased their share of the business.

The cases showed although high levels of performance, capabilities and relationship were determinants for value or price capture, they were specific to each situation and therefore do not necessarily need to be present at in all situations.

Discussion: value capture in the absence of operational performance and change

In the absence of operational performance and change, power is a sufficient condition for capturing value through price. This is not surprising from an academic point of view because in this situation there is no differentiation left. Differentiation helps suppliers to compete, achieve a temporary monopoly, increase buyer´s willingness to pay or help buyers discriminate competing suppliers (Ulaga & Eggert, 2006). When absent, the party that has the strongest bargaining power determines who captures the largest amount of value, (Bowman & Ambrosini, 2000; Ellegaard et al., 2014).

This was found in the software and ISO cases. The focal firm (FIN) has relative high power within its supply base because suppliers are relatively dependent of FIN´s volumes and need to do business with them to develop unique capabilities that are valuable in the market. Within the cases, suppliers that did not show high levels of operational performance were forced to reduce price regardless their level of capabilities and relationship because the buyer was not willing to pay higher prices to suppliers that do not perform. For example, one supplier mentioned that prices did not change in the last two years despite inflation, and according to another supplier:

> *"Price renewals are happening like this: I renew [the contract] with you but will pay 30% less. Do you agree?"*

Value capture through volume requires a combination of high levels of power, capabilities and relationship. The theoretical relevance of each of these factors has already been discussed and explains why this combination is applicable in specific situations. When there is a lack of differentiation the party with stronger bargaining power who captures the largest amount of value (Bowman & Ambrosini, 2000; Ellegaard et al., 2014), and the firm that controls valuable, rare, inimitable, and non-substitutable capabilities holds a strong power position. Therefore, even if one party has high levels of power, volume will not be shifted unless the other party has the necessary capabilities. The SET complements this combination because in dyadic relationships there is tendency

for commercial relationships to be interwoven with personal ones (Zaheer & Venkatraman, 1995) and as the duration and intensity of interactions increase the embedded relationships generate trust, discourage opportunism and lead to more relational and informal governance, thus reducing transaction costs and increasing performance (Zaheer & Venkatraman, 1995). As a result, when a partner has low levels of operational performance and high levels of power and capabilities, relationship quality may be an additional and complementary value needed to increase volume.

Specific cases found in this study support this argument. For example, the more informal governance helped an ISO supplier to quickly set-up a promotion for the buyer and get the additional volume. According to the supplier:

> *"several times they called me and said: I need [to set-up] a promotion with five sales people but do not have the sum to pay you.* In this situation the supplier responded: *Ok, I will send the people and we can settle the situation later, in another promotion"*

Conclusions, limitations and future research

This paper combined an embedded case study and QCA to investigate different combinations between the dimensions of value creation and moderating factors that increase value capture. The findings recognize that the TCE, RBT and SET can explain the core and non-core dimensions of value creation and demonstrate the principle of equifinality through six different combinations that increase value capture. From a methodological perspective it showed how to conduct QCA starting with a qualitative approach using interviews (Russo, 2019) and fulfilled the need to move towards QCA methods (Su & Yang, 2017). For managers, it brings a practical understanding of the mechanisms and options available to increase value capture (Ellegaard et al., 2014).

The limitations can be addressed through future research. Value was explored only through three dominant theoretical perspectives and future research can consider other theories found in OM research, such as the resource advantage, contingency or agency (Soosay & Hyland, 2015), to determine other combinations that increase value capture. The combined methodology has its own limitations and constraints because the cases and truth tables were based on judgement, thus replicating this method in different contexts would help to better understand QCA. The sample consisted of firms within the financial services industry in Brazil and future research should test other industries, countries, cultures and settings to increase the generalizability of the findings.

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Profit-sharing scheme to create a sustainable relationship

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Abstract

This study investigates a reasonable sharing rule for a strategic alliance based on a hub-and-spoke network. Individual firms cooperate to gain additional benefits and the distribution of the joint profit is crucial for a sustainable partnership. Our research is an application of cooperative game theory which suggests proper profit allocation methods. The link-based integer programming model calculates extra outcome of horizontal cooperation between logistics companies, which benefits from better resource utilization with aggregative demand. Insight into reasonable allocation methods provide an academic and practical intuition for further research.

Keywords: Cooperative game theory, Supply chain collaboration, Profit sharing

Introduction

The rapid change of industrial structure and the acceleration of technology development including information and communications technology have a great impact on the business ecosystem. Coopetition, a term coined for cooperation with a competitor, is all about evolution. In particular, self-interested firms choose a strategic alliance which is mutually beneficial and collaborate to gain extra outcome. A variety of benefits of the strategic alliance leads companies to cooperate and to strengthen their competitiveness (Baum et al., 2000; Dyer and Singh, 1988; Gomes-Casseres, 2015; Kogut, 1988; Powell et al., 1996; Shapiro and Willig, 1990). Specifically, the cooperation of logistics companies improves profitability through vehicle utilization and economies of scale. For example, an airline joint venture, which involves tight cooperation, is an emerging strategy in the airline industry. Back in 1997, the first joint venture between KLM and Northwest airline was formed over the transatlantic routes. Even though the antitrust law concerns of dominance by big carriers in the early days, the consumer benefits generated by airline cooperation (Brueckner, 2001) allow for granting an antitrust immunity and airlines to collude in the contract routes. Today, passengers receive benefits of increased frequencies or diverse schedules (Armantier and Richard, 2008; Dennis, 2005; Weber,

2005) and airlines get extra revenue improved from enlarged network (Park et al., 2001; Wright et al., 2010).

The existence of additional profits is the main purpose of the relationship between the individual firms, while maintaining the relationship is a different story. In other words, whether profit is generated or not is most important in alliance-formation, on the other hand, the distribution of profit among members should be reasonable for sustainable relationship.

A primary interest of our research is based on how to allocate the joint outcome among incumbents and cooperative game theory provides frameworks for analyzing situations in which players interact as well as collaborate. By comparing various solution concepts in conventional cooperative game theory, we investigate the distribution and validate the possibility of sustainable partnership.

Model

In most transportation systems, including the airline services, which are based on a hub-and-spoke network, economies of scale and economies of scope are main advantages by cooperation. Therefore, aggregated demand and resources based on an extended network are the key to achieve extra outcome from an alliance. Through cooperation participating firms get increased revenues as well as reduced costs. In our study, we examine passengers' path along with the decision of aircraft types, considering transfer in hub airports. Assuming horizontal cooperation between airlines, a mixed integer programming model presents the optimal value of joint profits of the profit maximization problem.

The customer demand is known for each origin-destination pair and the costs, which consists of the fixed cost of aircraft type on a specific line segment and the variable cost based on each passenger for their whole path, are also known. The number of passengers traveling on a particular aircraft type of each link, which means a line segment of a direct trip between two airports, and the number of aircraft types utilized on each link are the decision variables of our model.

The objective function is assumed to be the same regardless of cooperation, that means all coalitions have same profit structure related to the demand and the cost presented in the model. Note that we presume identical costs in both airlines and the coalitional demand is aggregated followed the new network since we does not account for any other impact on demand. Our proposed mixed integer programming model is presented as follows after notations including all sets, parameters and decision variables as shown in Table 1.

Notations

Table 1 – Sets, decision variables and parameters

T_a	set of aircraft	$\forall a \in A$
A	set of arcs	
O	set of origin-destination pairs	
P_o	set of paths	$\forall o \in O$
N	set of nodes	
$s(o)$	source node of the origin-destination pair o	$s(o) \in N$
$A^S_{s(o)}$	set of arcs including the source node $s(o)$	
A^P_n	set of arcs including the node n as the sink node	$\forall n \in N$
A^S_n	set of arcs including the node n as the source node	$\forall n \in$N

S	set of collaborating players (coalition)	
x_{op}	number of passengers traveling by path p with the origin-destination pair o	$\forall p \in P_o$, $o \in O$
x_{opat}	number of passengers on each aircraft type t on the arc a over the path p of the origin-destination pair o	$\forall t \in T_a$, a ∈ A, $p \in P_o$, $o \in O$
y_{at}	1 if an aircraft t is decided to be operated on the arc a, 0 otherwise	$\forall p \in P_o$, o ∈ O, $t \in T_a$, a ∈ A
r_{op}	airfare on path p of the origin-destination pair o	$\forall p \in P_o$, $o \in O$
f_{at}	fixed cost of aircraft type t on the arc a	$\forall t \in T_a$, $a \in$ A
c_{op}	variable cost per passenger on path p of the origin-destination pair o	$\forall p \in P_o$, $o \in O$
D_o	demand of the origin-destination pair o	$\forall o \in O$
U_t	capacity of the aircraft type t	$\forall t \in T_a$

The model

$$\text{Maximize } \sum_o \sum_p (r_{op} - c_{op}) x_{op} - \sum_a \sum_t f_{at} y_{at} \quad (1)$$

subject to

$$\sum_o \sum_p x_{opat} \leq U_t y_{at}, \ \forall\, a \in A, \ \text{t} \in T_a \quad (2)$$

$$\sum_p x_{op} = D_o, \ \forall\, o \in O \quad (3)$$

$$x_{op} = \sum_{a \in A^S_{s(o)}} \sum_t x_{opat}\,, \ \forall\, o \in O, \text{p} \in P_o \quad (4)$$

$$\sum_{a \in A^P_n} \sum_t x_{opat} = \sum_{a \in A^S_n} \sum_t x_{opat}\,, \ \forall\, o \in O, \text{p} \in P_o, n \in N \quad (5)$$

This model solves the number of passengers on the assigned aircraft *t* between each airport which is presented as an arc *a*, and total demands are satisfied with achieving the maximum profit. We let *Z(S)* be the total maximum profit (i.e., the maximum value of the objective function in the above model) of coalition *S*. Constraint (2) is bounded at the upper capacity levels of aircraft type which means the maximum number of seats allowed. Constraint (3) aims to satisfy the required demands for each origin-destination pair *o* of coalition *S* by employing each path *p*. In our model, we assume that the transfer is allowed and even mandatory for the origin-destination pair *o* with more than two links.

Numerical illustration

In order to figure out a reasonable allocation rule which can guarantee the sustainable partnership with all alliance members, we illustrate a numerical example of an airline joint venture in a basic two-hub network. In our example, each link is demonstrated as a player and thus a player is a link between one hub airport and one non-hub airport or two hub airports only. For the sake of brevity, the whole network consists of only two hub airports and one non-hub airport connected each. Figure 1 shows the network example.

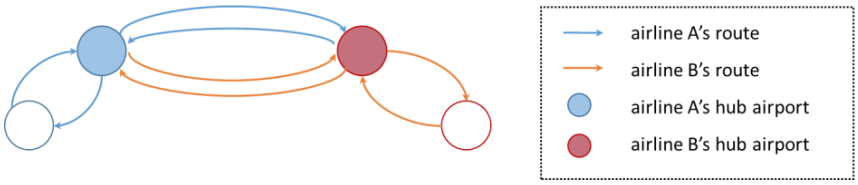

Figure 1 – Network example

There are four types of aircrafts with different capacities; two long-haul aircrafts are only travelled between hub airports, while links between a hub airport and a non-hub airport are allowed for all aircraft types. Same aircraft types have homogeneous costs in the same distance without reference to different airlines. Demands from collaborating are defined from the joint network, which means the network expansion considered, and be aggregated by each demand before cooperation. Both costs and demands are known. From our mixed integer programming, we find the optimized maximal profit and calculate profit increasing in fifteen possible coalitions. Table 2 summarizes the results.

Table 2 – Optimal profit for each of the possible coalitions

Coalition *S*	*Z(S)*	*V(S)*
{A}	1,292,183	0
{B}	4,834,819	0
{C}	4,403,477	0
{D}	-121,661	0
{AB}	7,831,011	1,704,008
{AC}	7,504,422	1,808,761
{AD}	1,170,522	0
{BC}	9,403,740	165,443
{BD}	5,415,661	702,502
{CD}	4,418,289	136,473
{ABC}	12,426,343	1,895,864
{ABD}	8,558,099	2,552,758
{ACD}	7,661,113	2,087,114
{BCD}	9,906,240	789,605
{ABCD}	13,113,084	2,704,266

Using three different solution concepts of cooperative game theory, i.e., the Shapley value, the τ–value and the nucleolus, we suggest the allocation of increased profits in Table 3. The profit distribution by the τ-value and the nucleolus is similar, while the Shapley value allocates lower distribution value to player A and higher distributions to player B and C.

Table 3 –Allocation of the joint profit according to the Shapley value, the τ-value and the nucleolus (in millions)

player	Shapley	τ -value	Nucleolus
{A}	1.2323	1.7978	1.8238
{B}	0.6430	0.3434	0.3534
{C}	0.4109	0.0828	0.0758
{D}	0.4180	0.4803	0.4513

Based on above allocations, we suggest a new index, the *expectation*, coined for the possibility of deviation. The *expectation* ($E_S(V)$) of each coalition *S* is derived as the excess value of the sum of distributions among coalitional players in the grand coalition compared to the profit increasing of that coalition. For example, the *expectation* of a coalition {AB} with the nucleolus is $0.4732(= 1.8238 + 0.3534 - 1.7040)$. This is calculated exactly in the same manner as the satisfaction (Lozano et al., 2013; Yea et al., 2018). By comparing the *expectation* of all coalitions, we can infer whether the grand coalition maintains. In Table 4, we compare the *expectation* values of each coalition scenario as the absolute term $E_S(V)$ and the relative term $E_S(V)/Z(S)$, which is a percentage of total profits *Z(S)* in the corresponding coalition. Understandably, in our example, the maximum values exist in a coalition {AD}, which is cooperation of both players having a link between a hub and a non-hub node. This means that a coalition {AD} is willing to create the grand coalition to have the extra benefit. On the contrary, all the case of the minimum *expectation* is presented in a coalition {ABD}. This implies that once a coalition {ABD} is formed and then they do have little incentive to invite an extra link, the player C, because the network of player A, B and D has enough profit increasing. For example, when the grand coalition is formed, total distributed values to a player A, B and D is $2.2862(= 1.2323 + 0.6430 + 0.4180)$ based on the Shapley value, which is even smaller by 3.0% than the profit increasing of the corresponding coalition {ABD} in itself (i.e., 2.552).

Table 4 – Coalition expectations for the Shapley value, the τ-value and the nucleolus

Coalition *S*	Shapley	τ -value	Nucleolus
{A}	1.2323	1.7978	1.8238
	95.4%	139.1%	141.1%
{B}	0.643	0.3434	0.3534
	13.3%	7.1%	7.3%
{C}	0.4109	0.0828	0.0758
	9.3%	1.9%	1.7%
{D}	0.418	0.4803	0.4513
	n/a	n/a	n/a
{AB}	0.1713	0.4372	0.4732
	2.2%	5.6%	6.0%
{AC}	-0.1656	0.0718	0.0908
	-2.2%	1.0%	1.2%
{AD}	1.6503	2.2781	2.2751
	141.0%	194.6%	194.4%
{BC}	0.8885	0.2608	0.2638
	9.4%	2.8%	2.8%
{BD}	0.3585	0.1212	0.1022
	6.6%	2.2%	1.9%
{CD}	0.6924	0.4266	0.3906
	15.7%	9.7%	8.8%
{ABC}	0.3903	0.3281	0.3571
	3.1%	2.6%	2.9%
{ABD}	-0.2595	0.0687	0.0757
	-3.0%	0.8%	0.9%
{ACD}	-0.0259	0.2738	0.2638

	-0.3%	3.6%	3.4%
{BCD}	0.6823	0.1169	0.0909
	6.9%	1.2%	0.9%
Min $E_s(V)$	-0.2595	0.0687	0.0757
Min $E_s(V)/Z(S)$,	-0.3%	0.8%	0.9%
Max $E_s(V)$	1.6503	2.2781	2.2751
Max $E_s(V)/Z(S)$,	141.0%	194.6%	194.4%

Interestingly, more satisfied players are links having a non-hub node. In other words, a link between two hub nodes is allocated with relatively lower contribution on profit increasing. In our example, player B and C are links connecting the hub airports, which means that they are backbones of the whole network. This might be the reason of the network expansion effect by additional links in the network game. More demand, the origin-destination pair as well as the number of demand, raises the revenue in an extended network. Nevertheless, the whole network is completed with the backbone link and even benefits from the network expansion are not realized without them. Because, for example, those links deliver not only the demand of their own, direct trip between hub nodes, but also the demand of collaborating, transfer trip via the link. The result of our research that the maximum expectation of the alliance {AD} changes to the minimum of {ABD}, just by inviting a player B, reveals the significant contribution of a player B, which is the link connecting two hub nodes.

Suppose that an airline considers creating a joint venture with other airline and decides how much effort to put in the coalition. In practice, if the rewards for pooling resources are not satisfied and there is another way to get more rewards, a firm doubtless chooses the latter strategy. For example, an airline who operates a link traveling between two hub airports might reduce frequencies or capacities of the trip, due to adding a link from a hub node to another node outside results in higher profit allocation than putting extra effort into the existing link. Then, that airline gains competent profit distributions even though the whole network works but not efficiently. What is worse, a firm prefers to exclude that link if anticipated advantage from joining of a particular segment is not relevant.

This supports needs of another sharing rule imposed of contribution through existence itself. Because with the above distributions, which are suggested in a conventional cooperative game theory, we might ignore some important point of a specific situation, the network game. Although our example is limiting in homogenous marginal cost between airlines and assuming the simplest network, the result shows that the network game has a characteristic of a value of connecting. In this context, we could infer the maintenance of the grand coalition has the value. Although network expansion by attaching a new route is compensated, most distribution methods of cooperative game theory are a flagrant disregard for the existence value of the link connecting the hubs. Thus we need to present a new allocation scheme designed for sustainable cooperation, which emphasizes the significance of maintaining the grand coalition.

Conclusion

In this paper, we attempt to examine the sustainable relationship through reasonable allocation scheme of an airline joint venture by comparing different solution concepts in conventional cooperative game theory. We set an airline joint venture which is a horizontal cooperation between airlines to enlarge their networks and to reduce costs. Since our model, based on each link as a player, assumes passenger trips on the transfer at hub nodes, benefits from cooperation include revenue growth by extended network and cost savings by efficient utilization of the resources. A mixed integer programming model

solves the maximum profits of all possible coalitions in a numerical example and the profit increasing of each alliance is derived as the characteristic function value of cooperative game. Then we apply three different allocation solutions in cooperative game theory to split the profit increasing among the coalitional members. In particular, we apply the Shapley value, the τ-value and the nucleolus for the profit-sharing scheme. In our numerical example, *expectations* of all possible coalitions present that the alliance between players having non-hub nodes is the most satisfied incumbent in the grand coalition, whereas the minimum *expectation* exist in the coalition having the whole network, which excludes the duplicated link. This result highlights a momentous impact of cooperation in a network game and the structure of a network could be the most critical for the long term.

Research area applied cooperative game theory still remains relatively underexplored. Our study addressed the validity of a logistics collaborating, which is quite limited research topic. The numerical illustration provides practical guidance to existing airlines and also to logistics managers on how to assign the distribution of joint profits. In a continuous work, we undergo the research targeting to propose a new allocation rule for sustainable partnership which guarantee properties of the core. As further research, we plan to supplement the limitations such as homogeneous costs and airfares, constant demand without consideration of influence based on increased customer utility caused by cooperation.

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Why suppliers seem reluctant to adopt supply chain finance: insights from UK SMEs

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Abstract

Supply Chain Finance (SCF) is often praised as a tripartite-win arrangement. However, its adoption rates by suppliers are surprisingly low. This raises an important question around why suppliers hesitate to participate in such a beneficial arrangement. SCF allows buyers to extend payment terms to improve working capital while suppliers can receive early payment. However, SCF relationships are rather complex, despite being initiated by buyers, the target adopters are suppliers. This study employs an inductive multiple-case study approach to examine why UK SMEs are not using SCF and seek to understand how SCF adoption decisions and supply chain relationships are interrelated.

Keywords: Supply Chain Finance, SMEs, Transaction Cost Economics

Introduction

Limited availability of funding after the 2008 financial crisis led many corporate firms to employ a "squeezing strategy", either paying their less powerful suppliers late or negotiating extended payment terms to improve their own working capital and financial performance (Boer et al., 2015). SMEs suppliers are often helpless and end up involuntarily accepting longer payment terms. This results in suppliers needing to borrow money to bridge a wider gap between getting paid by large buyers and paying their own suppliers. As suppliers typically pay higher interest rates compared to corporate buyers, this squeezing practice poses a higher risk to suppliers and may eventually lead to financial instability. Deferred payment can also affect service levels or quality of products delivered (Hofmann and Kotzab, 2010).

Supply chain finance (SCF), a form of financial collaboration between large buying firms and SME suppliers through third-party financial institutions, has increasingly gained attention from both scholars and practitioners as a potential solution to fund the gap and ease the tension between buyers and suppliers in managing cash flow and working capital (Templar et al., 2016). SCF is initiated by a buyer who arranges with its bank a pre-agreed loan (overdraft-like) for its selected suppliers, giving the suppliers an option to receive early payment for any

approved invoice(s). Upon request, the bank pays the invoice(s), less interest or fees, instantaneously to the suppliers. At the due date of each invoice, the buyer pays back the bank the face value of the invoice(s). Figure 1 illustrates how SCF works.

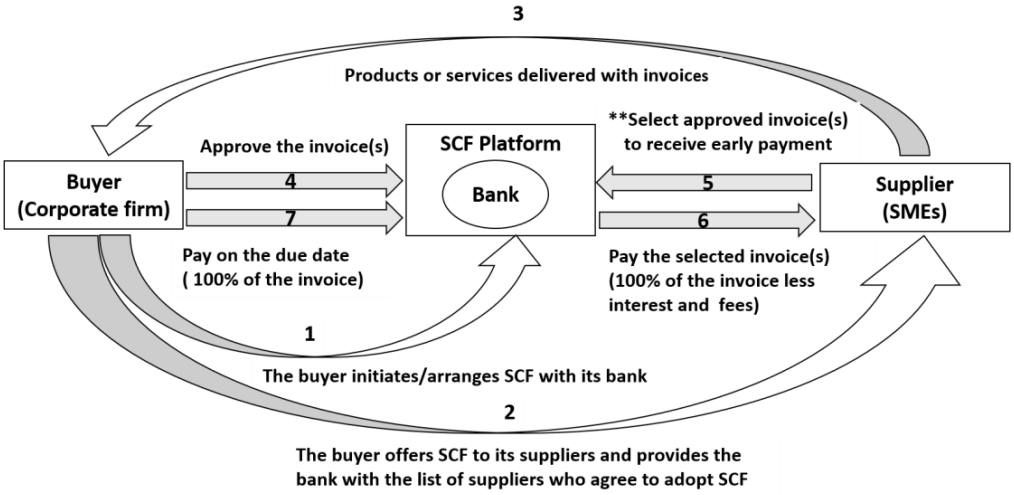

Figure 1 – SCF relationships (Based on GSCFF, 2016)

SCF is repeatedly praised as a tripartite-win arrangement. However, SCF adoption rates by suppliers are surprisingly low (Boer et al., 2015, Wuttke et al., 2016). This raises an important question around why suppliers are hesitant to participate in such a beneficial arrangement. Although potential benefits of SCF can be subject to the nature of individual supply chains, especially in terms of relationships and collaboration between trade partners, previous studies give most attention to financial activities and monetary benefits of SCF, ignoring relations and collaboration aspects (More and Basu, 2013). To address this gap, this paper investigates SCF adoption decisions and SCF relationships through suppliers' perspective.

The remainder of the paper is structured as follows. Firstly, SCF and related literature is reviewed. This is followed by research objectives, design and methodology. Next, the results of semi-structured interviews, observation and documentation are presented. The final part is our conclusions where limitations of this study and future research are also discussed.

Literature review

Supply Chain Finance (SCF) has been introduced in literature in 1990s (Nienhuis et al., 2013). Although SCF has been a topic of interest for decades, the definitions and scopes of SCF are acknowledgedly inconsistent and confusing. Global Supply Chain Finance Forum, GSCFF (2016) admittedly states:

> "The novelty of the subject matter of Supply Chain Finance led to the usage of a range of expressions, terms and terminology that were – and remain today – often inconsistent, opaque and even contradictory".

In general, there are three main definitions/scopes of SCF. First, SCF is generally referred to research in relation to management of financial flow in supply chains. Alternative terms include financial supply chain management (FSCM) and financial supply chain (FSC) (Pfohl and Gomm, 2009). Second, SCF is used as an umbrella term encompassing several finance options for supply chains such as factoring, invoice discounting and letter of credit

(Camerinelli, 2009). The third definition/scope, SCF is referred to a rather new tripartite financial arrangement between a buyer, suppliers and a financial institution, often referred to as *reverse factoring*. This definition is arguably confusing as this so-called *reverse factoring* is also categorised as one of several finance options under a SCF umbrella in the second definition/scope.

These definitions/scopes are also in line with the two main streams of SCF research proposed in literature, supply chain-oriented and finance-oriented perspectives (Caniato et al., 2016, Gelsomino et al., 2016). The former is consistent with the first definition whereas the latter fits with the second definition. The third and our definition is the combination of the two perspectives in response to the earlier call for future research by Gelsomino et al. (2016) who argue that there is a lack of a SCF framework taking both supply chain oriented and finance-oriented perspectives into consideration. Figure 2 illustrates the three SCF definitions and scopes.

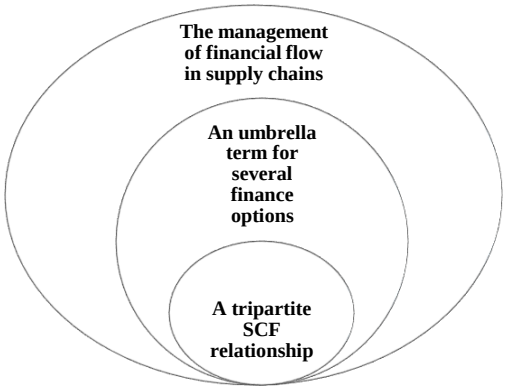

Figure 2 – Three main definitions/scopes of SCF

Although this paper adopted the third definition/scope where SCF is a tripartite financial relationship, given the inconsistency and confusion of definitions and scopes of SCF, we were open to all terms, definitions and scopes that were mentioned by the participants to ensure that we did not miss important information. Furthermore, various finance options currently used by SME suppliers or provided by financial institutions were also explored.

In this definition, SCF is often referred to as "reverse factoring" indicating that SCF is a reverse process of "factoring" which is a short-term financing where suppliers sell their invoices at a discount to receive immediate cash from a financial institution (Klapper, 2004). However, we argue that SCF is neither just a finance option nor a reverse process of factoring. Rather, SCF is a tripartite relationship approach aiming to integrate physical, information and financial flows to reduce cost and increase the competitiveness of the supply chain as a whole. There are several key differences between SCF and factoring, particularly in terms of parties involved and their relationships as well as an initiating and obligatory party.

SCF relationships involve three parties. First is a buyer, an ordering party and also an obligatory party (borrower) who is a large organisation with a high credit rating. Second party is suppliers (sellers) who supplies goods and services to the buyer. Suppliers can be any size from micro, small to medium which are generally referred to as SMEs. The third party is a service provider who is either a financial institution partnering with a SCF platform provider or vice versa. In contrast, factoring and its newly similar finance option, invoice discounting (ID), involve only two parties: a supplier as a borrower and a financial institution. Unlike factoring and ID which can be initiated by a supplier without the buyer's involvement, SCF must be initiated by a buyer who subsequently selects target suppliers to participate so the

financial institution (typically the buyer's bank) can offer the suppliers option to sell their invoices once approved by the buyer (Klapper, 2004).

Both factoring and ID start when a SME arranges with its bank or other financial institutions to sell all of its invoices (from all buyers). The bank advances 75- 90% of an invoice amount within 1-2 days without the need for approval and the remaining 10-25% of the invoice paid once the full payment is received from the buyers (GSCFF, 2016). On the contrary, SCF allows suppliers to receive 100% of an invoice upon request from the day the invoice is approved by the buyer (GSCFF, 2016).

The key difference between factoring and ID is who collects the payments from the buyer. For factoring, financial institutions collect payments on SMEs' behalf whereas SMEs can maintain their own credit control processes by collecting payments themselves when using ID. This makes ID preferable for SMEs than factoring since most suppliers believe selling invoices indicates financial problems in which they do not want buyers to know. Moreover, the costs for using factoring is higher than ID since financial institutions charge the costs for payment collection. Only SMEs with good credit control process and credit rating can opt to use ID.

SCF also differs from factoring and ID in terms of risks involved and costs of finance. Regarding risks, by entering SCF relationships, a supplier can transfer its risks to the buyer's bank while this is not the case in factoring and ID where risks of buyers' default are still with suppliers (Lekkakos and Serrano, 2016). In terms of costs, the interest rate or discount rate paid by suppliers in SCF arrangements is calculated from the buyer's credit rating whereas a SME's credit rating is used to calculate interest rate in factoring and ID. This means, theoretically, SCF is much cheaper than factoring and ID (Wuttke et al., 2013). Nonetheless, since buyers often offer SCF in exchange of payment extension, this may affect the cost of finance paid by suppliers. Table 1 compares traditional invoice finance and SCF.

Table 1 – Traditional invoice finance vs. SCF

	Traditional invoice finance		**SCF**
	Factoring	**Invoice Discounting**	
Initiating party	Supplier		Buyer
Parties involved	Two: Supplier and Financial institution		Three: Buyer, Supplier and Financial institution and/or SCF platform provider
Invoice to sell	Invoice from all buyers		Invoices from only one buyer
Need for invoices to be approval	No		Yes
Percentage of an invoice available	75-90%		100%
Interest rate based on	Supplier's credit rating		Buyer's credit rating
Relative interest rate	Most expensive	Moderate expensive	Least expensive
Confidentiality	No	Yes	No
Withdrawal amount	Any amount		The total amount of each invoice
Payment extension	No		Yes

As mentioned earlier, the monetary benefit of SCF may be compromised by how long the payment term is extended. The longer the extended duration, the higher the interest rate suppliers need to pay to receive early payment. For example, if the buyer extends the payment term from 30 to 60 days, suppliers will be charged the interest rate for approximately 60 days. If the buyer extends to 90 days, the interest rate is charged for about 90 days. Figure 3 serves as an illustrative example for calculating finance costs.

Suppliers receive £10,000 early payment on day 7, Interest rate is 5%

- Extended payment term:60 days, suppliers pay interest 60 - 7 =53 days. Thus interest = $\frac{5}{100}\ x\ 10{,}000\ x\ \frac{53}{365}$
- Extended payment term:90 days, suppliers pay interest 90 – 7 = 83 days Thus interest = $\frac{5}{100}\ x\ 10{,}000\ x\ \frac{83}{365}$

Figure 3 – An illustrative example of finance costs

Nonetheless, SCF have both quantitative and qualitative benefits (see Table 2). Quantitative benefits are only gained from the difference between higher cost of finance of the supplier and the lower cost of finance of the buyer taking into account the duration of extended payment terms. There are also several qualitative benefits such as real time accurate information and transparency through automation of invoice process. It is also suggested that SCF may enhance supply chain relationships through collaboration between buyers and suppliers (Templar et al., 2016). These benefits take both supply chain oriented and finance-oriented into consideration.

Table 2 – Benefits of SCF (Based on Templar et al., 2016)

Buyer	Supplier	Financial institution	Supply chain
• mitigating risk • optimising working capital • strengthening relationship with its suppliers • extending payment terms	• reduction of required working capital • less constrained cash flow • receiving earlier payment	• income from interest and fees • new customers (suppliers) • cross-sell opportunity	• supply chains remain resilient in the long term • trust, commitment and better profitability

Theoretical framework

This paper employs transaction cost economics (TCE) as a theoretical lens to examine SCF adoption decisions and SCF relationships for several reasons. First, a supplier's decision to adopt SCF means they choose to enter into a longer-term relationship where they often need to invest in relationship-specific assets (asset specificity) (Williamson, 1975). There are two main types of asset specificity: human specificity (e.g. training staff for specific purpose) and physical specificity (e.g. invest in IT or equipment) (Williamson, 1975).

In addition, as the primary objective of the buyer in initiating SCF is to extend payment terms, suppliers are prone to opportunistic behaviour. Literature identifies the possibility of lock-in effects which are often caused by high switching costs (Bals, 2018). These effects are comparable to hold-up problems in TCE where suppliers are locked in the relationship and become more vulnerable to opportunism (Holcomb and Hitt, 2007). This opportunistic behaviour may occur over time due to changes in relationships where suppliers may be negotiated to extend payment terms or reduce price in exchange of being in SCF relationships.

Research objectives, design and methodology

Given TCE theoretical background, our research objective is to understand why suppliers are not using or hesitate to adopt SCF. We seek to understand how SCF adoption decisions and supply chain relationships are interrelated.

UK SMEs are the focus of this study. It is acknowledged that SMEs are vital to any nation's economy. UK SMEs account for about 99% of all businesses, 60 % of employment, and 50% of revenue (BEIS, 2017). The unit of analysis is an individual firm rather than a triad, to avoid

influences from powerful buyers. We employed qualitative multiple case studies to explore hold-up problems and opportunism among suppliers (Williamson, 1975). We aim to interview 30 - 40 SMEs from diverse industries, combined with insights from financial institutions, buyers, SCF platform providers, and SCF experts to triangulate the findings.

Interviews were conducted with 15 informants from SMEs, financial institutions as well as experts both academics and practitioners. We used a semi-structured interview approach to ensure that certain aspects of SCF were covered while being flexible to explore any theme emerged in the interviews. Based on literature review, the second definition/scope of SCF was also examined (i.e. other finance options used by SMEs or offered by financial institutions).

Within-case and across-case analyses were used to identify similarities and differences between SCF stakeholders' views of SCF adoptions, in particular SMEs' views. In this preliminary phase of the research, we analysed primary data from interviews and secondary data drawn from financial institutions' as well as SCF platform providers 'websites, and documentation provided by the participants.

Findings

In total, we have interviewed 15 participants including 8 SMEs (2 micro, 6 small), 3 financial institutions (2 banks, 1 non-bank) and 4 experts (2 scholars, 2 practitioners). We intend to include buyers and SCF platform providers in future interviews.

SMEs' participants were founders, directors or managing directors from both production and service businesses. All of them have large, powerful customers. While late payments from large customers are common among these SMEs, the reasons could be either the buyers' intention or their unreasonable bureaucracies. Table 3 gives details of SMEs' participants.

Table 3 – SMEs participants

Firms	Participants	Size	Business
S1	Managing Director	Micro	Service (Education)
S2	Director	Small	Manufacturing (Food)
S3	Finance Director	Small	Manufacturing (Construction)
S4	Operations Director	Small	Manufacturing (Navigation System)
S5	Chairman	Small	Service (Recruitment)
S6	Founder	Micro	Manufacturing (Food)
S7	Director	Small	Manufacturing (Food)─ Family business
S8	Managing Director	Small	Manufacturing (Construction)

Finance options

Table 4 shows SCF and other finance options used by UK SMEs. It is clear that personal fund and overdraft were the two most popular finance options among these SMEs. Three established SMEs (S2, S3 and S5) found traditional invoice selling ─ID handy as they are currently growing their businesses and having several invoices that can be sold to financial institutions for early payment. S6 also agreed that ID is useful. However, ID cannot cover a huge gap between production and delivery due to the nature of his business that needs to invest a lot of cash in production and inventory. This takes weeks before invoices can be issued thus invoice finance or SCF is not a viable option.

Apart from S1 who has no access to ID due to its size, S4, S7 and S8 despite being established SMEs were avoid using traditional invoice finance due to their negative perception of selling invoice. They believed that invoice finance indicates cash flow problems to their

customers although they know that ID is confidential. However, all of them are interested in using ID and SCF for growing their business in the near future.

Established SMEs seemed to have good access to invoice discounting and overdraft with relative low interest rate compared to early stage firms. Despite its expensiveness compared to other finance options, most SMEs have had overdraft "just in case" as they found it was straightforward in terms of access and use (S3, S5, S7and S8).

Table 4 – Finance options used by SMEs

Firms	SCF awareness	Have used/used SCF	Traditional invoice selling	Other finance Options used
S1	No	No	No	Personal fund/Credit card
S2	**Yes**	**Yes**	Invoice Discounting	Personal fund
S3	**Yes**	No	Invoice Discounting	Overdraft/Credit card
S4	**Yes**	No	No	Personal fund
S5	**Yes**	**Yes**	Invoice Discounting	Overdraft
S6	No	No	Invoice Discounting	Personal fund
S7	No	No	No	Overdraft
S8	No	No	No	Overdraft

Awareness and perception

Among these eight SMEs, three of them had been offered and perceived pressure from the buyers to adopt SCF. S4 managed to decline while S2 and S5 unwillingly participated. SCF offers came with the extension of supplier payment terms. S5 found using SCF is more expensive, compared to ID. As he had already used ID, participating in SCF meant he had to move one big buyer from the portfolio of buyers for ID. This action could have raised the interest rate charged by S5's bank. Fortunately, he was able to negotiate to maintain the interest rate due to his good credit history. He also found the need to withdraw 100% of an invoice inflexible and expensive. Nonetheless, S2 found SCF a good option because he did not have a better finance option.

Apart from the three SMEs who were offered SCF and one SME who was acknowledged by a financial institution, other SMEs were not aware of SCF. Two experts (1 scholar and 1 practitioner) had not heard about SCF as well. In contrast, all 3 financial institutions had good awareness and knowledge about SCF even though the terms and definitions differed among themselves as well as from our definition and scope.

Third Party: Financial institutions

We interviewed three financial institutions: two were banks (F1and F3) and one was non-bank (F2). All financial institutions adopted the second definition/scope of SCF where SCF is an umbrella term for various finance options as shown in Figure 4. The tripartite SCF is currently provided by F1 and F3 with totally different names and criteria. All the three financial institutions did not use the term "reverse factoring" as well. We can differ our SCF definition from other finance options by looking at the process and relationships of the parties involved. Both F1 and F3 partner with SCF platform providers who provide a system that matches invoices with purchase orders.

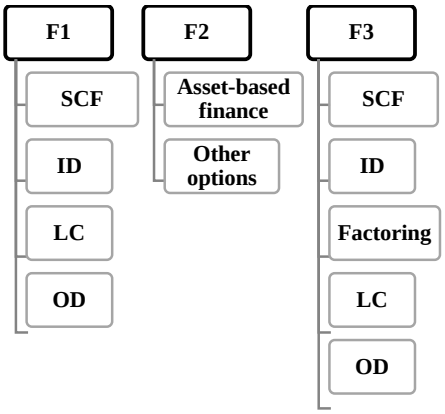

Figure 4 – SCF and other finance options (*OD: Overdraft, LC: Letter of Credit)*

Examples of the criteria for a buyer to initiate SCF include turnover at least £100 million, facility at least 5 million, being in Business Grade 1-11 (this is the bank's own credit rating/scoring system ranked from 1 the best to 21 the worst), and a maximum term 180 days of drawing down (F1). These criteria are totally different from F3 where SCF is available for a business trading for at least three years with a turnover of £2.5 million. In contrast, ID is available to SMEs with a turnover of £250,000 at one financial institution but another non-bank financial institution requires a turnover of £500,000 and above.

Experts' views

Two experts (E2 and E4) define SCF as any finance involved up and down supply chains which is the second definition/scope and consistent with the three financial institutions. E1 and E3 were not aware about SCF but able to comment about finance in general. Regarding opportunities, SCF allows two companies to have different payment terms but it is only appropriate when circumstances are right. With regard to obstacles, interestingly, E3 acknowledged that UK SMEs are normally stuck with only one bank. They are only a few bigger SMEs who may use more than one financial institution (E3). This is in line with S2 who argued that banks were the main obstacle in SCF adoptions. Similarly, all financial institutions (F1-F3) also mentioned that typically they would require SMEs to use one bank only for the reason of visibility. It is also costly to change banks due to the need to refinance all the facilities (i.e. finance options in use). There are also exit penalties if SMEs wanted to leave early.

Discussion

Why suppliers are reluctant to use SCF

It appears that lack of awareness regarding availability, nature, benefits, and drawback of SCF among SMEs is the primary reason for SMEs not currently using SCF. SMEs who often have limited resources rely upon accountants or financial institutions to educate them about available finance options. Since SCF is rather new, awareness and knowledge about SCF mainly comes from third parties (banks and SCF platform providers) who tend to give most attention to large companies who are initiators, overlooking the target adopter, SME suppliers.

Unlike dynamic discounting where buyers offer early payment in exchange of a discount (buyer-supplier) or most finance options (supplier-bank) which are dyadic relationships, SCF is a triad where all the three parties play important roles. In particular, financial institutions play a key role either as an enabler or inhibitor. In addition, SMEs' decisions to adopt SCF mean they need to work with both the buyer's bank and their own bank concurrently. As mentioned earlier, this can affect costs of finance for the existing finance options in use.

Furthermore, most established SMEs already have other finance options such as overdraft or ID. Compared to ID, SCF may not be a much better option in term of flexibility and costs. In contrast, early stage SMEs and very small SMEs (micro) often have limited access to most finance options. Thus, SCF seems to be more appropriate and beneficial to these types of firms than established SMEs. However, they often too small to be included in SCF programme by the buyer.

What's more, nature of business also indicates whether SCF is right for SMEs. For example, businesses that have a year-round stable level of orders are more suitable for invoice finance both traditional and SCF. However, this is not the case if the company's products are seasonal in which invoices may not available for selling when SMEs need cash. Construction businesses were also mentioned as inappropriate for invoice finance due to their unique contracts. Since there is a certain period after the work is done before suppliers can actually receive money, SCF might not be an appropriate option.

Transaction Cost Economics

Suppliers who agree to adopt SCF need to register with the buyer's bank and undergo the due diligence process which involves a lot of paperwork. This is generally referred to as onboarding process which takes time and effort. Although there is no need for installing IT-related equipment at the suppliers' side, there is still the need for training staff how to use SCF platform to upload invoices and request for early payment. Suppliers typically have limited resources especially staff to invest in this specific relationship.

It can also be costly for UK SMEs to change or use more than one banks. Adopting SCF means SMEs have to use the buyer's bank at the same time they still have to use their bank for other finance options (e.g. factoring, ID). As a result, SMEs' banks often increase interest rates and fees for the existing facilities (e.g. factoring, ID) in order to cope with an increase in risks since the large buying firm's invoices are excluded.

It is evident that all the four SMEs have learnt about SCF from their buyers and a financial institution. They were also to some degree pressured to adopt SCF. Since SMEs can choose whether they want to withdraw early payment, if SCF is more expensive than the existing finance options they have, SMEs may rarely withdraw the money. This can affect the duration need to compensate the setup costs invested in the SCF technology/platform. As the costs may be allocated to interest and fees, suppliers are prone to be charged higher costs to use SCF.

Conclusion

Insights from the interviews corrobarate high asset specificity in SCF relationships, particularly human specificity due to the need for training. There are also high setup costs for installing a technological platform, known as SCF platform that may need to be allocated among the three parties and suppliers may be suceptible to opportunistic behaviour over time. Furthermore, the lack of standard terms and procedures, combined with paperwork needed can be challenging for resource-constrained suppliers or even discouraging them from adopting SCF.

Although SCF is often praised as a tripartite-win arrangement where all the three parties: buyer, supplier and financial institution are supposed to benefit from the relationship, our early investigation suggests that suppliers, the target adopter of SCF may not benefit from SCF relationships. This is because SCF is often offered by large buying firms in exchange for payment term extension. The longer the payment terms the higher the cost of finance suppliers need to pay to receive early payment. Moreover, SCF may not enhance buyer-supplier relationships since it seems most SME suppliers are forced to adopt SCF by powerful buyers.

SMEs are reluctant to use SCF because most of them are unaware of the availability and lack an understanding of the benefits and drawbacks of SCF. As the information regarding finance options and eligibility primarily comes from SMEs' banks, these banks can become an

inhibitor of SCF adoption depending on each bank' available products and policies. In addition, most banks who offer SCF pay more attention to a large buying firm who initiates SCF rather than suppliers who are target adopters or end customers.

Furthermore, SCF currently targets established SME suppliers who often have other finance options in place. This not only makes SMEs end up using two banks concurrently, but also makes the cost of existing finance options, especially traditional invoice finance (e.g. ID) more expensive. Our findings suggest that SCF appears to be more beneficial to newly started firms who do not have sufficient historical record to use other finance options or a rather small SME who is not eligible for a cheaper option such as ID.

Our initial findings are limited in terms of number of SMEs who were aware of or had used SCF since we intended not to approach SMEs through large buyers to avoid bias. Moreover, financial institutions who are key sources of information regarding costs and criteria of SCF are often unwilling to reveal the information due to confidentiality and competition. Not all financial experts know about SCF as well. This study is so far based on initial empirical data from SME suppliers, financial institutions and experts. As a next step, we will be interviewing more participants in these three groups of stakeholders as well as including large buying firms and SCF platform providers to gain a thorough understanding of SCF relationships and SCF adoption.

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Buyer-Supplier Conflict Resolution: Timing, Tactics, Resources, and Relationship Quality

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Abstract

Buyers are often faced with supplier-induced conflicts. Literature on conflict resolution has primarily explored aggregate conflict resolution strategies using cross-sectional surveys. However, little is known about specific resolution tactics and their effectiveness over time. Using a multiple case study, we explore a more fine-grained taxonomy of tactics throughout the entire conflict episode. We identify a) a taxonomy of resolution tactics deployed based on tactics' content and temporal orientation, b) factors that impact conflict resolution dynamics including resolution misalignment, relationship quality, and buyers' resources availability, and finally c) the effectiveness of resolution tactics over the conflict episode.

Keywords: conflict resolution tactics, relationship quality, resources, and time.

Introduction

Buyer-supplier exchanges always include the potential for conflict (Deutsch, 1994) that, if not properly managed (Griffith et al., 2006), can generate significant dis-benefits for all parties. For example, in 2016, the German automaker Volkswagen (VW) experienced a major conflict with two of its critical suppliers: CarTrim, which makes seats, and ES Automobilguss, which produces gearboxes cast iron parts. VW cancelled orders without providing any justifications, thereby affecting suppliers' revenues. In return, the suppliers withheld their deliveries resulting in production stoppages across six of VW's 10 German factories costing VW over £86m in production losses. To resolve the conflict, VW had to pay the suppliers nearly $15m in compensation but not before causing severe long term damage to the relationships (Reuters, August 23, 2016).

Although the above anecdote illustrates the important role of conflict resolution in purchasing and supply management, extant research in this area is scant and incomplete. Indeed, a review of major publications in the interorganisational conflict literature has revealed that the conflict resolution process has not been sufficiently studied, and studies "*only scratch at the surface of what is critical to consider when examining the conflict and conflict resolution processes in interorganizational exchanges*" (Lumineau et al., 2015, p. 52). Most extant research has adopted a macro perspective on conflict

resolution by analysing general dispositions, e.g. partners seek confrontation or collaboration (Koza & Dant, 2007). Although this approach has made significant contributions to the literature, using a "strategy" conceptualisation does not illustrate specific conflict resolution interventions (e.g. compensation) that parties use to manage conflict (Carton and Tewfik, 2016). Therefore, it could make it difficult to understand the complexities of the conflict resolution process.

Further, although prior research emphasised the dynamic nature of conflict (Frazier, 1999), prior studies have mainly based their research on static levels of conflict, largely ignoring the "the twists and turns" in a conflict episode. Nevertheless, we argue that conflict may move in an escalatory direction, and that an examination of conflict intensity is necessary. The resolution of different degrees of conflict represent a core theoretical and managerial concern that should be dealt with adequately to advance conflict research (Ellegaard and Andersen, 2015).

In an effort to fill the above gaps in the buyer-supplier conflict literature, this paper proposes and then, using multiple case studies of buyer-supplier conflict in the Automotive sector, refines a model of the factors that determine the level of intensity of a conflict, and the contingent mechanisms that moderate its dynamics. Specifically, we investigate a series of (supplier-originated) exchange problems that resulted in varying levels of conflict intensity over the entire conflict episode; from emergence to resolution. This helps us unpack the conflict resolution process and analyse process elements that are not accessible through traditional quantitative methods (e.g. illuminate how certain resolution tactics lose/gain effectiveness over time). In so doing, we respond to calls for more dynamic exchange conflict research (Ellegaard and Andersen, 2015, Koza and Dant, 2007).

Conceptual Background

Despite the repeated acknowledgement of the importance of effective conflict resolution in buyer-supplier relationships, there has been limited study of the details of conflict resolution (Lumineau et al., 2015). First, conflict is not a binary construct and yet relative intensity has received limited attention (Ellegaard and Andersen, 2015). Second, although the appropriateness and effectiveness of conflict resolution approaches varies as a function of conflict intensity levels (Andrews and Tjosvold, 1983), previous studies considered only static levels of conflict and no assessments have been made of the contingent effectiveness of various mechanisms according to conflict intensities. Finally, although conflict is a dynamic process most research presents exchange conflict resolution as a 'one-off' event, meaning there is a need for investigation of concurrent and sequential resolution strategies.

In order to better conceptualise exchange conflict intensity, we propose that – as other exchange conflict researchers have noted - conflict reflect buyers and suppliers differences in expectations or actual performance (Emiliani, 2003). Specifically, conflict will exist as long as there is a gap between the initiating (supply failure event) issue and perceived efficacy of the resolution intervention and, further, the extent of this misalignment determines the level of perceived conflict intensity (O'Neill et al., 2015). Salient or large discrepancies will generate high conflict levels, whereas minor discrepancies will result in low conflict. This means our model is essentially independent of the type and scale of the causal event. A simple concern that is poorly managed can engender higher levels of conflict, just as a major concern that is well handled can minimize conflict.

Conflict Intensity

Conflict intensity is an important dimension of a conflict episode. In the broader organisational behaviour literature, conflict intensity has been characterised by two constructs (Tsai and Bendersky, 2016), oppositional intensity and emotionality. For instance, a conflict may be expressed in variety of ways, from "tongue-in-cheek" comments to verbal abuse or even physical violence (Brown and Day, 1981). Emotionality refers to the degree of negative emotionality exhibited and felt during the conflict including annoyance, irritation, anger, rage, resentment, and dislike (Jehn, 1997). Different exchange conflict intensities are likely to exhibit different dynamics e.g., conflict spirals: (Emiliani, 2003) and therefore require different resolution mechanisms (Barker et al., 1988).

Conflict Resolution

Conflict resolution is defined as "*strategies oriented toward the resolution of the tension*" (De Dreu et al., 1999, p. 371). Researchers have classified these strategies and hence various models have emerged. These frameworks differ in the terms used to describe the strategies but their classifications are broadly based on two dimensions reflecting people's concerns for their interests and their concerns for the other party. Generally, five conflict resolution strategies were derived: (a) Collaborating is oriented towards achieving maximum satisfaction of both parties' concerns through high cooperation; (b) accommodating implies offering help and giving in to the desires of the other party; (c) forcing involves imposing one's will on others; (d) avoiding involves ignoring all concerns and reducing the importance of the issue; and (e) compromising presumes a mutual give and take so as to gain partial fulfilment of one's desires (Blake and Mouton, 1964). Essentially, the focus of this literature has been on examining conflict resolution strategies at an aggregate level, and not on the complexities and details that need to be addressed when resolving conflict episodes. Therefore, this research provides little guidance on how to apply these strategies in (supply) practice. Specifically, there is a need to move beyond generalized resolution strategies so far proposed in the conflict literature (Ellegaard and Andersen, 2015). There is some relevant research (Champenois et al., 2016) and, albeit to a lesser extent, in a buyer-supplier relationships. For instance, Ellegaard and Andersen (2015) suggested that inter-organisational communication by non-actors, inter-organisational communication by higher ranking executives, and the replacement of the core actor in the buyer-supplier exchange are effective interventions to resolve severely conflicting relationships.

Conflict resolution in Context

Finally, exchange processes between buyers and suppliers do not exist in a vacuum (Leonidou et al., 2002), the context in which issues emerge, conflict develops and resolution mechanisms are (successfully/unsuccessfully) applied plays a role in the severity and dynamics of conflict. Previous research has highlighted the impact of few variables that could potentially impact the choice of partners' strategies when resolving conflict including for instance communication strategy (Koza and Dant, 2007). However, to the best of the authors' knowledge, factors and contextual conditions that impact recipient's reaction (conflict intensity as experienced by buyers) to resolution tactics (provided by the supplier) have not been delineated in the literature.

Methodology

In this paper we use a multiple case study method and look at supplier-induced conflicts. We focused on a single industry – the Moroccan automotive industry – to

control for industry specific contingencies and minimize extraneous variation (Eisenhardt, 1989) that might be derived from industry characteristics. A theoretical sampling providing distinct contrasts along two dimensions of relationship quality pre-conflict episode (low vs. high) and conflict duration (short vs. long) has been used. This sampling frame enabled us to identify cases of different intensities and different dynamics and resulted in four matched dyads (Table 1)**.** These four cases were enough to reach a satisfactory level of theoretical saturation (Pagell and Wu, 2009). Figure 3 summarises the data collection process.

Table 1: Cases description

Cases	Conflict
WiringCo (C1B) - ElectroCo (C1S)	Triggering event: delivery issue; Duration: 4-5months
AutoElecCo (C2B) – CableCo (C2S)	Triggering event: quality issue; Duration: 3 months
SeatCo (C3B)- TextileCo (C3S)	Triggering event: quality issue; Duration: 12 days
AutoTechCo (C4B)– ConnectorCo (C4S)	Triggering event: delivery issue; Duration: 15 days

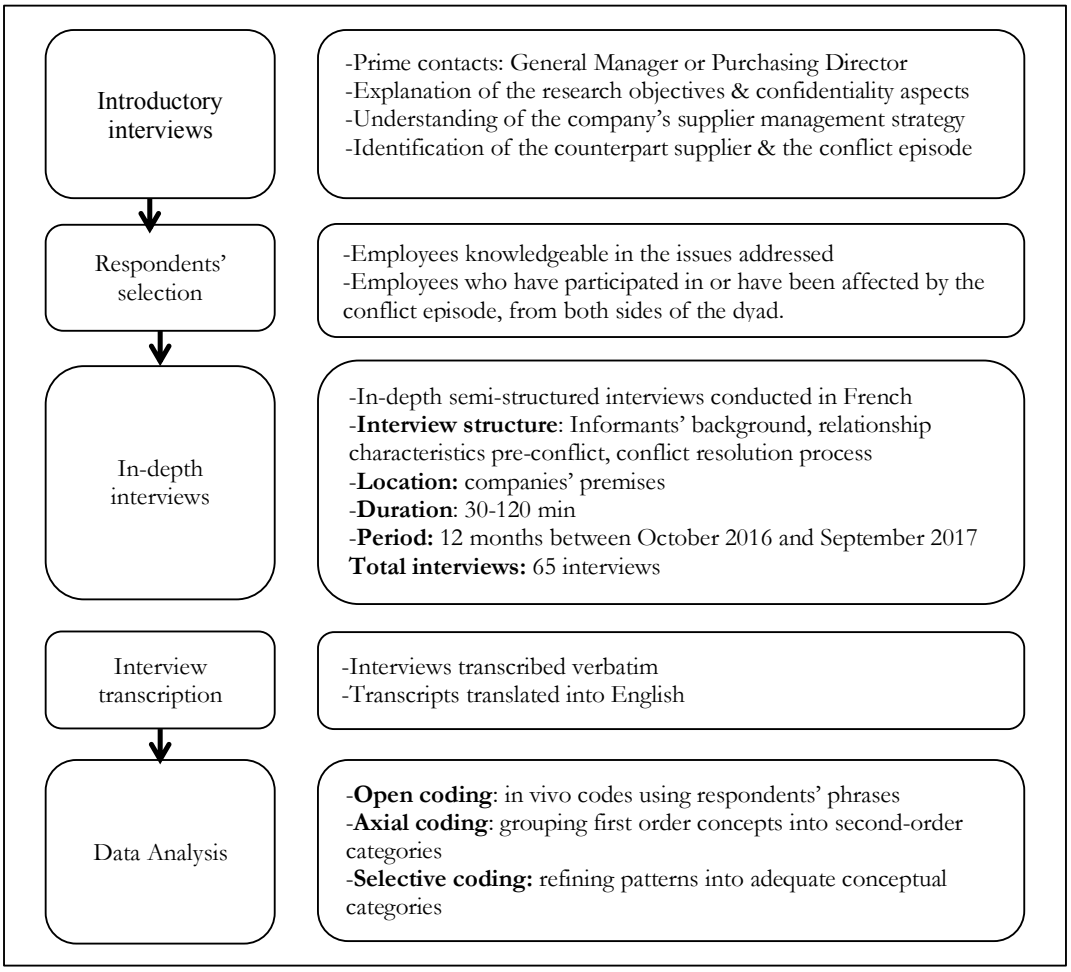

Figure 1 - Data collection and analysis process

Interview recordings resulted in more than 500 pages of textual material. Once this process was accomplished, the write-ups were then translated into English and imported into the qualitative data analysis tool QSR NVivo 10 for systematic coding and cross-case comparisons.

Cross-Case Findings

Resolution Misalignment - Conflict Intensities

The data revealed that misalignments in conflict resolution impacted changes in conflict intensity. Misalignments manifested either in the resolution tactics provided (a mismatch between the tactic and issue resolution) or the resolution time (a delay in response). Findings indicate that a gap existed between the requirement of issue resolution and the provided response. For instance, it was apparent from case 1 that when buyers expressed their concern over the conflict issue, they were expecting the supplier to deliver the product following their complaint. However, the supplier only promised that the product would be delivered before the production line stoppage date. Hence, while buyers were focused on a tangible delivery of products, suppliers only offered an explanation of the issue and a promise of issue resolution. A manager mentioned "*there was a lack of reactivity from the supplier, they did not provide any containment actions (…) and this got on our nerves*" (C3B- Quality Manager). Similar to a misalignment in tactics, cases also highlighted that a misalignment manifested in a delay of response. An interviewee echoed how the time taken to resolve the conflict impacted conflict intensity "*we had not received the goods on time, it is true that there was an effort from their side, but it was not timely, it was very irritating (…) and so it was a pure confrontation, the subject was escalated*" (C4B-Logistics Manager). Thus, across all cases, buyers seem to have come to view misalignment as impacting conflict intensity.

Buyers' Resources, Relationship Quality, and Conflict Intensities

Across the four cases, we observed the differential impact of the availability of buyers' resources and relationship quality as contingency factors that impact changes in conflict intensity. Consistent with Größler and Grübner (2006, p. 460), resources are defined as "*something a firm possesses or has access to (…) resources can be tangible, for example, specialized production systems, and intangible, for example, level of training of workers"*. In cases 1 and 2, when conflict occurred, possessing resources buffered escalation resulting from misalignment because buyers mobilised resources to reduce the discrepancy "*at the beginning, everything was fine [with the supplier]. Although the supplier couldn't replace the material, on our side we used the stock from the cables we used to buy from the former supplier (…) and that's how we unblocked the situation and carried out production activities*" (C2B-Supplier Quality Engineer). However, in cases 3 and 4, possessing resources escalated conflict "*unbeknownst to the supplier of course, we had some room for manoeuvre (…) So not only we were having problems because of their inappropriate reaction, but we also had to deploy extra resources (Deep breath), it was frustrating"* (C4B-Purchasing Manager). Respondents' also provided clear descriptions of how the quality of the relationship prior to the conflict episode impacted conflict resolution dynamics. In cases of low relationship quality (case 3 and 4), conflict rapidly escalated *"(...) So when the supplier rejected our claim, and our relationship with them was already very strained, there was no room for discussion, and this increased friction and animosity towards them"* (C3B-Operations Director North Africa, SeatCo). Conversely, in cases 1 and 2, relationship quality has both suppressed and activated conflict escalation. As the Purchasing Director from *AutoElecCo* explained "*[CableCo] were very helpful previously, they accommodated our orders' fluctuations, they satisfied our requests, (…) we don't forget that when they have a problem, and so we decided to solve the issue*" (C1B-Country Purchasing Director). On the other hand, the interviews revealed that although when relationship quality was high, conflict escalated and this was explained by reference to resources availability.

One manager emphasized "*(…) we could not work on a stressful mode until the issue is resolved. We didn't want to have issues with our customer (…) So we were putting pressure on them, pushing our requirements regardless of what they were going through"* (C1B-Purchasing Manager).

Conflict Dynamics and Sequence of Tactics

A mild conflict situation involved discussing the conflict issue as a debate, and was characterized by low entrenchment in the buyers' position. Supplier offered an apology, an explanation, and a promise to resolve the issue, and these tactics laid down positive expectations, and confirmed buyer's thoughts about the supplier's integrity and their ability to alleviate conflict. One manager recalled "*the supplier justified why this happened and informed us that they would deliver this quantity with the next scheduled delivery. So we let it go, we knew that the supplier did not have bad intentions...*" (C1B-Purchasing Manager). As conflict unfolded, buyers built expectations with regards to future behaviour in the next micro-episode. However, as a misalignment occurred, the dyad moved to moderate levels of conflict*"we actually discussed the issue with the supplier, we listened to the supplier, and we shared our concerns. It happened in a very friendly atmosphere. However, when it happened that the supplier did not respect what he has communicated to us, and the risk was increasing, tension and aggressiveness increased, we had to be firm, we had to make a point"* (C1B-Purchasing Manager). At this point, suppliers attempted to cover for all the potential losses generated by the conflict situation to prevent further escalation. This suggests that explaining the conflict issue or making promises lost credibility "*the supplier insisted and promised that they would solve the issue shortly (…) but this was not enough (…) So most importantly, in the meantime, they proposed that we could continue supplying from the previous supplier and they would continue to pay all the charges generated from this quality issue until the issue is completely resolved*" (C2B-Purchasing Director). Finally, our data also showed that high levels of conflict intensity represented cases where the misalignment was persistent that it impinged on the buyers' ability to continue the relationship. Therefore, tactics only targeting the resolution of the current issue were no longer sufficient. Suppliers deployed further actions that showed their commitment to the relationship "*so we had to invest in new equipment (…) it was a duplication of the production chains*" (C1S-North Africa Sales Manager).

Discussion and Implications for Theory

In examining the four cases, we have presented evidence for the dynamics of conflict resolution. Building on these findings, we offer a model in Figure 2 with the concepts of resolution misalignment, relationship quality, and buyers' resources at its centre.

Resolution Tactics

Tactics Bundles: The findings from the field interviews suggest that resolution tactics can be classified along two dimensions - content and temporal orientation. With regards to content, these tactics can be classified by whether they are psychological or tangible fixes. Psychological tactic conveys politeness, concern, effort, and empathy to buyers (Hart et al., 1990). In contrast to psychological tactics, tangible fixes refer to actions that the supplier deploy to resolve the task issue at the essence of the conflict (Miller et al., 2000). The data suggest furthermore that these two categories of actions can have a different temporal orientation. We distinguish "Reactive curative" tactics, wherein the focus is present-oriented, i.e. resolution of the immediate issue, and "prospective preventive" tactics, wherein the focus is oriented towards the prevention of conflict

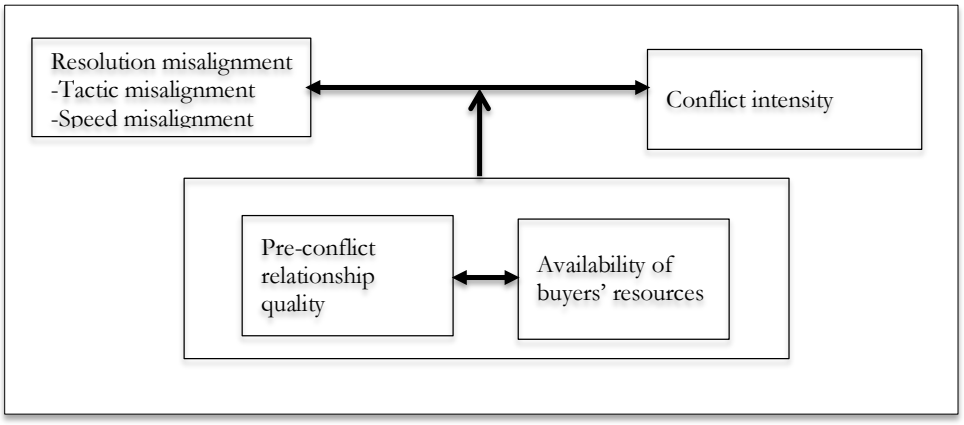

Figure 2 - Conceptual framework

reoccurrence in the future. Each of these tactic bundles could be employed separately or in combination depending on conflict intensity and contextual conditions.

Resolution Misalignment and Conflict Intensity

Our model shows that resolution misalignment is central to conflict escalation. Tactic misalignment generates feelings of frustration and dissatisfaction (Chen et al., 2018) thereby leading to increased conflict intensity. Similarly, the speed of suppliers' resolution efforts is equally critical as it tracks how the dyad is moving towards conflict resolution. A tardy response triggers negative emotionality, whereas a prompt resolution prevents further frustration and conflict escalation. Essentially, when there is a misalignment in conflict issue resolution, buyers fail to obtain the expected outcomes (Smith et al., 1999), lose resource, and therefore experience increased conflict.

The Interaction Effect of Buyers' Resources Availability and Relationship Quality

Our model in figure 2 positions buyers' resources in combination with relationship quality, wherein both interact in impacting conflict resolution dynamics. Four combinations have been derived:

Complete buffer: A "complete buffer" situation is characterized by high resources availability and high relationship quality. Possessing resources enabled buyers to absorb the lack of supplier's responsiveness to conflict (misalignment), and this was enabled by the relationship quality, which provided a psychological safety atmosphere where risk-taking was safe (Edmondson, 2002). Specifically, when relationship quality is high, buyers perceive misalignment as less threatening, and deploy more resources to reduce the discrepancy. Buyers who have a strong existing relationship with their suppliers as well as high resources availability would express low valence emotions; they would have a behaviour that supports the business relationship and would be more tolerant of the conflict situation.

Rapid escalation: Low resources lead to poorer conflict tolerance even though relationship quality is high. In the case of low resources availability, conflict escalates wherein buyers display a defensive and hostile stance to avoid further losses (Lam et al., 2017). Essentially, even though buyers and suppliers enjoy a strong relationship, in instances of low resources, a misalignment in conflict resolution is considered as a suppliers' failure to fulfil their obligations in the relationship, and thus generates negative feelings and doubt about suppliers' reliability (Grégoire et al., 2009). Accordingly, when resources are low, the quality of the relationship may backfire and intensify conflict in the exchange dyad, rather than buffer against conflict escalation.

Conflict persistence: When the relationship is weak, the possession of resources does not dampen the effects of resolution discrepancy, as the state of the relationship does not motivate buyers to mobilise resources and adjust to the situation (Ellegaard et al., 2003). In this case, buyers are obliged to resolve the issue unilaterally, and this further heightens conflict. Consequently, although buyers' activities secure fulfilment of their performance goals, it further contributes to the escalation of conflict with suppliers (Reimann et al., 2017) because the unilateral deployment of resources increased buyers' perception of resource loss. Additionally, the lack of responsiveness from the supplier further confirms buyers' beliefs about the exchange relationship, i.e. suppliers are misguided and are acting opportunistically.

Complete activation: A complete activation situation is characterized by low relationship quality, and low resources availability. Therefore, a resolution discrepancy is chaotic as the contextual conditions are not sufficient for absorbing any misalignments. Any misalignment is perceived with suspicion because relational ties are not sufficiently strong, and buyers are attempting to avoid further resources losses. Under such conditions, doubts linger close to the surface, and this could be costly and damaging to the buyer-supplier relationship (Emiliani, 2003). As such, conflict escalates steeply as buyers have an aggressive and a hostile behaviour.

Conflict Intensities and Resolution Tactics

In the case of a "complete buffer" situation, conflict is mild and psychological tactics are sufficient to resolve conflict. In such situations, offering a psychological response is completely effective, and this hold even though no tangible fixes are offered. This finding is consistent with the fair process effect (Collie et al., 2000), and also with Tomlinson et al. (2004) evidence of the strength, for instance of an apology, in buyer-supplier exchanges. In "rapid escalation", the use of psychological actions alone loses effectiveness because more resources have been lost or were being threatened. A number of examples in the cases showed that the endurance time of a psychological tactic is short and tappers off quickly because it is not sufficient to compensate for the continuous resources loss. Therefore, tangible fixes are deployed to complement the decay in the effect of psychological tactics, and are therefore more reliable when buyers make their judgments about the conflicting situation (Leventhal, 1980). In cases of "conflict persistence" exchanges are characterized by profit-seeking motives rather than social obligations (Robinson et al., 1994), and hence the deployment of well-targeted tangible fixes is effective in resolving the conflict. Finally, in cases of "complete activation", the deployment of prospective tactics that act as "prophylactic" measures against future conflict occurrence is necessary.

Conclusion

In this research, we provide an empirically grounded taxonomy of conflict resolution tactics beyond the conventional categorisation of aggregate resolution strategies (Blake and Mouton, 1964). Based on two characteristics, content and temporal orientation, we proposed four categories representing the range of resolution tactics suppliers have at their disposal including reactive psychological, reactive tangible fixes, prospective psychological, and prospective tangible fixes. As a second contribution, we introduced "resources availability" as a factor unrecognized in conflict research. Our findings add to the conflict literature that organisational constraints (Janowicz‐Panjaitan and Krishnan, 2009), in the form of firm's tangible and intangible resources, influence buyers' adaptability to and tolerance of conflict. We also contributed to the literature by highlighting the strength of a multi-level view (Klassen and Menor, 2007) as the

interaction between buyers' resources and relationship quality explained more fully the impact on conflict intensity than each separately. Finally, our research sheds light on the effectiveness of conflict resolution tactics over time, paving the way for scholars to understand the pitfalls of certain tactics and the untapped potential of others as the conflict episode evolves.

Limitations and Future Research Directions

The findings of the current research should be viewed in light of the study's limitations, which provide avenues for further research investigations. First, we limited our study to supplier-induced conflicts. As such, we did not examine instances of conflicts emanating from the buyer (Johnson and Sohi, 2016). Future research should adopt such approach to understand whether different or similar dynamics occur. Moreover, another limitation of our study is related to our data collection approach. We have chosen to collect data on a limited number of cases and this may limit the generalizability of our findings. However, focusing on four cases gave us the opportunity to gain deep understanding of the conflict from both sides of the dyad.

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Supply chain collaboration in circular supply chains: The example of Swedish steel recycling

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Abstract
The aim of this paper is to investigate the role of supply chain collaboration between buyers and suppliers in the reverse flow of a system of circular supply chains. The empirical context is Swedish unalloyed steel recycling, i.e. recycling of steel with a low proportion of additional components. The paper applies a framework on mechanisms of coordination and supply chain flows to discuss the underlying rationale for how the Swedish steel recycling industry organizes coordination. At the activity level, it is shown how the inherent uncertainty of reverse flows is handled through voluntary cross-industrial cooperation and standardization.

Keywords: Supply chain collaboration, circular supply chain, steel recycling

Introduction
In recent years, a number of studies in different research fields have identified underutilized value in the materials of end-of-life products (see e.g. waste electric and electronic equipment (Cucchiella et al., 2015), spent lithium-ion batteries (Ku et al., 2016), and textile waste (Leal Filho et al., 2019). A recurring problem with utilizing the material value in these end-of life products is to get the right material to the right place at the right volume in an efficient way, as exemplified by plastic waste (Geyer et al., 2017).

The end-of-life product domain is a complex issue involving a plethora of actors who collaborate outside typical supply chain boundaries (De Angelis et al., 2018). As discussed by Batista et al. (2018) and De Angelis et al. (2018) this kind of flow can be termed as *circular supply chain*s, that is, a circular economy approach applied to supply chain operations. Conversely, a circular supply chain is similar to a *closed-loop supply*

chain (Guide and van Wassenhove, 2009) with focus on coordination of forward and reverse supply chain flows. On the other hand, the circular supply chain takes a more holistic approach to value creation with focus on the triple bottom line rather than the financial bottom line. The integration of the supply chain is commonly recognized as positively and directly linked to supply chain performance (Prajogo and Olhager, 2012). Although this link is questioned by Fabbe-Costes and Jahre (2007) at a general level, it is confirmed by Gimenez et al. (2012) for buyer-supplier relationships and the forward flow of the supply chain when characterized by high supply complexity.

Today, the comprehensive approach to sustainability expands the scope of circular supply chain operations with added supply complexity of circular supply chains (Batista et al., 2018). A particular characteristic of this is that supply complexity and uncertainty in the reverse flow is inherently higher than in the forward flow. The supply complexity is due partly to the additional activities in reverse flows compared to forward flows, e.g. acquisition, reverse logistics, sorting, and testing (Guide et al., 2003), and partly related to various differences between reverse and forward flows, e.g. difficulties in forecasting, transport from several different locations to one, and variations in quality of supply (Tibben-Lembke & Rogers, 2002).

While there is agreement in the literature on the importance of supply chain collaboration in circular supply chains amongst many actors across several industries, there is limited empirical evidence on the nature of these collaborations. So far research on coordination mechanisms in reverse flows has been focusing on contracts (Guo et al., 2017) even though mathematical models of contract arrangements do not fully capture the evident complexities and uncertainties. However, the interest in social capital theory in operations and supply chain management literature has enriched our understanding (e.g. Min et al. (2008), and Matthews and Marzec (2012)). Especially of micro-processes as drivers for relationship building to uncover the informal dimension of buyer-supplier relationships. Regardless, it may still be argued that there are limitations to the literature and that the existence of complexities and uncertainties in regards to the organization of coordination activities has not been fully grasped.

Against this background, the aim of this paper is to analyze the role of supply chain collaboration between buyers and suppliers in the reverse flow of a system of circular supply chains. Building on the definition by Tsou (2013) on supply chain collaboration and applying a conceptual framework on the *mechanisms of coordination* (Martinez and Jarillo, 1990), and *supply chain flows* (Mentzer et al., 2001), we empirically investigate coordination at the activity level between buyers and suppliers involved in Swedish unalloyed steel recycling. This industry is global and an example of an integrated system of supply chains working circular for a long time, which has also succeeded in reaching high supply chain performance. The use rate of recycled steel is close to 90% (Material Economics, 2018) because of the ability to satisfy special requirements applying to high quality steel production. Thus, this industry provides a good illustration of supply complexity and uncertainty of the reverse flow in circular supply chains.

Research design and framework

This study is phenomenon-driven (Eisenhardt & Graebner, 2007) since the research question has a broad scope and is motivated by a lack of previous empirical studies of the phenomenon of circular supply chains applying supply chain collaboration. We use an explorative qualitative case study method to capture the complexity of the reverse flow for the context of Swedish unalloyed steel recycling. Thus, we strive to develop theory on supply chain collaboration through studies of coordination at the activity-level

between buyers and suppliers in the reverse flow of circular supply chains. The case study design is holistic, in accordance with Yin (2009), examining the global nature of organization within the context of Swedish unalloyed steel recycling. In addition, the procurement intermediary is of particular focus in this study, since it is the central node for coordination in Swedish unalloyed steel recycling. Thus, in this study we start with the procurement intermediary and continue with studies of the other parts of the system. Figure 1 shows a simplified system schematic and the delimitation of this study to exclude small scrap dealers. The organizations involved in the studied system are five Swedish steel producers, a procurement intermediary, and eight scrap dealers.

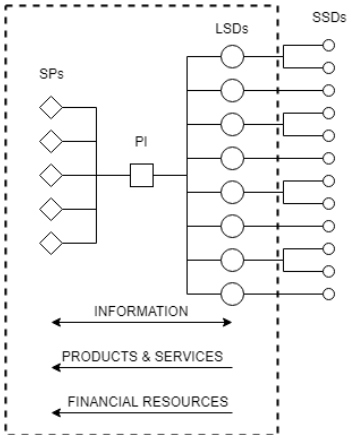

Figure 1 – Simplified system schematic of flows in Swedish unalloyed steel recycling and the scope of this study. Note: SSDs – small scrap dealers; LSDs – large scrap dealers; PI – procurement intermediary; and SPs - steel producers.

Data collection

The primary data source is semi-structured interviews with company representatives from the Swedish steel industry, scrap dealers and the procurement intermediary. We chose the interviewees with knowledge of the organization of the studied activities with support of previous interviewees. In addition, we use secondary data such as company and industry reports, company webpages, and observations (see Table 1). Furthermore, experts with long experience from working in or with the system provide data for the study and check the study's rigor.

Table 1 – Empirical data overview

Data collection method	**Type of data**	**Number of data sources**	**Details**
Semi-structured interviews	Interviews in person and using Skype or telephone	4	Notes, transcripts
Document analysis	Documents	5	Webpages, project reports, presentations
Other	Expert meetings	5+ hours	Meeting notes

Framework

The Swedish steel industry is global, competitive and has a long history. In the Swedish recycling sector for unalloyed steel there are five steel producers, one procurement

intermediary, and eight scrap dealers. Consequently, there exist supply chain flows and supply chain coordination mechanisms. Since the section of the circular supply chains in this study bears more resemblance with a network than a chain, we conceptually build on the framework by Martinez and Jarillo (1990). Especially, the framework is more comprehensive with regards to informal mechanisms than e.g., Arshinder et al. (2008) who specifically identifies coordination mechanisms within the supply chain, or the strategic elements of supply chain collaboration (Barrat, 2004). Indeed, Martinez and Jarillo (1990) divide the coordination mechanisms into structural and informal coordination mechanisms. The structural mechanisms include departmentalization, centralization or decentralization, formalization and standardization, planning, and output and behavioral control (see Table 2). Informal mechanisms consist of lateral relations, informal communication, and socialization. The second dimension of the framework is supply chain flows (Mentzer et al., 2001). Information includes demand and forecasts, which are separate in the original work of Mentzer et al. (2001). Further, products and services merge into one, since they follow the same pattern. The final framework thus includes the three main flows information, products and services, and financial resources.

Table 2 – Framework

Coordination mechanisms		**Information**	**Products and services**	**Financial resources**
Structural and formal mechanisms	**Departmentalization**	Grouping of activities following the principle of division of labor		
	Centralization or decentralization	Determines where and how decision-making is carried out		
	Formalization and standardization	The extent to which policies, rules, job descriptions, etc. are written down in manuals and other documents, and procedures are established through standard routines		
	Planning	Systems and processes like strategic planning, budgeting, establishment of schedules, goal setting, that intend to guide and channel the activities and actions		
	Output and behavioral control	Output control is based on the evaluation of files, records, and reports submitted by the organizations. Behavior control is based on direct, personal surveillance.		
Informal mechanisms	**Lateral relations**	Cut across the formal structure and includes direct contact among managers of different departments that share a problem, temporary or permanent task forces, teams, committees, integrating roles, integrative departments, etc.		
	Informal communication	The creation of a "network" of informal and personal contacts among managers across different units of the company, corporate meetings and conferences, management trips, personal visits, transfers of managers, etc.		
	Socialization	A process of socialization of individuals by communicating to them the way of doing things, the decision-making style, and the objectives and values of the company. Performed by training corporate and subsidiary managers, transferring them across different units, managing their career paths, measuring and rewarding them in appropriate ways, etc.		

Findings

In the organization of Swedish unalloyed steel recycling we identify a central node for coordination in the system, the procurement intermediary. The first part introduces this organization. In the second part, we analyze the findings from our empirical study at the activity-level with our framework.

The procurement intermediary

The procurement intermediary is a small organization with a long history of being a vital node in the recycling of Swedish unalloyed steel that was established over a century ago. The procurement intermediary is owned by some of the largest steel producers in Sweden and its goal is to provide the sector with unalloyed steel scrap. Further, the scrap procurement involves optimization of logistics to minimize transport expenses for the owners. Since actors in the Swedish steel industry compete on different niche markets, with high costs associated to a switch between niches, there is limited or no competition between the owners of the procurement intermediary. The limited competition and the small size of the procurement intermediary exempts the organization from EU-regulation on cartels, while increasing the national competitiveness of Sweden and in particular the competitiveness of the entire Swedish steel industry. From its establishment in 1917 and until Sweden became a member of the European Union in 1994, sourcing of unalloyed steel scrap was national. When Sweden joined the European Union export of unalloyed steel scrap became accepted, thus enabling the current practice of international sourcing of unalloyed steel scrap.

The procurement intermediary sets the price for unalloyed steel scrap on the last day of each month for the following month. However, prior to the price decision, steel producers capture the market trends from scrap dealers, use international contacts for information, and read trade publications to align with the international market price for unalloyed steel scrap. It is important for the steel producers that the assigned price is acceptable also for scrap dealers, since they will not sell nationally otherwise and the price then will need to be adjusted. However, some unusual circumstances still occur that the steel producers and scrap dealers agree require price revisions. An example is sudden market disruptions causing the international price to increase or decrease by 8 percent or more from the procurement intermediary's assigned price calls for a revised price mid-month. The Swedish monthly unalloyed steel scrap price is unusual in Europe where a combination of a monthly average and a specific price for a specific deal is most common. The ultimate goal of this is for the procurement intermediary's owners to procure national unalloyed steel scrap at a lower price than international unalloyed steel scrap. In this, they succeed through coordination of logistics among steel producers.

Analysis

We discuss the findings from our case study with our conceptual framework. The analysis follows the structure of the framework. In other words, the 'structural and formal mechanisms' comes first and 'informal mechanisms' thereafter.

<u>Structural and formal mechanisms</u>

The five structural and formal mechanisms of coordination are 'departmentalization', 'centralization or decentralization', 'formalization and standardization', 'planning', and 'output and behavioral control'. We structure the analysis accordingly and include the three supply chain flows 'information', 'products and services', and 'financial resources', for each coordination mechanism.

Departmentalization

The organizations involved in the studied system are five Swedish steel producers, a procurement intermediary, and eight scrap dealers. These actors handle unalloyed steel scrap sourcing activities both among themselves and externally. For information flows in the system, a procurer at the procurement intermediary is central to the everyday contact with both steel producers and scrap dealers. The procurer collects information on the desired upcoming monthly demand for unalloyed steel scrap from steel producers in the middle of each month. Thereafter, the procurer asks the scrap dealers how much unalloyed steel scrap is available in the upcoming month. The procurer with knowledge of both aggregate demand for and supply of unalloyed steel scrap then prepares a recommendation for how the unalloyed steel scrap should be divided among the steel producers in the upcoming month. Further, the procurer completes the recommendation with planning of logistics to minimize transport costs before presenting it for the procurement committee for final decision around the 22nd each month (see 'centralization or decentralization' below). After a final decision on unalloyed steel scrap allocation among steel producers is taken, the procurer informs a third party logistician on what unalloyed steel scrap goes from where to where. The third part logistician is thus responsible for material flows in the system. Financial resources flow in the system directly between steel producers and scrap dealers. However, the procurement intermediary has an online portal for all bills of lading and thus support the scrap dealers with invoice data on a daily basis.

Centralization or decentralization

The central decision-making entity is the procurement committee. The committee consists of three representatives from the steel producer buying most unalloyed steel scrap, two representatives from the steel producer buying second most unalloyed steel scrap, and one representative each from the other three steel producers buying unalloyed steel scrap. Based on the procurement intermediary recommendation on allocation of unalloyed steel scrap among the steel producers, negotiations take place in a monthly meeting. Even though the unalloyed steel scrap demand is rather static, the supply of unalloyed steel scrap never perfectly matches the demand. Eventually the procurement committee decides whether unalloyed steel scrap needs to be imported by the procurement intermediary or not. However, this is both more timely and costly than national unalloyed steel scrap procurement due to longer transportation and a weaker bargaining position towards international scrap dealers. Further, since the unalloyed steel scrap demand remains the same, the transport flows are also predefined with preferred routes. Even so these transport flows are subject to disruptions by e.g. weather, which requires the procurement committee to decide if an increase in logistics cost is preferable to an increase in time for delivery. In essence, the central decision-making lies with the procurement committee where mutual decisions are taken. However, the procurement intermediary's board of directors set the goals for the procurement intermediary, which the procurement committee work to fulfil.

Formalization and standardization

Documentation is essential to unalloyed steel scrap procurement in Sweden. 'The Swedish Scrap Book 2012' specifies unalloyed steel scrap grades and delivery conditions for the Swedish market. Published first in 1951, and updated regularly and jointly by the Swedish steel producers and scrap dealers together with the procurement intermediary, it currently contains 27 classification of different types of unalloyed steel

scrap, each of a volume which is considered satisfactory enough to be included. The procurement intermediary publishes 'The Swedish Scrap Book', which involves publication of revisions on their website. This is of importance since this is a kind of standard classification for sorting of unalloyed steel scrap in Sweden. Accordingly, the use of the document is widespread. Firstly, for financial resource flows in the system the document is the foundation. The monthly price of unalloyed steel scrap is assigned for each class separately. As previously mentioned, these prices apply for actors in the studied system. However, national actors outside the studied system use the same unalloyed steel scrap classifications and monthly prices for each class. Consequently, 'The Swedish Scrap Book' is the price setter for Swedish unalloyed steel recycling both inside and outside of the studied system. Secondly, for material flows in the system the document is central in unalloyed steel scrap operations both for scrap dealers and for steel producers. 'The Swedish Scrap Book' states what steel producers permit and what they cannot allow for each class of unalloyed steel scrap and thus, everyone working in the scrapyard has a copy. Likewise, workers in the steel producers' scrapyards control the incoming material to ensure its quality. If the quality is poor, the document also specifies repercussions for the scrap dealers. With this in mind, the procurement intermediary educates scrap dealers in unalloyed steel scrap classification for different mixed metal scrap.

Planning

The previously mentioned purchasing committee (see 'centralization or decentralization above) plan allocation of unalloyed steel scrap for the upcoming month and if import of unalloyed steel scrap is necessary. Based on the procurement committee's decisions, the procurer at the procurement intermediary (see 'departmentalization above) finalizes logistics planning. Prior to allocation, each steel producer decides their need for unalloyed steel scrap. E.g., for one steel producer the logistics department is responsible for demand forecasting since it possesses knowledge of the current unalloyed steel scrap stock and planned production. The decision is then communicated to the purchasing manager who represents the organization in the procurement committee.

Output and behavioral control

Swedish scrap dealers have a historical legacy of scams and fraud, which has earned them the title of 'dirty businesses'. In light of this, the consolidation of scrap dealers into large entities and thus creating a serious industry aligns well with increased transparency throughout the industry. Today the scrap dealers perform quality controls before transport of unalloyed steel scrap to avoid issues downstream and allow site audits from the procurement intermediary several times per year. 'The Swedish Scrap Book' (see 'formalization and standardization' above) is the foundation for the quality audit at the scrapyard of the steel producer. Operators check the alloy grade, contamination, and radiation for the different classes of unalloyed steel scrap. Further, the steel producers perform rigorous quality controls in several steps of the steel production process.

<u>Informal mechanisms</u>

The three other informal mechanisms of coordination are 'lateral relations', informal communication', and 'socialization'. We structure the analysis accordingly and include the three supply chain flows, 'information', 'products and services', and 'financial resources', for each coordination mechanism.

Lateral relations

The procurement committee (see 'centralization or decentralization' above) gathers primarily purchasing managers from the Swedish steel producers in a monthly meeting at the head office of the procurement agent. The meeting enables direct contact among managers who all represent their organization's demand for unalloyed steel scrap, without any direct competition between the organizations in their final markets but with direct competition for the unalloyed steel scrap. Further, the procurement committee consists of sub-groups for supplier evaluation, for supplier site audits, and for unalloyed steel scrap quality through which these purchasing managers also meet. While the procurement intermediary and steel producer representatives meet on a monthly basis through the procurement committee, there is no such recurring meeting also including the scrap dealers. However, a temporary task force that includes the scrap dealers is the project team for development of 'The Swedish Scrap Book' (see 'formalization and standardization' above). In addition, the radiac collaboration includes both the Swedish steel industry and scrap dealers under the procurement intermediary's leadership.

Informal communication

The procurement intermediary collaborates with the recycling industry and the steel industry in general. In addition, the procurement intermediary takes part in research activities for the Swedish steel producers' association. Further, the current CEO of the procurement intermediary was previously employed by the steel producer that purchases most unalloyed steel scrap of all steel producers in Sweden. This has provided the CEO with a large number of informal and personal contacts within the main buyer of unalloyed steel scrap in Sweden. In addition, the procurement intermediary is located in the same building as both the steel producer's head office and the Swedish steel producers' association.

Socialization

The CEO of the procurement intermediary brings experiences from his previous employer (see 'informal communication' above). With the significant influence of the steel producer on the procurement intermediary in mind, we see this as training for the position of CEO for the procurement intermediary.

Discussion and conclusions

This paper has empirically shown how coordination is organized in the Swedish unalloyed steel recycling. The analysis has been done at the activity-level with a conceptual framework on the mechanisms of coordination (Martinez and Jarillo, 1990), and on supply chain flows (Mentzer et al., 2001). However, the underlying rationale for how the coordination is organized has not yet been answered and is thus in this part the main point of discussion.

The system of circular supply chains in this study involves five steel producers, one procurement intermediary, and eight scrap dealers. A primary reason for the organization of Swedish unalloyed steel recycling with a procurement intermediary as a central node for coordination is efficiency. Firstly, flows of information and financial resources are either steel producer to/from procurement intermediary or scrap dealer to/from procurement intermediary. Thus, the number of flows are lower than in a situation where each actor interacts with others individually. In Swedish unalloyed steel recycling, interaction between one steel producer and one scrap dealer is not sufficient due to limitations in available unalloyed steel scrap. Secondly, a monthly meeting

among steel producers is enough to decide on unalloyed steel scrap allocation for the upcoming month. Since the procurement intermediary acts upon what is decided in this meeting, the steel producers can dedicate little resources to procurement of unalloyed steel scrap. For instance the procurement intermediary arranges logistics for material transport from scrap dealers to the steel producers. Thirdly, the recurring monthly procedure of pricing and allocation of unalloyed steel scrap is efficient since it is well established. This brings stability to the system that the actors also work jointly to preserve. All in all, these three efficiency improvements align with Williamson's transaction cost approach (1981).

A different reason for why Swedish unalloyed steel recycling is close to circular is the continuous support from formalization and standardization. The five steel producers and eight scrap dealers join in voluntary cooperation for standardization with 'The Swedish Scrap Book' to handle the issue of economies of scale in unalloyed steel recycling, precisely as De Angelis et al. (2018, p. 433) suggests. The effects of an agreed standard on the system of circular supply chains exceed the system boundaries, e.g. classification and price used by other actors. Within the system boundaries, the standard creates formalization, e.g. use of 'The Swedish Scrap Book' in operations. In addition, the common standard enables lateral cross-industrial relations through recurring revision of the standard.

In spite of the close connections cross-industry and among the Swedish steel producers through the procurement intermediary, the system of circular supply chains acts according to EU-regulation on cartel formation. There are three main reasons for why this specific supply chain collaboration between buyers and suppliers in the reverse flow of a system of circular supply chains is legal. First, the limited competition among the Swedish steel producers in their final markets. Second, discussions in the procurement committee only relate to allocation and not to price. Third, the small size of the procurement intermediary.

To our knowledge, this study is one of the first to introduce the phenomenon of an existing system of circular supply chains applying supply chain collaboration. By studying how coordination is organized between buyers and suppliers involved in the reverse flow of the circular supply chain we systematically uncover the formal and informal mechanisms of coordination underlying supply chain collaboration.

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The role of network in supply chain sustainability: A systematic review and research agenda

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Abstract

This study investigates the supply chain sustainability from a network perspective. To do so, a systematic literature review is conducted to find the relevant academic articles. Drawing on the evidence from the selected conceptual and empirical articles, the study distinguishes two prevailing network properties in driving sustainability in supply chains. Following the analysis, the study presents a conceptual model in form of a set of propositions linking various network properties to the sustainability performance of firms and networks. This study is one of the first attempt towards synthesizing dominant scholarly discourses and, thereby provides an organising lens for future scholarship in this area.

Keywords: Network perspective, Supply chain sustainability, Systematic literature review

Introduction

Supply chain sustainability is the management of environment, social and economic impacts throughout the life cycles of products and services. Specifically, it involves the "management of material, information and capital flow as well as cooperation among companies along the supply chain taking goals from the three dimensions of environmental, social and economic into account" (Seuring and Müller, 2008, p. 1700). Given the ever-increasing number of actors involved in the design, production and delivery of products and services, firms more and more engage and invest in developing and maintaining relationships with external upstream and downstream actors to achieve sustainability goals (Chen et al., 2017). The role of supply chain collaboration in general (Vachon and Klassen, 2008) and the specific aspects of supply chain relationships (Cheng et al., 2008) in driving supply chain sustainability has been extensively studied in the literature. While the focus has been largely on the dyadic perspective giving little attention to the broader network of supply chain relationships in which firms are

embedded, in recent years, a growing number of articles has begun to highlight the importance of adopting a network lens in supply chain management in general (e.g., Borgatti and Li, 2009) and in explaining and investigating supply chain sustainability in particular (Tate et al., 2013). For instance, Hartmann and Moeller (2014) suggest that although a focal firm has little control over its suppliers' unsustainable behaviour when the suppliers are beyond the first tier, these indirect relationships can negatively affect the sustainability performance of the focal firm. Because external stakeholders (i.e., consumers, non-business actors) often hold a focal firm to account for the sustainability impact of its internal operations and operations of its. For instance, consumers still attribute responsibility to the focal firm for the non-compliant products (Hartmann and Moeller, 2014); NGOs still put more scrutiny on the focal firm regarding ethical issues (Saunders et al., 2017); government still requires the focal firm to disclose relevant information concerning the sustainability misconduct (Airike et al., 2016).

Thus, it is stated that the achievement of sustainability requires the engagement of actors from multiple tiers where often conflicting sustainability ambitions, objectives, and capabilities prevail (Villena and Gioia, 2018). Comparing to tier-one suppliers, lower-tier suppliers may exhibit more passivity in addressing sustainability issues because not all of them feel connected to the sustainability standard (Prajogo et al., 2014) and they perceive a very low risk of being penalized for not doing so. Furthermore, even though Global 250 companies have established a supply chain code of conduct towards the sustainability, half of these do not disclose the detailed information of the process and mechanisms by which they activate and monitor these sustainability standards across the supply chain. These may inhibit the organization acquiring information, resources and knowledge by combining direct or indirect network interactions and implementing supply chain sustainability effectively (Hung et al., 2014).

Focusing on the patterns of connectivity in supply chain networks, recent research also suggest that firms are more likely to adopt environmental standards or comply with the ethical codes of conduct in the process of sourcing and production when they are embedded in highly dense supply networks (i.e., they receive more monitoring from multiple actors in the supply chain) (e.g., Beckman et al., 2009; Vurro et al., 2009). Therefore, the dyadic level does not capture the essence of a network and the adoption of network lens provides an opportunity to deeply address the supply chain sustainability management.

Whilst the notion of network is a common underpinning theme, connecting these findings, the scholarly literature lacks a synthesis of major findings and a reflection of the current development of this area. Specifically, a more systematic, theoretical articulation of how different properties of networks connecting firms in supply chains reinforce the sustainability performance of embedded firms and network is still absent. Yet many articles have begun to concentrate on issues of non-economic dimension, still very few articles have systematically addressed the environmental and social dimensions from the network lens. Therefore, it is crucial to undertake in-depth analysis in terms of this research area to date. Thus, the purpose of this study is to systematically review and assess the current status of research on supply chain sustainability from a network perspective and provides an organising lens for future scholarship in this area.

To address the above issues, this study aims to conduct a systematic literature review (SLR) approach and selects 54 articles from 17 peer-reviewed international journals. Further to that, this study also develops a novel conceptual framework regarding supply chain sustainability in relation to different network properties (i.e. relational properties, structural properties). This study seeks to address the following review questions:

RQ1. What network properties are examined in relation to supply chain sustainability?

RQ2. How do the network properties (i.e., relational properties, structural properties) of supply networks affect sustainability performance at focal firm, dyadic and network levels?

This study contributes to the existing literature in several ways. First, our study extends the understanding of network perspective by highlighting and explaining the inconsistencies in the literatures. This study is the first attempt towards synthesizing dominant scholarly discourses on supply chain sustainability from a network perspective and provides an evaluation of the scientific status of the field. By synthesising the current conceptual and empirical literatures, this study provides an original and better understanding of the phenomenon.

Methodology

In order to address the research questions, this study adopts an SLR approach in terms of a comprehensive synthesis of academic literatures (Tranfield et al., 2003). Unlike the traditional review approach, this approach allows researchers to explore the knowledge base systematically, collect the relevant information and represent them properly. As described by Tranfield et al. (2003), the SLR approach includes four below steps: (1) searching (2) screening (3) extraction and (4) synthesis.

Searching

Following the systematic process, this study searches from peer-reviewed articles in relevant research area. The initial scoping of the relevant articles contains identifying the relevant keywords and constructing the search strings (shown in Table 1). The search string included is to answer the research questions and obtain the relevant information in terms of three key subjects. Three electronic databases (i.e., Scopus, EBSCO, and ABI/INFORM) are selected to collect the articles regarding titles and abstracts included at least one of the search terms from all three themes.

Table 1 Keywords and Search Strings

Key Subject	Related Keywords	Search String
Sustainability	Sustainability OR Environment OR Corporate Social Responsibility OR Green	("child* labour*" OR discriminat* OR ethic* OR "human* right" OR "work* welfar*" OR "employee welfar*" OR sustainab* OR "environment* W/10 practices" OR green OR "social* responsib*" OR recycl* OR "carbon footprint")
Supply Chain	Supply chain OR Supply network	(suppl* OR logistics OR "demand chain")
Network Perspective	Network OR Social Network OR Embeddedness	(network OR "structural properties" OR alliance OR interaction OR embed* OR "multi* tier" OR triad* OR "graph theory " OR inter-organi?ation* OR collaborat* OR "cross-sector" OR partners* OR "inter*firm")

Screening

This process screens the articles' titles and abstracts informed by the inclusion and exclusion criteria. In accordance with that, these selected articles were assessed against the inclusion and exclusion criteria to test their relevance in terms of research questions. After screening the titles and abstracts of these articles, 1605 articles are rejected because

they do not focus on the required area and most of them are discussed about inter-firm or inter-organisational performance at dyadic relationships. After that, the remaining 406 articles are considered to be valid for full-text screening. Following that, a further 352 articles are rejected because they did not clearly identify the network perspective in supply chain sustainability. In the end, 50 articles are selected and 4 additional articles are added from cross-referencing to the review list for further in-depth analysis.

Data extraction and synthesis
It is identified that dataset from the selected articles was heterogeneous and from multiple contexts, with empirical, e.g., majority of them are qualitative and only a few are quantitative, and theoretical articles included. The content of selected 54 articles are recorded and summarized in Excel spreadsheets for descriptive analysis and findings. Based on the findings and discussions, the propositions and a novel conceptual framework is then developed. Additionally, the synthesis of different information are cross-validated by the authors before it reached an agreement.

Descriptive analysis
This study provides brief description of the selected articles and assess the descriptive findings by the different nature of information (i.e., journal and rankings distribution, underpinning theories, sustainability dimensions, and unit of analysis).

Journal and rankings
In line with the SLR results, the reviewed articles are situated widely across the different journals in different rankings. It is identified that majority of them come from journals rank 3 (e.g. 30 out of 54 articles), while only 6 out of 54 articles rank 4 and 4 articles rank 4*. To be more specific, Journal of Cleaner Production have the highest numbers of articles, followed by Journal of Business Ethics, International Journal of Operations and Production Management, Supply Chain Management: An International Journal and Journal of Supply Chain Management. Additionally, these results imply a stable growth in the publication regarding this area is growing, with 41 articles published in recent 5 years from 2014 and onwards.

Underpinning Theories
Underpinning theories offer a theoretical understanding of how the questions in a scholarly study are examined. It is identified that network theory was the most frequently cited theory, which provides a broader lens to understand the role of network actors in achieving sustainability in supply network beyond the dyadic lens. In light of the growing concerns of sustainability issues, stakeholder priorities and pressures are increasingly influential to the organisations' sustainable practices. Stakeholder theory is also frequently cited followed by the network theory.

Supply chain sustainability performance: Definitions and conceptualizations
Organisational sustainability performance is usually assessed from three dimensions, i.e. economic, social, and environment. However, this study aims to focus on social and environmental dimensions in supply networks. In reviewing these selected articles, it is identified that the majority of them examine the sustainability performance in environmental dimensions. Furthermore, although social dimension is still in lack, the research interests have gradually expanded to social dimension over time.

Unit of analysis

In terms of network perspective, the unit of analysis is another important basic element to describe and explain constructs, that is, the level to which generalizations is appropriate. Three types of unit of analysis are categorised, i.e. focal firm, dyad, and network levels. It is identified that articles analysing the sustainability performance of the focal firm as the unit of analysis are still in majority, while the dyad level is very rare. Furthermore, there is a growing trend to adopt whole supply network as the unit of analysis in recent years. The network unit may generate a better understanding of relationships among organisations. The choice of unit of analysis has implications for the relevance of supply chain sustainability measurement and increase researchers and practitioners' awareness of this issue.

Findings and discussion

This study distinguishes two prevailing network properties in driving sustainability in supply chains. The two properties: relational (i.e., the attributes and quality of network relationships as well as the governance mechanisms supporting and sustaining interactions among participating actors to enhance the likelihood of achieving sustainability goals) and structural (i.e. the architecture or patterns of supply chain relationships) are conjectured to affect both the environmental and social aspects of sustainability.

Network-level collaboration in supply network

The notion of "embeddedness", referring to the contextualisation of actors (e.g. individuals, firms) within the patterns of inter-organisational relations and the consequent behavioural and performance implications. Relational embeddedness has been also referred to as the strength of inter-organisational relationships or ties (Granovetter, 1973). Different from the dyadic-level collaboration, network-level collaboration for sustainability (more than two actors) provides a broader lens of the interconnected relations of the whole network and explains how information and resources could be disseminated among the extended relationships

It is identified that collaborative relationships in supply network mostly occurs in for-profit organizations in implementing effective sustainability strategy. Those types of collaborations in business communities have different dimensions, i.e. horizontal, or vertical. For instance, Fontana and Egels-Zandén (2018) examined that interlinked suppliers use horizontal collaborative approach (i.e., collective behaviour) to improve the whole network's CSR engagements, e.g. labour conditions. Soundararajan and Brammer (2018) supported that viewpoint by taking the intermediary (first-tier suppliers)-sub suppliers dyads as the unit of analysis in their study. They argued that a collaborative approach, such as knowledge sharing related to working conditions, leads to the enhanced social sustainability management. Vertically, collaboration among focal buying firms, suppliers and sub-suppliers, usually trigger the transformation of embedded CSR values from focal firms to their multi-tier suppliers, leading to an ethical commitment to CSR, clear addressment on CSR theme regarding the focal firm's sustainability codes of conduct (Lim and Phillips, 2008).

In addition to that, actors embedded in the for-profit organisations network also seek for complementary resources (i.e., capabilities, process, knowledge, and information) from non-business sectors, e.g. NGO, government. It is suggested that the network-level collaboration among NGOs and business firms enable the creation of social value and help business firms learn about the origin of issue of sustainable practices. Additionally, the development of focal firm's sustainability initiative also relies on the involvement of government. On the other hand, government involvement gives credibility to the

sustainability initiatives of the focal firm. Furthermore, Meehan and Bryde (2015) highlighted that co-opetition with network actors also becomes a way to achieve sustainability in the field. The main reason behind this is due to the lacking in abundant resources and skills, dyadic partnership alone is difficult to get a governmental-funded capital program. For instance, they found that companies competing for the governmental contracts are more likely to form the procurement consortia in that individual housing associations lack the resources and skills to manage contracts. Thus, this study proposes:

Proposition 1. Network-level collaboration positively affect sustainability performance at focal firm, dyad, and network levels.

Network governance mechanisms in supply network

To support and sustain collaboration among participating actors to enhance the likelihood of achieving goals, a set of governance mechanisms is needed. Network governance (more than two actors in network) is to manage the whole network involving all the interconnected actors rather than interdependent actors who interact with each other. Also, given the properties of network structure and relationships embedded, network governance provides a theoretical lens to investigate how the actual mechanisms are used to manage the network-level collaborations.

Formal network governance mechanisms refer to "an explicit way by using structural arrangements to affect the network actors' behaviour" (Tachizawa and Wong, 2015). They can include command structures, incentive systems, standard operating procedures, and documented dispute resolution procedures (Alvarez et al., 2010). To be more specific, formalisation of sustainable supply chain management activities can be realized through a set of corporate codes of conduct, criteria/standards and contracts. A few authors have investigated the impact of formal mechanisms on sustainability performance in terms of different unit of analysis. For instance, at a focal firm level, Wong (2013) observed that formal mechanisms can act as a driver for focal companies quickly adapt to new markets demand for developing new environmental-friendly products or services. In social dimensions, formal mechanism, e.g. labour regulation, or setting sustainability expectations in contracts, also help focal buying firms reduce the riskiness of managing the lower-tier suppliers. This can act as a normative pressure in the supply network and drive lead firms to monitor their lower-tier suppliers for the compliance of sustainability requirement and the non-compliant suppliers would be removed. At supply network level, Tachizawa and Wong (2015) also observed that complying with a set of corporate codes of conduct and international environmental standards, e.g. ISO 14001 enables network actors to implement sustainability (i.e. reduce waste).

Informal network governance mechanisms, in contrast, govern the networks through social forms of control and focus on the soft issues, e.g. trust, power, culture and values, social norms and relationships (Alvarez et al., 2010). In reviewing literatures, this study identifies some informal mechanisms (i.e., trust, power, cultural contents) contribute to sustainability performance. Extant articles state that a trusting relationship can lead to a quicker information and knowledge sharing in that suppliers would be more willing to accept the green practices from focal companies and provide support to the lower-tier suppliers (Dou et al., 2018; Lu et al., 2018). Additionally, Van Bommel (2011) has also investigated the use of power is beneficial for the diffusion of environmental practices. With power, e.g. non-coercive power, focal companies can exert more moral influence and put pressure on their suppliers when requesting implementation of environmental programs. Additionally, cultural contents, e.g. values and perceptions of fairness, also serve as social forms of control. Actors in supply network are actually the carriers of their

own values or culture (Wu and Pullman, 2015). This culture embeddedness may serve as an underlying motive for actors to implement focal firm's sustainability initiatives.

More importantly, a plural form of governance mechanisms (i.e., a mixture of formal and informal governance mechanisms) is also suggested to effectuate supply chain sustainability. Tachizawa and Wong (2015) stated that relational cooperation may compensate the inflexibility of contractual governance. For instance, governments and citizens have paid increasing attention to the environmental protection and sustainable production in the palm oil sector. Solely relying on the international standards cannot guarantee the activities of production would not harm the planet. Practitioners and researchers suggest that palm oil stakeholders should share their perspectives with small holders, or increase their awareness on certification standards, along with formal mechanisms can effectuate the sustainable cooperation for palm oil. Therefore, this study proposes:

Proposition 2. Network governance mechanisms including formal, informal and plural forms affect sustainability performance at focal firm, dyad, and network levels.

Supply network structural properties

Structural properties of the supply network refers to the patterns and connectivity of supply network actors' embedded in the network context. Drawing upon the "embeddedness" concept, structural embeddedness, which is the focus of our study, encompasses the quality of dyadic relations in which the actors are embedded (Gulati et al., 2000). Structural embeddedness could be seen as a conduit for diffusing information and knowledge about embedded actors strategy and behaviours which affect sustainability performance in supply network (Tate et al., 2013).

Firms embedded in supply networks are not equally affected by the level of sustainability issues due to the specified position of a focal node. Accordingly, firms' unique network positions such as centrality and structural hole as well as whole network-level connectivity patterns such as density and complexity. For instance, Vurro et al. (2009) identified that both network density and node-level centrality of the focal organisation are likely determinants of central actor's responsiveness to sustainability implementation in that it affects the ease of communication and efficiency of information flow across actors in the supply network. The central actor receives increased monitoring from other actors when the density increases. On the other hand, it also becomes easier for focal firm to transfer the knowledge which facilitates the sharing of sustainability-related activities when density increases. In line with this, network density interacted with node-level centrality largely determine the ways a focal firm react to its stakeholders regarding implementation of sustainability practice (e.g. authentic CSR efforts). Focal firms with high centrality will use power and influence to encourage other actors, e.g. suppliers, to adopt more responsible practices.

Additionally, other articles (i.e.,Wilhelm, 2014; Meinlschmidt et al., 2018) highlight the importance of supply network complexity on focal firm's sustainability performance. A high structural supply chain complexity may indicate the probability that buying firms lack sufficient knowledge of their lower tier suppliers is also high. Consequently, focal firms need more efforts to generate transparency to those undirected (lower-tier and beyond) actors.

Considering the linkages among focal firm and its undirected actors (i.e., lower-tier suppliers and beyond), the concept of structural hole proposed by Burt (1992) help explain how the information is passed across the supply network. A bridging tie links two nodes whose respective contacts are not linked and by definition a weak tie. Applying these concepts, Roscoe et al. (2016) suggested that focal firm should build weak ties with

suppliers that bridge structural holes in supply network. Bridging weak ties may help facilitate greater information access and enable focal firms to tap into the resource base of an entirely different network. This also indicates that focal firms may benefit from new knowledge and opportunities for finding innovations to enhance sustainability performance (i.e., discover radical eco-innovations under the conditions of technological uncertainty). Hence, this study proposes:

Proposition 3. Supply network structural properties including density, centrality, complexity and structural hole, affect the sustainability performance at focal firm level.

Based on the findings and discussion above, a conceptual framework is established in Figure 1 below:

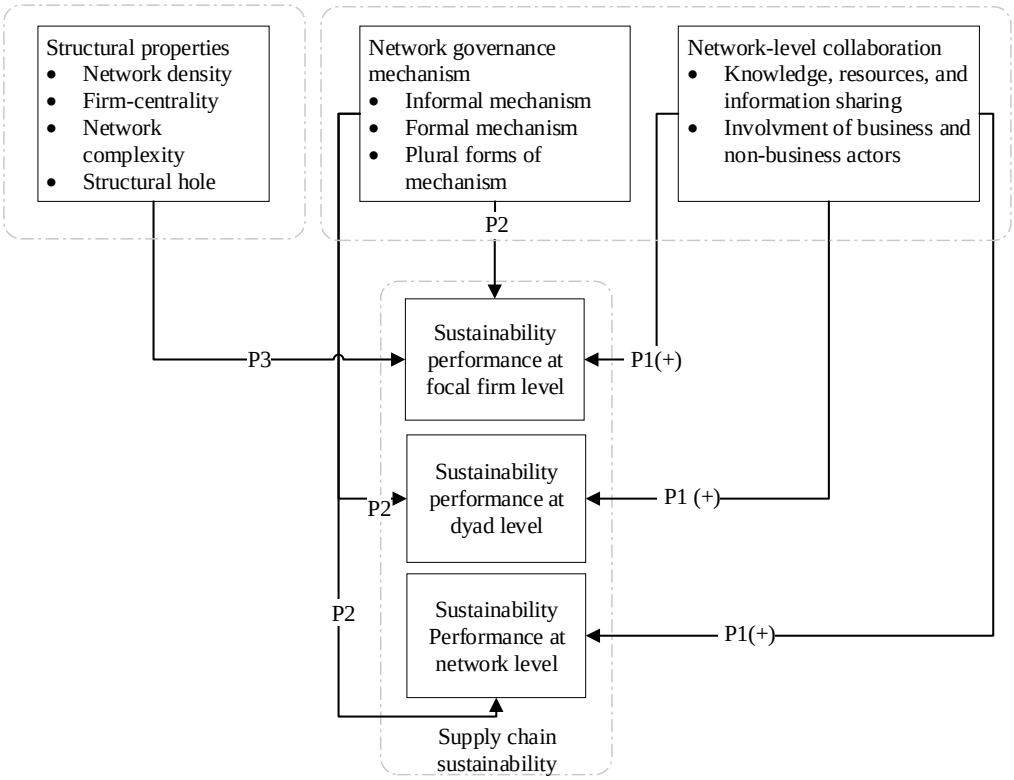

Figure 1 Conceptual framework

Conclusions and future research

Given the network perspective proposed by Grannovetter (1973) and Burt (1992), this study analysed the influence of network on supply chain sustainability. This study examines the existing literatures focusing on the relationships that occur among three actors and beyond in the supply network. This study provides the insights of current state of the art in the role of network in managing supply chain sustainability. Additionally, this study specifically differentiates the sustainability performance at different unit of analysis. In accordance with this, this study generates 3 theoretical propositions and a conceptual framework for understanding the supply chain sustainability that goes beyond the dyadic relationship, contributing to the future research.

From the managerial perspective, this study synthesizes the various viewpoints of the importance of network perspective on supply chain sustainability. It shed light on the importance of considering the perspectives of sub-suppliers as the management of them are often neglected. Their perceptions/understanding towards sustainability will greatly

affect sustainability implementation and also influence the way they behave in the process of supply chain, e.g. sourcing ethically, compliance to sustainability standards, etc.

After reviewing the relevant findings, this study found out some gaps and suggest some avenues for future research. The overview of them is briefly outlined in Table 2.

Table 2 Future research structure

First order theme	Second order theme
· Expanding the sustainability measurements to a broader level regarding the different unit of analysis, e.g. interaction between dyad and dyad, the whole network.	Sustainability measurements from a network view
· Having more exploration in the role of network on different dimensions of sustainability.	A distinction between social and environmental dimensions of sustainability in identifying network determinants
· Identifying how different network determinants affect the embedded firms differently in terms of social and environmental dimensions.	
· Identifying the potential risk created by the sustainability-related factors in social and environmental dimensions in supply network.	Creation of a sustainability risk index using a network lens.
· Identifying how the sustainability risk could be sorted from the network perspective.	
· Examining the quality and strength of relationships at network level, in conjunction with structural properties	Developing a network relational strength (an index) for sustainability performance
· Expanding the boundary of research context, i.e., from industry-specific to cross-industries, single case study to multi-case-studies	Validating the generality of research

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Green initiatives in supply chain inter-organisation relationship governance

Keywords: supply chain relationship, green collaboration, the automotive industry, governance mechanism

Topics: Managing Inter-firm Relationships in Supply Chains, Supply Chain Management, Behavioural Operations

Word count: 1000

Purpose

Supply chain inter-organisation relationship between supply chain partners developed over some time to push their boundaries and make them collaborate with their partners to asses and ensure they are socially responsible. Latest trends of green supply chain collaboration refer to the responsibility of partners to coordinate their procedures, processes and decisions to comply with social, environmental and ethical standards (Gunasekaran et al., 2015). The benefits of green collaboration result in less waste, a reduction in environmental damage, improve market and financial performance, streamline manufacturing, enhance the company's public image and reputation, and have a positive impact on the costs associated with the supply chain (Dangelico and Pontrandolfo, 2015).

Hence, the challenging question that lies among researchers and practitioners is how supply chain members should collaborate greenness. Furthermore, it is not clear how buyers and suppliers are going to be benefited through green initiatives governance. This gap was noted by Gunasekaran et al. (2015), that how should buyers and suppliers design incentive structures for green initiatives and how should they appropriately reward members across the supply chain.

The relationship is the essential aspect of achieving collaboration. Sheu (2014) discussed in the green supply chain collaboration context it differs where the buyers and suppliers have to strengthen the engagement based on certain long-term agreements, goodwill and trust. Two variables, certainty and dependency, can be used to define these relationships. Researchers can gain a perspective on green collaboration by viewing it from the economic, technological and social standpoints (Sheu, 2014; Green et al., 2012).

For a green supply chain to emerge and be implemented effectively, the relationships, such as buyer-supplier, which form part of the chain are key to success (Gunasekaran et al., 2015). The study by Luo et al. (2015) assessed Guanxi's role between buyer and supplier, and the effect it had on green performance in China, analysing how cultural factors, and the interpersonal relationships between suppliers and manufacturers, impacted on overall green performance. The observation-based research considered the effects of asset specificity, volume certainty, the frequency of transactions and the competition, on collaborative performance in the green supply chain. Above all, this research plan to explore *How do green initiatives governance mechanic supply chain inter-organisational relationship,* example as Chinese automotive groupings.

Design/methodology/approach

Investigate and build theories addressing the interrelated inter-organisational relationships, initiatives such as trust, goodwill, inter-personal relationships as mentioned in the research questions, a multi-case study approach is employed in the study to collect empirical evidence that is sufficiently cover a variety number of suppliers and manufacturers within the Chinese automotive industry. Through a comprehensive review and analysis of the literature regarding the inter-organisational relationship, a proposition of multi-level relationships management is developed. The proposition is then engaged with the empirical evidence that is classified by the dimension, supply chain green collaboration, and trust context within the multi-level relationship. The classification has been considered as an effective configuration method to build theories (Bailey, 1994). The case study evidence is collected through in-depth interviews with four to six senior directors and supply chain managers from each case.

Findings

The analysis of the data provides a deeper understanding of the Chinese automotive industry conditions and confirms the manufacturers and suppliers as 'an activity system' when renewing the supply chains in relationship developing stage. The supply chain inter-organisational relationships facilitate the ongoing status of green initiatives. The long-term relationship it is, the competitive environment relationship it is, meaning there is a higher degree of trust and relationship satisfaction between partners, and reduce the uncertainties. Methodical and effective knowledge sharing cannot only assist partners in governance roles but contribute positively to the greener of supply chain inter-organisation relationship. While the overall development of the inter-organisation relationship, all our cases use governance mechanisms initiatives which increase the confidence of manufacturers and suppliers in a long-term relationship.

Relevance/contribution

This study expressed in the form of the effective inter-organisational relationship governance mechanism and green supply chain collaboration 'knowledge'. Based on data analysis, the best universal practices of governance mechanism initiatives in supply chain relationships are discussed and offered that will reflect exploration as far as monitoring and control of green supply chain relationship tasks. This study reconfigured and developed governance mechanism initiatives within the supply chain inter-organisation relationships (RQ). One of the key factors in bridging the gap between the literature on the green supply chain collaboration in theory and the limited case study is the study insights into the effects of manufacturers and suppliers' behaviour. The governance initiatives of green supply chain inter-organisation relationship can be considered to be the point at which theory meets practice. By providing an in-depth case study account in which SCC criteria of particular relevance in multicultural collaborators are both identified and addressed, the research provides an original and much-needed contribution to knowledge.

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Buyer-supplier relationships in Industry 4.0 – A comparison across industries

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Abstract

Industry 4.0 implies a future digitalized and interconnected industrial value creation and has the potential to transform buyer-supplier relationships. These relationships differ among industry sectors because of industry-specific circumstances. This paper sheds light on future buyer-supplier relationships in the context of Industry 4.0 focusing on industry differences. Qualitative semi-structured expert interviews with 65 experts from German industrial enterprises serve as empirical basis of the exploratory multiple case study. The results reveal how future buyer-supplier relationships differ among various industries. The paper contributes to the current state of research from a management perspective triggering further research in this area.

Keywords: Industry 4.0, Buyer-Supplier Relationships, Industry-comparison

Introduction

"Industry 4.0", also known as the "Industrial Internet of Things", indicates a de novo change in industrial value creation based on digitalization and interconnection (Kagermann et al., 2013). People, machines, objects, and information and communication technology systems get intelligently, horizontally, and vertically interconnected (Schneider, 2018). Given its far-reaching technological developments along with its revolutionary character for value creation, Industry 4.0 provides numerous opportunities and potentials, e.g., efficiency, quality, and flexibility improvements (Kagermann et al., 2013).

Industry 4.0 implies a digitized, real-time capable, and intelligent interconnection of value creation chains, networks, and ecosystems (Bienhaus and Haddud, 2018; Kiel et al., 2017; Tu, 2018; Wang et al., 2006). Technological developments enable collecting, processing, analyzing, and sharing data (Thun, 2010; Wang et al., 2006). In this context,

digital technologies may create new forms of collaboration, cooperation, and integration and change buyer-supplier relationships (Obal and Lancioni, 2013). A more intense collaboration, further integration of partners, usage of platforms, and cross-company systems transform the shape of future competition. Given substantial industry specific differences in terms of value creation, analyzing buyer-supplier relationships requires a separate consideration.

Buyer-supplier relationships in the context of Industry 4.0 have scarcely been analyzed so far and consequently little is known about particular differences in various industry sectors (Haddud et al., 2017). However, analyzing the interconnection of companies, cross-company cooperation, and shared value creation is relevant for several reasons. Firstly, analyzing these aspects is vital to unveil how to further develop and improve industrial value creation (Vanpoucke et al., 2013). Secondly, buyer-supplier relationships represent a great source of competitive advantage, e.g., reducing sourcing costs, especially against the backdrop of decreasing value creation depth (Tan et al., 2002; Wang et al., 2006). Thirdly, cross-company interconnection represents a central element of Industry 4.0 and thus asks for an investigation (Büyüközkan and Göçer, 2018).

Whereas it is expected that companies cooperate and interact more closely in the future (Vanpoucke et al., 2013; Wang et al., 2006), it is unknown how buyer-supplier relationships are characterized in the context of Industry 4.0. Both research and practice show great interest in discovering setting levers for future buyer-supplier relationships (Schneider, 2018; Tu, 2018).

For this reason, the study addresses the following research questions:

RQ 1. How are present buyer-supplier relationships characterized in various industry sectors?
RQ 2. What are the distinct characteristics of future buyer-supplier relationships in the context of Industry 4.0 dependent on companies' industry sectors?
RQ 3. What drivers and causes can be identified why buyer-supplier relationships are transformed in the context of Industry 4.0?

The study sheds light on industry-specific differences in buyer-supplier relationships in the context of Industry 4.0 and indicates areas for future research. Aside from contributing to research, the derived recommendations and implications serve managers and corporate practice, which in turn ensures the study's practical relevance.

Theory

Industry 4.0

Based on an ongoing digitalization and interconnection, Industry 4.0 implies a new paradigm shift of industrial value creation. Cyber-Physical Systems and the Internet of Things form its technical basis. Cyber-Physical Systems are characterized by physical objects being complimented with communication systems and technologies that exchange digital data and allow an autonomous and independent coordination (Blau, 2014; Kagermann et al., 2013; Lasi et al., 2014). By means of information and communication technologies, the Internet of Things interconnects physical and virtual objects and systems alike, and in so doing, enables comprehensive communication and vast interactions (Kagermann et al., 2013; Lasi et al., 2014). Applying these technologies paves the way to merge and interconnect the physical and virtual world in industrial value creation. The inclusion of Internet of Things solutions and applications in industrial value

creation is also referred to as Industrial Internet of Things, why this term can synonymously be used to Industry 4.0.

Given its far-reaching implications for industrial value creation, Industry 4.0 provides both strategical and operational potentials for individual companies. First, it paves the way for new, data-driven business models, e.g., platforms, and it may also transform existing business models (Kiel et al., 2017). Second, modular product designs and flexible production processes help to produce individual products nearly in a similar quantity and efficiency like mass production ("mass customization") (Kiel et al., 2017). Third, value creation efficiency and productivity can be improved, for instance via optimizing capacity utilization and turnaround time. Fourth, Industry 4.0 can decrease overall risks by increasing transparency of the value creation process and fasten responsiveness to adapt to changes (Rong et al., 2015).

Aside from affecting individual companies, Industry 4.0 has the potential to reshape entire value creation processes forming integrated cross-company value creation chains and networks (Hofmann and Rüsch, 2017; Kiel et al., 2017; Vanpoucke et al., 2013). Against this backdrop, a broad and comprehensive horizontal and vertical interconnection represents a key to tap Industry 4.0's full potential (Kagermann et al., 2013; Müller et al., 2018a).

Industry 4.0 in Supply Chain Management

Supply Chain Management aims at optimizing the performance of the value creation process, for instance improving quality, time, and cost, and building up competitive advantages (Tan et al., 2002; Vanpoucke et al., 2017). Supplier Management's objective is to create, manage, and develop buyer-supplier relationships in order to efficiently organize and manage value creation (Choy and Lee, 2003). Being a central element, supplier integration represents a form of vertical cooperation. It is a set of strategies to design buyer-supplier relationships in a collaborative and cooperative manner, combining resources and capabilities to conduct common activities (Bienhaus and Haddud, 2018; Schoenherr and Swink, 2012; Tan et al., 2002; Thun, 2010; Vanpoucke et al., 2013).

Buyers and suppliers alike benefit from collaboration, cooperation and integration (Bienhaus and Haddud, 2018; Haddud et al., 2017; Tan et al., 2002; Vanpoucke et al., 2017). Intensifying cooperation allows conducting joint activities, for instance, carrying out common research and development projects (Bienhaus and Haddud, 2018; Tan et al., 200;). Integrating new or unrelated partners ensures access to further resources and expertise (Rong et al., 2015; Vanpoucke et al., 2013). On an operational level, closely working together reduces costs of value creation. First, it decreases process complexities and in turn increases process efficiency, e.g., via lower coordination efforts and less manual reworking. Second, it reduces inventory levels following greater information transparency. On an output level, it increases flexibility, agility, and responsiveness of value creation chains. Further, cooperation helps to address customers' demand providing individual solutions and services (Bienhaus and Haddud, 2018; Dweekat et al., 2017; Vanpoucke et al., 2017; Wang et al., 2006).

Industry 4.0 affects Supply Chain Management and transforms buyer-supplier-relationships intensifying the interconnection of value creation chains. Technologies, such as the Internet of Things, Big Data, and Cloud Computing, enable real-time data analysis and data management across company boarders (Bienhaus and Haddud, 2018; Büyüközkan and Göçer, 2018; Dweekat et al., 2017; Thun, 2010; Wang et al., 2006). Thus, Industry 4.0 increases information transparency improving efficiency of Supply Chain Management functions, decision-making, and overall business performance (Bienhaus and Haddud, 2018; Dweekat et al., 2017; Vanpoucke et al., 2017; Wang et al.,

2006). In addition, the supply chain is improved as for robustness, flexibility, responsiveness, and agility, for instance, using smart products that advance traceability and further automating processes (Wang et al., 2006). Furthermore, digital technologies pave the way to create new forms of collaboration, cooperation, and integration, for instance transferring value creation to digital platforms, and subsequently change buyer-supplier relationships (Obal and Lancioni, 2013). Intense vertical integration and ongoing collaboration does not only apply for first-tier suppliers, but includes suppliers of further value creation stages (Dweekat et al., 2017; Müller et al., 2017). Consequently, future competition will no longer be amongst individual companies, but between corporate network structures and ecosystems (Kiel et al., 2017).

Methodology

Using a qualitative explorative empirical research design and applying a multiple case study approach, the study analyses how buyer-supplier relationships differ in various industries in the context of Industry 4.0 (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007). Exploratory case studies are used to investigate complex, novel, and evolving, phenomena (Yin, 2009). Multiple cases increase the results' accuracy, reliability, generalizability, and robustness (Eisenhardt and Graebner, 2007; Yin, 2009).

The empirical data comprises semi-structured interviews with 65 experts from German and Austrian companies of heterogeneous firm sizes and different industry sectors conducted between August 2018 and March 2019 (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007). The companies' characteristics vary in sales volume (av. = 29,200 million EUR) and number of employees (av. = 83,000). They were analyzed in their role as buyers and stem from the automotive (n = 8), automotive suppliers (n = 15), consumer goods (n = 4), electronic and electrical engineering (n = 13), mechanical engineering (n = 13), and raw materials processing (n = 12) industries. All experts hold management positions with an average company tenure of 8.55 years and they are involved in or responsible for Industry 4.0-projects. The experts' names and companies are anonymized for confidentiality reasons. The sample's heterogeneity enables generalizing results and counteracts potential negative effects of sample biases (Yin, 2009). Selecting competent and knowledgeable experts strengthens the findings' reliability (Huber and Power, 1985).

The interview guideline was informed by literature but followed the principles of openness and flexibility. The first part deals with questions about personal facts and company contexts. The second part focuses on current buyer-supplier relationships and the third part deals with future buyer-supplier relationships. To concretize some aspects and to reveal further information, individual questions slightly deviated from the original guideline. All interviews were audio recorded and transcribed which reveals more than 820 pages of text material. Whenever possible, secondary data was used to verify the experts' statements for triangulation purposes, which increases validity and reliability (Eisenhardt and Graebner, 2007; Yin, 2009).

In order to answer the research questions, a qualitative content analysis was used to identify pattern, themes, and categories in the empirical material (Miles and Huberman, 1994). The study follows an inductive coding procedure that facilitates theory building but the categories were partly informed by literature to allow new aspects to emerge (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007; Krippendorff, 2013). In a first step, first-order (informant-centric) categories were developed. Second, the categories were synthesized into second-order themes. Third, the themes were distilled into general dimensions. The process was conducted in a research team consisting of three authors to ensure validity and objectivity of the coding procedure (Weston et al., 2001).

Results

The results are divided into three subsections addressing the paper's research questions in a buyer-to-supplier perspective: First, it is described how present buyer-supplier relationships are characterized in differing industry sectors. Second, we describe to what extend buyer-supplier relationships change in the context of Industry 4.0 and how future relationships vary in several industries. Third, drivers and causes are presented why buyer-supplier relationship are transformed. Given the limited space of the paper, the chapter does only present and discuss those categories that are predominantly named to be relevant for the industries regarded in the sample. Table 1 depicts the results differentiated by industry sectors:

Table 1 – Aspects of buyer-supplier relationships differentiated by industry sectors

	Present buyer-supplier relationships	Future buyer-supplier relationships	Drivers and causes for transformation
Automotive	▪ Digital, automated data exchange ▪ Low level of trust	▪ Real-time data ▪ Relationship of trust ▪ Selection criteria for suppliers	▪ Improving competitiveness ▪ Customer demands and value offering ▪ Market dynamics and volatility
Automotive suppliers	▪ Non-automated data exchange ▪ Personal and direct contact ▪ Dependent on suppliers ▪ Low level of trust	▪ Digital platforms ▪ External expertise, support of start-ups ▪ Relationship of trust ▪ Personal contact	▪ Optimization ▪ Customer demands and value offering ▪ Information sharing and transparency ▪ Market dynamics and volatility
Consumer goods	▪ Personal and direct contact	▪ Direct contact remains important ▪ Lower supplier base	▪ Improving competitiveness ▪ Information sharing and transparency
Electronic & electrical engineering	▪ Positive and well established relationships	▪ Digital platforms and cloud computing ▪ Automated processes	▪ Optimization ▪ Technological changes
Mechanical engineering	▪ Long-term oriented relationships	▪ External knowledge ▪ Earlier integration of partners ▪ Concentration on strategic suppliers	▪ Optimization ▪ Cost pressure ▪ Technological changes
Raw materials processing	▪ Positive and well established relationships	▪ Integration in product development ▪ External knowledge ▪ Selection criteria for suppliers ▪ Automated processes	▪ Market dynamics and volatility

Present buyer-supplier relationships

Interviewees from the automotive industry state that automated data exchange is how they share data with suppliers. Interestingly, automotive suppliers predominantly use non-automated data exchange with their respective suppliers in contrast.

Automotive suppliers and companies from the consumer goods industry indicate that personal and direct contact to their suppliers is of utmost importance in the present. In the automotive supplier industry, however, the frequency of direct contact with their suppliers is largely dependent on the respective suppliers' importance.

For mechanical engineering companies, in the present long-term relationships with their suppliers play a crucial role. Those relationships are of close nature, for instance integrating suppliers in innovation and product development processes from early on.

As far as level of trust is concerned, especially representatives from the automotive industry and from automotive suppliers perceive a rather low level of trust in their present buyer-supplier relationships. In contrast, representatives from mechanical engineering and electronic and electrical industries predominantly describe their current buyer-supplier relationships to be positive and well established.

Future buyer-supplier relationships

Automotive suppliers and raw materials processing companies name digital and automated data exchange to be part of their future buyer-supplier relationships. Foremost companies from electronic and electrical engineering state that the importance of platforms and cloud computing increases. In contrast, automotive suppliers indicate that direct and personal contact still remains important in the future, which is also true for the consumer goods industry. In the automotive industry, real-time data exchange is a central characteristic of future buyer-supplier relations. Representatives of raw materials processing enterprises name an enhanced traceability as crucial for future collaboration in their industry. In the electronic and electrical engineering and raw material processing industry major manual activities, e.g., procurement processes, are automated in the future.

Mechanical engineering enterprises predominantly focus on strategic suppliers and companies from consumer goods industry keep a smaller supplier base in the future. Mechanical engineering enterprises and companies from raw materials processing aim at further integrating external knowledge, especially IT-related expertise. Representatives from automotive suppliers as well as raw materials processing companies apply different selection criteria to choose suppliers in the future.

Companies from the automotive industry and automotive suppliers predominantly aim at intensifying buyer-supplier relationships in the future. In addition, automotive suppliers try to intensify and broaden cooperation with start-ups. Companies from raw materials processing intend to cooperate more closely with their suppliers when it comes to new product development. Representatives from the mechanical engineering industry state that they prospectively integrate their suppliers at an earlier stage compared to the present.

Drivers and causes for transformation

Industry 4.0 and accompanying technological developments play a central role in the transformation of buyer-supplier relationships according to all interviewees' statements. Various interviewees express that well-established and smooth buyer-supplier relationships are required to successfully implement Industry 4.0 across companies and subsequently profit from its entire set of potentials.

Several drivers can be observed why buyer-supplier relationships are transformed that differ in various industry sectors. First, companies from mechanical engineering, electronic and electrical engineering, and automotive suppliers see potential for

optimization in reshaping buyer-supplier relationships. In addition, competitiveness, both on an individual and a supply chain level, is strengthened through enhanced buyer-supplier relationships foremost for companies from the automotive and consumer goods industry. Apart from this, representatives from the automotive industry and automotive suppliers indicate that demands from their customers, e.g., higher flexibility, reliability, and product availability, drives changes in their buyer-supplier relationships. Transforming future buyer-supplier relationships enables companies from those industries to create new forms of value offerings for their respective customers. Data exchange across the supply chain, for instance via platform solutions and horizontal and vertical data exchange, requires new relationships between buyers and suppliers. Especially interviewees from automotive suppliers and consumer goods industry state that the possibility to share information and to increase transparency drives the transformation of their future buyer-supplier relationships.

External causes why buyer-supplier relationships are transformed can be found manifold as well. Representatives of automotive, automotive suppliers and raw materials processing companies name an increased market dynamic and volatility as well as an increasing competition as influence factors for a transformation of buyer-supplier relationships. Especially companies from mechanical engineering face increasing cost pressure they address with transforming their buyer-supplier relationships. Technological changes, e.g., digital technologies for digital data exchange and analysis, pave the way for future transformations, mainly in the industries of mechanical engineering and electronic and electrical engineering.

Discussion

As far as present relationships are concerned, the study uncovers that significant industry differences in buyer-supplier relationships can be observed. Among others, the results show that present buyer-supplier relationships in the automotive industry and automotive suppliers are built upon rather low levels of trust. In contrast, buyer-supplier relationships in the mechanical engineering and electronic and electric engineering industries are characterized by higher levels of trust. For the majority of industry sectors, present buyer-supplier transactions and information sharing are mostly conducted via non-automated, analogue, and manual processes. In this context, personal and direct contact are frequently used and are very important in present buyer-supplier relationships.

Our study reveals that buyer-supplier relationships are transformed in the context of Industry 4.0, but the extent of transformation varies among industry sectors, given differing status quos and intensities of changes. The automotive industry and their suppliers prospectively aim for improving current rather mediocre relationships with suppliers, whereas other industries aim at deepening and intensifying already well-established relationships, for instance, further integrating suppliers. In this regard, the paper contributes to the current state of literature emphasizing that well-established relationships are a prerequisite for successful supplier integration. Further, the paper confirms that intense buyer-supplier relationships pave the way to streamline value creation and to provide a superior value proposition that is aligned on end customers' demand which in turn serve to build up a competitive advantage (Schoenherr and Swink, 2012; Tan et al., 2002; Thun, 2010).

Extant research has shown that the automotive industry and its suppliers perceive Industry 4.0 rather from an operational, than from a strategic perspective, in contrast to, for instance, mechanical engineering and electrical and electronic engineering companies (Kiel et al., 2017; Müller et al., 2018b). Our paper partly confirms these results revealing that for instance, companies from mechanical engineering and raw materials processing

concentrate on strategical aspects of buyer-supplier relationships, e.g., integration of partners in product development.

The results show that prospectively information sharing will increasingly be conducted via digital and automated processes in all regarded industry sectors. However, the extent and the forms differ as indicated by the results. For instance, in the automotive and automotive supplier industry, especially real-time data plays a crucial role. Digital platforms become relevant predominantly in the electronic and electrical engineering and automotive supplier industry. Sharing information increases productivity and decreases inventory levels, maintenance efforts, and value creation costs (Vanpoucke et al., 2017; Wang et al., 2006). Whereas on an operational level, information sharing might increasingly be conducted digitally (Hofmann and Rüsch, 2017; Müller et al., 2018a), the results indicate that on a strategic level, personal communication remains important in the future. The paper extends literature in adding that direct personal contact will remain of high importance in buyer-supplier relationships in the context of Industry 4.0.

Responsible for a great proportion of value creation, small and medium sized firms keep on working with manual and semi-digitized solutions in many cases for technical and financial reasons. Subsequently, this requires a strategy that both strives for digital data exchange and develops buyer-supplier relationships on a personal level to unfold the entire potential (Dweekat et al., 2017; Müller et al., 2018a).

Changes in future buyer-supplier relationships can be referred back to several drivers and external causes. Literature has revealed that collaboration, cooperation and integration provide several benefits (Bienhaus and Haddud, 2018; Haddud et al., 2017; Tan et al., 2002; Vanpoucke et al., 2017). Our study adds to the current state of research differentiating between industries and providing an industry comparison.

Our paper extends studies that highlight the importance of buyer-supplier relationships for smooth supply chains in the digital era (Tu, 2018; Wang et al., 2006). Information and communication technologies and digital supplier integration efforts pave the way to establish digital value creation networks in the context of Industry 4.0 (Vanpoucke et al., 2017; Thun, 2010).

Conclusion

Industry 4.0 has the potential to transform future buyer-supplier relationships. Despite its importance for research and corporate practice, there is still little research about Industry 4.0 from a Supply Chain Management perspective. Using a unique sample of empirical data comprising interviews with 65 experts from German industrial companies, the study analyzes how buyer-supplier relationships in the context of Industry 4.0 differ in various industry sectors.

The study entails some limitations as for the data sample and its method that are worth to discuss. First, the data sample exclusively includes German companies that may limit the results' generalizability. Second, the study focuses on selected industry sectors, which must be kept in mind when transferring its implications to other contexts. Third, the study does neither differentiate between different levels of value chain stages, e.g., first-tier versus second-tier suppliers, nor does it analyze differences that stem from various company sizes, e.g., small and medium sized versus large companies. Fourth, the study solely analyzes buyer-supplier-relationships from buyers' perspectives. As far as methodical limitations are concerned, developing solid theoretical implications from explorative, qualitative research is rather difficult. However, the study consolidates empirical data from individual cases while keeping relevant content, and in so doing, is able to work out theoretical contributions. In addition, various biases, e.g., key informant

and retrospective bias, are addressed by our methodological approach and discussed along with measures to reduce their impact.

In the course of the analysis, the study uncovers space for future research. Given the study's limitations and contributions, further research could shed light on the following aspects. Quantitative research may complement the study and, for instance, may quantify and statistically prove the discussed effects. Future research can add the supplier's perspective to analyze buyer-supplier-relationships, focus on small and medium sized firms, and differentiate between levels of value chain stages. Going beyond the study's scope, research could focus on the following further aspects. Research could investigate the incentives to integrate suppliers and incentives to intensify cooperation and collaboration. Future research studies are ought to analyze how supplier integration is to be conducted operatively, what efficiency gains and economical outputs can be expected, and which implications for future value creation can be derived. In addition, platforms possess the potential to revolutionize buyer-supplier-relationships and therefore call for special attention leaving great space for future investigations.

The study and its findings reveal several implications for management and corporate practice. First, well-established buyer-supplier relationships can be regarded as a prerequisite for close cooperation and supplier integration in the digital era, which is why establishing such relationships, is of utmost importance. Second, cooperating and collaborating is crucial in the context of Industry 4.0 to acquire knowledge about IT-processes, especially for traditional industry sectors, such as mechanical engineering. Third, companies are advised to consider present relationships with suppliers and to harmonize digital information sharing and transactions across the supply chain. Fourth, the role of digital data exchange across a supply chain, particularly by using digital platforms, must be supported in future buyer-supplier relationships, given their potential for value creation. Keeping these aspects in mind, may help to prepare companies for future challenges and unfold the potential Industry 4.0 poses for industrial value creation and Supply Chain Management.

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Toward a middle range theory of agency in inter-organizational relationships: A systematic literature review

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Abstract

Two organizations with a mutual interest frequently form an inter-organizational relationship (IOR) to gain operational synergies. Despite an inherent pursuit of cooperation, IORs are subject to agency problems caused by residual self-interest and information asymmetry between the independent organizations. The first steps towards a mid-range theory of agency in IORs are taken through a review of literature in operations management, general management, marketing, and economics. Identified similarities (e.g., explicit focus on information asymmetry) and differences (e.g., assumptions about self-interest and opportunism) between the four disciplines form a conceptual basis for further theorizing on governance of agency problems in IORs.

Keywords: Principal-agent theory, Agency problem, Buyer-supplier relationships

Introduction

Organizations increasingly engage in collaboration with one another in order to gain access to resources and new markets. Such relationships are labelled as inter-organizational relationships (IORs) in which two independent organizations engage in collaboration and cooperation to pursue a mutual interest, hence, going beyond purely transactional exchange (Cropper et al., 2006). Despite the inherent ideal to go beyond arm's length transactions, IORs as social interactions are still subject to agency issues when the independent organizations have their own goals to pursue and private information about their capabilities and actions, leading to challenges such as risk sharing and incentive design (Lassar & Kerr, 1996).

Whilst principal-agent theory specifically focuses on incentive design, it has remained a surprisingly underutilized lens for IORs in operations management when compared to other mainstream theories such as transaction cost economics or the resource-based view (Walker et al., 2015). Instead, empirical agency theory has predominantly focused on a

specific case of corporate governance or how owners should incentivise managers to work towards the owners' best interests (Dalton et al., 2007). Quite the contrary, economic contract theory has adopted a highly general, yet mathematical, treatment to define the most optimal contract (i.e. an incentive game) to govern agency relations (Gibbons, 2005). We argue that in addition to these aforementioned extremes, there is a need for a mid-range theory that is more cognisant of specific dilemmas in various IOR forms, which are set up to increase collaboration but are typically plagued by asymmetric information leading to risk of agency problems. In addition, given the cross-disciplinary nature of IOR studies, such mid-range theory should resonate across multiple disciplines. Hence, the aim of this study is to 1) provide a systematic review of the use of agency theory in studying IORs and 2) to provide the first steps towards a mid-range theory by reconciling potentially discrepant views of the four disciplines.

Method

We systematically reviewed 26 leading journals in the disciplines of operations management (7 journals), general management (8 journals), marketing (6 journals), and economics (5 journals), to identify articles specifically examining agency theory in IORs. The standard in review methods among management scholars has been to include only the highest ranked journals (see e.g. Bergh et al., 2019). This is particularly suitable when seeking to control for research quality in epistemologically diverse management research as compared to, for example, medicine with its clearer hierarchy of evidence (Tranfield et al., 2003). Therefore, with two exceptions, all journals selected were ranked as 4* and 4 journals according to Chartered Association of Business School's Academic Journal Guide (AJG) 2018. Two operations management journals were ranked on AJG level 3 but still considered as top journals due to inclusion in the UT Dallas ranking (*Manufacturing and Service Operations Management*) and due to a substantially high impact factor (*Journal of Supply Chain Management*). Despite such purposefully induced limitations, we obtained a large enough, yet focused and high quality baseline sample giving us the sufficiently reliable and profound account on the usage of agency theory in the IOR domain.

We conducted title-keyword-abstract searches from four major databases (Web of Science, EBSCO Business Source Complete, ABI/INFORM, and Scopus) by using a generic agency theory search string ("agency theory" OR "principal agent" OR "agen* problem" OR "agen* relation*") in order to retrieve all agency theory articles from the selected journals. Some databases utilize advanced search algorithms using special keywords created according to article's bibliographical details (e.g. Web of Science's Keywords plus). We did not switch off such features.

After merging the results and removing duplicates, we were left with 1192 articles for abstract screening. We aimed to include only articles explicitly discussing agency theory in IORs (e.g. corporate governance articles were excluded). Two independent evaluators conducted the screening utilizing a traffic light approach (red = excluded, yellow = unsure, green = included). All articles receiving a disputed decision were discussed *ex post* between the evaluators to reach a unanimous decision. This resulted in 70 articles being accepted (green), 961 articles being rejected (red), and 161 articles (yellow) for a further full text review as the abstracts did not provide clear enough details. The same two evaluators then re-evaluated the yellow cases based on the full texts and evaluated potential mixed decisions. Through these steps, we ended up with 100 articles but during the review we decided to discard a further 15 articles as "false positives" not meeting the criteria leaving the final synthesis sample of 85 articles. At this stage of the research, we analysed the sample by coding the epistemological and ontological stance of each article

together with methodological choices as well as identified the IOR type, empirical context and application domains, roles of principal and agent, and any supporting theories used. These constructs then formed the conceptual basis for our mid-range theory. The complete list of the full synthesis sample is not presented here due to space constraints but is available from the authors. For the same reason, the articles discussed in the following synthesis section and its four sub-sections are not listed in the reference list since all cited articles belong to the synthesis sample (i.e. treated similarly as data).

Descriptive statistics of the synthesis sample

Articles in our sample were clearly divided into empirical and non-empirical papers (44 and 41 papers respectively). Empirical papers predominantly relied on theory testing using quantitative methods, either through surveys (20 papers) or secondary data (17 papers). The sample also included four qualitative case studies, one mixed-methods paper, and two papers combining modelling with empirical methods (an experiment and secondary data analysis). The predominant design in non-empirical papers (as well as in the whole sample) was mathematical modelling (32 papers). We also included 9 review papers which clearly developed agency theory in the specific domain of IORs.

The distribution of articles per discipline varied considerably (economics 10, general management 20, marketing 14, and operations management 41). Operations management dominance is explained by the high number of articles appearing in *Management Science,* (15 articles in total) which we counted into the OM discipline but which appeared to share more intellectual legacy with the economics discipline. Interestingly, out of 26 journals only 22 appeared in our final sample, mainly due to their non-IOR focus. The distribution of articles per journal is illustrated in Figure 1.

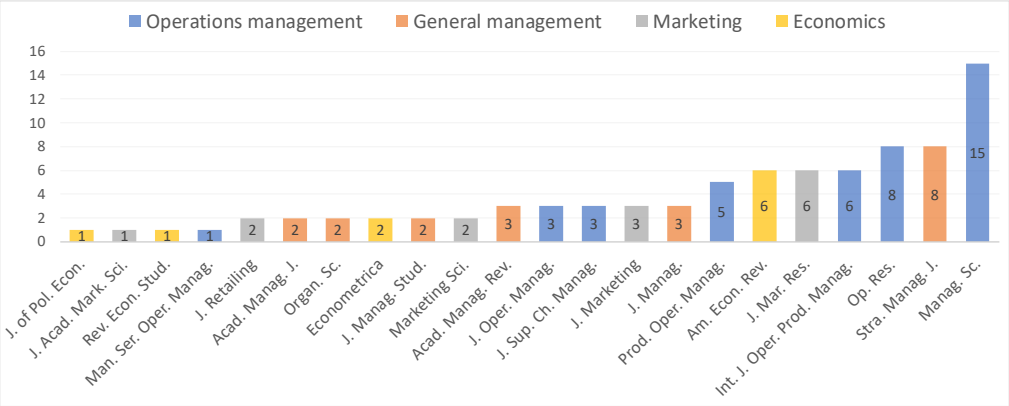

Figure 1 - Number of articles per journal

Agency theoretic approach on IORs in the four disciplines

In the following sub-sections, we will summarize the key themes of each four disciplines.

Operations management

Within the operations management sub-set of data, we distinguish between two streams: empirical operations management (discussed in the beginning of this sub-section) and more mathematical modelling-based operations research (discussed in the latter part of the sub-section). The former is in line with positive agency theory used more widely in general management and marketing disciplines while the latter clearly shares intellectual legacy with economic contract theory or principal-agent research.

Overall, as Zu and Kaynak (2012) note, agency theory has so far seen relatively minor use, and its constructs little operationalization in empirical operations management. Within this literature, applications of agency theory seem to be a rather recent phenomenon, with most of the articles published post 2010. The most common research approach is theory testing, with surveys as the dominant method. The research is focused on buyer-supplier relationships as the IOR type, with several application domains. In particular, agency perspective is used to study monitoring issues in supply chains such as in domains of quality management (e.g. Zu and Kaynak, 2012; Handley and Gray, 2016) and risk management (e.g. Shafiq et al. 2017; Hajmohammad and Vachon, 2016; Zsidisin and Ellram, 2003).

However, with the notable exception of Handley and Gray (2016), agency theory is typically not accompanied with a clear articulation of the agency problem studied in the context nor an explanation of how the problem is caused by the opportunism of the supplier (rather than contextual issues). Such omissions may suggest it is used more as a governance mechanism to solve a risk-sharing problem rather than an agency problem in supply chains.

Only very few articles use another named theory to support or complement their analysis, though different streams of OM/SCM literature (e.g. supply risk management, forecast sharing, sustainable supply chain management and quality management) are often discussed extensively in the papers. Perhaps as a result, the contributions of the studies are typically not discussed in relation to agency theory, i.e. how the research enhances our understanding of agency problems and their governance in buyer-supplier relationships, but rather in relation to the operations management issue examined using an agency perspective. Notable exceptions to this are for example Broekhuis and Scholten (2018), who demonstrate that behavioural standards established ex ante the formal contract are important pre-requisites for the appropriate creation and management of said formal contract. Handley and Gray (2013) also note how their findings on the substitute nature of contractual penalties and monitoring are not in line with most of the principal-agent literature. Steinbach et al. (2006) provide potentially the strongest of agency theory critiques in our sample. They argue that in focusing on the 'flawless principal' and the 'malicious agent', prior contracting research has neglected the customer (principal) behaviour and customer role in outsourced service co-production in relation to outcome-oriented contracting. Finally, Wilhelm et al. (2016) introduce an interesting addition to agency theory in the form of the double agency role of the agent in long supply chains, i.e. "first-tier suppliers will act as agents who fulfil the lead firm's […] requirements (i.e., the primary agency role) and implement these requirements in their suppliers' operations (i.e., the secondary agency role)" (p. 42).

Two articles raise power issues as important contingencies in the use of agency-based governance mechanisms in supply chains. Hajmohammad and Vachon (2016) develop a framework that suggests buyer power and dependence on the supplier has an impact on the monitoring mechanisms used for risk management in supply chains, while Wilhelm et al. (2016) note that a powerful buyer enforcing requirements to its lead supplier is at risk of decoupling in relation to the double agency role of the supplier.

Operations research deviates from empirical OM by relying almost exclusively on mathematical modelling. As shown earlier, articles published in *Management Science* comprise the majority of the articles in our set and nearly all (12 out of 15) of them utilized economic models in general and principal-agent framework in particular as a research design. Similarly, all 8 articles included from *Operations Research* used modelling as well as 4 out of 6 articles in *Production and Operations Management*.

Indeed, operations research seems to give slightly more ecological validity to rather generic economist treatment of principal-agent problems (see further discussion in the Economics sub-section). Typically, operations researchers focus on buyer-supplier relationships and are interested in modelling actual supply chain management problems as a principal-agent situation. Supply chain topics include inventory management (e.g., Corbett, 2001; Gilbert & Weng, 1998) technology licensing (Crama et al., 2008), outsourcing of services (Jain et al., 2013; Kalkanci & Erhun, 2012; Kim et al., 2007) and organization of health care services (Fuloria & Zenios, 2001) to mention a few. Another IOR type is franchising involving some empirical work (e.g. Fladmoe-Lindquist & Jacque, 1995; Kosova & Sertsios, 2018).

Many papers utilize the standard economics models of adverse selection and moral hazard. Interestingly, two papers (Jain et al., 2013; Roels et al., 2010) focus on double moral hazard indicating that it is not always the principal who suffers from lack of information concerning the agent's actions. The agent's welfare is equally compromised when she does not know the principal's actions. Roels et al. (2010) emphasize co-production of value in consultancy, where performance of the consultant is significantly affected by the efforts of the client. Finally, some papers claimed to go even beyond the classical economics models and adopt more dynamic modelling in order to build more real-life type of models (e.g., Feng et al., 2015; Fuloria & Zenios, 2003).

General Management

Within the general management journals, four types of IORs feature most frequently: franchisor-franchisee relationships (6 articles), buyer-supplier relationships (6 articles), joint ventures / syndicates / partnerships (3 articles), and manufacturer-distributor/retailer relationships (2 articles). These IOR forms are explored in a wide variety of application domains and empirical contexts. These include mergers, where the bidding firm or target firm acts as a principal and the investment bank representing one of these firms in negotiations act as the agent (Kesner et al., 1994); professional service agency, where a client firm hires a professional service organisation (agent) to perform knowledge-intensive tasks (Sharma, 1997; Dawson et al. 2014); partner selection (Meuleman et al., 2010; Obloj & Zemsky, 2015; Ruer & Ragozzino, 2006) and evolution of inter-firm collaborations (Argyres, 1999; Ring & Van De Ven, 1994) such as strategic alliances, partnerships, coalitions, joint ventures, collaborative new product franchises, research consortia, and various forms of network organizations; supply chain risk (Camuffo et al., 2007), performance (Lado et al., 2008), and alignment with firm strategy (Lassar & Kerr, 1996); and franchising (e.g. Combs & Ketchen, 1999; Perryman & Combs, 2012; Combs & Ketchen, 2003; Combs et al., 2004; Shane, 1998a and 1998b).

Two research strategies and associated designs dominate. Theory testing papers use secondary data and more limitedly surveys to test hypotheses. In some cases, secondary data is combined with other sources such as structured interviews (Camuffo et al., 2007) or surveys (Combs & Ketchen 1999). In contrast, theory elaboration papers are largely conceptual and typically present propositions for future testing. Illustrative of this approach are Sharma (1998), who develops a framework and associated propositions outlining four types of restraints to professional service agent opportunism, and Ring and Van De Ven (1994), who focus on the evolution of cooperative IORs. Modelling is used in two theory elaboration papers. For example, Makadok and Coff (2009) seek to model the conditions under which different hybrid governance mechanisms are most suitable, with particular attention on the importance of cross-task synergies as a selection factor. Finally, just one paper in this sub-set adopts a case study research design to examine issues of agency. Argyres (1999) elaborates agency theory, transaction cost economics,

and information processing theory using qualitative interview data from partners involved in the B-2 Stealth Bomber project.

Interestingly, a significant number of studies highlight the limitations of agency theory in explaining various IOR phenomena. For example, Meuleman et al. (2010) note that "given the complexity of partner selection […] a single theory approach may be unsuitable for understanding complex phenomena" (p. 995). This perspective has resulted in many proposing extensions to standard agency perspectives or using supplementary theories to improve explanatory power. For instance (perhaps unsurprisingly), transaction cost economics features alongside agency theory in a number of reviewed studies (e.g. Ring & Van De Ven, 1994; Mahoney, 1992; Argyres, 1999; Lassar & Kerr, 1996; Lado et al., 2008). For example, Lassar and Kerr (1996) combine the two to examine the influence of competitive strategy on the nature of agent controls used by manufacturers within their distribution networks. Ring and Van De Ven (1994) also combine these theories to make propositions on the process of IOR emergence, growth, and dissolution.

In a different direction, Combs and Ketchen (1999, 2003) demonstrate how a resource (capital) scarcity perspective can provide additional explanatory power in firm decisions to expand via franchising as opposed to hierarchy ownership models. In later work, Combs et al. (2004) highlight the limitations of both agency theory and resource scarcity theory in understanding why firm initiate franchising and its performance effects. They argue for greater theoretical diversity through use of upper echelons theory, resource-based theory, and institutional theory in this application domain.

In a professional service context, Sharma (1997) challenges some of the key assumptions of agency theory such as those concerning power asymmetry and the emergence of knowledge asymmetry effects. Sharma draws on ideas from sociology of work in the professions' literature to propose self-control, community control, bureaucratic control, and client control as important restraints to potential opportunistic behaviour by professional agents. Finally, using secondary data of syndicate collaboration in buyouts, Meuleman et al. (2010) combine agency theory with relational network theory to test hypotheses concerning the boundary conditions to the embeddedness approach to partner selection. They find that, when agency risks are low, relational embeddedness is less critical in partner selection, and that relational embeddedness can be partially substituted for reputational capital.

The use of supporting theories perhaps highlights the relative maturity of the general management discipline in using (positive) agency theory. In effect, as studies have moved away from the more transactional principal-agent relationships, upon which many of the assumptions of agency theory are arguably based, and towards the more cooperative end of the relational spectrum (i.e. towards IORs) that characterise many of the application domains seen in these papers many researchers have appreciated the need to supplement the mainstream theory. And yet, conversely, the sheer variety of additional theories adopted points to a relative lack of maturity, in so much as little consensus exits on how best to deal with the deficiencies of standard agency theory.

Marketing

Four IOR types feature in the marketing subset: franchisor-franchisee relationships (6), manufacturer-distributor/retailer relationships (3), manufacturer-supplier relationships (3) and a licensor-licensee relationship (1). The twelve empirical papers are all theory testing papers. Concerning research design, survey (7) and secondary data (5) dominate, with one remaining paper using a non-empirical modelling approach. The final paper in the sub-set is a review paper (Bergen et al., 1992) which is considered a landmark conceptual paper on agency theory in marketing.

The twelve empirical papers cover a diverse set of empirical contexts and application domains with varying definitions of the principal and the agent. Grünhagen et al. (2017) study business format franchising across the US, and define franchisor and franchisee as both principal and agent since both have access to private information (a so-called model of dual agency). The other five empirical papers on franchising define the franchisor as the principal and the franchisee as the agent. Dahlstrom & Nygaard (1994) study the governance modes (franchising vs. corporate owned outlet) in the Norwegian oil industry. Antia et al. (2013, 2017) use court records to study franchise relationships across the US. Kashyap et al. (2012) analyse survey responses and contracts to study franchise relationships in the US automotive industry. Three papers (Celly & Frazier, 1996; Gilliland & Kim, 2014; Israeli et al., 2016) study relationships between manufacturers (as principals) and their downstream channel partners (as agents). In contrast, three papers studying upstream buyer-supplier relations (Heide, 2003; Heide et al., 2017; Stump & Heide,1996) treat a buyer as a principal and a supplier (i.e. a manufacturer) as an agent. Finally, Jayachandran et al. (2013), study license agreements between US or Canadian firms (as the principals) with their contract partners all over the world (as agents). From these studies, it is interesting to glean that any party in the supply chain can be defined as the principal or the agent. Almost all papers make a choice whether to call the upstream partner in the supply chain the principal or the agent; only Grünhagen et al. (2017), as one of the most recent papers in this subset, uses a model of dual agency.

The majority of papers rely on single-sided data. For studies that measure opportunism this raises the interesting question of who reports on assumed opportunistic behaviour? Similarly, do principals report what governance mechanisms they use, or do agents report what governance mechanisms they experience? Such choices vary per publication. For survey studies, two rely on principals reporting on the governance mechanism they use (Stump & Heide, 1996; Heide, 2003), one study relies on agents reporting on the governance mechanisms they experience (Celly & Frazier, 1996), and three studies rely on agents reporting on their own levels of opportunistic behaviour as well as the governance mechanisms they experienced (Kashyap et al., 2012; Gilliland & Kim, 2014; Heide et al., 2017). Agents reporting on their own opportunism raises potential issues of social desirability bias in the data.

Most papers combine agency theory with other theories or literatures. The most frequently used theory as support is transaction cost economics. Literatures on organizational control, contracting or franchising are also regularly used. Gilliland & Kim (2014) use stewardship theory on equal footing with agency theory to build hypotheses about how agents perceive incentives, and to add non-traditional governance mechanisms to their conceptual model. The authors suggest that a reseller may simultaneously play the roles of both steward and agent.

A number of interesting contributions to "traditional" conceptualizations were found. First, Celly et al. (1996) note that unlike for intra-organizational principal-agent relationships, formal authority relationships are not nearly as strong between independent organizations, making monitoring and evaluating distributor behaviours and specifying desirable behaviours relatively difficult. Stump & Heide (1996) present a non-traditional type of incentive. Whereas incentives are generally thought of as rewards from the principal to the agent, they operationalize incentives as specific investments made by the supplier that function as a hostage. Heide (2003) formalizes and tests "plural governance" (i.e. make and buy as simultaneous sourcing options) as a governance mechanism in a principal-agent relationship. Heide et al. (2007) add another governance mechanism: microlevel social contracts, i.e. informal agreements between parties on either output of behaviours. Antia et al. (2017) propose qualification (of suppliers, franchisees) as an *ex*

ante governance mechanism, as do Stump & Heide (1996). Moreover, Antia et al. (2017) also propose socialization as an ex post governance mechanism, although the bankruptcy-reducing effect of socialization in franchising relationships appeared weak in their study.

Kashyap et al. (2012) propose two additions to agency theory: first, that monitoring should be separated from enforcement (as discovered deviances do not always lead to enforcement), and second, that compliance should be separated from opportunism as "[f]ranchisees may fail to comply for a variety of reasons, such as a lack of resources, a poor understanding of the desired behavior, or a belief that the particular obligation is not appropriate to the local operating conditions" (p265). Both Jayachandran et al. (2013) and Grünhagen et al. (2017) discuss "dual agency", with risk of pre-contractual and post-contractual opportunism on both sides and agency costs on both sides. Finally, various papers emphasize the effect of legal and regulatory context on governance decisions (Antia et al., 2013; Jayachandran et al., 2013; Grünhagen et al., 2017).

Economics

We use the term *contract theory* to describe this specific branch of information economics focusing on principal-agent relations. As with economics in general, contract theory is purely based on mathematical modelling. However, it is not just the notation and design which distinguishes contract theory from the positivist approach dominating management research – there are also differences in the key theoretical focus areas. The positivist stream focuses on different formal and informal governance mechanisms to curb opportunism. It seems surprising that contract theory actually pays rather limited attention to opportunism *per se* and simply emphasizes the value of information. In the economists' world, every social actor is a self-interested utility maximiser but not a single economics paper in our sample explicitly mentions opportunism or *self-interest with guile* (Williamson, 1985). In addition, no paper focuses on any other governance mechanism than a contract between the parties. To contract theorists, a contract does not equal a legal contract but instead can be seen as a game between two or more players (i.e. principal[s] and agent[s]), which defines their action structure.

Hence, from an economist's perspective the aim is to optimize (or minimize) the compensation that the principal pays to the agent while simultaneously ensuring the agent's highest possible level of effort. Actual payment schemes (i.e. game structures) may vary substantially in terms such as duration (short-term vs. long-term, see e.g. Hart & Tirole, 1988), the contract menus offered to an agent (e.g. fixed-price vs. fixed price cost reimbursement, Rogerson, 2003) as well as opportunities to renegotiate (Gagnepain et al., 2013). Therefore, the models very quickly become extremely complicated mathematical optimization problems. Arguably, too complicated which is why Rogerson (2003) in his classic paper argues that simple contract menus can attain three quarters of gains achievable by the fully optimal complex menu.

Contract theorists are therefore not deeply interested in whether an agent is opportunistic but simply focus on minimizing *information rent* which the principal needs to yield up to the agent while not knowing the agent's type *ex ante* (i.e. an adverse selection model) or not being able to monitor her actual effort *ex post* (i.e. a moral hazard model). Hence, it is relevant to consider possible goal incongruence (or reasons behind it) since incongruence always exists when the agent's compensation does not equal the principal's welfare. Such generic information-focused approach has its benefits. For instance, the difference between an adverse selection and a moral hazard problem is simply timing (i.e. the game structure). In adverse selection, the agent possess private information about her intended effort level before the principal offers the contract and in a moral hazard model the agent's private information about her induced effort becomes

valuable after signing the contract (Lewis & Bajari, 2014). Naturally, the solutions to these problems differ since finding the optimal solution (i.e. equilibrium) depends on the game structure. Another clear benefit is that to contract theory it is indifferent who is the principal and who is the agent since the agent is always the one who possesses private information. Therefore, as our sample shows, the principal can be the buyer not knowing the intended effort of its suppliers (Arve & Martimort, 2016) but also the supplier not knowing the demand of the buyer (Kalkanci & Erhun, 2012).

Unfortunately, this is also the clear limitation of the highly generic treatment of the problem since the economic theory of agency becomes nearly indifferent to the actual type of the social actors (e.g. individual vs. organization), which may lead to loss of ecological validity since the specific context of IORs affects the very nature of information and its communication between parties. Therefore, for our IOR focused purpose the most relevant articles in this sub-set are the econometric papers, which were unfortunately a clear minority in our sample (3 out of 10 articles). These papers provide slightly more empirically sound notions such as that renegotiation improves commitment of agents in outsourcing public transport services (Gagnepain et al., 2013), the role of deadlines as governance mechanisms in procurement of highway projects (Lewis & Bajari., 2014) and the importance of the financial health of agent to the welfare of the principal (Fan et al., 2017). Despite their importance, these papers still adopt relatively partial perspective, in favour of the principal, and do not treat IORs as collaborative structures providing benefits to both parties.

The final clear challenge of contract theory towards ecological validity is that it very often assumes that the agent knows her type (e.g. cost structure to undertake the principal's desired effort) before accepting the contract (in adverse selection models) or learns it while the game progresses (moral hazard models). Crémer and Khalil (1992) provide an important exception by focusing on cost of gathering information. However, they conclude that the high cost of acquisition of information *ex ante* for the agent is always more feasible to the principal since it decreases information asymmetry and thus information rents given to the agent. In real life this sound bizarre since it would mean that the principal should favour agents who do not know their cost structures potentially leading to disastrous outcomes and even bankruptcy of the agent!

Concluding remarks

Based on our review, information asymmetry appears to be the key concept and common denominator between the disciplines forming a basis for IOR agency problems. As collaborative structures between two organizations with mutual interests, IORs are in fact set up to gain access to specific information or knowledge (Barringer & Harrison, 2000) i.e. to decrease information asymmetry between two organizations for example by engaging into collaborative practices or forming a joint venture or other cooperative structures (Parmigiani & River-Santos, 2012). However, we accept the notion that whilst IORs decrease information asymmetry when compared to purely transactional relations, there will always exist *residual information asymmetry* in IORs, which is contingent to various factors and can still cause agency problems. For instance, the type of IOR affects the extent to which information asymmetry may realistically be lowered. In franchising for example, the principal (franchisor) may have direct access to inventory and sales data of the agent (franchisee), while in collaborative buyer-supplier relationships these may still be private information of the two parties who may share information in other fronts (e.g. technical specifications, process control etc.). In similar vein, joint ventures may be particularly effective in decreasing information asymmetry, as both organizations have legal decision-making right and access to confidential information of the jointly owned

company/operation. Naturally, there also exists variation within each IOR category, when two organizations engage into collaboration and develop more situated practices and governance mechanisms to coordinate their interaction.

The assumption remaining contested between the four fields is the assumption on self-interested or even opportunistic behaviour of the principal and the agent. For economists, self-interest of economic actors is "just" a standard assumption not the core focus. Instead, empirical operations management strongly emphasizes opportunism (self-interest with guile) and has focused on finding the best remedies to extirpate it. Interestingly, general management has taken a leap (and marketing is following the lead) towards repairing and expanding the assumptions of agency theory by incorporating thoughts from other theories. Such an approach has its virtues but may also lead to too strong theoretical pluralism compromising the parsimonious ideal of agency theory.

Based on our review, we conclude that agency theory can be a viable lens to IORs but is not sufficient to fully explain the complex nature of IORs. Instead, it is at its best explaining the problems arising from (residual) information asymmetry between the two parties. The clear room for further elaboration lies in the adoption of more equal stance taking into account two-way information asymmetry (e.g. double moral hazard/dual agency) as well as empirically more fine-grained explanations behind information asymmetries (e.g. failure in communicating vs. deliberately concealing information). We argue that developing these ideas further will take us closer to a mid-range theory of agency in IORs, which should be the focus of future work.

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A Relational Framework for Collaboration in Temporal Supply Chain Contexts

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Abstract

The present research investigates the relevance of the relational view enablers and barriers in temporal supply chain contexts. Applying a multiple case study approach situated in industrial projects environment in Italy, this paper develops a relational framework for supplier horizontal collaboration. The findings reveal that, in temporal contexts, the most adopted enabler to co-generate competitive advantage is investing in partnership-exclusive assets whilst other enablers have less importance. Asset interconnectedness and resource indivisibility are two barriers found to be insignificant to co-generation of competitive advantage in temporal contexts, whilst partner scarcity and governance institutional environment can greatly deter horizontal collaboration efforts.

Keywords: Supply Chain Collaboration, Relational View, Temporal Contexts

Introduction

Supply chain collaboration is established in literature as an enabler of value co-creation that couldn't be otherwise generated (Lamming ,1993; Simatupang and Sridharan, 2002). Collaboration in a supply chain setting comes in different forms, among which; trust, information sharing, managing change, joint conflict resolution and forming joint cross-functional teams (Barratt, 2004). As such, the main challenge becomes how to alienate organisational boundaries between different supply chain actors to enable sharing of risks and benefits so as to enhance the incentives of collaboration (Frohlich and Westbrook, 2001). Successful collaborative initiatives between supply chains members could lead to sustained differentiated performance, yet inter-firm collaboration often fails due to

misalignment of incentives and strategies (Fawcett et al., 2008). Collaboration can be vertical (i.e., across the members of the same supply chain), horizontal (between the members who provide similar activity in the supply chain or competitors) or lateral (Barratt, 2004).

Collaboration has been addressed in supply chain literature using a number of theoretical lenses; as a dynamic capability that needs competence development using the resources based view, as a property of the network and the relationship using the relational view (Fawcett et al., 2012). The relational view (RV) (Dyer and Singh, 1998) provides beneficial insights on co-generation of competitive advantage among different actors in networked environments, in which the unit of analysis is the relationship rather than an individual firm. The central theory of RV suggests that performance could be bolstered through the exploitation of resources that belong to the inter-organisational relationships. Such supernormal profit is jointly generated and becomes a property of the relationship (Dyer and Singh, 1998).

Such theoretical perspective is usually adopted and examined in alliances and long-term vertical inter-organisational relationships, little is known on its appropriateness to temporal contexts (Sabri et al., 2017). Whilst literature has explored supply chain vertical collaboration in continuous transactional supply chain relationships, however, establishing horizontal collaborations in temporal contexts, such as projects environment, is yet an unexplored topic that needs further research. Projects environment usually involves a large number of suppliers and a general contractor where contractors often squeeze suppliers to get lowest prices (Sabri et al., 2017). The situation for these suppliers becomes more challenging in countries like Italy, the second exporter of such products to industrial projects after China, where many of the suppliers are small and medium (SME) and often family owned. The context of this research is supply chain in industrial projects environment, where firms form a temporary networked organisation dealing with non-repetitive activities (Turner and Muller, 2003) with high complexity and uncertainty (Fearne and Fowler, 2006) due to supply chain fragmentation and rivalry.

To this end, this research investigates the readiness of small and medium suppliers to establish horizontal collaboration in the energy projects' sector in Italy. The present research examines the level of horizontal supply chain collaboration by reflecting on the four mechanisms and four challenges of RV. This study contributes to supply chain literature by testing and reporting on the applicability of the RV in a rarely explored context.

Supply Chain Horizontal Collaboration in Temporal Contexts

Supply Chain Collaboration is defined as "*the ability to work across organizational boundaries to build and manage unique value-adding processes to better meet customer needs"* (Fawcett et al., 2008; p.93). That entails establishing high levels of openness and trust, where firms can co-develop sustainable competitive advantages, achieve scale of economies, process improvements, information and risk sharing (Soosay et al., 2008; Walker et al., 2013). Projects require multiple resources and are composed of many activities performed by a temporary coalition of firms; each one with a well-defined role (design, engineering, procurement, manufacturing, assembly, commissioning and decommissioning) (Hicks et al., 2000). Projects are non-repetitive and have limited time extension, which are reasons for a strong focus on time and costs. Large complex project environments is characterised by iterative flows in transitory networks where main actors are customers, consultants, contractors and suppliers (Gosling and Naim, 2009; Pryke, 2009). In projects environment, to determine if a relationship is worthy of the time and

resources needed to fully develop into a partnership, it's advisable to rely on a structured multi-criteria partner selection (Eriksson, 2015), that also considers the features of the projects portfolio.

Considering all involved actors as a single entity, supply chain horizontal collaboration can be a tool to break the isolation of small suppliers, overcome dynamic market challenges, pursue technological innovation and face global competition (Gnyawali and Park, 2009; Kumar and Singh, 2017). SME suppliers adopt customer-oriented strategies to meet customers' needs (Kumar et al., 2014), but they are usually in an unfavourable position against bigger competitors. They suffer many market pressures, deal with resources and organizational constraints, and are strongly exposed to market risks (Kumar and Singh, 2017) and may face difficulties in getting certified and appear on customers' vendors lists. In such context horizontal collaboration could be beneficial, leading to a development of suppliers (Simatupang and Sridharan, 2002).

The Relational View

It is well established in literature that a firm's critical resources and capabilities may go far beyond their boundaries. Dyer and Singh developed the Relational View (RV), focusing on the relationship/network routines and processes as an important unit of analysis. According to RV, firms can establish idiosyncratic inter-firm linkages, making relation-specific investments and combining resources in unique ways, co-generating competitive advantage by collaboration (Dyer, 1996a; Dyer and Singh, 1998). In contrast to the resources-based view of the firm, the resources and capabilities in the relational view become a property of a network of interconnected firms (Dyer and Singh, 1998), hence beyond the control of, and can't be duplicated by, an individual firm. They identify four enablers and four barriers for co-generation of competitive advantage through collaboration. First, **Enablers**. These are the mechanisms if jointly-leveraged on by partners, can lead to generate sustainable competitive advantages:

Exchange and investment in partnership-exclusive assets; these can be physical, human or site specific assets. Specialized assets represent a conjunction between partners' assets that is fundamental for collaboration purposes (Amit and Shoemaker, 1993). Length of safeguards, volume of transactions and trust influence partners' decision to joint invest (Dyer and Singh, 1998; Walker et al., 2013)

Knowledge and information sharing that boosts joint-learning helps partners in cogenerating new ideas and innovating (Dyer and Singh, 1998). Establishing inter-firm knowledge-sharing routines facilitates transferring, recombining or creating specialized knowledge (Grant, 1996). But firms need also absorptive capacity, "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p.128).

Combining of scarce resources and capabilities results in joint creation of unique new products, services and technologies, but also in economies of scale/scope thanks to inter-firm procurement procedures or reduced bureaucracy (Walker et al, 2013). Generally, firms can share equipment, facilities, warehouses and know-how resources. The greater is resources complementary, the greater are the synergistic effects coming from their combination (Dyer and Singh, 1998).

Governance mechanisms that yield to lower transactional costs generates relational rents improving efficiency and influencing the willingness to engage in value-creation initiatives (Dyer and Singh, 1998; Walker et al., 2013). Dyer and Singh (1998) identified three types of agreement that can be enforced by third parties or not, if not, they can be

formal or informal. The latter are the most effective and least costly safeguards but require time and trust to be established.

Second, **Barriers** to co-generation of competitive advantage are the challenges towards relational rents development, or isolating mechanisms:

Inter-firm asset interconnectedness is based on cumulative bundles of joint investment decisions, where initial partnership-specific investments put premises for future ones that wouldn't be profitable alone (Dyer and Singh, 1998). Bundles creation represent a barrier because it requires much time and money, and growing interdependence is difficult to manage (Touboulic and Walker, 2015).

Partner scarcity may lie in the easiness of finding a partner or partner willingness and collaboration experiences (Dyer and Singh, 1998). It may be necessary to find partners having local market knowledge, contacts and a widespread distribution network to entry foreign markets (Dyer and Singh, 1998).

Resources Indivisibility, Idiosyncratic combination and coevolution of resources and capabilities lead over time to resource indivisibility; making resources and capabilities increasingly hard to imitate. This leads to loss of flexibility, difficulty in redeploying resources and loss of control over resources and capabilities (Dyer and Singh, 1998).

Institutional environment may obstruct cooperation and raise transaction costs (Walker et al., 2013). Matters influencing relational rents go far beyond firm boundaries, expanding to a broader, country level (Dyer and Singh, 1998). Main barriers in an institutional environment can be legal, organizational and country-specific (cultural) restrictions, since geographically dispersed firms may have different legislations, cultures, conflicting local politics and different priorities (Walker et al., 2013).

Methodology

The literature search was performed using Scopus and Science Direct databases. To avoid the fragmentation in supply chain collaboration literature, we used the following keyword combinations to capture all relevant studies; "supply chain*" AND "collaborati*" OR "relation*", "partner*", "tempora*", "integration", "coordination", "horizontal collaboration", "lateral collaboration", "inter-organizational". The final pool of selected papers was selected following a two-steps approach. First, the search results were narrowed down by performing a preliminary qualitative content analysis of abstracts. Second, the contents of the selected papers have then been analysed and classified to find common topics and properly conduct literature review.

The empirical settings of this research is a multiple case study methodology; with its focus on contextualisation (Yin, 2014), it becomes best suited to address the objectives of this research. The respondents are managers of 14 suppliers of valves and boilers. This supply network is located in *Lombardia* region northern Italy, and is composed of mostly SME suppliers for the energy projects sector. The motivation behind this selection is in the high competitiveness and temporality of this supply base.

Semi-structured interviews are applied to collect data, we developed a questionnaire with 36 mixed queries (open/closed ended, and 5-point Likert scale questions). The questions have been devised to cover the RV concepts, enablers and barriers, as well as firms' characteristics and their approach to the market. In particular, we carefully designed the questionnaire to address the four RV mechanisms and four barriers above-outlined in the literature review section.

Interviews were audio recorded and then transcribed. Thematic coding analysis was performed, in which the responses are coded, aggregated and reorganized in themes in

order to obtain significant information to explain the overall collaborative phenomena (or lack of it), considering potential trends and correlations.

Findings

Supply Chain Management in Temporal Contexts: Projects Environment in Italy

When a project owner (i.e., end-user) decides to develop a new project, they prepare a call for tenders, and contractor offering the best solution/price trade-off wins the bid. Contractor breaks the project into several activities and identifies the needed products and/or services. Together with the project owner, the contractor defines vendor lists for each category to approve qualified suppliers. In this context *"Qualification is a very complex process"* for suppliers, but fundamental to participate in tenders. Qualified suppliers can participate tendering to access the short vendor list. In this phase it is impossible to collaborate as a manger notes "[contractors] *put suppliers against each other"*. The main discriminant is price, but local content and presence in relevant markets contribute in defining a supplier's tendering score. Italian suppliers are considered leaders in supplying high-quality components and products for the construction of extraction platforms, pipelines, refineries, and others. Since technology is in a mature phase, the few innovations occur mostly on material. Small and medium suppliers need contractors to outreach larger markets, to win the bid, suppliers need to obtain certifications required by contractors. As a result of the global financial crisis, fluctuating oil prices, and changing global economic/geopolitical relationships, with strong repercussions on oil&gas (O&G) sector. Profit margins along the supply chain are reduced, facilitating the entry of suppliers from lower-cost countries. To overcome such situation, a group of suppliers started to foster lighter versions of collaborations, as one manager notes "[we] *developed a network of firms specialized in different O&G sector activities"* (e.g., painting, welding, heat treatment). Moreover, a new big challenge for Italian suppliers in this context is the local content clauses in project contracts *"Local content will be a strategic discriminating factor for O&G supplies over the next 15-20 years"*. Governments, especially in Middle East, want that contractors buy locally rather than importing from Europe. This leads suppliers to change their 'business as usual' approach and to initiate collaborations with local partners, both suppliers and agents, yet they "*cannot open their own facilities everywhere"*.

Supply Chain Collaboration in Temporal Contexts

The findings reveal that horizontal supplier collaboration, in projects environment, is heterogeneous. The strongest, most collaborative relationships are maintained with lower-tier suppliers. Among the different Italian lower-tier suppliers there are ongoing informal relationships from many years that allowed to simplify communication, reduce transaction costs, lead time and from time to time make innovations. These are tacit collaborations, without written rules, and often there are no common strategies or goals. Anyway, it's fundamental to keep doors open to everyone, since contractors may impose other supply chain participants, and this translates in many one-time collaborations. Among competitors delivering the same product/service range, there is little evidence of horizontal collaboration, as one respondent notes *"You cannot [fight] every day your competitors and then make the agreement"*; even if sometimes contractors push suppliers to work together. Yet not all contractors will be happy having horizontal collaboration in their supply base *"contractors understand if there are any set-ups"*, as collaborations and mergers threaten competitiveness and may increase final costs endured by contractors. Further, several Italian suppliers tried horizontal collaboration with competitors

"horizontal expansion of multinational groups through acquisitions pushes italian suppliers towards collaboration with adjacent suppliers", but rarely with success. The major obstacle is probably a cultural barrier, since they are territorial of their know-how.

There are few interesting collaborations between complementary products suppliers, such as valves and actuators, boilers and gas turbines. These collaborations may occur to enhance competitiveness of the offering *"to offer packages technically and commercially competitive for customers"*. In this case, supply chain collaboration can help expanding the product portfolio or to approach markets requiring local content. Hence, few long-term horizontal collaborations between complementary products suppliers diffused over time. With local agents or service providers there is horizontal collaboration since it's often mandatory to have local partners in foreign countries in order to properly serve local customers and meet local content requirements. These can be local agents, distributors or other service providers and actors that, when required, may also help in having local content production. Most of these agents provide commission-based commercial services. They can represent different suppliers, but not competitors (i.e. those proving the same product/service range). Local agents and distributors often provide technical support, assistance, installation and maintenance in reference countries. It's impossible to have facilities everywhere, so manufacturers tend to use existing local agents/partners' structures without major investments.

With contractors there is little evidence on establishing collaboration. Respondents agree that having long-term relationships with contractors isn't feasible, because the contractor's priority is to have competition in vendor lists to lower prices and maximize profit. Hence, suppliers become defensive to protect their know-how, but sometimes cooperate with them to engineer alternative solutions, solve technical problems and properly deliver the project.

With end-users there may be good relationships that however can be considered more as marketing strategies rather than collaborations. Tailor-made strategies are necessary to establish exclusive long-term relationships, but "it's difficult to have written contracts where end-users commit to buy a certain amount". Some manufacturers have regular meetings with end-users, and larger ones may also have dedicated staff "to few trusted end-users". They may also decide to invest abroad to fulfill local content requirements or to be more responsive towards important end-users. Overall, tendency to have informal approaches, making themselves flexible and available, isn't collaboration but marketing strategy, because there aren't joint objectives.

Discussion

In this section we analyse the findings using the RV theoretical lens, to understand which enablers and/or are most relevant in temporal contexts.

Enablers of Competitive Advantage Co-generation in Temporal Contexts

As depicted in Figure1. Six suppliers out of the 14 have invested in partnership-exclusive assets. Several of them would like to invest in site-specific assets, mainly for the localization of production facilities abroad. These investments are usually undertaken with local partners in order to offer local content production. And many of the investments in equipment and tools or human resources are needed to complement such investments in production facilities abroad. Italian suppliers share knowledge and information on an occasional basis rather than implementing structured mechanisms and routines. Further, respondents perceive the combination of scarce resources and capabilities doesn't lead to value cogeneration. Sharing of facilities, warehouses,

equipment and tools, of course, occur as a consequence of investments in partnership-exclusive assets. While know-how sharing occurs in the ways previously described.
Hence, *exchange and investment in partnership-exclusive assets* for geographical approximation is found to be the most adopted enabler to gain a competitive advantage against competitors. Italian suppliers often use this tactic when they want to target a particular foreign market and find they have to collaborate with a partner to penetrate the market (e.g. competitor, complementary products' Italian manufacturer, local supplier or agent), which leads to enhancing competitive advantage. There is a tendency to include a percentage of local content in many developing countries, further, suppliers who have local facilities are in an advantaged position in tenders.

Italian suppliers need to carefully weigh opportunities to understand which countries are most beneficial, where contractors can guarantee higher revenues prospects. If a supplier has high sales levels with a contractor or in a specific country, this encourages the adoption of partnership-exclusive assets with local commercial agents or branches; which can even be extended to owning spare parts warehouses and provide prompt assistance and maintenance services. At this point, the wisest move is to co-invest locally together with current local partners (e.g. commercial agents, suppliers) or complementary products' manufacturers, to offer contractors and project owners a wider product portfolio.

Italian suppliers prefer to avoid investments in tangible assets (e.g., equipment and tools), leasing the burden to local partners and only sharing know-how strictly necessary to collaborate. This situation inevitably doesn't enhance the availability of scarce resources or capabilities needed to collaborate in a given project. In particular, Italian suppliers share part of technical know-how (which they are very reluctant to share) to train local employees, while local partners support by sharing their commercial know-how. This, over time, leads to a human asset specificity increase without monetary investments. Usually, however, no routines are defined for knowledge and information sharing that boosts joint-learning. This is because Italian suppliers are reluctant to share their know-how, and try to only share essential layers of information without delving deeper and usually on occasional basis.

There are no particular governance mechanisms that can be used to effectively protect partners against possible opportunistic behaviours. The respondents perceived contracts as less protective to all involved partners, indeed contracts can be formalized fairly, without placing too many constraints on partners. When suppliers decide to collaborate with a partner in Italy, instead, the exchange and investment in partnership-exclusive assets don't appear particularly effective. Co-investment in partnership-specific equipment and tools with suppliers can reduce outsourced processes' costs, but there aren't many examples of co-investments in such physical assets. With some suppliers there is high human asset specificity, which isn't the result of monetary investments, but of a long series of interactions that took place for many years between Italian firms. This led to the development of the precious know-how of Italian manufacturers and firms working closely to them. However, neither in this case there are real structured mechanisms for knowledge and information sharing that boosts joint-learning. Rather, there are several examples of occasional know-how sharing among Italian actors.

Barriers to Competitive Advantage Co-generation in Temporal Contexts
Respondents weren't particularly concerned about barriers like asset interconnectedness or resource indivisibility. Certainly, creating cumulative bundles of joint investment decisions in some countries may be difficult for legal or bureaucratic issues, while sharing resources may result in loss of flexibility due to long-term collaboration; but Italian

suppliers think these are situations still manageable and not really problematic. This also could be because their collaborations are still in its infancy, so they haven't reached critical levels of asset-interconnectedness or resources indivisibility.

As depicted in Figure 2. Partner scarcity has instead turned out being a real barrier. In Italy, apparently there are few possibilities to find new partners, because Italian firms have known each other for decades, relationships are informal and well established, and newcomers are rare or unwelcomed. Abroad, instead, candidate partners abound, but suitable candidates are scarce, for different reasons; i) they offer lower quality products/services, ii) inconsistency of their leadership and business culture, collaboration usually stems from the will of few people in the firm, who, if they trust each other and agree, can lay the foundations for future collaboration development. iii) cultural barriers, as italian suppliers often find it difficult to trust foreign partners, and iv) unwillingness of SME suppliers, especially those who still a family business, as they prefer to remain small and flexible, without ceding part of their decision-making power.

Another great barrier is represented by restrictions imposed by institutional environment. There are legal restrictions mainly linked to the presence of local content requirements and embargoes in some countries, which are induced by political restrictions. There are legal restrictions from competition point of view, not so much because of possible antitrust authorities' interventions, but because of contrast actions that contractors can undertake to punish and hinder horizontal collaboration among the competitors in their supply base. Furthermore, there may be patent issues, or various specific restrictions in different countries.

Figure 1. RV Enablers in Temporal Contexts

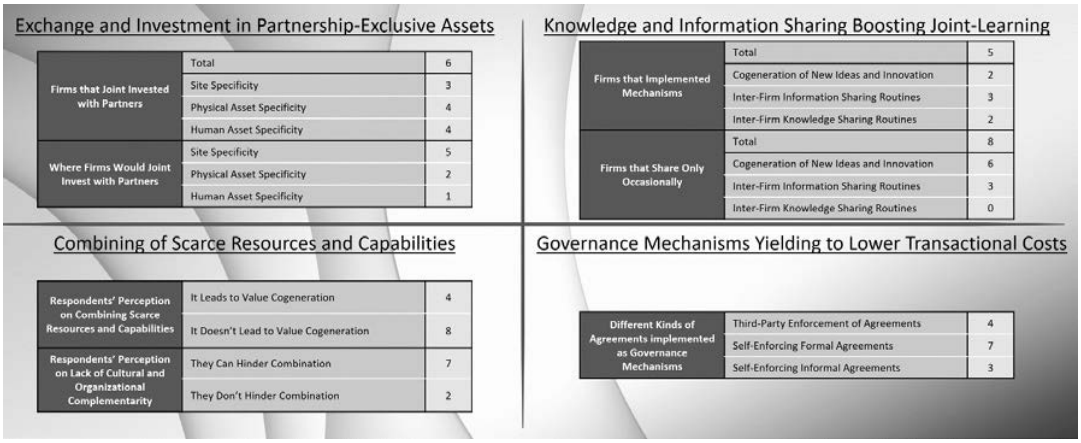
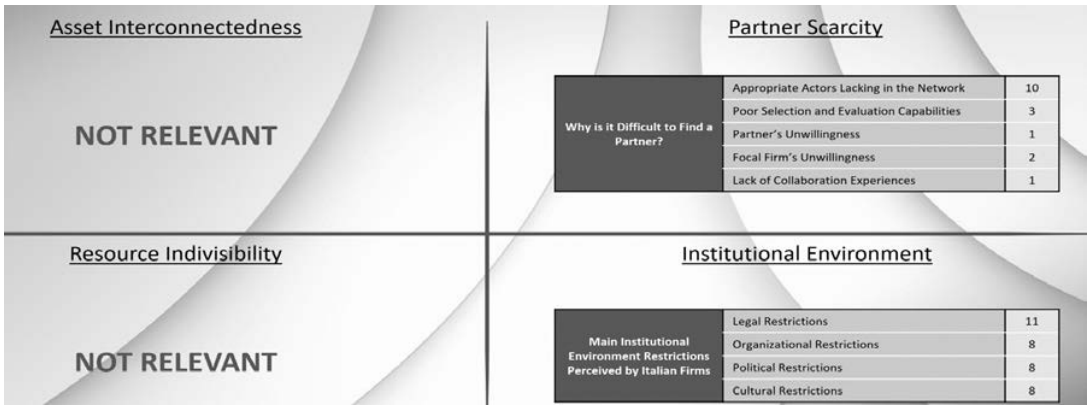


Figure 2. RV Challenges in Temporal Contexts



The Competitiveness of SME Suppliers in Temporal Contexts

Whenever an opportunity arises for cogeneration of innovation, or when there is need to solve any problem to satisfy a customer, Italian suppliers don't hesitate to consult Italian universities or lower-tiers suppliers of materials, components and outsourced processes. These, however, are occasional technical discussions, which do not follow well-defined procedures and are possible only between firms having good relationships for a long time. The real enabler that guarantees shared competitive advantages to these Italian SME suppliers is represented by governance mechanisms managing their relationships. Indeed, the high level of trust, respect and mutual esteem present between many Italian firms, as well as the string of inter-firm relationships that characterized their history, have led to an informal management of relationships between manufacturers and suppliers of different tiers. This constitutes an enormous competitive advantage which, in addition to a transaction costs reduction, allows continuous improvement, albeit marginal, of Italian firms' know-how. Among Italian SME suppliers, however, there are still cultural barriers that must be demolished to collaborate, but there is a noticeable change with new generations of the families are becoming in charge.

Further, there are some organisational challenges, for example it's very challenging for SME suppliers, who have extremely flexible management, to collaborate with multinationals, who can be rigid and bureaucratic. Moreover, there may also be organizational restrictions induced by cultural differences existing between Italian and foreigner firms, precisely at the level of conception of the way of working itself. In a global market, such as the O&G, it is assumed that firms shall deal daily with various political and cultural restrictions. So, no matter how much obstructing these restrictions could be, Italian SME suppliers have learned to develop capabilities to manage them. On the national dimensions, respondents perceive significant cultural restrictions in Italy. These are mainly given by Italian SMEs' strong entrepreneurial spirit. Many Italian SME suppliers still have a family ownership managing the business in more of an 'emotional way', which leads to avoiding collaboration all together. This to avoid sharing their know-how and leaving part of decision-making power they have on their firm. On the contrary, managers usually manage firms in a more detached and impartial way.

Conclusion

Italian SME suppliers for the energy projects suffer market pressures, and have to deal with constraints pertaining to resource availability and their maturing organisational settings. They are exposed to market risks and face difficulties in the qualification process or in appearing on the preferred vendors list.

The present research investigates the appropriateness of applying the relational view in such temporal projects contexts, with a focus on horizontal collaborative activities. The findings reveal that Relational View theory can be applicable in temporal contexts, but within certain limits. Thus we propose extend the applicability of the relational view to temporal environments by considering the context of the business and market environment. The complete lack of collaboration leads to suggest that RV theory becomes less effective as we move away from the ideal context for which it was designed (e.g., long-lasting alliances).

This study makes several contributions to supply chain theory and practice. First, to the authors' knowledge, this is one of the first studies to empirically investigate the appropriateness of the RV theoretical perspective in a temporal supply chain context. Such investigation helps identifying which mechanisms to leverage on, and how to be better prepared to the challenges of supply chain collaboration.

The findings guide supply chain managers on how to exploit the benefits on horizontal collaboration to avoid SME suppliers isolation, and overcome dynamic market challenges. Several topics for future research are identified. One main avenue to consider is a cross-case analysis for supply base of private projects versus those of governmental projects, where the relationship dynamics can significantly vary. Another avenue for future research is to complement this study by analysis through the Resource Based View lens. By doing so, it would be possible to understand if there is a correlation between private resources of partners and their ability to collaborate sharing such resources to co-generate value. As such, it would be possible to identify the most important resources to be owned or researched in partners, to successfully establish collaboration.

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Managing the Operations Interface within Organisations

Negotiations and conflicts in decentralized supply networks

The supply chain through direct trade in agribusiness coffee: a look at the perspective of its agents

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Abstract

The main objective of this study is investigate how the new model of coffee trade, known as Direct Trade Coffee has increased worldwide and how it has changed the supply chain in coffee trade. Through interviews by multiple-case method, the agents of supply chain coffee as producers, roasters and cafeterias demonstrated your perceptions in trade production, distribution and selling specialty coffee. The Transition Cost theory was used to understand how large the asymmetric information, opportunism and limited rationality impacts the supply chain value overall. This study is value to support the understanding of short and more fair coffee negotiate.

Keywords: Supply Chain**;** Direct Trade Coffee; International Trade

Introduction

In an increasingly dynamic and integrated economy, which information is constantly permeability in the agro-industry sectors, the informational symmetry and economic development of both producers and roasters are put in the agenda, requiring a rational and behavioral analysis of their agents. Factors such as negotiation, contracts and mutual relationship between sellers and buyers, begin to reconfigure the coffee production chain, peculiarly the specialty coffees (special or gourmet ones).

This article aims to demonstrate the new trend that has grown worldwide in the supply chain of specialty coffee market known as *Direct Trade*. This new model aims not only to shorten the supply chain's coffee, but also seeks to increase the relationships between the agents since the coffee producer to the final consumer changing, in this way, the traditional supply chain's coffee. Although studies about *Direct Trade* in coffee agribusiness have grown in the last decades, especially in the last few years linked to research on the Third Wave of Coffee, which is focused on specialty coffees, there are still, few studies that try to understand the supply chain of *Direct Trade* at coffee trade as a whole.

Therefore, this article sought to deepen an understanding the impression of this theme through face-to-face interviews with the agents involved in the coffee supply chain as producer and roasters and/or cafeterias in Brazil and abroad. It was evident through this research that Direct Trade is a trend in the specialty coffee market, but its similarity with the principles of coffee certification and requires further studies would be developed to consolidate the shortening of the coffee supply chain and optimize the aggregation of value of all links in the coffee chain.

Literature Review

Theoretical Background

Global coffee consumption has increased considerably in recent years. Brazil is the largest producer of coffee in the world and the second in consumption. A range of coffee varieties arises dynamically, requiring the coffee sector methods and actions aimed not only at increasing production but also at analysing the impacts these increases have on the environment, people and the economy (Silva, 2006).

The coffee certifications as FairTrade, UTZ Certified, RainForest Alliance Certified appear with the objective to certifying producers that, throughout the production, have to fulfil environmental and social standards, characterizing to be a specialty coffee, although this is not an affirmative condition that they will be able to obtain a quality coffee (Pinhero, Nagai, 2014).

On the other hand, the demand for specialty coffees has altered the dynamics of the global market, as buyers are investing directly in coffee growers, taking risk instead of facing future market price volatility. Certified coffees have been a trend in recent decades and the causes of their growth are the benefits that certifications bring. High prices paid to coffee growers, openings to new markets, maximization of production longevity and valorization of labor routines are the "flagship" of Certifications (Guimarães, 2016).

In order to optimize the process between growers and roasters, a new model of coffee bargaining arises, with the objective of paying a "real fair price" to the coffee grower in the acquisition of a higher quality coffee. Direct Trade is a business model that aims at a direct trade relationship between the coffee grower and / or roasters, eliminating the so-called "negotiators", reducing operating costs and retaining the coffee farmer to the buyer (Counterculture Coffee, 2015).

Thus, in the coffee market, paradoxically, there is a great demand for the consumption of specialty coffees, but the supply of quality grains which are produced in a sustainable manner is below the conventional market, despite its consumption of rapid growth, especially in developed countries.

The Waves Coffee

Direct Trade is most faced to specialty(and gourmet) coffees and also, presents in part, as an extension of coffee certification as FairTrade, RainForest and UTZ Certified, etc. but

works in a short supply chain and more direct relationship between agents, as it is concerned with offering superior quality coffees, unique and exclusive, with the characteristic soft drink with high added value, with 'traceability' and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization local infrastructure and the community as a whole, with school construction, support for workers, empowerment of coffee growers, gender equality, among other actions that make up the premises of certifications. To clarify further the results, Borrella, Mataix and Carrasco-Gallego (2015) and Guimarães (2016), explain the Waves Coffee.

The first wave of coffee is attributed to the expressive increase and worldwide dissemination of beverage consumption, especially in the late nineteenth and early twentieth centuries. More specifically in the United States of America, this movement gained momentum with the Great Depression and World War II, requiring minimal time and effort in its preparation. (Reis, 2018; Guimarães, 2016).

The second wave arises when, introducing the new concepts of roasting, in order to reach certain beverage profiles and the consistency of the supply, as well as new notions of origin, recognizing that this, at country level, influenced the quality and some characteristics of the grains (Andrade et al., 2015; Guimarães, 2016).

The third wave appeared in the mid-90s, when only specialty coffees and grains of the Arabica species were used, as well as the vaporization of its numerous aromatic and flavor notes, highly influenced by its origin of production, Thus, coffee goes through a process of total "decommoditization", being considered as a complex, exclusive and seasonal product and compared to other specialty products (Reis, 2018).

The Direct Trade as the State of the Art of Supply Chain Coffee

The traditional Supply Chain Management (SCM) has many agents which are linked each other in the whole chain. Mentzer et al. (2001), infers that SCM can be understand as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" Mentzer et al. (2001).

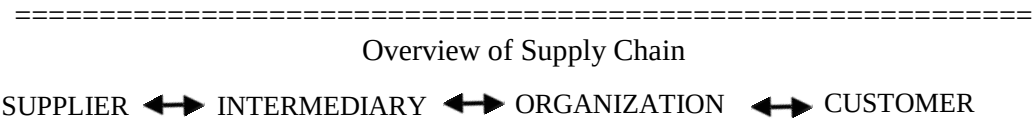

Figure 1 – The Supply Chain – Mentzer et al (2001), adapted.

Below, the figure 1 shows the complexity of SCM as a pipeline, proposed by Mentzer (2001). At this model it is clear that there are innumerable intermediary agents and in the coffee chain it is not different, being these intermediaries: cooperatives, associations, brokers, exporters, roasters and coffee shops.

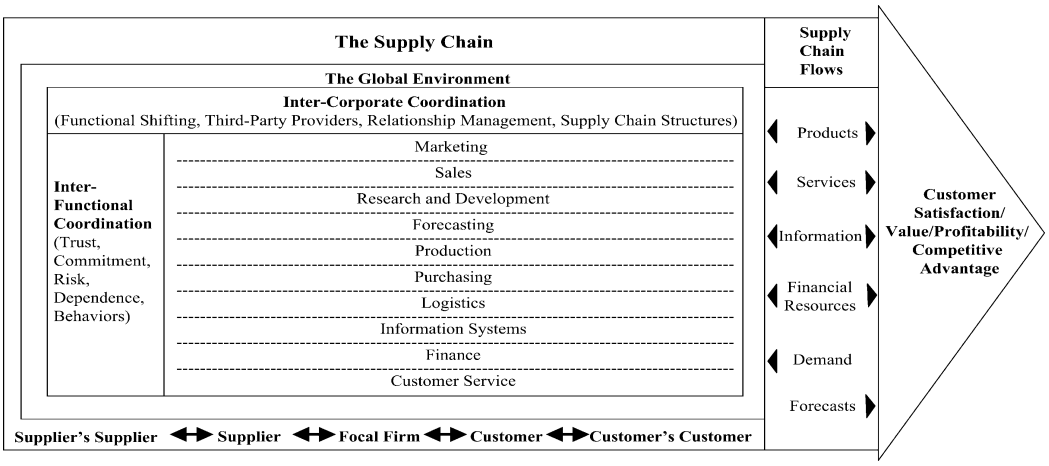

Figure 2 – The traditional Supply Chain Extended – Mentzer et al (2001)

Severins (2015) infers that the traditional supply chain of coffee typically contains seven levels: growing, harvesting, hulling, drying and packing, bulking, blending and roasting. The entire SCM coffee is further extended by several intermediaries, including global transporters as well as exporters and retailers.

The State of the Art of Direct Trade is how the whole chain is shorter and with this, the considerable reduction of costs with the intermediaries along the whole chain, which in turn, allows higher financial gains for the producers and coffee shops. For Badiyan-Eyford (2013), Direct Trade arises because of a strong tendency to offer quality coffees to the market with a close relationship between producers. For this type of trading, there are no pre-designed templates, nor standard terminology.

Direct Trade presents itself as a relationship of stability, trust and equality between the roaster / cafeteria and the producer (Brown, 2012), which is increasingly valued and highlighted in the marketing of the final product. The actors in this chain would thus share their knowledge and work together in a coordinated way in order to optimize the supply chain, increase the quality and supply of specialty grains *or* beans, as well as "empower" coffee growers and, above all, reduce costs along the chain.

Assumptions of Transaction Cost Economics

In order to obtain an analysis of transactions between agents within a business network, or more specifically, in order to develop this research on coffee agribusiness, we have the Transaction Cost Economics. Transaction Cost Economics, also known as ECT, was developed by Ronald Coase in 1937, when it was published in The Nature of the Firm (Langlois, Foss, 1999, Thielmann, 2013).

Silva Filho (2006) highlights the main factors in the transactions: (i) the limited rationality of agents, which prevents them from taking, over time, decisions that maximize well-being; (ii) the opportunistic behavior of the agents, which motivates them to act in order to obtain benefits at the expense of other agents with which they are related; (iii) the asymmetry of information, which implies unequal access of the agents to the information pertinent to the exchange made by them, preventing it from being given in the most advantageous manner from the point of view of society.

Methodology

For this research, it was characterized as qualitative with a descriptive-exploratory character and it was adopted the study of multiple cases, to understand the behaviors of the coffee agents that act in the direct form of commercialization and to explore what the risks and advantages in the relations between the agents (Labuschagne, 2003; Yin, 2014). In this way, an attempt was made to offer a description of the environment in which the agents are inserted and how their behaviors affect the structure of the chain of acquisition of coffee and the relationships with the coffee growers.

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Agents were chosen that act directly in the direct trade of coffee in each chain link. For this, a non-probabilistic sample was used as sampling (Yin, 2001). Sample convenience was used because, for Miles, Huberman and Saldãa (2013), such sampling is only targeted to agents that meet the requirements of the study in question. As this research aims to understand how agents act to reduce costs between buyers and sellers of coffees, known as chain intermediaries, seven agents in total were interviewed.

As it assumes that each agent via Direct Trade has a mutual relationship between each link in the chain, the focus on each was delimited in the search for possible asymmetries of information, opportunism of some agent or limited rationality of one or several agents. If any of these actions prevails between the negotiations, it will modify the structure and dynamics of direct trade, weaken mutual trust between the parties and strengthen opportunism.

Interviews

The interviews were semi-structured and have basic questions that are supported by theories and hypotheses that are interrelated to the research theme (Triviños, 1987, p.146). The interviews took place in Brazil and in the United States, among producers of specialty coffees, roasters and coffee shops.

The choice of the seven interviewees is justified by the following considerations: a) search of the perspectives of the agents participating in the governance structures in the coffee chain; b) the need to understand the practices of international agents; c) to confront or find "gaps" between what is said and practiced among the agents; d) the search for the design of a non-active agent in the direct trade of coffee. These interviews allowed the agents' visions to be intercalated, generating results (or lack thereof) that could respond to the research objective in line with the theory of transaction costs.

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interview script, considering the theoretical propositions of the Transaction Cost Economy and its impacts within the coffee supply chain.

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Findings

This research has revealed a number of important points about the relationships between agents in the supply chain via Direct Trade. Access to information and transparency in negotiations and contracts are vital for reducing information asymmetry and the opportunistic actions of agents outside of Direct Trade.

Another very important point is the need to demystify that Direct Trade is a direct purchase and sale action between producer and cafeteria (or roaster). There will always be an intermediary within the chain, whether it is an exporter for buyers from other countries or an internal transport company sale made within the producing country. Thus, the structure of Direct Trade is lean (figure 3), but does not completely eliminate the intermediates of the chain.

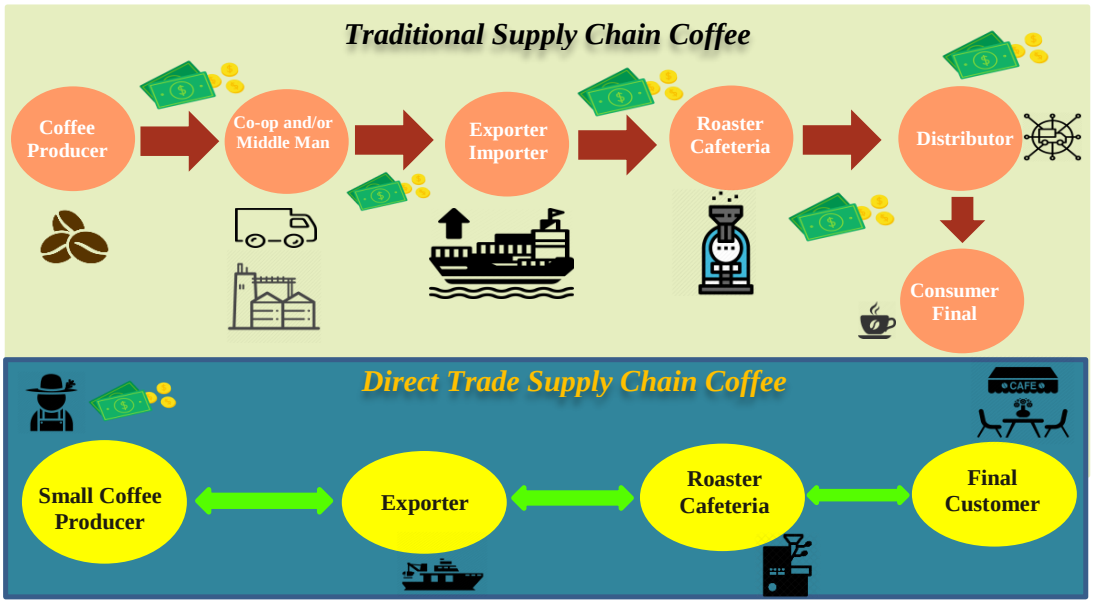

Figure 3 – Traditional versus Direct Trade Coffee Supply Chain - By Authors

The Institutional Environment, of the transactions and the behaviors of the agents
It was observed that the transactions between the agents are not clear when asked about the expectations advocated by agents. While coffee shops have argued that coffee growers receive direct attention from their sponsors, such as trainings, support and / or technical visits on their farms, whether semi-annually or annually, coffee growers, in turn, have explained that obtaining the quality of their coffees is an action derived from its own dedications and the correct management of the coffee, without, necessarily, the intervention of some agent of the roaster or cafeteria.

Limited Rationale
It was observed that all Direct Trade agents interviewed are intended to be rational about their assignments within the specialty coffee chain; but it was noted that this rationality is achieved in a non-integral way, that is, it proves to be a limited rationality, which for Williamson (1989), such rationality is an intrinsic behavior to agents. The rationality of the interviewee P2 demonstrates the limitation on the possibilities or perspectives proposed by the Interviewee T1. Although they seem simplistic perspectives on the same theme, they generate asymmetries of information in the structure of governance and loopholes so that opportunism arises and modifies the entire organizational environment.

Opportunism
It can be explained that the main opportunistic behaviors reported among coffee growers were: restriction of information, concentration of access to new markets (for coffee resale); high rates of logistic payment for the outflow of production (paid more, besides the necessary, for not having competition) and mystification of the export processes.

Asymmetry of Information
It was unanimous among the interviewees P1, P2, P3 and P4 that they were unaware of the practices adopted by the roasters or coffee shops, regarding technical visits and support in the production processes of the specialty coffees to be sold to them. This is due to the fact that, while roasters and international coffee shops are proposing to offer support (in different ways) to their peers, one can see how many coffee growers do not even know of the possibility of winning an extra prize in their coffees and, above all, increase the networks of transactions between people who offer assistance to the coffee management and the more widespread, increase the transactions with the agents of the post-harvest, which, in turn, increase the risks of opportunism in the relations.

Discussion

This research has brought significant contributions regarding the direct trade model of the direct trade model, which, in the coffee agribusiness, focused almost exclusively on the commercialization of specialty coffees, is still incipient its performance in the traditional market (commodity) or certified coffee, but in turn have shown an exponential growth in the last decades, requiring special attention to their growth.

Thus, this research identified by the theory of Transaction Cost Economics (ECT) the existing gaps, in this almost unprecedented chain of direct coffee trade, in whose organizational environment the coffee grower and roaster, because they are distinct, either in the rational model, in the geographic environment, lead to a discrepant informational asymmetry between these agents, making it clear that, while coffee shops focus on the quality of their coffees sold, coffee growers do not demonstrate knowledge about the various 'resources' made available by roasters in this segment.

The small coffee growers producing specialty coffees do not have certain information that would generate market advantages, since their rationalities are directed to the traditional coffee marketing model: 1) it produces; 2) benefits; 3) stock; 4) seeks buyers in the coffee market or sell to cooperatives; 5) sell coffee; 6) It pays the bills and what about is profit. This attitude offers the possibility of intermediaries accessing the chain and reselling specialty coffees to specific markets with a higher premium, but that is not (re) passed to the coffee grower, maintaining the same chain structure.

As for the increase in sales in the international market, it should be pointed out that in view of the difficulties reported by coffee growers in reaching the external market by themselves, as a small-medium producer, it is believed that in the domestic market, it is easier to negotiate prices, , etc., for two reasons: (1) the ease of language (communication); (2) the growing public interest in higher quality coffees (or better sensitization). The rationale for coffee export processes, as previously reported, corroborated (or corroborated), to a certain extent, the growth of the domestic market in the consumption of specialty coffees.

Conclusions

Although studies on Direct Trade in coffee agribusiness have grown in recent decades, especially in the last few years linked to research on the Third Wave, which is focused on specialty coffees, there are few studies that seek to understand this chain of direct trade as a whole.

In this way, it is possible to infer, albeit prematurely, that Direct Trade is an extension of certification, concerned with offering superior, unique and exclusive quality coffees with the characteristic soft drink with high added value, traceability and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization of local infrastructure and the community as a whole, building schools, support workers, empowering coffee farmers, equality between genders, among other.

In this way, this work can be glimpsed by the theory of the Economy of the Costs of Transaction in which Direct Trade allows a structure of governance leaner than the traditional coffee agribusiness chain; reduces opportunistic actions when the information asymmetry is small, that is, when there is an efficient bilateral relationship and broadening the rationality of the agents regarding the possibilities of gains among the agents.

Acknowledgments

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Next generation operations

The supply chain through direct trade in agribusiness coffee: a look at the perspective of its agents

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Abstract

The main objective of this study is investigate how the new model of coffee trade, known as Direct Trade Coffee has increased worldwide and how it has changed the supply chain in coffee trade. Through interviews by multiple-case method, the agents of supply chain coffee as producers, roasters and cafeterias demonstrated your perceptions in trade production, distribution and selling specialty coffee. The Transition Cost theory was used to understand how large the asymmetric information, opportunism and limited rationality impacts the supply chain value overall. This study is value to support the understanding of short and more fair coffee negotiate.

Keywords: Supply Chain**;** Direct Trade Coffee; International Trade

Introduction

In an increasingly dynamic and integrated economy, which information is constantly permeability in the agro-industry sectors, the informational symmetry and economic development of both producers and roasters are put in the agenda, requiring a rational and behavioral analysis of their agents. Factors such as negotiation, contracts and mutual relationship between sellers and buyers, begin to reconfigure the coffee production chain, peculiarly the specialty coffees (special or gourmet ones).

This article aims to demonstrate the new trend that has grown worldwide in the supply chain of specialty coffee market known as *Direct Trade*. This new model aims not only to shorten the supply chain's coffee, but also seeks to increase the relationships between the agents since the coffee producer to the final consumer changing, in this way, the traditional supply chain's coffee. Although studies about *Direct Trade* in coffee agribusiness have grown in the last decades, especially in the last few years linked to research on the Third Wave of Coffee, which is focused on specialty coffees, there are still, few studies that try to understand the supply chain of *Direct Trade* at coffee trade as a whole.

Therefore, this article sought to deepen an understanding the impression of this theme through face-to-face interviews with the agents involved in the coffee supply chain as producer and roasters and/or cafeterias in Brazil and abroad. It was evident through this research that Direct Trade is a trend in the specialty coffee market, but its similarity with the principles of coffee certification and requires further studies would be developed to consolidate the shortening of the coffee supply chain and optimize the aggregation of value of all links in the coffee chain.

Literature Review

Theoretical Background

Global coffee consumption has increased considerably in recent years. Brazil is the largest producer of coffee in the world and the second in consumption. A range of coffee varieties arises dynamically, requiring the coffee sector methods and actions aimed not only at increasing production but also at analysing the impacts these increases have on the environment, people and the economy (Silva, 2006).

The coffee certifications as FairTrade, UTZ Certified, RainForest Alliance Certified appear with the objective to certifying producers that, throughout the production, have to fulfil environmental and social standards, characterizing to be a specialty coffee, although this is not an affirmative condition that they will be able to obtain a quality coffee (Pinhero, Nagai, 2014).

On the other hand, the demand for specialty coffees has altered the dynamics of the global market, as buyers are investing directly in coffee growers, taking risk instead of facing future market price volatility. Certified coffees have been a trend in recent decades and the causes of their growth are the benefits that certifications bring. High prices paid to coffee growers, openings to new markets, maximization of production longevity and valorization of labor routines are the "flagship" of Certifications (Guimarães, 2016).

In order to optimize the process between growers and roasters, a new model of coffee bargaining arises, with the objective of paying a "real fair price" to the coffee grower in the acquisition of a higher quality coffee. Direct Trade is a business model that aims at a direct trade relationship between the coffee grower and / or roasters, eliminating the so-called "negotiators", reducing operating costs and retaining the coffee farmer to the buyer (Counterculture Coffee, 2015).

Thus, in the coffee market, paradoxically, there is a great demand for the consumption of specialty coffees, but the supply of quality grains which are produced in a sustainable manner is below the conventional market, despite its consumption of rapid growth, especially in developed countries.

The Waves Coffee

Direct Trade is most faced to specialty(and gourmet) coffees and also, presents in part, as an extension of coffee certification as FairTrade, RainForest and UTZ Certified, etc. but

works in a short supply chain and more direct relationship between agents, as it is concerned with offering superior quality coffees, unique and exclusive, with the characteristic soft drink with high added value, with 'traceability' and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization local infrastructure and the community as a whole, with school construction, support for workers, empowerment of coffee growers, gender equality, among other actions that make up the premises of certifications. To clarify further the results, Borrella, Mataix and Carrasco-Gallego (2015) and Guimarães (2016), explain the Waves Coffee.

The first wave of coffee is attributed to the expressive increase and worldwide dissemination of beverage consumption, especially in the late nineteenth and early twentieth centuries. More specifically in the United States of America, this movement gained momentum with the Great Depression and World War II, requiring minimal time and effort in its preparation. (Reis, 2018; Guimarães, 2016).

The second wave arises when, introducing the new concepts of roasting, in order to reach certain beverage profiles and the consistency of the supply, as well as new notions of origin, recognizing that this, at country level, influenced the quality and some characteristics of the grains (Andrade et al., 2015; Guimarães, 2016).

The third wave appeared in the mid-90s, when only specialty coffees and grains of the Arabica species were used, as well as the vaporization of its numerous aromatic and flavor notes, highly influenced by its origin of production, Thus, coffee goes through a process of total "decommoditization", being considered as a complex, exclusive and seasonal product and compared to other specialty products (Reis, 2018).

The Direct Trade as the State of the Art of Supply Chain Coffee

The traditional Supply Chain Management (SCM) has many agents which are linked each other in the whole chain. Mentzer et al. (2001), infers that SCM can be understand as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" Mentzer et al. (2001).

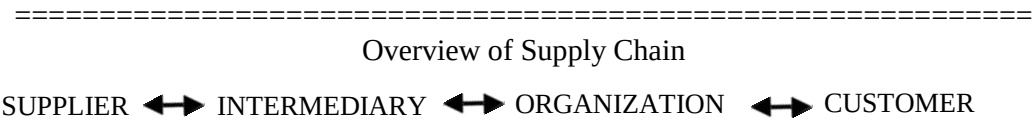

Figure 1 – The Supply Chain – Mentzer et al (2001), adapted.

Below, the figure 1 shows the complexity of SCM as a pipeline, proposed by Mentzer (2001). At this model it is clear that there are innumerable intermediary agents and in the coffee chain it is not different, being these intermediaries: cooperatives, associations, brokers, exporters, roasters and coffee shops.

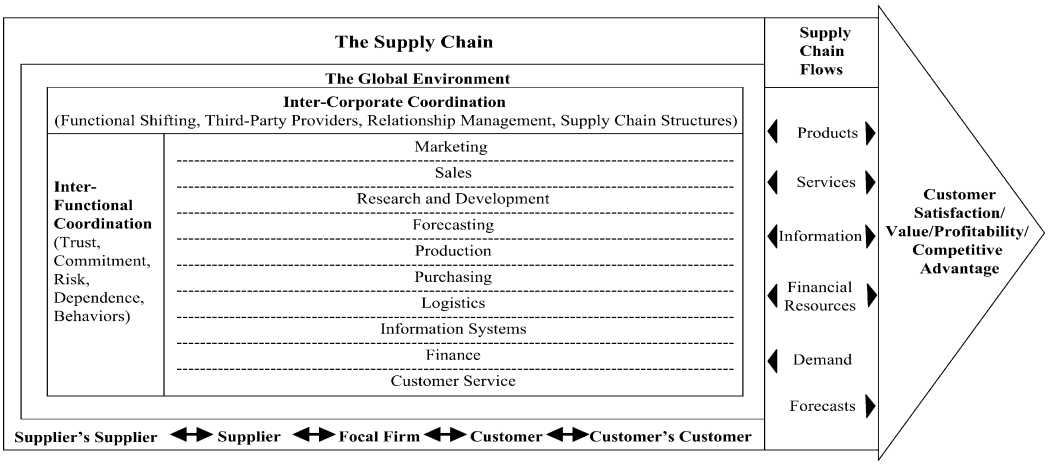

Figure 2 – The traditional Supply Chain Extended – Mentzer et al (2001)

Severins (2015) infers that the traditional supply chain of coffee typically contains seven levels: growing, harvesting, hulling, drying and packing, bulking, blending and roasting. The entire SCM coffee is further extended by several intermediaries, including global transporters as well as exporters and retailers.

The State of the Art of Direct Trade is how the whole chain is shorter and with this, the considerable reduction of costs with the intermediaries along the whole chain, which in turn, allows higher financial gains for the producers and coffee shops. For Badiyan-Eyford (2013), Direct Trade arises because of a strong tendency to offer quality coffees to the market with a close relationship between producers. For this type of trading, there are no pre-designed templates, nor standard terminology.

Direct Trade presents itself as a relationship of stability, trust and equality between the roaster / cafeteria and the producer (Brown, 2012), which is increasingly valued and highlighted in the marketing of the final product. The actors in this chain would thus share their knowledge and work together in a coordinated way in order to optimize the supply chain, increase the quality and supply of specialty grains *or* beans, as well as "empower" coffee growers and, above all, reduce costs along the chain.

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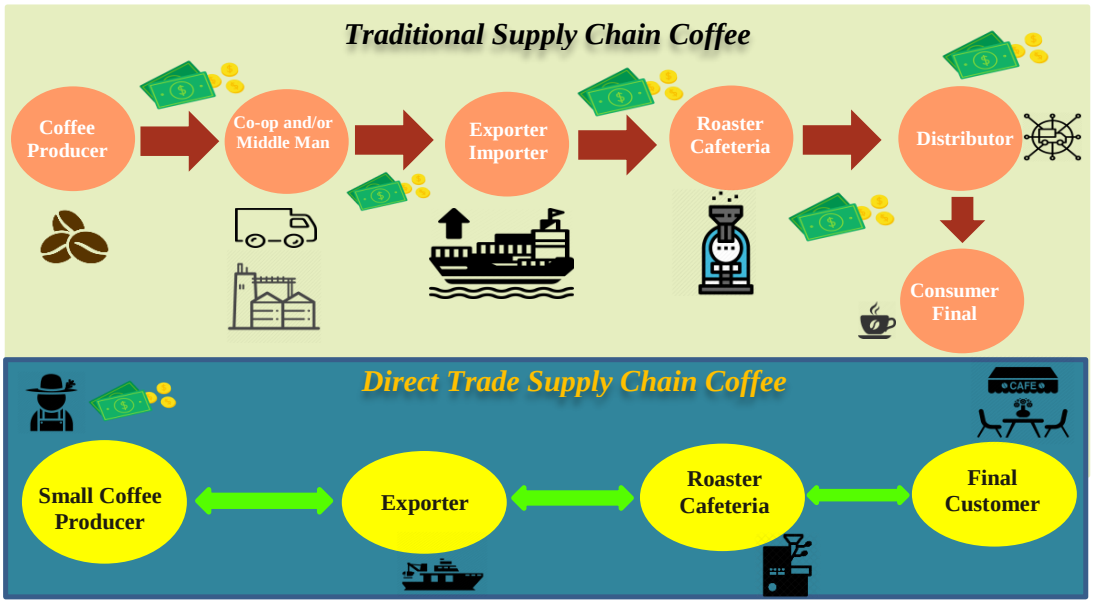

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It can be explained that the main opportunistic behaviors reported among coffee growers were: restriction of information, concentration of access to new markets (for coffee resale); high rates of logistic payment for the outflow of production (paid more, besides the necessary, for not having competition) and mystification of the export processes.

Asymmetry of Information
It was unanimous among the interviewees P1, P2, P3 and P4 that they were unaware of the practices adopted by the roasters or coffee shops, regarding technical visits and support in the production processes of the specialty coffees to be sold to them. This is due to the fact that, while roasters and international coffee shops are proposing to offer support (in different ways) to their peers, one can see how many coffee growers do not even know of the possibility of winning an extra prize in their coffees and, above all, increase the networks of transactions between people who offer assistance to the coffee management and the more widespread, increase the transactions with the agents of the post-harvest, which, in turn, increase the risks of opportunism in the relations.

Discussion

This research has brought significant contributions regarding the direct trade model of the direct trade model, which, in the coffee agribusiness, focused almost exclusively on the commercialization of specialty coffees, is still incipient its performance in the traditional market (commodity) or certified coffee, but in turn have shown an exponential growth in the last decades, requiring special attention to their growth.

Thus, this research identified by the theory of Transaction Cost Economics (ECT) the existing gaps, in this almost unprecedented chain of direct coffee trade, in whose organizational environment the coffee grower and roaster, because they are distinct, either in the rational model, in the geographic environment, lead to a discrepant informational asymmetry between these agents, making it clear that, while coffee shops focus on the quality of their coffees sold, coffee growers do not demonstrate knowledge about the various 'resources' made available by roasters in this segment.

The small coffee growers producing specialty coffees do not have certain information that would generate market advantages, since their rationalities are directed to the traditional coffee marketing model: 1) it produces; 2) benefits; 3) stock; 4) seeks buyers in the coffee market or sell to cooperatives; 5) sell coffee; 6) It pays the bills and what about is profit. This attitude offers the possibility of intermediaries accessing the chain and reselling specialty coffees to specific markets with a higher premium, but that is not (re) passed to the coffee grower, maintaining the same chain structure.

As for the increase in sales in the international market, it should be pointed out that in view of the difficulties reported by coffee growers in reaching the external market by themselves, as a small-medium producer, it is believed that in the domestic market, it is easier to negotiate prices, , etc., for two reasons: (1) the ease of language (communication); (2) the growing public interest in higher quality coffees (or better sensitization). The rationale for coffee export processes, as previously reported, corroborated (or corroborated), to a certain extent, the growth of the domestic market in the consumption of specialty coffees.

Conclusions

Although studies on Direct Trade in coffee agribusiness have grown in recent decades, especially in the last few years linked to research on the Third Wave, which is focused on specialty coffees, there are few studies that seek to understand this chain of direct trade as a whole.

In this way, it is possible to infer, albeit prematurely, that Direct Trade is an extension of certification, concerned with offering superior, unique and exclusive quality coffees with the characteristic soft drink with high added value, traceability and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization of local infrastructure and the community as a whole, building schools, support workers, empowering coffee farmers, equality between genders, among other.

In this way, this work can be glimpsed by the theory of the Economy of the Costs of Transaction in which Direct Trade allows a structure of governance leaner than the traditional coffee agribusiness chain; reduces opportunistic actions when the information asymmetry is small, that is, when there is an efficient bilateral relationship and broadening the rationality of the agents regarding the possibilities of gains among the agents.

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Developing IoT projects in manufacturing

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Abstract

This paper exploits secondary data provided by a large database of IoT projects and applies hierarchical cluster analysis to classify projects into homogenous groups by technological novelty, complexity of competences, functional areas of applications, expected impacts and realized benefits, and firm size. The clusters allowed identifying different "developmental stages" firms go through in building their competences in IoT.

Keywords: Internet of Things, Innovation, Digitalization

Introduction

The Internet of Things (IoT) is one of the pillars of the Industry 4.0 (I4.0) paradigm. IoT envisages a network of machines and devices connected and interacting with each other. Within firms, connectivity can greatly improve specific value chain activities ranging from inventory systems, to production, and customer support systems. In addition, some applications are overturning the way in which business is conducted (Rymaszewska et al., 2017). Although the literature on IoT is blooming, most contributions in the area of OM focus on defining and explaining technologies belonging to the IoT family, on identifying areas of applications within the firm and the supply chain (Lee and Lee, 2015), and on understanding risks and challenges (Birkel, et al., 2019; Kamble et al., 2018).

Little empirical evidence exists about the characteristics of IoT projects currently adopted by firms, in terms of novelty and complexity (Henderson and Clark, 1990). This analysis may not only provide a description of what firms are currently doing in terms of IoT but they may also throw light on the dynamic capabilities (Teece et al., 1997) required to develop and implement IoT projects.

To address these issues, this research exploits the information provided by an extensive database of IoT business cases, and applies cluster analysis to identify homogenous groups of projects, in terms of technological complexity, novelty, and functional areas of applications.

IoT literature background

The term "Internet of Things" (IoT) came into existence for the first time to represent the globally emerging Internet-based information service architecture (Ashton, 2009). Weber (2009) defined IoT as "an emerging global, Internet-based information service architecture facilitating the exchange of goods in global supply chain networks".

IoT technologies include network, software and algorithms, hardware, and data processing (Wu et al., 2016). The network is the backbone of the IoT, as it refers to uniquely identifiable objects (things) and their virtual representations in an Internet-like structure. Objects rely on software to communicate effectively with each other and to deliver enhanced functionality and connectivity. Hardware is driven by the customised IoT devices, which generate enormous quantities of data that need to be aggregated and analyzed in real time to provide information regarding status, location, functionality, and environment of the devices. The optimization of data processing is critical to timely processing of the continuous stream of massive amounts of data. In recent years, research has followed the state of the art of IoT solutions in order to facilitate their definition and identify future trajectories (Da Xu et al., 2014).

Lu et al. (2018) provide a systematic review of the business literature on IoT, from the user and organizational perspectives, while Mishra et al. (2016) performed a bibliometric analysis to identify the research networks and the main contributors from an academic point of view. Ben-Daya et al. (2017) explore the role of IoT and its impact on supply chain management through an extensive literature review, finding that most studies have focused on conceptualizing the impact of IoT with limited analytical models and empirical studies.

Incorporating new technologies into existent business environments, structures, and models has always been a challenge. This also remains the case when the IoT is implemented (Pfisterer et al., 2016). However, while there are fine-grained analyses of IoT technical aspects (Whitmore et al., 2015), there is still a paucity of studies on IoT adoption in different businesses and on its impact (Haddud et al., 2017).) Despite the importance for social and economic growth, the development of IoT technologies has not yet received a thoughtful examination from a managerial perspective (Ardito et al., 2018).

Research strategy

In order to identify the main types of IoT projects, we exploit secondary data obtained from an extensive publicly available database (IoT ONE, https://www.iotone.com) that contains over 1000 cases of organizations in a variety of industries that have adopted IoT technologies all over the world. The database provides information on technological maturity of the project (mature technology, emerging, cutting-edge), required capabilities in hardware and software (measured on a 1-5 scale), areas of impact within the firm, key types of expected impacts and realized benefits, and a description of the IoT solution adopted. In addition, the research team collected information on the adopting firm's industry and size. Finally, scope of project, whether narrow (i.e. affecting less than three functional areas) or broad, was assessed through the reading of the case.

The dataset was consulted in May 2018 and cases for this study were selected on the base of the possession of all the information listed above. The final number of projects included in this study was 583.

The first step for the analysis of the case studies required to extrapolate the main information and transform it in numerical values. In particular, since information on the project expected impacts and realized benefits was in narrative form, its transformation to allow a quantitative analysis required coding. This was done through Nvivo 11.0. Initial analysis consisted in creating nodes for Nvivo corresponding to aggregations of keywords

used to identify impacts and benefits. Nodes were then further aggregated using exploratory factor analysis. Appropriate steps for exploratory factor analysis were followed (Hinkin, 1998). First, principal component analysis was used to extract factors, and Kaiser criterion was applied to select factors with eigenvalues above one. Nine factors satisfying this condition were identified for expected impacts, explaining 60% of variance, a percentage considered acceptable (Hinkin, 1998). Seven factors were identified for realized benefits, explaining 56% of variance. Next, varimax rotation was applied to the data. Nearly all items exhibited loadings above 0.6 and all clearly mapped onto one factor. Uniqueness in the final solution was also calculated, with the aim to assess the proportion of factor variance explained by each item

Hierarchical cluster analysis using Ward method was applied to identify groups of homogeneous projects by functional area of impact within the firm, project scope (narrow vs. broad), novelty of the technology (measured by three degrees of technological maturity), hardware and software capabilities required, expected impacts and realized benefits. Firm size and industry were also added to the clustering variables. The results of the cluster analysis suggest that a five-cluster solution best fits the data. This conclusion was reached by checking dendrograms that show distance between different cluster solutions and by examining changes in the squared Euclidean distance. The significance of inter-cluster differences along the various variables and dimensions included in the cluster analysis was tested through the "test value" criterion (Lebart, 2000).

Results

Table 1 below summarises the key characteristics of the five clusters. Frequency for the characteristics that are statistically more frequent in the cluster than in the sample overall are shown, whereas the other characteristics of the cluster are shown in italics if they are not statistically more frequent than in the other clusters. The table provides insights on the size of the companies involved in the projects assigned to each cluster, on the degree of novelty of the technologies used, and on the complexity in terms of hardware and software capabilities required. With respect to project scope, four clusters out of five include predominantly narrow scope projects, while broad scope projects are grouped in Cluster 4. SMEs tend to implement narrow scope projects either using mature technologies (Cluster 1) or emerging ones (Cluster 3). As for expected impacts, improving efficiency through data collection and management seems to be the most common goal (Cluster 2, 4, 5), while the need to monitor and control systems appears to characterise Cluster 1 and 3.

Figure 1 positions the clusters in terms of degree of novelty of the technology used in the IoT project (X axis) and of the level of capabilities the project required for Hardware and Software, used as a proxy of the project complexity (Y axix). The figure also shows the scope of the project using the colour code (green = broad scope). Some specific observations emerge. First, Cluster 1 is the sole cluster with low degrees of both complexity and novelty. This finding positions the typical Cluster 1 project as an easy "entry" project that can be handled by any company without encountering significant challenges. Not surprisingly, this is the most frequently encountered type of project. Next, Cluster 4 is the sole cluster in which projects have a broad scope and exhibits relatively higher software and hardware capabilities with respect to the overall sample of projects. This characteristic positions Cluster 4 as a cluster of strategic projects that build on a mixture of mature-emerging-cutting-edge technologies to transform a firm and its operations. Cluster 5 groups projects with the highest degree of ambition in terms of technology innovation. Emerging and cutting edge technologies are applied to narrow

Table 1 – IoT project clusters

Cluster Description	Firm's Size	Technological Maturity	Expected impacts	Specific realized benefits	Functional areas	Scope of project	Industry	Competence levels in SW/ HW	Cluster size
C1. Narrow scope projects using mature technologies to optimise time, low intensity of investment	SME (58%)	Mature (69%)	*Safety&Security Compliance (26%), System Control (39%)*	Growth (6%)	Environmental Health and Safety (23%), Warehouse Management (7%), *Logistics (15%), Quality Assurance (9%)*	Narrow (86%)	Aerospace (6%), Construction (5%), Healtcare Services (6%)	Hardware (1.89), *Software (2.19)*	177
C2. Narrow scope projects using mature software technologies for data management	Large (98%)	Mature (82%)	Quality (19%), Efficiency through data management (59%), *Improved resource utilization (14%)*	Operational efficiency (47%)	Information Technology (44%), Maintenance (57%)	Narrow (82%)	Automotive (15%)	*Hardware (1.48)*, Software (3.52)	124
C3. Narrow scope projects with emerging technologies	SME (44%)	Emerging (84%)	System control (49%)	*Security and network integration (45%)*	Facility Maintenance (20%)	Narrow (92%)		*Hardware (1.22)*, Software (3.58)	101
C4. Broad scope projects aimed at tehnological advancement	*Large (63%)*	*Mature (43%), Emerging (39%), Cutting Edge (19%)*	Efficiency through data management (59%)		Field Services (23%), Maintenance (68%), Production - manufacturing (40%), Logistics (27%), Information Technology (56%), Procurement & sourcing (5%), *Product Development (25%)*, Sales & Marketing (10%)	Broad (98%)	Paper & Pulp (4%)	Hardware (1.91), Software (3.31)	101
C5. Cutting edge technologies	Large (96%)	*Mature (1%),* Emerging (68%), Cutting Edge (31%)	Efficiency through data management (64%)			Narrow (100%)	Retail (4%), Furniture& HomeAppliances (7%)	Hardware (2.12), *Software (2.93)*	80

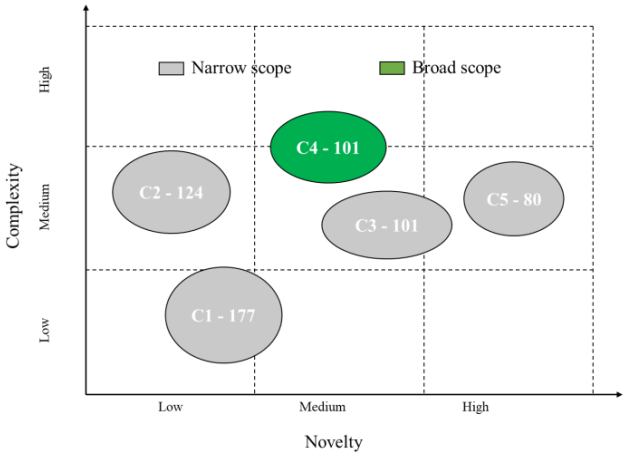

Figure 1 - Positioning of the IoT Project Clusters in a Complexity/Novelty Matrix

scope projects which require relatively more advanced hardware capabilities. These characteristics suggest Cluster 5 include projects undertaken by companies that use IoT strategically and experiment with new solutions. Finally, Cluster 2 and Cluster 3 appear to encompass more software intensive projects with diverse degree of technology novelty (mature for Cluster 2 and emerging for Cluster 3).

Analysis of selected case studies

In the second stage of the analysis, a few case studies in the IoT database were selected and analysed in greater depth. The selection criterion was the following: for each cluster, cases were searched that exhibited the highest number of characteristics distinctive of the cluster. Among cases selected, preference was then given to those for which supplementary information from press sources or company's reports was available. Three cases were selected for each cluster. Combining the results of cluster analysis with an in-depth reading of individual case studies allows arriving at a more articulate description of the five clusters that includes information not only on the structural characteristics of the IoT projects (maturity, complexity, scope) but also on the specific technologies used and capabilities deployed.

Cluster 1: IoT beginners

This cluster includes organisations, most of which SMEs, which used IoT to monitor a single critical asset. Technologies used in such projects are mature, their prices have gone down over the years and their performance is reliable. They allow monitoring specific assets in order to eliminate very specific risks and issues that can have significant impact for the firms. This cluster includes many projects that tackle security, quality, health and safety matters. Such projects require limited investment, while offering significant and immediate benefits. Common expected impacts were compliance with safety and security regulations and achieving better control of the specific object/asset. In terms of capabilities, this kind of projects requires slightly higher than average hardware competences, given that the project often involves the installation of monitoring devices. On the other hand, software capabilities required are low, as the company performs very elementary data analysis tasks at this stage. These projects are easy to implement and help to demystify the technology, thus providing an entry experience to IoT.

Cluster 2: Using data management to enhance access to information

In this cluster, we have large organisations that used mature data management technologies to enable, simplify and accelerate access to information. Such projects

aggregate data from multiple sources, radically simplify the access to large amount of information and allow to produce valuable reports that support decision making. The most immediate benefit of such projects is to establish a rapid and user-friendly access to all relevant information. Consistently, the expected impact of many of these projects was to exploit data collection and management to improve operational efficiency, a benefit that accrues to 47% of the projects in this cluster. In terms of capabilities, a significant leap in software capabilities is required, since the firm has to make itself acquainted with real time data analysis tools. In turn, the firm has to develop capabilities for turning real-time information into fast decisions. These projects are still narrow scope and frequently introduce smart maintenance.

Cluster 3: Using emerging software technologies to control operations

In this cluster, we have both SMEs and large organisations that used emerging software technologies to control and manage their operations. Industrial operations generate data which is injected in the software developed as part of such project. This is used to regulate and support operations. As the applications are very specific to the activities of the organisation, emerging technology is used. When applied to a technically complex production process, such projects require an advanced understanding of what happens at physical level in order to use data effectively. Therefore, companies who design the machines and equipment are best placed to support their client on such projects.

Cluster 4: Using IoT to bring the power of software to new fields of activity

This cluster includes predominantly large organisations that deploy IoT to bring the power of software to new fields of activities. Example of industries impacted by such projects include agriculture, energy distribution, or public transportation. Such fields are characterised by dispersed and sometime mobile assets that were not previously connected to an information system. These projects bring the power of data management and software technology to the clients of the firm that undertake them. They are complex, broad scope projects that offer a wide range of functionalities and significant benefits for the firm implementing them. Some of them can be considered radical innovations. Such projects can lead to the development of new competitive advantages, but they require significant strategic support and development. The cases fully illustrate the scale of the projects implemented. They connect a broad number of assets using a mixture of newer and mature hardware technologies, and they leverage the data collected through the development of specific software applications. Even if some of the technologies are well established and therefore affordable, such projects require significant investment due to their scale. Such projects are often undertaken progressively. They can be divided in sub-projects that can build on each other over time. While some benefits can accrue right from the earlier investment, a critical mass of assets and data sources needs to be connected in order to realise the full benefits of such projects. This nevertheless requires a broad vision on the full programme, as specific investments might not be justified if they are undertaken independently of the whole programme.

Cluster 5: Leveraging on new generation technology

In this cluster, large organisations take advantage of emerging and cutting-edge technologies in software intensive fields of activities. These projects typically focus on a critical sub-system, but they often enhance the performance of the broader system. This cluster contains strategic projects for the firms that have undertaken them, leading to significant benefits. Firms with significant prior experience in electronics and software undertook most of the projects in this cluster. Combining different technology and different sources of data into one technical system can require working on the projects with suppliers who have very different knowledge base and culture. This is something that needs to be managed adequately to reach success.

Discussion

The cluster analysis has allowed identifying five main types of IoT projects, differing by scope, novelty, technological capabilities required, operational impacts and firm characteristics. In addition, looking at specific case studies has allowed shedding light on the possible relations among the different clusters and on the importance of integration and network capabilities for the successful implementation of the more challenging projects. In what follows, we elaborate on these two aspects with the aim to suggest future directions for operations and business research on IoT.

Concerning the relation among different project types, clusters suggest a possible path of development that links firms' capabilities with types of projects undertaken and impacts sought (Utterback and Abernathy, 1975). The clusters also suggest a trajectory (Patel and Pavitt, 1997) whereby firms start with Cluster 1 type of projects. Such projects can be performed with a limited investment and offer an immediate and high return. Then, as more objects are connected, Cluster 2 or Cluster 3 projects can be implemented to generate data driven efficiency improvements. These projects allow collecting and aggregating a large amount of data across similar or interconnected assets and produce timely data visualisation and reports. In some circumstances, achieving higher levels of performance requires the integration of multiple novel technologies together (Cluster 3). Here, the higher degree of technological novelty requires not only to invent new components but also to explore what type of architectures allow achieving the desired performance and handling key constraints. Finally, Cluster 5 projects allow generating higher order benefits for firms with ample experience in digital technologies, who transfer some of these benefits to customers by harnessing the power of the most advanced technologies (e.g. the vehicle manufacturer infotainment project).

The sequence of cluster 1-2-3-5 projects lends itself to be interpreted as a cumulative innovation process, offering non-linear levels of performance while firms progress towards more novel and more complex technological capabilities. This development path appears to suit also SMEs, for which cluster 1 and 3 are characteristic. A SME can gain new competitive advantages from Cluster 3 projects, as the case of the bottling company illustrates. Figure 2 illustrates this cumulative innovation process.

On the other hand, Cluster 4 suggests the co-existence of an alternative trajectory whereby firms can "leapfrog" to more novel technologies and more complex capabilities (Lee and Lim, 2001), and use them in large-scale projects. This seems to be true especially for industries that have not been software-intensive in the past. In our case examples, innovative development and benefits accrued to firms whose activities were characterised by dispersed and mobile assets (e.g. the agricultural project). Connecting these assets to a single data management system was, in the past, either unreliable, too expensive or technically challenging. However, such developments require a business vision and a clear system architecture to anticipate key implementation steps. Understanding the broader system, its goals and architecture is essential to take the right decisions related to technology adoption, timing of different sub-project, feasibility and management of changes.

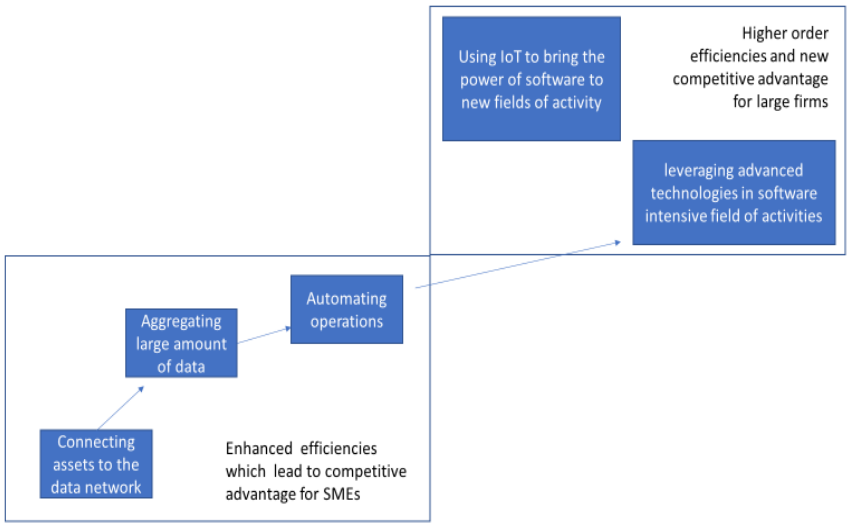

Figure 2: Development path envisaged by the cluster description

Our results also suggest that more "developed" stages of IoT implementation, characterised by more novel technologies and/or more complex technical capabilities, may only be achieved by firms that possess "second order" or dynamic capabilities (DCs) (Teece et al., 1997). These DCs allow to constantly re-assess, re-deploy and re-configure resources as is required in periods in which the industry business model and/or the dominant technological paradigm is being overturned. In an area close to IoT, Wamba et al. (2017) underlined that the effective use of big data analytics requires process-oriented DCs, defined as the extent to which a firm can develop competences to change business processes in a more robust way than its competitors.

In addition to firm level DCs, Rothaermel and Hess (2007) show that s firm's innovation is a positive function of its network of new technology providers, a finding that points to effectively orchestrating the network of actors who play a role in implementing innovation projects (Eisenhardt and Martin, 2000) as one possible manifestation of a DCs. These DCs are crucial when the firm has to manage the most challenging and strategic IoT projects, which require mobilising diverse individuals and teams within an organisation and across a network of suppliers and partners. Such projects require managing effectively loosely coupled networks (Orton and Weick, 1990). Projects using mature technology will tend to build on pre-existing and standard interfaces that allow a modular design process while projects that integrate within a dedicated architecture cutting edge technologies, require designing the architecture and the components concurrently. When standard interfaces exist, projects can be coordinated by providing the different teams with interfaces; changes are permitted only within a predefined range. In this context, IoT projects can be coordinated across different teams through information and knowledge sharing activities. Challenges arise from the many variables at stake and the potential divergence of interpretation across the f teams involved in such projects. Such projects require an ability to learn and react rapidly through the active management of the relationships across teams. Each team can work on specific independent components and as challenges arise, they can be brought together to share information, to learn and to react rapidly together. A clear example of this type of

DC is the implementation of a connectivity solution for public buses, enabling user-friendly payment, route scheduling capabilities and Wi-Fi.

However, without standard interfaces, a more active design and management will be required to integrate diverse objects and sources of data together using diverse technologies. The need will arise to coordinate the resolution of ill-defined problems through the exploration of multiple solutions by an intellectually diverse yet cohesive group of individuals (Brusoni and Prencipe 2013). As technologies are mostly emerging and cutting edge, they need to be integrated into a coherent architecture often imbedded in a broader system which is also imposing a set of constraints on them. To manage such projects, organizations need to bring together at an early stage teams with very distinct knowledge bases. They will have to explore multiple solutions in order to integrate technologies, components and sources of data. These integrative DC underscore the development by an automotive company of a secure solution for infotainment, advanced driver assistance and in-car time sensitive application (Cluster 5).

Finally, several of the cases have brought to our attention that projects in clusters characterised by more novel technologies or engendering a more strategic orientation (3-4-5) are undertaken in close partnership with providers of new technologies, who, in many cases, co-develop solutions with the user firm and accompany the firm's future IoT developments. This finding is in line with past research on the importance of network level DC for innovation processes (Rothaermel and Hess, 2007), and on the role of networks in providing access to knowledge not readily available via market exchanges (Gulati, 1998).

Conclusions

This paper has built on secondary sources of information on IoT adoption to try to identify a typology of IoT projects. This is an area of investigation where seldom empirical evidence exists on a large scale. The analysis led to identify five clusters of projects positioned along varying degrees of complexity, novelty and scope. The clustering of projects also allowed shedding light on patterns of involvement of firms of different size (e.g. large firms vs. SMEs) in IoT projects. These findings are particularly relevant to understand what firms currently do with IoT.

Our discussion has tried to elaborate on the existence of possible development paths or trajectories in IoT project implementation and on the dynamic capabilities enabling adoption and success of different project types. This analysis is eminently data-driven and should be considered suggestive of future research directions. Therefore, a more precise understanding of the dynamics of IoT adoption and of enabling capabilities is necessary. In particular, longitudinal analyses of firm-specific and sector-specific trajectories from infancy to higher order achievements should be undertaken. For instance, projects in fields such as agriculture should be studied to develop a grounded theory of leapfrogging in IoT. Finally, future research can be carried out to further explore the dynamic capabilities identified as critical in this paper. In this direction, primary case-based research could throw light on how diverse knowledge bases are mobilised to develop and implement IoT project and on how external partners are integrated in such activities. To conclude, a broad range of research activities is still required in this emergent field of investigation.

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An analysis of improvement potentials and impacts of digitalization on manufacturing performance

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Abstract

The intensified digitalization efforts of recent years enable companies to put emphasis on designing and developing innovative management approaches. This leads to the implementation of improved operational processes and to superior decision making in operations management. The Electronic Components and Systems industry (ECS) and corresponding suppliers from other industries represent the main study context. The implementation of smart factory systems provide a new perspective on key drivers for competitive sustainable manufacturing. In order to model these dependencies, a discrete event simulation model (DES) has been developed that supports analysis how the effects of fast-paced technology can influence industrial operations.

Keywords: Digital Transformation, Process Improvement, Simulation Modeling

Introduction

The Electronic Components and Systems industry (ECS) is characterized by long lead times and high market volatility. Aside from this, fast technological developments within this industry and cyclic market up- and downturns are influencing the market (Mönch et al., 2011). Furthermore, too low inventory of required products can cause a loss of opportunity costs by not reaching customer satisfaction, service level and product availability. Therefore, investments into process and quality improvements are key success factors for companies to survive (May and Spanos, 2006). This paper proposes a model based on a single manufacturing process to assess the value of process quality

improvement. The implementation of additional sensors and intelligent software applications for improved quality inspection of production processes supports the detailed analysis presented in this paper. In addition, we analyze the impact on manufacturing performance, i.e. costs (operating costs), productivity (cycle time, utilization and variability) and quality (process and product quality). The benefit of process improvement for operations management is based on understanding the costs and advantages of collecting and analyzing new insights from process and product data. Finally, value is generated from existing data by exploiting specified key findings within defined data sources (Sjödin et al., 2018). Manufacturing processes must be designed in a way to reach an optimum between quality, productivity and costs (Plunkett and Dale, 1988). This leads to the following research questions:

- *RQ1: How can manufacturing companies improve operational performance through digitalization?*
- *RQ2: What is the impact of digitalized manufacturing processes on costs, productivity and quality, and how can this impact be evaluated?*

Theoretical foundations

For the purpose of this study we apply queuing network theory in combination with simulation modelling. With this we aim at explaining the impacts of the solution developed in one industrial case from an ECS supplier on process quality, product quality and overall production effectiveness and efficiency. In general, the increase in process variability negatively impacts process performance. Therefore, our main investigation subject is to evaluate how digital process improvement can reduce variability in production processes within plants (Hopp and Spearman, 2001). Analytical approaches based on queuing theory serve as a fundamental instrument to explore what-if questions. Queuing models make cycle time estimation based on the assumption of stochastic arrival and service processes possible. In typical queuing models as given in the so-called *G/G/1* model in Figure 1, the arrivals (i.e. demand) of a product at the workstation are often modelled as a stochastic process where inter-arrival times are random variables following specific (unknown) distributions. Based on machine configuration and process requirements, processing times are prone to be stochastic as well. Products that arrive but cannot be processed directly are placed in the waiting queue. The stochastic components are represented by their first two moments what is explained in detail below, i.e. mean and coefficient of variability (Hopp and Spearman 2001).

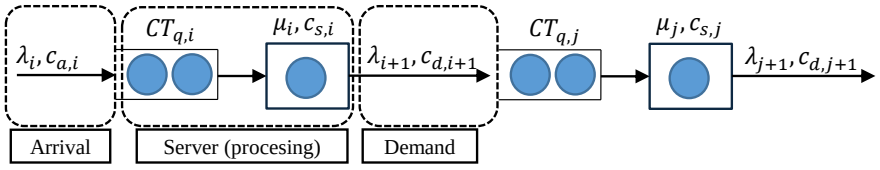

Figure 1: Simplified process model

Little's law can describe a simple and stable process, where the inflow and outflow rates are identical (Little, 1961). However, the analysis of complex processes, requires more than the long-run average values set by Little's law. For example, Wu (2005) applied Little's law and the G/G/1 queueing formula to estimate the variance of a simple factory with single toolsets. He identified certain basic properties that provide managerial insights on how variability affects the production performances. Furthermore, the author pointed

out that the variability of bottleneck toolsets should be reduced to achieve fast cycle time. The following conditions apply for a stable process:

$$\rho = \frac{\lambda}{\mu} < 1, \tag{1}$$

where ρ is the utilization, λ is the unit arrival rate and μ is the service rate. λ and μ are defined by

$$\lambda = \frac{1}{t_a}, \tag{2}$$

$$\mu = \frac{1}{t_e}, \tag{3}$$

where t_a denotes the inter-arrival time of units and t_e the effective process time. The approximation for waiting time (CT_q) of a single process, is given by

$$CT_q = \frac{\rho}{(1-\rho)}\left(\frac{c_a^2+c_e^2}{2}\right) t_e, \tag{4}$$

where c_a^2 is the squared-coefficient-of-variation (SCV) of the inter-arrival time (t_a), and c_e^2 is the SCV of the effective process time (t_e). The effective process time includes the raw process time (t_s) and all time losses due to setup, breakdown, unavailability of operator, and any other source of variability (Wu, 2005). The throughput rate of a single server is defined by

$$r = \frac{\rho}{t_e}, \tag{5}$$

and the cycle time is defined by

$$CT = CT_q + t_s. \tag{6}$$

The raw process time represents the sum of times a unit spends on a server, such as load/unload and processing. It is to be noted that the internal service ($c_{a,i}; c_{s,i}$) as well as the external arrivals and demand for sub sequential stations ($\lambda_i; c_{d,i}$) variability of the system have effects on the waiting time (CT_q). Additionally, this performance measure is strongly linked to the utilization of the system which is in turn determined by the arrival and the service rates ($\mu_j; c_{s,i}$). In this regard, waiting times and service times are both significant parts of the cycle time (see Figure 2) where the former is a non-productive component and must be reduced to a minimum.

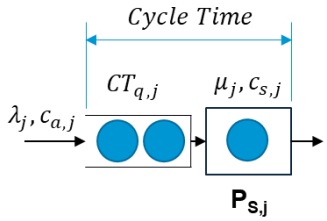

Figure 2: Cycle Time of a single server process

Variations within the defined processing limits cause variation in the final product, visible e.g. in quality inspections after the process. The compilation of individual process variations may increase the product scatter and lead to yield losses, long cycle times, high costs and low service levels. The improvement of manufacturing processes has a direct impact on the overall cycle time reduction, especially for products on the critical path. In an industrial environment, most operational processes are characterized by dynamic operating conditions and complex interrelationships that cause changes in inputs, operations and outputs. Variability results in non-conformities that have a negative impact on operations processes. Product characteristics and product quality, as well as process attributes (e.g., process time, set-up time, process quality, equipment breakdowns and repairs) are subject to non-conformance (Klassen and Menor, 2007). Thus, the reduction of variability improves operational performance, such as throughput, lead-time, customer service, quality, etc. (Hopp and Spearman, 2001). The effect of variability reduction on the cycle time and capacity utilization lead to the following results:

a) Lower variability leads to a reduced cycle time at unchanged capacity utilization.
b) Lower variability enables higher capacity utilization and therefore a higher throughput rate.

These insights serve as fundamental basics for our proposed simulation model which is outlined in the next section and forms the basis for the further quantitative impact evaluation.

Methodology

This article is based on single case study research including one industrial case which serves as data source for the developed simulation model. The case focuses on the integrated analysis and optimization of the internal processes of heating and hot rolling of molybdenum plates for the production of sputtering targets. The main objective is to increase the proportion of sputtering targets complying with the quality required for the semiconductor industry and thus, to improve process efficiency. From a methodological viewpoint, case study research is an appropriate method for answering the research question of this paper. It serves as a promising methodology for defining propositions and describing upcoming phenomenon within its real-life context – here return on quality through digitalization (Yin, 2003, Voss et al., 2002, McCutcheon and Meredith, 1993). The fundamental process improvement here is covered by the implementation of a model based control tool. Our study connects the competitive value of data analytics and performance measures to enhance manufacturing excellence. When disruptions within a system occur, these methods enable the development of scenarios and recommendations that facilitate instant managerial support. For our process modelling and evaluation we have mapped the process in a discrete event simulation (DES) model. The modelling software is Anylogic 8.2. DES models are networks of queues and activities with coupled resources. This means that units that are called agents in the model language move between different stations during the process time (Banks, 2010). Performance measures are for instance the utilization of resources, the processing times of the target variable, waiting times, the length of queues, the system throughput or bottlenecks (Borshchev, 2013, Buzacott and Shanthikumar, 1993).

Case Introduction

Initial situation

The production of sputtering targets is a powder metallurgical process, which has lot of critical production steps and tight requirements. The sputtering targets were treated in

production lots of up to 10 pieces each. Only a few process parameters were recorded along the supply chain, and merging of this data with the production lots was a manual task. The main production step “hot deformation” was planned manually and the heating times were estimated. The challenge is to bring a single piece traceability into the whole production chain and enhance accuracy in the main production process step.

New technical solution
Single piece traceability was realized by a unified unit number (UUN), which was implemented in the ERP/MES and on each single material ingot. With tailored process models and advanced model-based control tools, the production step deformation is now controlled in a more efficient and accurate way. In the final production steps, single piece production together with almost paperless production was installed. The UUN was implemented which can handle each individual piece of sputtering target along the production chain. A 2-D barcode is graved on each piece and tracked along the production steps. ERP/MES systems were adapted to process this number and all order information is stored including process data. In the main process step new control and optimization tools were developed by extending established methods with tailored mathematical process models. This requires mathematical modelling, parameter identification and model validation, advanced nonlinear process control, and combinatorial optimization like timetabling algorithms or flexible job-shop scheduling (Aschauer et al, 2018; Roetzer et al. 2018). On production level, the process steps from a pressed and sintered plate to a hot-rolled sheet of molybdenum is affected. Rather than focusing exclusively on maximizing the throughput of sputtering targets, the targets for the desired quality have been expanded to include less waste and the energy efficiency of the production plant. Another target was to decrease the work in process in order to reduce the lead time of the manufacturing process.

The case was driven by following challenges:

- *Increased quality:* The temperature control of the plates has a decisive influence on the product quality. In order to achieve here an optimum temperature, a "virtual sensor" is implemented, acting as an estimator for the temperature development of the plates.
- *Process improvement:* The focus on a zero-defect strategy requires the cooperation of the operator and a corresponding focus on quality. For this purpose, the optimization algorithm should provide recommendations to the operator in terms of which products are when, where and how produced.
- *Increase of energy efficiency:* Since the heating of the furnaces is the main energy factor, the optimal use of heated furnaces and the potential decommissioning of unused furnaces strongly contribute to energy efficiency.
- *Reduction of lead time:* The pool of orders that can be optimized by bundling products with similar process steps leading to increased efficiency was remarkably reduced. The order optimization period was limited by two days.

The Process Model
In the following section, we outline the process model development. We use some elements of queuing theory to show how an improvement of a single process step can have several impacts on the production system as well as on the whole value and supply chain of an organization. We further illustrate that decision-making at this particular step must consider the overall impact, i.e., improvements made at particular stages do not necessarily generate value for the whole system and can sometimes be detrimental to

overall performance. Please note that due to reasons of confidentiality exact operational numbers as well as process details (which are unimportant for the study) are omitted.

Heating time estimation

Since the plate cools down during the rolling and handling process, the optimum reheating time is calculated based on the processing time and waiting times of the rolling and handling processes. In the static calculation (earlier) it was therefore not possible to determine the exact temperature of the plate and therefore a safety time had to be taken into account in order to produce a quality plate. This leads to additional process times and thus to an increase in resource utilization and a reduction in throughputs. By using modern sensor technology and UUN, it is now possible to determine the temperature of the plate in real time and thus determine the optimum reheating times of the plates in the furnaces. This has the effect that the times can be optimally adjusted and thus resources and energy can be saved. Another effect is represented by improved cycle times and throughput. In addition, the quality of the product can be determined at an early stage, since temperature variations can be tracked earlier and in real time. Early detection of deficient quality has the effect that an additional unit can be launched at an early stage and thus costs, resources and energy can be saved.

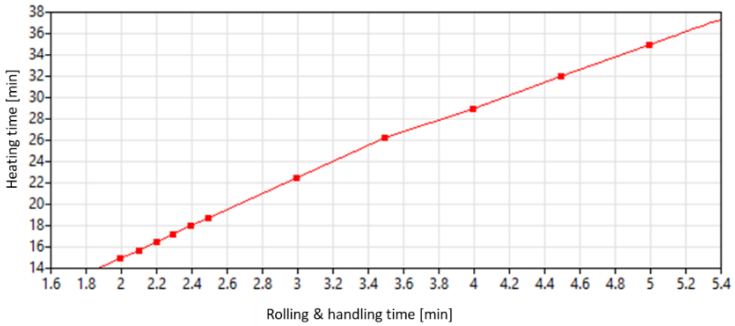

Figure 3: Heating time based on intermediate heating sequences

Here, Figure 3 shows an estimation of the relationship between heating times and the composition of time between rolling and handling. Detailed calculations including a specific temperature model showed a potential decrease of cycle time and therefore, decrease of utilization, of about 8-10%, and a potential throughput increase of about 3-5%. The optimization algorithm is based on a material stock of two to three daily quantities and production orders for the next 24 hours. This facilitates a switch from manual scheduling to semi-automated decision-support system. Figure 4 illustrates the entire process of transforming raw materials to finished plates.

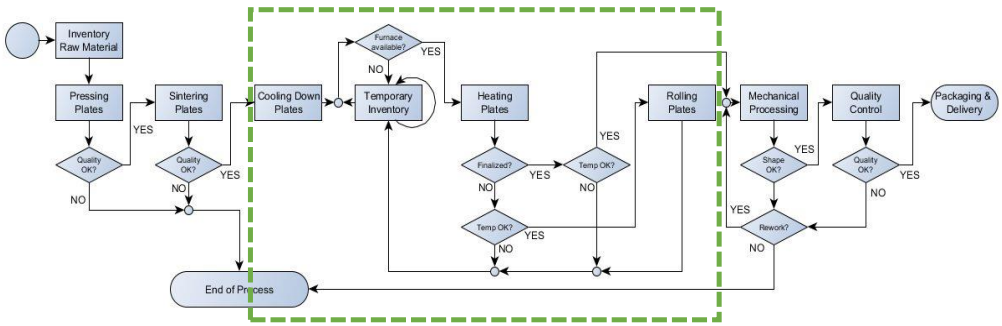

Figure 4: Process Flow Model

Due to our objective to analyze the heating process in detail and as the sub-process forms a natural unit in operations, we focus on processes within the green box highlighted in Figure 4. This flow chart served as initial starting point for the model description and was used to analyze and discuss the process and to build the simulation model based on it.

Development of simulation scenarios

Several simulation scenarios are considered, which combine different furnace settings, heating configurations and heating times as well as other parameters, such as different arrival distributions, various arrival rates, and variability levels. The main process is that the plates are heated to a specific rolling temperature – what takes *x* minutes depending on the initial temperature – and afterwards rolled; this process is repeated several times. The *x* min. are estimated based on the cool down time during the rolling process (as given in Figure 3). In some scenarios, an additional safety time is added to ensure that the core temperature of the plate reaches the desired temperature. Please note that due to confidentiality the number of furnaces for initial heating/reheating (IRF) and final treatment (FT) is shown as a ratio.

The following scenarios and sub policies were used for evaluation, whereby all three scenarios in Table 1. are based on two configurations with a *static* heating time of 20 min and 25 min (P_20 and P_25), and one *dynamic* configuration where heating time is based on the actual rolling and handling time (P_Opt):

- **Scenario 1** shows the basic furnace setting within the case company where the relation between the number of initial heating/reheating furnaces and final heat treatment furnaces equals to 1:1.
- **Scenario 2** shows the furnace setting where the relation between the number of initial heating/reheating furnaces and final heat treatment furnaces equals to 1:0,5.
- **Scenario 3** shows the furnace setting where the relation between the number of initial heating/reheating furnaces and final heat treatment furnaces equals to 1:0,33.

Table 1: Simulation scenarios

Scenario	Furnace setting	Heating configuration	Heating time	Policy
S1	1:1	static	20	P_20
	1:1	static	25	P_25
	1:1	dynamic	opt	P_Opt.
S2	1:0,5	static	20	P_20
	1:0,5	static	25	P_25
	1:0,5	dynamic	opt	P_Opt.
S3	1:0,33	static	20	P_20
	1:0,33	static	25	P_25
	1:0,33	dynamic	opt	P_Opt.

Findings

Basically, the evaluation focuses on various performance measures such as utilization, throughput rate and work in progress (WIP). Another important indicator is the determination of the optimal processing time and its impact on the overall performance of the system.

Impact on Capacity Utilization

In general, it is desirable to achieve a high capacity utilization in production system. However, too high workload can lead to instability and infinite waiting times. In this model it can be observed that the use of a higher number of initial heaters (S1/S2) leads

to relatively high and stable utilization (~96%) in both scenarios (see Figure 5). In S3, the utilization decreases by about one third (65-70%), since the ratio favors IRF:

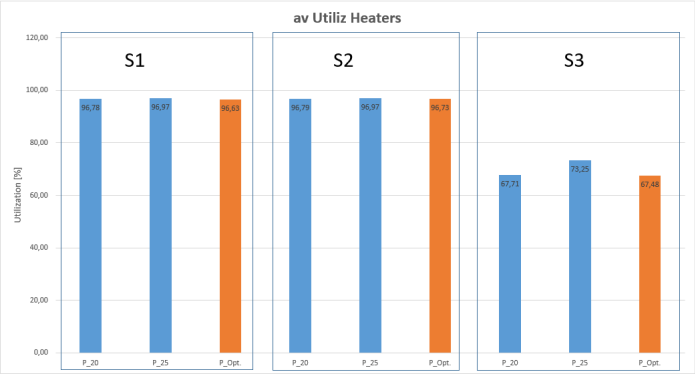

Figure 5: Capacity utilization of initial heaters

The average utilization is not depending on the static or variable dynamics of the heating times. The initial heater in this system represents the bottleneck. The use of a higher number of initial heaters leads to a high capacity utilization. If a greater number of IRF is used, the load is reduced by approximately one third. Regarding the capacity utilization of the initial heaters, S1 and S2 achieve the same results. The closedown of a FT (S2) leads to an improved utilization. The use of a higher number of heaters would be inefficient if the cost factor of energy was also taken into account, since a FT can achieve between 60 and 70 percent capacity utilization. Thus, the system remains stable and no bottlenecks arise.

Impact on Throughput Rate

The throughput rates in S1 and S2 do not differ at all. This is interesting, because in the second scenario a heater is switched off. This means that additional heaters in the final heating phase do not affect the throughput rate. However, the main focus should be on the differences between static and dynamic policies.

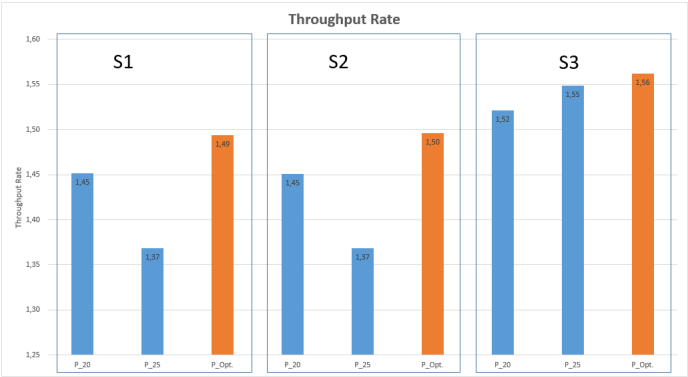

Figure 6: Impact on Throughput Rate

Moreover, the throughput rate from P_20 to P_Opt can be increased by ~3% and that from P_25 to P_Opt by ~10%. Additional data/information to determine the exact heating times have direct influences on the throughput rate (in all scenarios). With reference to the bottleneck of the initial heaters, it can be demonstrated that the throughput rate is limited by the number of initial heaters. In each scenario the dynamic heating configuration achieves the best result.

Impact on Work in Progress (WIP)
The WIP generally represents stocks in the current system and also tied capital. A high WIP means that the system is running at high capacity and can lead to unstable processes. This effect is clearly visible under S1 and S2 in the static area.

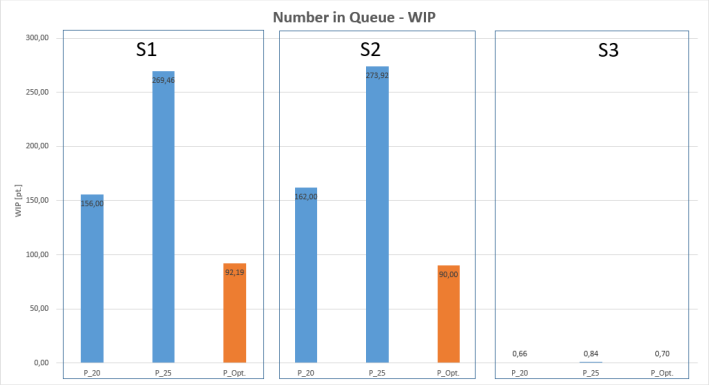

Figure 7: Impact on Work in Progress

Due to the improved process times under consideration of additional information for the initial heating, the number of waiting jobs under P_Opt is lowest at simultaneous high utilization. Based on the high capacity utilization in S1 and S2, policy P_25 shows that inventories are increasing to an equal degree. The simulation showed that the static configuration (P_25) is unstable. The capacity utilization is directly related to the WIP (S1 + S2 vs. S3). Additionally, exact information of plate temperatures have a direct influence on the WIP (P_Opt). The use of a higher number of initial heaters (S3) leads to a low utilization of the system and consequently to a very low or even inexistent WIP.

Impact on total processing time
Here, the process time of the initial heaters is documented. Since the process time is independent of the load and the resources made available, similar results exist in all three scenarios (see Figure 8).

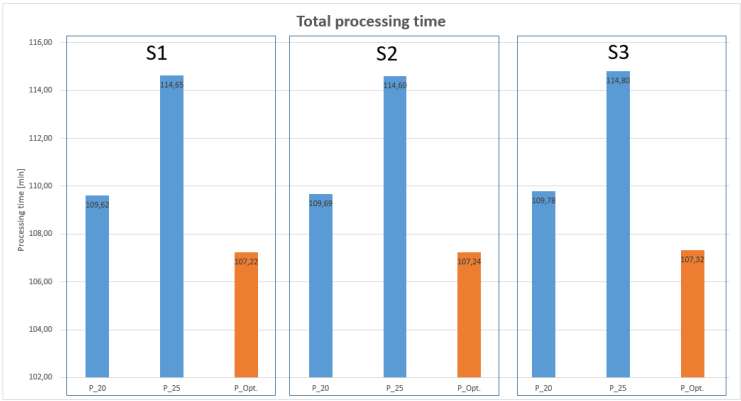

Figure 8: Impact on total processing time

An improved information acquisition, ensured by the developed and implemented algorithms and sensor technologies, leads to faster processing times. This effect is illustrated in Policy P_Opt. This shows that a reduced process time leads to lower inventories and improved throughput rates.

Conclusion

Different real scenarios were simulated over a period of several months. The generated simulation results underline the qualitative statements given in the introduction of the paper. The case shows that the throughput rate was increased due to the improved process times of the furnaces. A direct connection with the technologies developed in and their influence on the production environment can therefore be proven and validated. In particular, we illustrate the influences of improved data acquisition, digitization efforts and new software solutions (algorithms/sensors) on the production area. However, the collection and analysis of manufacturing information for evaluating potential impact factors is cost-intensive. Based on such a procedure, costly further steps can be avoided if a fail regarding quality requirements can be detected. Furthermore, insights of the effect of learning from data over time reveals important potentials for future developments in Industry 4.0 development projects. In order to provide reliable results from collected and analyzed data, further scenarios have to be tested. Evaluations with the recently installed measuring system lead to higher accuracy in the temperature measurement of plates. Overall, this results in improved manufacturing performance, which is nothing more than increased productivity, quality and costs.

Acknowledgement

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Sustainable Customer Relationship Management for BIM Procurement in the Ornamental Stones Cluster under Industry 4.0

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Abstract

The construction industry competitive environment has been demanding buildings conforming with the dynamic customer/owner requirements put together with the procurement of adequate personalised natural materials *made to order* in integrated value networks. But, the technological push has introduced BIM procurement as a mandatory industry best practice that demands standard mass produced materials (*made to stock*) to be introduced in IFC e-libraries ahead of their selection by technical specialists, not the owner. A three experts focus group generated an innovative Cyber Physical System conceptual model (research contribution) to solve this apparent paradox arising from an in depth literature review (theoretical contribution).

Keywords: Customer Relationship Management and BIM procurement, Ornamental Stones under Industry 4.0; IFC libraries and personalised smart materials.

Introduction

This paper will focus on the relationship with the built asset customers (building owners) to define and offer adequate and conforming personalized natural materials for the buildings, such as the Ornamental Stones. The study of this relationship will provide further insights to the replacement of the traditional procurement processes in the Architecture, Engineering and Construction (AEC) sector (Marinho, 2014). So, the overall research exercise will explore new forms of generating sustainable value supported by Digital Business Platforms, under a Building Information Modeling (BIM) approach for construction, design and operations in the AEC.

A framework supported by Service Science Theory (Vargo and Lusch, 2016) that promotes a customer-centric approach (Rajah et al., 2008), will accommodate the positive impact of the I4.0 production control model in transforming the threats resulting from BIM procurement, in the AEC industry, into opportunities. However, this is possible, if materials suppliers firms have a flexible manufacturing system supporting the dynamic offer of new *customized* materials or objects, by *quickly* redesigning them and being able to *fully adjust* the supporting processes (Zawadzki and Żywicki, 2016) to sustain the *evolving* customer (owner) requirements/expectations within the scope of a co-creative participation (Rajah, et. al, 2008). On the other hand, products/materials in the emerging BIM procurement context must be expressed in a standard format (e.g. Industry Foundation Class - IFC) and so, commercially available in the BIM-web-libraries, ahead of their choice. Only then, customers can choose them, which currently occurs under a traditional push approach that makes to stock (MTS) standard products in high volumes. However, if one follows a pull approach, materials should be first customized in conformance to their specification, aligned with the building one and, only then, made electronically available for selection from e-libraries. In addition, nowadays, this spec is mostly expressed as the material being "mouldable" to the area to be clad (i.e. the built asset geometry), including a certain type of holding system and, also surface texture, everything according to the architect's (or building technical team) creativity. There is no objective link with the requirements/expectations of the building owner.

Thus, there is a conceptual conflict (paradox), because a major advantage of BIM usage concerns the standardization of the virtual objects to be part of the building, in order to bring in more stability to the construction business by a more transparent and stable procurement process itself. Therefore, the main objective of this paper concerns the introduction and operationalization of a dynamic "virtual element" designated as a [quasi-] Smart Object (Motamedi et al., 2016), co-created with the customer. This should be made available in a IFC standard (ISO16739:2013), on small enough time gap to be competitive with the standard materials, despite being personalized and made to order (MTO). So, this paper starts by establishing the type of customer relationship that should be specified, adopted and operationalized to target Sustainable networked Value Co-creation by pursuing a Service Science approach enabling a significant Strategic Business Positioning to accommodate the response of the Portuguese OS SME to the threats resulting from BIM procurement.

The chosen path to address the previously expressed paradox is, as follows: (i) firstly, by objectively recognizing that there is an increasing and unstoppable trend towards not only customization but personalization, not compatible with mass production products; (ii) secondly, by defining a role for the new digital technologies in the business change process; (iii) thirdly, by identifying new business models and processes aligned with the competitive context progress; (iv) fourthly, by proposing a much more effective support to the MTO option, supported by digital technologies and coming from an accepted

internal change dynamics that might not be objectively dismissed and also, from focusing the customer relationship on the customer/owner interest.

Next sections of this paper are, as follows: 1) the Literature Review, where topics (i), (ii), (iii) are covered; 2) the Methodology, where an exploratory abductive approach based on a focus group is explained; 3) the Empirical Findings, where the topic (iv) is addressed. So, in this section it is put together a conceptual proposal for a Cyber Physical system that enables to introduce a «quasi-smart» personalized material in the IFC library to cope with the challenging initial paradox; and, 4) the conclusions.

Literature Review

The competitive context progress and new business models

World population will increase 2 billion in the next 20-30 years, most of it concentrated in urban areas. As the Construction Industry (CI) is one of the largest consumers of raw materials and energy (Perspectives and Economics, 2015), it is imperative to find new solutions and innovative products that can contribute to the construction of sustainable cities, since along with sectors such as transport, the planet's sustainability (Gao et al., 2015) will depend on the CI. Moreover, the Portuguese Ornamental Stones as a subsector of the Construction Industry also shows a significant national importance deserving to be investigated in line with the pursued record of research in the cluster (e.g. Peres and Costa, 2006; Frazão, 2016).

On the other hand, several researchers have argued that the firms' competitiveness will progress across new management models concerning the integration of their operations in value networks (Lusch et al., 2009). However, in most cases, the customer is still seen as a strange element, independent and far away from the production sites (Lusch and Nambisan, 2015). So, a strategic business operations model promoting inter-organisational collaboration is definitely a solution to be seriously taken into account (Silva et al., 2016). For instance, in the Mass Personalization Paradigm (MPP) customers are intensively integrated into the production process (Wang et al., 2017). MPP requires product fulfillment to be changeable, adaptable, and configurable. In addition to the final product, the basic design and product structure must be able to differentiate at the module and parameter level to meet individual unique needs. Thus, for I4.0 to involve customers in products' co-creation, the customer must be considered an indispensable actor (Vargo and Lusch, 2016), a situation still not very common, as several Service Science authors were considering. Nevertheless, Camarinha-Matos et al. (2017) confirm that the customers involvement in product design as well as close interaction among engineers of different nodes along the value chain require effective collaboration between manufacturers and customers, and so, it is argued that new sustainable Customer Relationship Management (CRM) models are on high demand. However, Forgues and Koskela (2009) made explicit the nature and fragmentation of procurement within the "design-bid-build" process and the client's lack of understanding of its role in a new integrated design process, in the AEC sector. So, the role of the built asset owner within the construction networks should change and become clearer, in addition to the building technical team, i.e. architects, engineers and other specialists. An opener network interaction is required, where specialised and integrated agents increase end-user interactions with users, flexibility and iterative facilities design (Grilo et al., 2013).

Naoum and Egbu (2015) still argue for the need to break the fragmented approach of the traditional route and to encourage cooperation through an integrated method of procurement, communication and ideas able to be shared. This means that the construction industry's poor performance with adversarial procurement practices causing high fragmentation, lack of quality outputs, and low productivity were still going on, as

Latham (1994) and Egan (1998) have reported 20 years earlier. In between this time gap many other researchers have considered that new procurement modes were required to transform the relationships dynamics between the client and the members of the supply chain, improving performance (e.g. Forgues and Koskela, 2009). It should be noted that any construction project involves several stakeholders like client, architects/engineers, developers, manufacturers, general contractors, subcontractors, suppliers and consultants. Moreover, construction material information systems are isolated, with no interaction between them (Kong et al., 2004). In general, it is difficult for a contractor to find all the information using one system and, even more difficult, to do a comparison of the products supplied by different suppliers based on criteria such as product specification, cost, availability, and delivery time (Empirica GmbH, 2007). According to Al-Bizri and Gray (2010), procurement approaches were not creating an organizational framework to deal with fragmentation of the building process and with the cultural issue. One of the biggest problems is the difficulty in implementing widespread team working and collaboration, primarily due to cultural barriers – something that BIM boasts as one of its main attributes (Naoum and Egbu, 2015). Some authors also pointed out specific consequences of unclear and performed ad hoc partner responsibilities, in construction networks, such as conflict of resources and coordination efforts (Legner and Wende, 2006; Magdaleno et al., 2007). Therefore, an end-to-end Supply Chain (SC) approach appears to be needed at the AEC sector. However, besides the problem of aligning business processes from different organisations there is the problem of lack of transparency. Even minimal process visibility in BIM-based projects often provides business benefits to business partners, e.g. regarding technical and managerial decision-making (Grilo et al., 2013). In addition, Forgues and Koskela (2009) have identified another gap concerning the absence of recognized code of practice or Body of Knowledge (BoK) to support the new form of collaborative work inherent to that SC streamline approach. So, the BoK related to collaborative networks should be considered in this assignment.

In addition, Bullen and Davis (2003) highlight that the use of the traditional procurement process creates a professional barrier to innovative change that is required by sustainability. Furthermore, Hamza and Greenwood (2007) added that under the traditional design and build procurement arrangements it may prove to be a very challenging task to design environmentally sensitive buildings as the iterations required are at odds with the contractor's incentive to avoid delays and extra cost.

The role of new business platforms such as Building Information Modeling

BIM can support project collaborative working environments for enabling: (i) the built asset owner to develop an accurate understanding of the nature and needs of the purpose for the project; (ii) the design, development and analysis of the project; (iii) the management of the construction of the project and (iv) the management of the operations of the project during its operation and decommissioning (Grilo et al., 2013). BIM is an extension to CAD, as regards its design dimension. New functionalities coming from CAD 4D are mentioned in the literature. For instance, the combination of 3D CAD and 4D animations, e.g. virtual building modelling or energy performance graphics, can dramatically improve communication, coordination, and planning of construction projects while reducing risks and costs (Kymmell, 2015). Other sub-dimensions of design are also found in literature, as such concerning time-programming, costing or sustainability (Redmond et al., 2012). For non-design disciplines, such as contractors and project managers, BIM is more like an intelligent Data Management System (DMS) that can quickly take off data from CAD packages directly (Singh et al., 2011). Oreni et al.

(2014) add up the following functionalities, in both previously defined categories: (i) a single repository including both graphical documents - drawings - and nongraphical documents - specification, schedules, and other data; (e.g. ArchiCAD) (ii) a modeling of both graphical and non-graphical aspect of the entire Building Life cycle in a federated database management system (e.g. Bentley); (iii) a building design and documentation methodology characterized by the creation and use of coordinated, internally consistent computable information about a building project in design and construction (e.g. AutoDesk).

Thus, BIM does impact the business performance, by a technological push resulting into: (i) functional integration along the supply chain (Papadonikolaki et al., 2016); (ii) data standardization that defines the information formats, geometry, behaviour and presentation of BIM objects to maximize consistency, efficiency and interoperability across the construction industry, e.g. IFC (NBS National BIM Library, BIM Object Standard, 2019); (iii) data interoperable usability (Lee et al., 2006); (iv) inclusion of ICT frameworks that support collaboration with stakeholders over projects life-cycle (Motawa and Carter, 2013); (v) cloud-based sharing of the lists of products and materials with Suppliers (BIM Object - BIM Supply, 2019) and, (vi) better materials conformance (NBS National BIM Library - BIM Object Certification, 2019) through adequate procurement. In fact, as more disciplines of the construction industry adopt BIM, integrated design, and delivery work processes, the need for interoperable applications grows clearer (Lipman et al., 2011). So, BIM application may help to leverage construction procurement performance, particularly by emphasizing the role of information throughout the procurement cycle and, mostly, by allowing the automation of several procurement processes, diminishing the probability of errors and processes duration (Costa and Grilo, 2015). As each building/engineering project tends to be unique, it is critical to the success of e-procurement that the BIM approach considers the use of universal interoperability standards for the various dimensions, i.e., not only on the e-Tendering, e-ordering, e-invoicing or e-Catalogues, but also on product and process models (Grilo and Jardim-Goncalves, 2011). Thus, data interoperability and standardization provide *sine qua non* technical support to the claim that fully integrated procurement methods that include Design, Build and Project Management are most appropriate and significantly contribute to the buildability of the project change (Naoum and Egbu, 2015), i.e. to save time, costs and cost of change (Ma et al., 2013). Through the use of a common standard, the integration of building and materials information and, its effective use becomes possible (NBS National BIM Library, BIM Object Standard, 2019). Electronic integration in heterogeneous, distributed environments, business interoperability research intends to determine how and to what extent the potential of these concepts can be reclaimed for realising seamlessly integrated value chains (Li et al., 2008). In addition, BIM-based e-procurement vision may extend the buying capabilities requirements for procurement, also to design and develop products, manufacturing processes, logistics, and distribution strategies (Presutti, 2003; European Commission, 2010). Enhanced collaboration needs to be developed in the AEC sector and BIM requiring changes not only in the information systems. For example, service-oriented architecture (SOA) based BIM, new business processes and employees and culture, along with new management of business relationships are other major required changes (Grilo et al., 2013).

Role of the new digital technologies in the business change process

The fourth industrial revolution is characterized by an increase in digitalization and interconnectivity of physically separated manufacturing systems (Camarinha-Matos et al., 2017). While the digitalization of the systems of machines is made through the use of Cyber-Physical Systems (CPS), the interconnectivity is enabled by the Internet of Things technology (IoT) (Hermann et al., 2015). The Cyber Physical Production System is application of CPS to traditional manufacturing system with a CPS where Internet, manufacturing and cloud computing work side by side (Singh et al., 2019). So, by integrating CPS with production, logistics and services in Ornamental Stones' suppliers today's factories would turn into an Industry 4.0 (Lee et al., 2015) generating "quasi-smart" materials able to dynamically adjust to the building specification and customer/owner requirements. IoT could then communicate data throughout the building value chain (VC) if adequate care is put on data standardization and interoperability. This is the core base to support the implementation of BIM procurement with information flowing seamlessly along the VC to feed both technical and management systems associated with the building apecification, design, construction and management.

In this way, the horizontal integration of data flow between partners, suppliers and customers, as well as the vertical integration within the organizational structure, involving factors related to the development of the final product and combining the real world with the virtual world (Abreu, 2018) would enable novel forms of personalization (Wang, et al., 2017; Abreu, 2018). This is the proposed theoretical way to overcome the paradox resulting from the introduction of BIM procurement as highlighted before. Therefore, the real world would be connected with a virtual one, ensuring more efficient use of available information (Zawadzki and Żywicki, 2016) to produce individual products at the cost of the mass production (Wang, et al., 2017) of standard materials. Thus, it is argued for the application of Industry 4.0 as a collective term for technologies and concepts to organize the value chain organization (Wang et al., 2017) by enabling real-time planning of production along with dynamic self-optimization (Abreu, 2018).

Methodology

An exploratory qualitative research was conducted by putting together a focus group of specialists that were carefully chosen and so, by asking about their perceptions, opinions, beliefs, and attitudes towards the presented ideas. Three engineers were participating. Topics were clearly and precisely defined based on the literature and there was a focus on enabling an interactive discussion between participants. The participants had common professional characteristics related to the topic being discussed and they were encouraged to discuss and share their points of view without any pressure to reach a consensus. These discussions were run for several times lasting for a total of 20h (10 sessions X 2hours), with the same participants. Questions to be considered were generated from the literature review. This exploratory assignment was expected to provide enough feedback to help to model the theoretical situation that has been previously described. Data were treated and processed according to adequate techniques that are usually used to process the focus group notes in qualitative analysis, i.e. contents analysis (Bell et al., 2018). Finally, the participants made an effort to put together a conceptual proposal for a CPS that enables to introduce a «quasi-smart» personalized material in the IFC library to cope with the challenging initial paradox. By the end this methodological choice configures the operationalization of an abductive approach.

Empirical Findings

The experts in the focus group agreed that the current trends on the competitive environment of the Construction Industry are requiring new business models for the Ornamental Stones SME to overcome traditional problems of the AEC Sector, such as: (i) disaggregation of the value network; (ii) SC fragmentation originating lack of visibility in operations, lack of transparency in procurement and lack of management of the SC as a whole entity (i.e. an end-to-end approach); (iii) favouring MTS mass production materials, which are not aligned with the competitive requirements that are asking for personalisation; (iv) exclusion of the building owner from the business processes concerning the design and construction of the built asset, excluding him/her from the interaction with the SC members, by promoting the imperative of the technocratic decision making; (v) replacement of the built asset owner by the technical specialists, such as architects and engineers among others, with no formal definition of a role for the building owner; (vi) favouring the minimisation of short term costs over costs discussed under the umbrella of a broader Life Cycle Assessment (LCA); (vii) no formal and explicit linkage to the use of local natural materials (e.g. stone), instead of global ones (e.g. glass, steel and concrete), in the category "sustainable cities and communities" of the UN sustainable development goals; (viii) lack of integrated information systems and data interchangeability.

BIM was praised by the focus group members as a powerful information platform to seamlessly and automatically exchange and share data coming from the strengthened CAD software together with other computer sources. These data might be used for several purposes, as follows: to feed Computer Aided Engineering Systems (CAE), e.g. studying the building envelope; for management and administrative purposes, e.g. the collaborative management of the project or of the SC; for better organisational arrangements, e.g. functional integration, fostering a collaborative culture; for innovative studies by putting together several sources, e.g. following the water pipes inside walls by augmented and virtual reality techniques; for supporting a different collaborative customer (owner) relationship both with the building technical team and with the other partners of the supply chain, e.g. with the help of electronic platforms for exchanging relevant information; and, of course, to foster and support a different type of materials procurement by introducing electronic means and bringing in transparency and visibility.

However, the focus group recognised I4.0 as the missing link to pursue sustainable value creation, in terms of the required updated technology to operationalise the new business processes arising from BIM procurement and a collaborative network. By associating the concept of CPS with the IoT, products and machines interconnect and communicate with each other and with the network they are part of, which also includes the final customer, i.e. the built asset owner. Digital technologies enabling the interconnections between the digital world and physical assets are made possible by sensory technologies for acquiring and exchanging data aiming to develop the "quasi-smart" object to include in the BIM IFC library to satisfy a personalized demand for a material (eventually an ornamental stone) on a MTO base. The experts agreed to fully adapt and renew the concept of Cyber Physical System of Silva (2018) to represent the required innovative CPS. The model mapped in Figure 1 is described, as follows.

Suppliers' manufacturing data such as material consumptions, workforce situations, machine statuses, and order progress are collected and automatically managed in real-time to answer quotation queries for a «quasi-smart» material defined according to its specifications coming from the material requirements expressed by CAE/engineering applications working on the building specification, the objective engineering criteria. However, a second set of criteria that are qualitative, e.g. the off-line application,

maintenance and demolition issues, will act as moderators of the main engineering criteria (first set) enabling a choice among alternative rival scenarios by the BIM modeler. This is the personalized offer (MTO) to be inserted both in the IFC library and in the ERP system. However, the CPS also operates MTS materials, by directly importing their definitions and standard ordering conditions from the ERP to the IFC libraries. One final remark to say that the above mentioned building specification results from the expression of requirements/expectations for the building by its owner, which are transformed into the spec by the building technical team (engineers, architects, others) through the design process. Finally, the term «quasi-smart» material was coined after the focus group discussions, to define a material of which spec is dynamic, depending on acceptable changes from the stakeholders, i.e. the technical teams, the built asset owner and other stakeholders. Then the CPS should be able to deal with these changes.

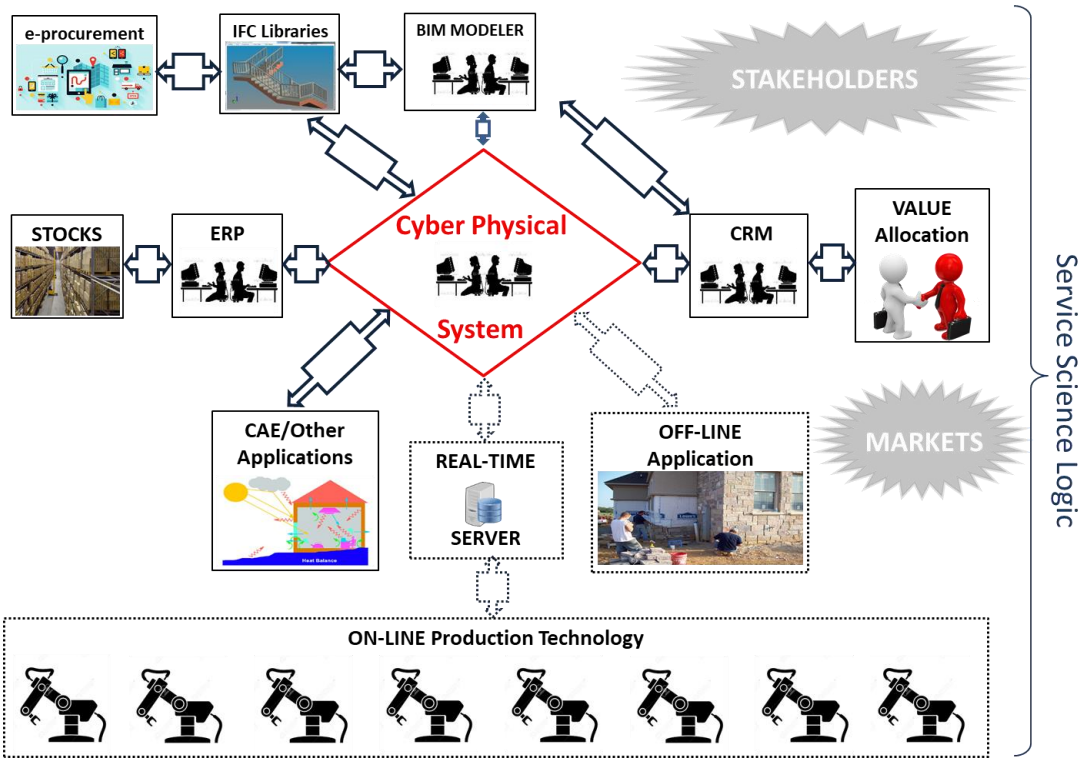

Figure 1 – Cyber Physical System (Adapted from Silva, 2018).

Conclusions

This paper introduced an innovative conceptual model of a Cyber Physical System (theoretical and research contributions). It aims at solving the conflict between the administrative requirements for the BIM-web-libraries for standard mass produced industrial materials and the electronic needs of «quasi-smart» personalized natural materials conforming with dynamic specs that connect to the requirements/expectations of the building owner. The CPS should only be a (semi-)automatic way to expedite the administrative process of inserting the personalized materials on the BIM e-library within a sufficient time gap to be competitive with the standard ones. However, it is argued that this initial question is a false question because the authors expect that the personalized material can offer other functionalities that the standard one cannot (practitioner contribution). For instance, it is expected the conformance of the personalized materials with a strict engineering criterion coming from the building specification (not only

aesthetical issues), or even the ability to adjust to dynamic customer/owner requirements for the building, which impact the materials' spec. In fact, this is what the construction industry "says it needs" and, also, what is on demand after analyzing the competitive environment of the AEC sector, as well as the flaws detected on the current business models requiring to be fixed. Thus, we conclude that the standard material is not competing with the «quasi-smart» personalised material (term coined on this paper). At most they might complement each other. Anyway, the CPS can cope with both situations. As a recommendation for further work, there is a need to find an engineering criterion strong enough to promote the linkage and conformance between the material to be procured, under a BIM paradigm, the building spec and the building owner requirements.

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Industry 4.0 in practice: a case-study based analysis from Central and Eastern Europe

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Abstract

Although, there are conceptual works on key I4.0 technologies and empirical findings about specific I4.0 applications, current literature offers only superficial empirical findings about organisation-wide I4.0 transformations. Our objective is to provide a framework for I4.0 implementation and discuss three case studies based on the framework. Based on our findings, even the large companies struggle with I4.0. Nevertheless, they already have digital strategy, digital transformation plan, and digital governance. But digitalization is still in a separated department. Efforts are usually made internally, in manufacturing. Replacing technologies can provide good, easy to estimate return, but will not lead to breakthrough transformations.

Keywords: Digitalisation, Industry 4.0, Sector

Introduction

Digitalisation has become the most recent buzzword in many field of business and management. Today, the digitalisation trend includes the appearance of Industry 4.0 (I4.0) in the manufacturing context (Valenduc & Vendramin, 2016). However, in practice, I4.0 goes well beyond the adoption of digitally based business innovations; novel and/or renewed physical technologies are also integrated in its core. In its vision, I4.0 exploits cyber-physical technologies to offer customized products with digitally enriched service content that is delivered by a reengineered value chain (horizontal integration) within a restructured supply chain (vertical integration) in which all participants are interconnected and share information (Schlechtendahl et al., 2015).

Although, there are many conceptual works on key I4.0 technologies and well-documented empirical findings about specific I4.0 applications, current literature offers only rather superficial empirical findings about organisation-wide I4.0 transformations. **Our objective is to provide a complex framework for I4.0 implementation and discuss three case studies based on the developed framework**. Our framework synthetizes the common dimensions of company level I4.0 maturity models (Fettermann, et al., 2018) (Geissbauer, et al., 2016) (Viharos, et al., 2017). It covers strategy formulation and deployment, classification of I4.0 technologies (e.g., maturity, human impact), and touches upon changes in the organisation. Given the current state of knowledge, case-study based research bears the potential of a notable contribution for both researchers and practitioners to better understand the phenomenon.

Industry 4.0 in the digital economy

Technologies in Industry 4.0

The emergence of the I4.0 concept shows that the development and adoption of digital and physical innovations has reached a critical mass. In *Table 1* we highlight eight core I4.0 technologies. *Table 1* is structured according to Schwab (2016) who has grouped the technologies into digitally and physically dominated categories. As *Table 1* indicates, authors with very different backgrounds and target audiences usually refer to the same core I4.0 technologies. In our opinion, these technologies are the building blocks of I4.0 efforts and the practical applications generally implement a specific technology (e.g., 3D printing) and/or the combination of technologies (e.g., digital quality management, predictive maintenance) (Goran, et al., 2017).

Table 1 – Core technologies of Industry 4.0

Appearance	Industry 4.0 technology	Target audience		
		Top managers	Policy	Researchers
		(Rüssmann, et al., 2015)	(Davies, 2015)	(Fettermann, et al., 2018)
Digital world	Internet of Things (IoT)	X		X
	Cloud computing	X	X	X
	Big Data (analytics)	X	X	X
	Simulation and modelling	X	X	X
	Virtual and augmented reality (VAR)	X	X	X
"Glue"	Sensors (including GPS)			
Physical world	Additive manufacturing (3D printing)	X	X	X
	Automation and Industrial Robotics	X	X	X

Literature review

The literature review is organized around the topics of strategy, technology and organization.

Strategy

Several papers argue that a shift in strategic orientation is required to drive a more effective implementation of new technologies (Lewis and Boyer, 2002), or that at least adoption strategies and firm-level business strategies need to be aligned for the successful implementation of any new technology (Kotha and Swamidass, 2000). Nevertheless,

recent findings suggest that this issue requires further verification, as the link between strategy and technology adoption is not always straightforward (Lucianetti et al., 2018). This is especially true in the case of the newly emerging I4.0 technologies and methods.

When introducing changes on the operational level, especially changes that require the application of new technologies, two important issues are discussed in the literature. The first aspect concerns whether the strategic planning is proactive or reactive (King and Teo, 2000). Proactive strategies imply that the company takes an active role in strategic innovation, seeking to introduce new processes or products ahead of competitors with the aim to seize arising opportunities and obtain a competitive advantage on the market. Reactive strategies mean that a company takes a passive role in strategic innovation, changing its strategic behaviour to comply with external pressures, react to the changes observed in the environment or to respond to challenges posed by its competitors.

Another aspect related to the strategic implications of new technology adoption concerns the extent to which a strategic planning process is formal or informal (O'Regan and Ghobadian, 2002). Formal strategic planning represents an iterative, comprehensive and systemic approach by which the management of the company analytically determines a strategic direction for the organization. On the other hand, informal planning relies only on the past experience and intuition of an organization to make decision regarding the future. This distinction is closely related to the top-down and the bottom-up nature of operations strategy formulation. While top-down strategies are a result of a formal, hierarchical planning process, bottom-up strategies are a result of the knowledge accumulated with the daily activities of an organization (Slack et al., 2010).

Thus, in order to classify strategic approaches to I4.0 implementation, at least two aspects need to be taken into consideration: (1) the reactive or proactive nature of strategic planning, and (2) the formality of strategic planning which is closely linked to the top-down or bottom-up nature of strategy formation.

Technology related concepts

The aim of the use of I4.0 technologies and the focus of I4.0-related company efforts can vary significantly. We introduce three different approaches to classify technologies.

The maturity of the technologies

Since sporadic application of I4.0 technologies will not lead to an organisational renewal, it is usually suggested to develop a strategy which builds on the interplay of many core I4.0 technologies (Ghobakhloo, 2018). However, core I4.0 technologies are at different stages of maturity. We assess the maturity of the core technologies based on the hype cycle of emerging technologies by Gartner (Gartner, no date). The annual hype cycle defines the actual stage of many emerging technologies alongside the following phases of a "life cycle": innovation trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment, plateau of productivity. Furthermore, the analysis also predicts the time horizon when the specific technology arrives at the plateau of productivity phase. To assess the maturity of the eight I4.0 technologies we have reviewed the Gartner analyses on emerging technologies for three selected years: 2009 (Hutch, 2009), 2013 (Gartner, 2013), and 2018 (Panetta, 2018) (Figure 1).

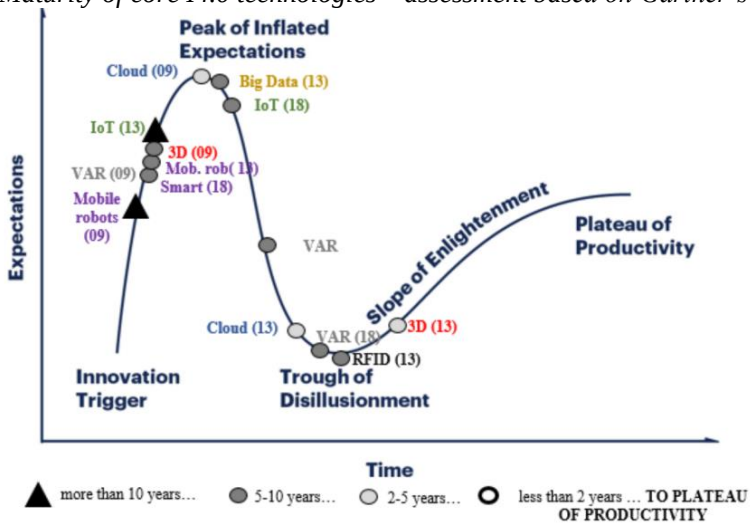
To assess a specific technology, we have looked at its appearance (yes/no), the date of appearance and the predicted year of arriving at the plateau phase. The eight technologies can be classified into four groups:

1. Long history and well-known technologies: simulation and modelling and sensor technologies were not mentioned on the hype cycle at all. While these

technologies have long history, other I4.0 technologies (e.g. IoT, big data) can leverage the applicability of them.

2. Mature I4.0 technologies have appeared a decade ago and are predicted (by different analyses) to have already arrived at plateau phase. Cloud, 3D and RFID belong to this group.
3. Several well-known technologies (IoT, VAR, smart robots) belong to the emerging group that will arrive at the plateau stage in the long term.
4. Big Data lies between the latter two groups. Despite its shorter history, it is predicted to be productive application at the start of the next decade.

Figure 1 – Maturity of core I4.0 technologies – assessment based on Gartner's hype cycle



Source: (Hutch, 2009) (Gartner, 2013) (Panetta, 2018)

The implication of technology on work force

Based on the implication of technology on work force Acemoglu (2017) differentiates replacing and enabling technologies. Enabling technologies are conceptualized as "*augmenting the capabilities of some workers and enabling them to perform new functions, increasing their productivity*" (Acemoglu, 2017, p. 4). Replacing technologies are "*explicitly replacing labor in some tasks*" (Acemoglu, 2017, p. 5). Robots usually impact repetitive tasks both in manual (industrial robot) and in cognitive (automatic order management) settings. On the long run, the promise of AI is that it might replace creative cognitive tasks.

Type of innovation boosted by I4.0

Different types of innovation can be boosted by I4.0. The most complex change is organised around business model innovation. The business model innovation considerably reshapes the relations with stakeholders, and it can also lead to the development of completely new modus operandi (eg., new processes, new competitors) in a particular industry. It necessarily relies on smart products or services that we regard as the second type of innovation. Finally, the exploitation of I4.0 in process innovation is also a viable adoption strategy. In this case the main (exclusive) aim is to make, usually internal processes of, the value chain more efficient. Manufacturing companies usually look for internal process integration and better operational performance (López-Gómez, et al., 2018). The process innovation approach is a quite narrow interpretation of I4.0.

Organisation and new organisational structure

Successful implementation of I4.0 can contribute to a long-term competitive advantage (Gilchrist, 2016). This is why the technology-organization-environment (TOE) fit of the manufacturing companies is more important today, then ever before. Tornatzky and Fleischer (1990) developed the TOE framework, which explains on the organization-level that three different elements of a firm's context influence adoption decisions and process. These three elements are the technological context, the organizational context, and the environmental context. All three are posited to influence technological innovation, which impacts directly the long-term profitability of a company.

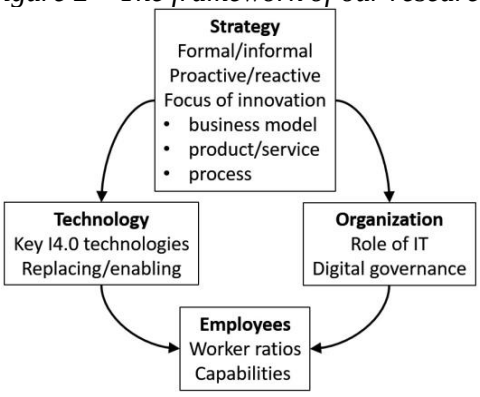
Operations management (OM) literature has researched both the technological level, and the environmental level, while we have little knowledge on the organizational perspective (Baker, 2012). Andersson and Tuddenham (2014) claim that organizational structures are rigid, therefore cannot change as fast as the digitalization process would make it necessary. They argue that digitalization should be part of a reinvented IT function, as it changes the demands on IT. These changes highlight the need for a new organizational governance in which the digitalization has a greater role. While this has regularly been claimed in the context of discussions on IT's strategic value in firms, it is seldom achieved (Legner et al., 2017; Andersson & Tuddenham, 2014).

A companywide successful digitalization project is driven by the CEO and business leaders, who consider it as one of their top priorities and not just as an "IT effort" (Andersson & Tuddenham, 2014). However, in order to meet the challenges of digitalization, the IT function must undergo a "*change that comprises new models of internal organization as well as new forms of collaboration and alignment with business departments*" (Legner et al., 2017, p. 307).

The research framework

Based on the literature review we developed a framework to grasp the key issues in an I4.0 transition.

Figure 2 – The framework of our research



Research methodology

We collected data from three companies in Hungary working in the automotive and electronics industry based on a uniform case study protocol. Companies were selected by convenience and based on their commitment to I4.0. Our interviewees were managers (manager of digital department (if applicable), senior manager, project managers) who could provide information on these topics. Interviews were recorded and transcribed. We also processed publicly available information, student works and company documents.

Table 2: The sources of data

	Company 1	Company 2	Company 3
Interviewees	4	3*	1
Department responsible for digital project	yes, this responsibility is integrated into lean department	no (it is supported by engineering)	yes, lean department is integrated into digital engineering department
Plant visit	YES	YES	Planned in future
Public documents	YES	YES	YES
Supervisory work of the co-authors at company / previous research project at the company	YES / YES	NO / YES	YES / NO

* 5 additional interviews at other subsidiaries of the company.

We apply the developed framework for single cases, and then we synthetize the information in the cross-case analysis to identify the specific characteristics of I4.0.

Case descriptions

Each case units' main business activity is to assemble electronic parts for the automotive companies in TIER1/2/3 positions. The business measures of the case units have improved considerably in recent years due to: (1) soaring production volumes in the European car markets, (2) accelerating offshoring towards Eastern European countries in the automotive industry, and (3) the increasing share of electronic parts in cars.

Company 1

C1 is part of a market leader global company with American roots, currently headquartered in Switzerland. The global company produces half a million different precision products in approximately 100 plants, with 70,000 employees worldwide. The subsidiary operates with 1500 employees in Hungary in the transportation solution business line that belongs to the automotive division and the EMEA region. The product variety, size differences and volumes are all at high level in the plant.

C1 had its first experiments with I4.0 in 2012 with the lead of its lean department. They placed thousands of sensors in machines to increase the machine connectivity level. Their first projects were the electronic andon and the digital dashboard in the production area. In 2014 the automotive division in the EMEA region had a workshop, where they collected the potential processes to improve, 160 processes altogether. The clear objective was to address process efficiency and costs. The Hungarian subsidiary became one of the two pilot plants due to its ambitious lean manager. They started new projects, such as the operator learning management system (OLMS) for operators' training, the e-QCPC (electronic quality control process chart) by digitizing and enhancing the existing QCPC system. The lean department has employed some IT experts to support these developments. They also have had pilots in predictive maintenance, understanding big data, but achieved limited progress so far. They received a 3D printer for metal to produce products for the aftermarket on this machine. The company has its own internal cloud. In 2016 the global division decided to organize a 6 weeks strategic meeting with the help of a big consulting company to prepare the digital strategy for the division, with a roadmap and a digital governance model.

In the digital governance model, the global division has a digital leader leading the so-called regional champions. Champions work with regional accelerators, 3 in the EMEA region, each of them is an expert in a specific I4.0 technology. In local I4.0 projects a) a subject matter expert (SME), knowing the area of intervention, b) a local accelerator, familiar with the digital technologies c) a project manager, usually someone from the lean

department, work together. A local digital champion represents the management and coordinate the work of the three experts. The subsidiary provides data analysis and SCRUM training for experts and project managers.

C1 involve employees into the developments (e.g. they can participate in designing the screen for the dashboards), provide online trainings, give rewards for ideas and contribution. The I4.0 applications support decision making (dashboard, eQCPC) and training (OLMS), increase visibility and transparency (dashboard), and hopefully will reduce costs in the future (predictive maintenance, 3D printing for small batches). All these efforts currently need more employees, especially engineers and IT experts.

Company 2

C2 is a Hungarian headquartered electronic manufacturing services (EMS) company, listed on the Manufacturing Market Inside' (MMI) EMS TOP50 list. Almost half of its turnover comes from the automotive segment. In the last few years, the segment have considerably improved its relative share in the turnover. The company have many subsidiaries. These subsidiaries are run by independent top managers with strong control from the HQ. At the company, we investigated two large subsidiaries (1000+ employees respectively). In this paper we use information from the automotive subsidiary.

Regarding process innovations, C2 is committed to lean management and recently to I4.0. However, given that subsidiaries have high degree of independence, no formal strategy or coordination exists for the deployment process. Until now, one meeting for top managers at the HQ was organized around I4.0 in 2018. The managers at all levels of the company share a "conservative" investment policy. It means that investments are usually triggered by specific customer request and short-term returns are expected.

C2 is in TIER2/3 position. High variety and low volume products give most of the product portfolio. The production processes rely largely on manual work. Only a few products are assembled in large volumes that are produced on automated production lines.

The subsidiary started its traceability system on a specific customer request several years ago. For today, this system has turned into a basic MES system. It's a monitoring system that covers automated processes and machine-based workstations in the assembly. However, there are still stand-alone stations, not connected. In the future the subsidiary could resolve machines connectivity and the integration of further internal functions (e.g., logistics). The subsidiary has developed the system on its own due to cost and independency/flexibility considerations exploiting internal programming know-how. Although, the initial trigger has come from a buyer, the upgrading of MES has been continuous due to functional managers' and supervisors' needs.

A few years ago the subsidiary launched an assembly robot on a high runner work station with the support of an integrator supplier. The robot replaces two operators per shift. Relying on M2M communication the assembly robot arm orders the next robot arm to select the scrap. At C2 this assembly robot is regarded as "automation" not as I4.0.

At C2 level the engineering department manages the I4.0-minded projects. This department is led by the chief engineer and by the head of new product introduction (NPI) group. The installation of the robot has delayed considerably despite having an integrator supplier. The potential installation of further robots is constrained by the product portfolio (low proportion of high runners) and in the case of some product the tolerance levels of input materials and shortcomings of product developments cause also difficulties.

Company 3

C3 is a subsidiary of a large automotive supplier, with more than 1000 employees. C3 is in TIER 1/2 position depending on the product. Its short-term plan is to double the

turnover without further increase in the number of employees, so they fully exploit the potential of the digital factory concept. The unit devotes its efforts to process innovation.

The company developed a division-wide Industry 4.0 strategy (digital factory concept). The digital factory is embedded into a high-tech IT context and it also assumes experts with proper digital skills. KPIs are developed to motivate and measure the advancement of the I4.0 applications. The strategy differentiates the I4.0 technologies and applications based on the proposed roll-out period. Robots (cobots, AGVs), additive manufacturing, shop floor management and reporting systems have been integral parts of operations for the recent years. C3 has installed dozens of robots. At the beginning it worked with integrator, today C3 has the installation competence. 3D printers (more than 10) are in daily use for non-production materials within the unit. Digital reporting system utilize the data collected by an extended MES system that covers production and logistics and integrates also information of other business functions (e.g., HR, development plans). The company has several centres of excellence that act as internal consultancy units. These units develop and test specific applications and then help the company-wide roll-out process. Beside the central initiatives there are minor I4.0-minded experimental pilot projects in the preparation phase (e.g., drone, gloves).

The deployment of the central I4.0 strategy is supported by a new department (digital engineering). The department has more than 20 employees and it has integrated the lean group as well. The digital department's main focus is on robot technology. IT department also has a crucial role in digital transformation, e.g., it has developed the MES system, the basis for reporting and BI.

The widespread impact of digital transformation has necessary influence on employees. The assumption is that successful digitalization strategy relies foremost on people. Training materials have been developed and skill matrix is also extended to digital competences.

Cross-case analysis

In order to compare our cases, we organized the key information into Table 3. Due to space constraints we cannot explain the table here.

Table 3 – Key I4.0 related information from case companies

Aspects	Company 1	Company 2	Company 3
Strategy	Start: informal, bottom up, Now: formalized, mixed	No formal strategy	Now: formalized top down
Type of innovation	Process improvement in manufacturing	Process improvement in manufacturing	Process improvement in manufacturing and internal material flow
Technologies	*Mainly enabling* Sensors, partial IoT, own cloud, (big) data solutions (dashboard, OLMS, eQCPC) and pilots (predictive maintenance), 3D printing	*Enabling and replacing* MES, robot	*Mainly replacing* Robot, simulation, drone (pilot)
Organisation	Start: loose network of unit's (experiments) Middle: coordinated efforts bw plants (pilot factories, roll-outs) Now: global and local digital governance (digital strategy and deployment)	Engineering department and NPI	Now: Digital department at the unit Center of excellence group (central digital strategy with KPIs)

Implication on the workforce (*type of task impacted*)	*Cognitive/manual, repetitive* (eQCPC, dashboard) *Cognitive, creative* (big data) No reduction in workforce Capability development (OLMS, SCRUM, data analysis)	*Cognitive, repetitive* (MES) *Manual, repetitive* (robot) Very limited impact (18 employees)	*Manual, repetitive* (robot) *Cognitive/manual, creative/repetitive* (simulation) Capability development (extended skill matrix, robot programming)

Discussion and conclusions

In our paper we developed a framework to grasp the main features of I4.0 transitions through three case studies. Based on our experiences we can draw some conclusions.

First, we found a limited approach towards I4.0 technologies, focusing only on process development in manufacturing and material flows, similarly to López-Gómez, et al. (2018). Results do not support the predictions made by consultancy reports (e.g. Rüssmann et al., 2015). This fact might be due to the positions of case companies in the supply chain (assemblers).

Second, all the efforts companies make are not about competitive advantage (at least yet) as explained by King and Teo (2000) or Gilchrist (2016). This is more about staying in competition and searching for opportunities for improvement. Even the best companies can only be considered as early adopters. Competitive advantage would be related more to product innovation or new business models, but our case companies serve the low-cost direction. It might be a context specific result though, and Western European companies – even within the network of our case companies – follow different path.

Third, consistently with the second finding, mainly mature technologies are in use, and there are only some limited experiments with others. High runner products are in focus. MES system and IoT could be the basis of Big data analytics serving better decisions, but they aren't yet. The lack of technology standards is a big constraint.

Fourth, digitalisation is "integrated" into business as usual operations, adjustments were made to provide the fit; but it did not transform the culture (Legner, et al, 2017). Companies develop digital governance structures that fits into the existing structure. It does not bring a considerable shift, it is "just" a new department. The level of structural change is made according to the level of changes. Less change (C2) does not require even a new department, bigger change (C1) gradually results in new structures.

Fifth, replacing technologies bring good and easy to estimate returns, while for enabling technologies business cases should be developed. However, enabling technologies bear the potential to transform from reactive to a proactive unit and can provide real productivity increase (Acemoglu, 2016, 2017).

Sixth, our case companies developed cooperation with technology providers and consultancy agencies, acquired start-ups if needed to get access to knowledge and develop their own capabilities. For small companies it is not an option.

Since we are currently in the data collection phase, it is still too early to formulate deeper conclusions.

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Using machine learning to improve manufacturing: Proposing and validating a data-driven framework

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Abstract

This paper proposes and validates a data-driven framework for production improvement. We take advantage of the latest developments in machine learning to address the complexity of today's manufacturing systems. Our approach models data from the entire manufacturing process chain in a factory to get a deeper understanding of how certain production factors affect product quality. We experimentally validate our framework at a semiconductor manufacturer and detect both known and unknown process problems. Our approach significantly reduces the fault detection time and provides insights where traditional methods fail.

Keywords: Data-driven production improvement, machine learning, SHAP value method

Introduction

Due to increasing automation and connectivity, modern production systems generate an enormous amount of data. Creating knowledge from these data assets enables superior decision making and can therefore help to gain a competitive edge (Harding *et al.*, 2006; Tao *et al.*, 2018). However, the vast increase of data complexity in today's manufacturing systems can be overwhelming and as a result most producers fail to capitalise on their data richness (Kusiak, 2017). Over the past years, companies have invested heavily in their IT infrastructure and adopted statistical process control techniques, leading to improved control and lower process variability (Heim and Peng, 2010). However, in the era of big data, traditional statistical methods are no longer enough to analyse complex production data, which is characterised by high dimensionality, sparsity, and multicollinearity. Guha and Kumar (2018) argued that companies should build profound capabilities in big data analytics to compete effectively in the future.

Data mining can help to address this challenge by identifying valuable information in large datasets. In data mining, algorithms are employed to discover hidden patterns in complicated data structures and to predict future events. Compared to statistical data models, algorithmic models can provide a higher predictive power, allowing for more robust and generaliseable conclusions (cf. Breiman, 2001). Also, predictive analytics can

be essential for building and testing theories (Shmueli and Koppius, 2011). Choi *et al.* (2018) suggest that algorithmic modelling is one of the most important research developments in the operations management field. However, despite its significance, big data analytics has received too little attention from the operations management society (Feng and Shanthikumar, 2018). Especially in manufacturing, computer scientists and engineers, whose contributions mostly focus on industry-specific applications, have dominated this important area of research.

In order to elucidate how machine learning can aid production improvement, this paper addresses the following research question:

- How can machine learning algorithms identify quality drivers from complex manufacturing data?

Encouraged by Feng and Shanthikumar's (2018) call for research, we contribute to the literature and practice of operations management by proposing and validating a data-driven framework that exploits untapped potentials for production improvement. The framework can consider data from the entire manufacturing process chain in a factory and implements an explainable machine learning concept to overcome the shortcomings of current methods. The principle of the framework is to model production factors, such as process parameters and sensor measurements, to investigate their impact on product quality. Since the developed approach is generic and flexible, it is applicable in any manufacturing sector with a high degree of automatic data capture (e.g. semiconductor, pharmaceutical, plastics, or metal industries). To validate our approach, we apply it at ABB Semiconductors, a producer of high power semiconductors.

The remainder of this paper is structured as follows. In section 2, we conduct a thorough literature review to answer our research question. Thereafter, we outline our data-driven framework (section 3) and describe the research setting at the case company (section 4). Section 5 presents the obtained model results and identifies quality drivers. In section 6, we discuss the developed approach and elaborate on implications for the future of operations management. Finally, section 7 summarises the main findings and concludes the paper.

Literature review

Two different streams of literature are particularly relevant for this paper. Firstly, we study the literature on machine learning applications in operations management to map our research domain and evaluate the current state of knowledge. Secondly, we review the directly related computer science and engineering literature on machine learning in production improvement tasks. As this work focuses on quality driver identification, we do not cover publications on predictive maintenance.

Operations management literature on machine learning applications

Operations management research on machine learning applications has been predominantly concerned with demand forecasting. For example, Ferreira *et al.* (2016) showed that bagged regression trees provide better demand predictions than traditional regression techniques. Also Cui *et al.* (2018) emphasised on the superior performance of machine learning algorithms, especially when dealing with high-dimensional data. The paper studies the operational value of social media information when predicting the aggregate daily sales of an online retailer. The study showed that social media information can improve sales forecasting and that complex machine learning algorithms, such as random forests and gradient boosting machines, outperform linear regression models.

Similar research was conducted by Lau *et al.* (2018), who designed a big data analytics methodology using a parallel aspect-orientated sentiment analysis for demand forecasting. The authors improved the overall model performance by mining customer-generated content and applying a co-evolutionary extreme learning machine. Carbonneau *et al.* (2008) studied the application of machine learning algorithms, including neural networks and support vector machines, to forecast demand in distorted supply chains. Neural networks have also been used by Chong *et al.* (2017) to predict the sales of electronic products in an online marketplace.

Compared to demand forecasting, other application areas of algorithmic modelling, like manufacturing, have received less attention in the operations management literature. For example, Saraiva and Stephanopoulos (1998) developed an exploratory data analysis approach with an interval-based optimisation framework to improve processes. The authors demonstrated the applicability of their methodology in four industrial case studies. Another example was provided by Ghosh and Maiti (2014), who proposed a machine learning framework based on the Define-Measure-Analyse-Improve-Control (DMAIC) methodology. The concept was applied in a foundry process and revealed significant cost saving potentials. Nevertheless, both of the aforementioned papers apply methods that no longer correspond to the state-of-the-art of machine learning.

Technical literature on machine learning applications in production improvement

Several technical articles apply algorithmic modelling to enhance both product and process quality in manufacturing (cf. Köksal *et al.*, 2011). Li *et al.* (2017) applied an extreme learning machine to optimise an iron ore sintering process. Ronowicz *et al.* (2015) implemented a regression tree to understand how different process parameters affect the pellet sphericity of medicinal products. Lian *et al.* (2002) also used a tree-based algorithm to diagnose variations in sheet metal assembly. Tsai (2012) used a self-organising map, k-means clustering, and a decision tree to infer solder defect patterns and to predict quality at an electronics producer. Ozcelik and Erzurumlu (2006) employed a neural network to model warpage in an injection moulding process.

Also in the semiconductor manufacturing industry, there is a range of papers that apply machine learning to improve manufacturing processes and product quality. Weiss *et al.* (2016) applied a selection of algorithms (e.g. boosted trees, support vector machine and a hidden-Markov-model-based method with lasso regression) to predict the final speed of microprocessors. The authors conducted an experiment with real-time production data and successfully identified 125 wafers with abnormal speed. Based on the predictions, it was possible to adapt the manufacturing process and to correct 25 wafers to normal operation. Skinner *et al.* (2002) discussed the advantages of using classification and regression trees to model and analyse wafer probe test data. Chien *et al.* (2013) proposed a framework based on principle component analysis, clustering, and decision tree algorithms to detect abnormal wafers from process data. A hybrid data mining approach was also employed by Hsu and Chien (2007), who extracted defect patterns from wafer bin maps. Chien *et al.* (2007) used k-means clustering and a decision tree to infer root causes for process faults from semiconductor manufacturing data.

While all of the listed papers clearly contribute to their respective application area, they tend to focus on specific industry segments. A more generic approach that can be applied in various manufacturing industries was introduced by Chen *et al.* (2005). The proposed method employs a rule-mining algorithm to analyse correlations between damaged products and the used production equipment. However, the presented approach neglects the fact that also other factors than the machine path can affect product quality. Therefore, critical production factors might remain undiscovered. A machine-learning-

based concept that considers both product characteristics and process parameters was provided by Wuest (2015). The author's theoretical construct incorporates data from multiple manufacturing processes to identify quality drivers. Nevertheless, the proposed method has a limitation. The applied support vector machine algorithm only determines global variable importance. For this reason, the respective influence of a given production factor on product quality cannot be explained sufficiently.

Implications for framework development

The literature review above provides two important implications for the development of our data-driven framework for production improvement. Firstly, it highlights that machine learning algorithms are suitable for identifying critical production factors from complex manufacturing data. Nevertheless, we find that previous research has not managed to handle the trade-off between model performance and explanation sufficiently. Getting a deeper understanding of the underlying variable relationships is a prerequisite for improving both product and process quality. Secondly, we discover that most manufacturing-related papers are published in technical literature and focus on a specific industry. This finding is consistent with the criticism of Feng and Shanthikumar (2018), who state that the big-data-related contribution of the operations management society has been insufficient. With this in view, we identify that there is a need for machine learning methodologies that are both practical in an operations context and independent from a specific industry segment. This work seeks to close this literature gap by developing a generic framework based on state-of-the-art machine learning methods.

Data-driven framework

The framework consist of the following three phases: (1) Data preparation, (2) data mining, and (3) in-depth analysis of variable relationships (Figure 1). The first phase provides a guideline on acquiring relevant manufacturing data for the subsequent data mining process. In the second phase, a gradient boosting algorithm is trained to explicitly learn the underlying relationships between production factors and product quality. The third phase assesses these relationships and identifies critical production factors. The derived insights can then be used to initiate production improvement measures.

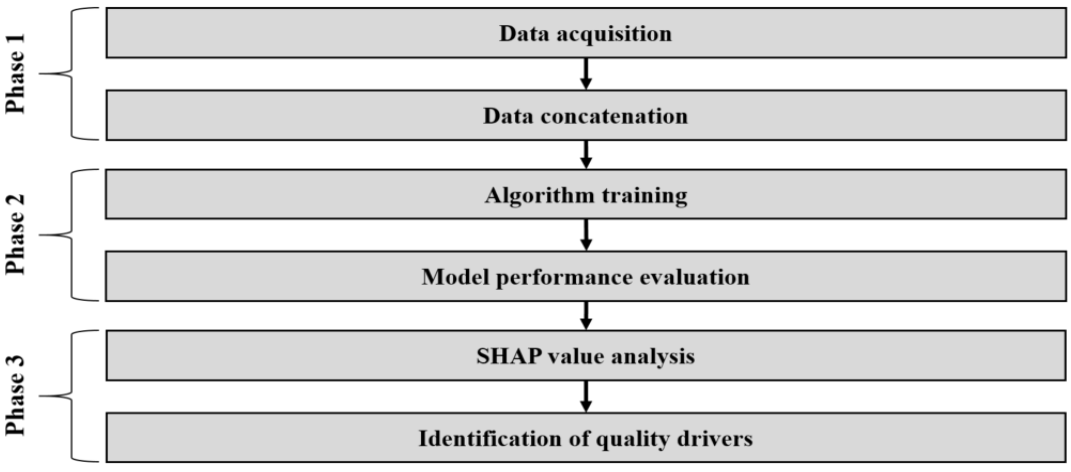

Figure 1 – Data-driven framework for production improvement

Phase 1: Data preparation

To model the interactions between fabrication processes, it is necessary to analyse manufacturing systems holistically (cf. Wuest, 2015). Figure 2 illustrates an example of a manufacturing system where the production factors are independent variables and the product quality is the dependent variable. Within our framework, we suggest to collect data with regard to the following four categories: (1) Operation history data, (2) environmental measurements, (3) product measurements, and (4) quality data. Operation history data (OH) concerns machine trace data and timestamps. Ideally it can be determined which equipment (EQ) has processed a specific product at a certain time. The corresponding timestamps allow computing the operation duration (OD) and the queue time (QT) between two processes. Product measurements (PM) collected during the manufacturing process describe the corresponding product properties. Environmental measurements (EM) comprise machine measurements and other environmental factors such as temperature. The dependent product quality (Q) can be defined through measurements, yield percentages or categories (e.g. pass and fail). Once the data from the four framework categories has been acquired, it must be merged into a single dataset.

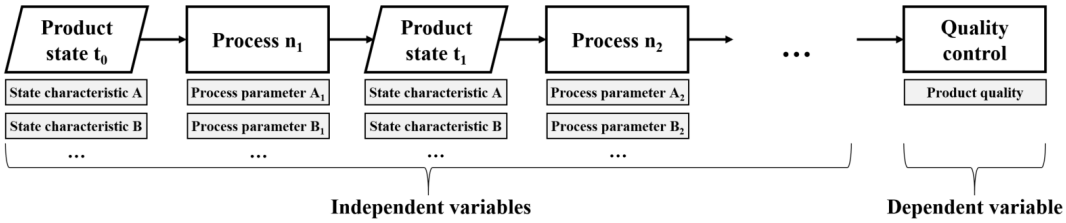

Figure 2 – Independent variables and dependent variable in a manufacturing system; system view notation adapted from product state concept (Wuest, 2015)

Phase 2: Data mining

When modelling the previously acquired manufacturing data to identify potential quality drivers, there is a need for an accurate and explainable model. However, satisfying both conditions is subject to the following conflict: While simple (and interpretable) statistical methods tend to have a poor fit with high-dimensional data (Cui *et al.*, 2018), complex algorithms such as neural networks are black box models (Waldrop, 2019). To overcome this drawback, we integrate an implementation of Friedman's (2001) gradient boosting framework in combination with the novel SHAP (Shapley Additive Explanations) value method by Lundberg and Lee (2017). Boosting algorithms are known for performing well on complex datasets and have already been employed in other manufacturing-related applications (e.g. Weiss *et al.*, 2016). To prevent overfitting and misleading conclusions, it is required to evaluate the algorithm's predictive performance. Only if the model performs well on out-of-sample observations, it can be ensured that the learned variable relationships are accurate.

Phase 3: In-depth analysis of variable relationships

As previously mentioned, it is considerably difficult to explain sophisticated models such as gradient boosting machines. The SHAP value method resolves this issue by making use of additive feature attribution. The underlying idea is that a complex model can be approximated by a simple explanation model. SHAP values can be interpreted as the marginal contribution of a variable to the overall model output. As SHAP values are derived for each observation separately, they allow to explain model behaviour on both a global population and the individual observation level. For further details, see Lundberg

and Lee (2017). Within our framework, we compute SHAP values for each production factor to understand its impact on product quality.

Research setting and data

Our case company belongs to a large conglomerate and is one of the leading producers of high power semiconductors. The proposed machine learning framework is validated by using wafer fabrication data from a complex transistor product. The company collects batch-level data according to all four data dimensions of our data-driven framework. The final dataset contains more than 6,000 independent variables from 191 processes and 1,916 production lots (Table 1). In order to protect confidential company information, the data has been anonymised. The dependent variable is a binary variable, which describes an electric quality parameter that causes more than 20% of all product failures. If a batch exhibits desirable quality properties, it is labelled as 1, otherwise as 0. The aim of our machine-learning-based analysis is to learn which specific production factors cause good (1) and poor (0) product quality. In order to ensure unbiased research, the case company did not disclose known process problems in advance.

Table 1 – Tabular structure of final dataset

Batch ID	P1-EQ	P1-OD	P1-QT	P1-PM1	P1-EM1	…	P191-EQ	P191-OD	P191-QT	P191-PM1	P191-EM1	Q
B_1	EQ_1	127	950	0.01	1,204	…	EQ_3	1,503	430	15.21	886	1
B_2	EQ_2	150	874	-	1,530	…	EQ_1	1,497	692	-	953	1
…	…	…	…	…	…	…	…	…	…	…	…	…
B_{1915}	EQ_3	139	934	0.13	-	…	EQ_2	1,511	3,051	14.14	859	0
B_{1916}	EQ_1	153	901	0.31	1,134	…	EQ_2	1,501	103	15.13	403	1

Identification of quality drivers

The model's predictive performance is evaluated with the area under the receiver operating characteristic curve (AUC). The hyperparameters of the algorithm are tuned with Bayesian optimisation and early stopping. To prevent overfitting, which can occur if the same data is used for both model tuning and evaluation (Cawley and Talbot, 2010), we randomly sample 80% of the data for model tuning and training. We perform a 5-fold cross-validation (CV) on the training dataset to select the optimal hyperparameters. Then we train the final model on the entire training data and evaluate it on the holdout dataset.

The implemented model performs well on the holdout dataset and no overfitting is detected (Table 2). In order to identify the critical production factors we conduct a SHAP value analysis of the top ten quality drivers (Figure 3). Each SHAP value represents the quality impact of a production factor (see y-axis) corresponding to a specific product observation. Positive SHAP values are associated with good product quality, whereas negatives ones suggest poor quality. The vertical dispersion in the plot indicates the density of product entities with similar SHAP values. We identify that four processes (P5, P159, P180, and P182) drive the product quality.

Table 2 – Model performance evaluation

Mean AUC (5-fold CV)	Std. dev. AUC (5-fold CV)	AUC Holdout Dataset
0.934	0.014	0.923

Process P5 has the largest impact on yield, as five of the ten most important quality drivers are associated with this process. It can be observed that missing values (grey data points; modelled as features) with regard to the P5_PM1, P5_PM2, P5_PM3, and

P5_PM4 measurements have a positive impact on product quality. Four different machines can perform process P5, yet, only three of these machines collect the four measurements of interest. In this particular case, the missing values are an indirect indicator that the machine that is not collecting the measurements has superior performance. Furthermore, high values of P5_PM1, P5_PM2, and P5_PM3 and low values of P5_PM4 affect yield positively.

In process P159, missing values concerning the P159_PM1 measurement have a positive quality impact. Similar to phenomenon in process P5, it can be concluded that machines that do not collect this measurement perform better than the others do. Moreover, high measurement values of P159_PM2 and P159_PM3 have a positive influence.

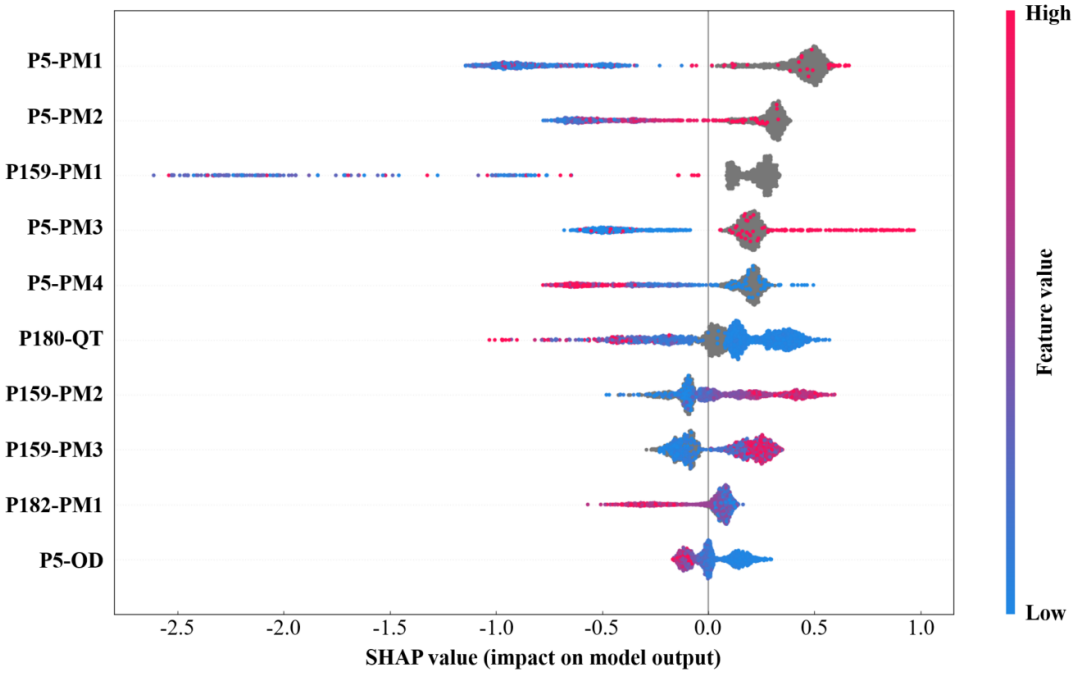

Figure 3 – SHAP summary plot for top ten quality drivers

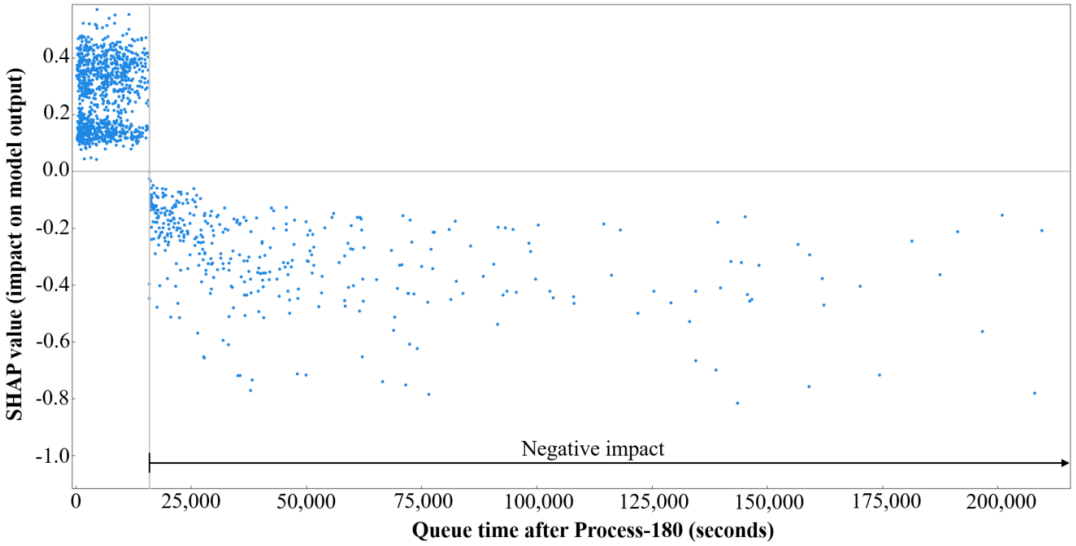

Figure 4 – SHAP dependence plot of queue time after Process-180

Another important finding is that long queue times after process P180 have a negative impact on product quality. In order to determine a critical threshold, the corresponding SHAP values are plotted against the observed queue times (Figure 4). The SHAP dependence plot implies that queue times exceeding 17,000 seconds (~4.7 hours) after process P180 decrease yield.

Discussion

Within the in-depth analysis of the variable relationships, we identified two dominant processes (P5 and P159) and a critical queue time. As previously stated, the case company did not disclose previously known process problems in order to ensure objective modelling. After the model results were available, the producer confirmed that the algorithm successfully identified two critical processes, where a set of problematic machines cause yield loss. A discussion with the product engineers revealed that three of the four machines in process P5 produce particles that induce chip failures. The damages caused in process P159 can be attributed to the loading mechanism of a specific machine type. According to the case company, the latter problem could not be detected with the company's current analysis tools and therefore it was undiscovered for a long time. In the end, the engineers recognised the process issue by conducting a time-consuming manual data analysis. Our machine learning framework immediately detected the conspicuous machines without any manual effort.

In addition to the known process issues, we also identified the queue time after process P180 as a quality driver. The critical threshold for this parameter could not have been determined with simple correlation methods. Since this specific problem was previously unknown, the reasons for yield loss are not yet explained. An educated guess is that the wafer surfaces start to oxidise if the waiting time after process P180 is too long. As an improvement measure, we suggest introducing a maximum queue time equal to the determined threshold of 17,000 seconds.

Even though our approach has proven to be both efficient and effective in locating production problems, it does not provide solutions on how to solve them. Additionally, we found that some of the identified quality drivers were only indirect indicators for process issues and the interpretation of the model output required domain knowledge. Therefore, we suggest that the human component remains crucial when using machine-learning-based methods for production improvement.

Since the title of this work is "*Using machine learning to improve manufacturing"* this work would not be complete without discussing the impact of machine learning on operations management. We believe that due to the drastic increase of data in manufacturing systems, companies must build interdisciplinary competencies. Those producers who leverage both manufacturing and machine learning expertise will gain a competitive advantage. Furthermore, we expect that data-driven approaches, such as the presented framework, will complement established production improvement programmes as well as support and inform the human problem solving process in the future.

Conclusion

In this paper, we proposed and validated a data-driven framework to improve product and process quality in manufacturing. The framework consists of three distinct phases: (1) Data preparation, (2) data mining, and (3) in-depth analysis of variable relationships. To overcome the limitations of current methods, our approach incorporates an explainable machine learning concept to model data from the whole manufacturing process chain in a factory. After the theoretical development, we applied the framework at ABB Semiconductors, a leading semiconductor producer, and uncovered several critical

production factors. The case company confirmed that the algorithm successfully identified also previously known process problems. Two of the three most important quality drivers could not have been discovered with the company's current analytics methods. Additionally, our approach reduced fault detection time and allowed determining threshold values for critical process parameters. Nevertheless, the data preparation and the interpretation of the models required human effort.

The contribution of this work is threefold. Firstly, it adds a flexible and generalisable machine learning framework to operations management literature. Secondly, it incorporates state-of-the-art machine learning methods that handle the complex nature of manufacturing data and allow for model explanation without compromising on model accuracy. Thirdly, it equips manufacturing companies with a framework that complements traditional production improvement programmes.

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Digital technologies to coordinate manufacturing networks: A Swiss pioneering perspective

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Abstract

Companies fail to leverage the full potential of their intra-company manufacturing network because many neglect the coordination layer. New technologies enable support of coordination activities for network managers. This contribution shows the status quo of technologies deployed in order to improve coordination. The basis is a national survey of the Swiss manufacturing industry. In addition, our research shows differences between companies that operate globally or locally regarding the use of these technologies. These differences relate to the structure of the manufacturing network, collaboration with third parties, customer criteria and innovation drivers. Finally, recommendations for actions are derived.

Keywords: Digital technologies, Coordination of international manufacturing networks, Coordination improvement

Introduction

The management of international manufacturing networks (IMN) is essential for the performance of a company (Cheng et al. 2011; Friedli et al., 2014; Liebetrau, 2015). Coordination is a key element in the management of IMNs (Cheng and Farooq, 2018; Ferdows, 1997a,b; Shi and Gregory, 1998). Coordination makes a significant contribution to increase efficiency and competitiveness (Rudberg and West, 2008; Szwejczewski et al., 2016; Dasu and de la Torre, 1997). However, despite the obvious advantages, many companies neglect this part of network management (Cheng and Farooq, 2018; Bitran et al., 1985).

The father of coordination, James d. Thompson, speaks of interdependencies between organizational units in complex organizations (1967). In such an environment, coordination serves to concert actions (Thompson, 1967). Generally, three types of coordination are distinguished depending on the degree of interdependence: coordination by standardization, coordination by plan, coordination by mutual adjustment (Thompson, 1967). In the sequence presented, the demands on communication and decision-making are constantly increasing (Thompson, 1967). Martinez and Jarillo (1989) distinguish between structural and formal mechanisms such as more informal and subtle mechanism. Coordination within the framework of the management of international manufacturing

networks includes, on the one hand, the degree of autonomy of the decision-making structure (Hayes et al., 2005; Mengel, 2017). In addition, the exchange of knowledge, information and resources as well as the setting of incentives are important components of coordination (Chew et al., 1990; Friedli et al., 2014).

Researchers have already dealt with the influence of IT on coordination and thus productivity (Sun, 2017; Goodhue and Thompson, 1995). Brynjolfsson and Hitt for example, state that IT can lead to an adjustment of organisational structures and, conversely, increase productivity (2000). In general, IT can be seen as an enabler of digitalisation (Vogel-Heuser et al., 2017). Digitalisation can have effects on the level of autonomy (Albano et al., 2018; Gerten et al., 2018), exchange of information (Treber and Lanza, 2018) and thus coordination (Vogel-Heuser et al., 2017). A multitude of technologies and use cases exist in regards of digitalisation (Huansheng and Sha, 2012; Morone, 1989; Torkkeli and Tuominen, 2001). The vast majority of such technologies are used to increase efficiency (Hooi and Leong, 2017; Lasi et al., 2014). Coordination indirectly increases efficiency at manufacturing network level (Colotla et al., 2003; Friedli et al. 2014).

It therefore appears appropriate to concentrate not only on technologies that directly increase efficiency, but also indirectly by means of supported coordination. Furthermore, there is a gap in research regarding the effects of digitalisation on coordination in the international manufacturing network context (Ferdows, 2018).

With this paper, we would like to contribute to the research of coordination with digital technologies in international manufacturing networks. Within the framework of this contribution, we intend to answer the following questions: Which technologies are used to coordinate manufacturing networks, what is the current implementation status in the industry and what are the prerequisites for successful deployment?

Method

The research reported in this contribution divides into three steps. In the first step, a literature review based on the concept of vom Brocke et al. (2009) was carried out. This led to the research gap mentioned in the introduction. Second, data from the Swiss Manufacturing Survey (Friedli et al. 2018) were extracted. It serves as the foundation for further investigations. Third, a comprehensive data evaluation has been conducted in order to analyse the revealed research gap. The chosen approach leads to findings which are of importance for science as well as practice.

The aim of the annual Swiss Manufacturing Survey is to identify the current situation of the Swiss manufacturing industry and to investigate long-term structural changes (Friedli et al., 2018). Within the framework of the survey, the questionnaire methodology is used as a research strategy to systematically quantify empirical facts (De Leeuw et al., 2008). Based on the research objectives (De Leeuw et al., 2008), the study provides information about organisation, employees, markets, customers, technology, innovation, global activities and performance. Observable variables were developed for operationalisation (Brancato et al., 2006). Open-ended questions were largely avoided. The target group consists of managing directors and operations managers of manufacturing companies. All types of manufacturing companies are eligible without size restrictions, but also individual business units or sites. The study cooperates with several associations in order to achieve the broadest possible picture of the Swiss companies that are considered pioneers in their sectors. Due to this cooperation, an unbiased response rate could not be calculated (Dillman et al., 1993).

For further analysis, the question "which digitalisation and Industrie 4.0 technologies have the highest and second highest potential for improving the coordination of sites" was

considered. It was compared with the question "which technologies have the highest and second highest potential for improving efficiency". For both questions and the corresponding technologies, the implementation status was checked. Based on this, the data was divided into two groups: companies with high and low implementation status. "High implementation status" comprises the upper three options on a six-point Likert scale "Working on the implementation", "Already in first use" and "Fully implemented". "Low implementation status" comprises the lower three options "Not relevant", "Observing" and "Researching and developing". Subsequently, based on this distinction, further questions were evaluated on industry, global footprint, manufacturing network, characteristics of Swiss sites, customer criteria, process innovation and digitalisation.

The selection of the technologies took place within the framework of the preparation of the study. Twelve future manufacturing technologies were selected from research in various white papers and trade journals for industry. The selection mainly contains digital technologies. The most striking features of digital technologies are the continuing exponential development of computer technology, large amounts of digital data and innovation through recombination (McAfee and Brynjolfsson, 2018). In addition to digital technologies, the selection also includes hardware-based technologies such as robotics and 3D printing. These technologies are also regarded as important drivers of manufacturing (De Carolis, 2017). Figure 1 and 2 present the entire list of technologies. The selection focuses on technologies that have the potential to improve coordination.

Due to the predominant use of Likert-scales, there are no particular conspicuous features with regard to data quality (De Leeuw, 2008). The numeric question types have no outliers. The data thus serve as a scientifically sound basis for analysis.

Results

Survey Results

The survey of companies took place between October 2017 and March 2018. In the course of 2018, 186 Swiss manufacturing companies participated. The managing directors of the companies mainly provided the information. The mechanical engineering sector accounts for the largest share with 28%, with more than eleven industries represented. 76% fall into the category of small and medium-sized enterprises and 52% are family-run enterprises. 45% of the companies have a global footprint and 37% have made changes to the global footprint in the last three years prior to the survey. In total, 158 companies have provided information on the implementation status of new technologies, which shows that Swiss companies are currently dealing with this issue.

Potential and implementation

The rankings of the most popular technologies to improve coordination and efficiency are shown in Table 1. The answers for the highest and second highest potential were cumulated, with the highest potential being given priority in the ranking.

In total, 91 of the 186 companies responded to the potential of technologies to improve coordination or to increase efficiency. Overall, more statements were made about technologies to increase efficiency. Companies value machine-to-machine communication as the technology with the highest potential for improving coordination. In order to increase efficiency, robotics is assigned the highest potential by a large margin. Three technologies can be found in both rankings, even if they are distributed differently. In general, it can be said that predominantly digital technologies have a potential for improving coordination. Whereas in the case of efficiency increases, technologies based on hardware also emerge.

Table 1 - Top five technologies to improve coordination / increase efficiency (N=91)

no.	Improve Coordination	100% (n=151)	Increase Efficiency	100% (n=161)
1	Machine-to-machine communication (M2M)	28%	Robotics	38%
2	Cloud Computing	21%	Machine-to-machine communication (M2M)	19%
3	Identification- or communication solutions (RFID, NFC, etc.)	18%	Mobile devices in production (e.g. Tablet, Smartphone)	18%
4	Mobile devices in production (e.g. Tablet, Smartphone)	18%	Big Data Analytics	13%
5	Big Data Analytics	15%	Additive Manufacturing (3-D Printing)	13%

Figure 1 and 2 show the implementation status of 158 companies regarding selected technologies. The order of the technologies corresponds to the associated potential for improving coordination. Companies that see potential in a certain technology to increase efficiency or to improve coordination generally have a higher implementation status than the average. This does not apply to the robotics area, where the average of the sample has a significantly higher implementation status.

Companies that regard identification/communication technologies, mobile devices, big data analytics and autonomous transport systems as coordination enhancing have a higher implementation status in this respect. The implementation status of digital twin technologies are on the same level, regardless whether it is considered as coordination or efficiency enhancing. Although cloud computing is not in the top five technologies to increase efficiency, the implementation status is higher for companies that consider this technology as efficiency enhancing. However, the highest implementation level, "fully implemented", is only achieved in companies that consider this technology to be coordination enhancing. Based on the findings so far, the next step focuses on those companies in detail that expect high potential in technologies to improve coordination.

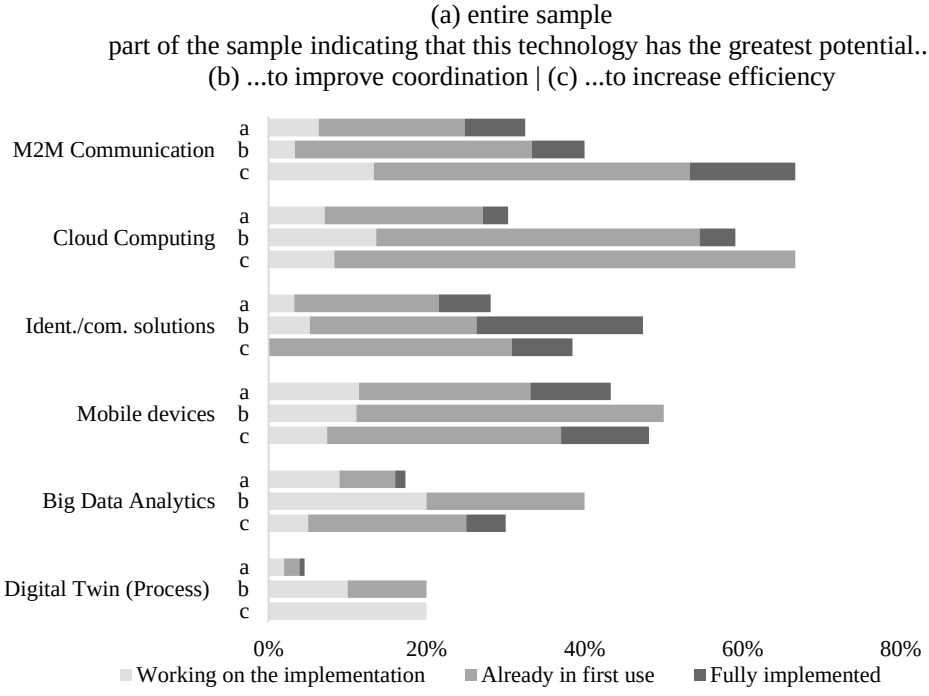

Figure 1 – Implementation status of selected technologies (no. 1-6) (N=158)

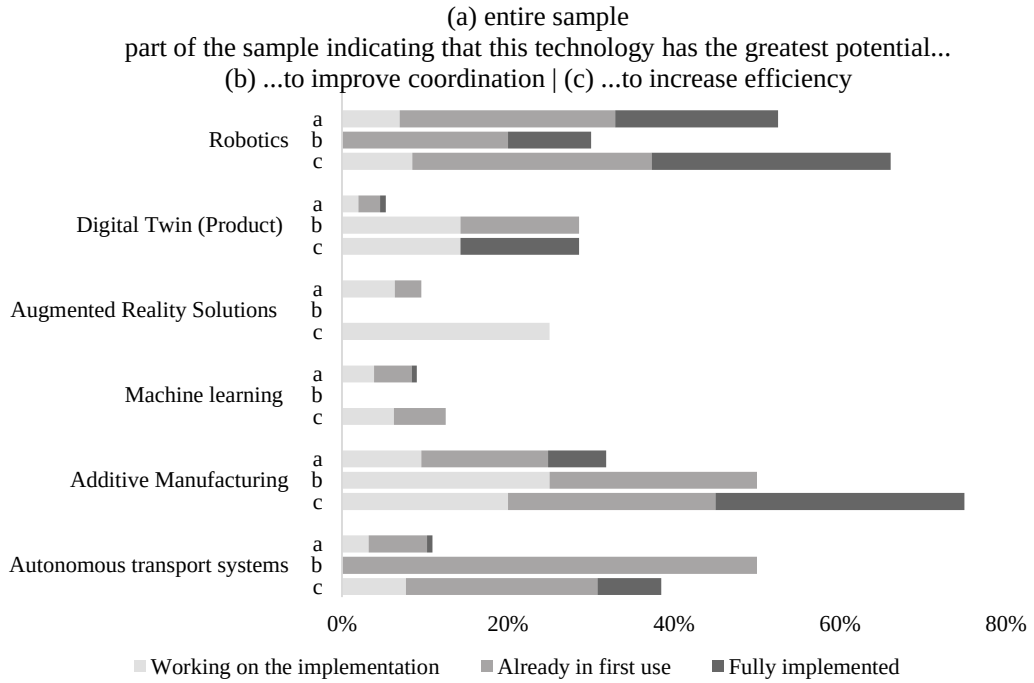

Figure 2 - Implementation status of selected technologies (no. 7-12) (N=158)

There are 88 companies that made statements as to which technology has the greatest potential to improve coordination. Those are divided into ten industries, with mechanical engineering being the largest (33%). Compared to the overall sample, the mechanical engineering sector is more strongly represented with a plus of 5 percentage points, the electrical equipment sector with additional 3 percentage points and the automotive sector with additional 3 percentage points.

The following differentiation groups companies that have either a high or low implementation status in the technology that they consider coordination enhancing. Those that have a high implementation status are called pioneers in the following. Those that have a low implementation status are called followers.

Figure 3 shows differences in the global positioning of the companies. Pioneers are clearly more global. This is reflected in three factors: Production and development sites are not exclusively located in Switzerland, adjustments have been made to the global footprint over the past three years and there is a rather high probability that activities will be relocated abroad in the next three years.

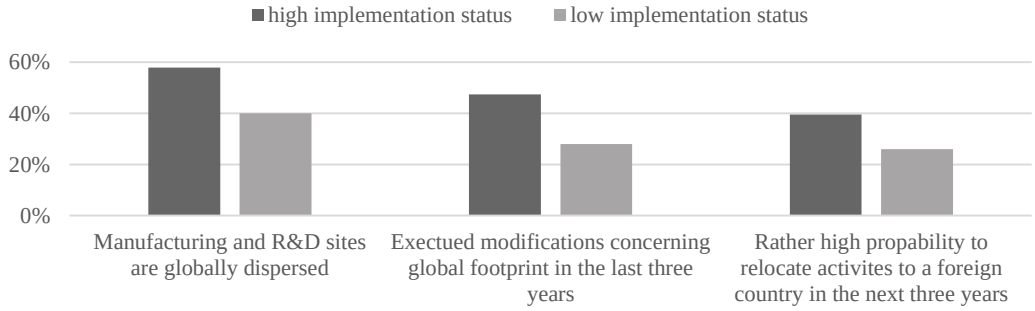

Figure 3 - Differences in the global footprint depending on the implementation status (N=88)

Global Pioneers

Since globally positioned companies tend to have a higher implementation status, it is interesting to analyse them more closely. Globally positioned companies with a high implementation status are referred to as global pioneers in the following. Those that have a low implementation status will be referred to as global followers in the following.

For global pioneers, it is noticeable that the categories "socio-economic factors", "low-cost labour" and "qualified labour" are particularly important (see Figure 4). The differences are less pronounced in the case of "economies of scale", "economies of scope" and "production volume".

Figure 4 - Importance of factors regarding the production network of Swiss global manufacturing companies (N=41)

Another interesting fact is that global pioneers assign less responsibility to Swiss locations. Global pioneers have similar competencies and responsibilities at all sites within the network. This applies to 48% of global pioneers and to only 30% of global followers. The differences are marginal in pilot production and the manufacture of complex and strategic products. E.g., pilot production in Switzerland is conducted by 70% of global followers and by 62% of global pioneers. The differences are more pronounced in global purchasing and the central interface between manufacturing and customers. E.g., in Switzerland, 70% of global followers have allocated global purchasing. In contrast, only 43% of global pioneers have allocated global purchasing to Switzerland.

Specific differences

The following section will focus on all 88 companies that have provided information on technologies with the potential to improve coordination. Consequently, both local and global companies are part of the sample.

It is noticeable that followers almost exclusively have higher customer requirements than pioneers (see Figure 5). Only with regard to service and sustainability are local pioneers exposed to higher customer requirements. Overall, delivery capability is the most important criterion for customers in the entire sample. Flexibility in volume and product design is particularly important for customers of local followers. Customers of global followers require greater geographical proximity.

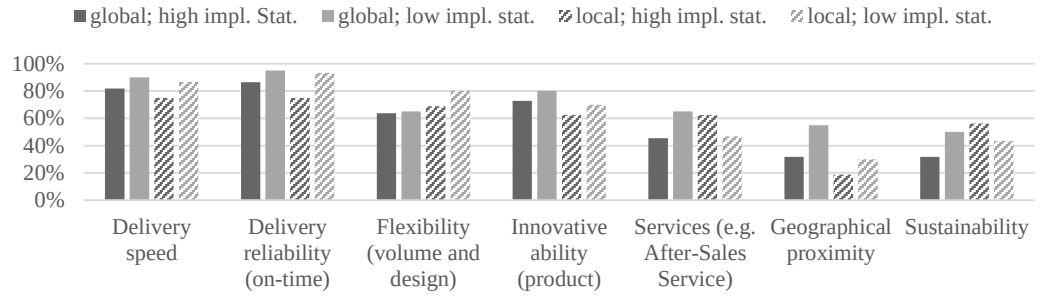

Figure 5 - Importance of customer criteria for local and global acting companies (N=88)

Most companies develop processes alone at their Swiss sites (see Figure 6). This is especially true for global followers and local pioneers. Local followers have the highest average of processes developed in Switzerland (87% in contrast to 69% of global pioneers). Global pioneers are most likely to work with third parties such as suppliers or competitors. Pioneers, whether global or local, work more likely with consultancies. Local pioneers work most likely with research institutions. The share of revenue invested in R&D is on average 8% for followers and 5% for pioneers.

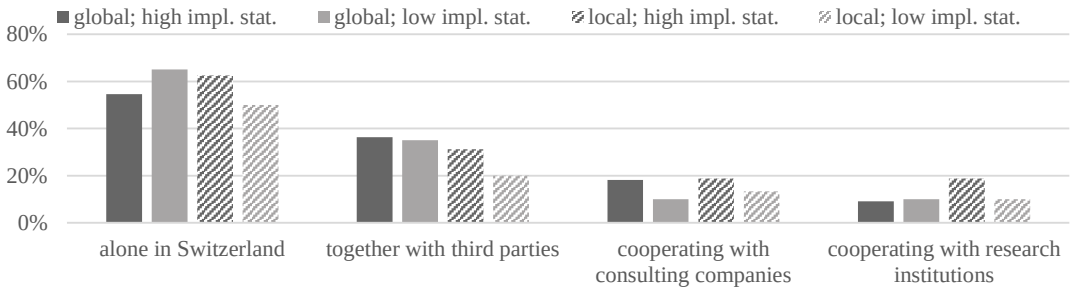

Figure 6 - Cooperation in process development (N=88)

Increasing production efficiency is the most important justification for digitalisation activities for all companies regardless of their global positioning and degree of implementation (see Figure 7). For global pioneers, it is also particularly important to offer new digital services and create new business models. Local followers agree more with all purposes rather than local pioneers. This phenomenon cannot be observed in global companies.

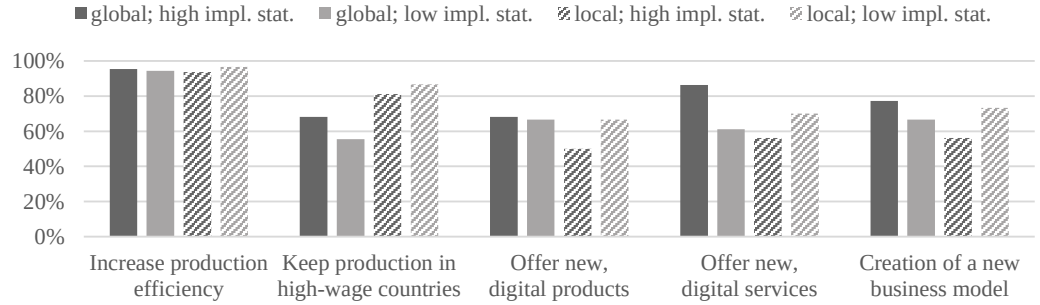

Figure 7 - Purpose of Industrie 4.0 and digitalisation activities for Swiss locally and globally producing companies (N=88)

Discussion

Potential and implementation

Overall, more statements have been made about technologies that have the potential to increase efficiency. This fits in with the statement that many companies tend to neglect coordination (Friedli et al., 2014). In general, companies tend to implement technologies that increase efficiency. Although technologies to improve coordination also indirectly increase efficiency (Colotla, 2003; Liebetrau, 2015), the effects of indirect measures are much more difficult to measure (Sun, 2017).

In contrast to the efficiency-enhancing technologies, exclusively digital technologies are listed in the top five of coordination-enhancing technologies. The digital interconnection of distributed plants in order to be able to control them effectively seems to be the primary driver here.

Global pioneers

Global companies have a higher degree of implementation because they tend to generate higher revenues, employ more people and thus have more resources at their disposal (Vaccaro et al. 2012). These resources are essential to carry out digitalisation projects. Global companies are exposed to international competition, which leads to greater pressure to find new ways to become more efficient. In general, however, globally positioned companies are more complex due to product diversity, number of customers, suppliers and other criteria (Hitt et al., 1997). This alone requires driving digitalisation in order to operate effective management. The result supports the discourse in academia that global companies are more innovative (Damanpour, 1992; Calof, 1993).

A further insight is that global pioneers are giving up responsibility in Switzerland and thus giving more autonomy to the sites distributed around the world. Those companies understand that a decentralised structure leads to higher productivity (Brynjolfsson and Hitt, 2000; Leavitt and Whistler, 1958).

Specific differences

The fact that followers are exposed to higher customer demands can may be explained by the fact that pioneers can better satisfy their customer needs and therefore attend to lower values. A further explanation would be that different levels of customer demands exist, depending on the line of business. Nevertheless, pioneers are exposed to higher customer demands for services and sustainability, as these are issues that have recently emerged.

Local companies benefit from independent development of process innovations at their Swiss locations. This does not apply to global companies. Furthermore, local companies in particular benefit from cooperation with research institutions, consultancies and third parties. Global companies tend to benefit primarily from cooperation with consultancies. Nevertheless, global companies engage in a lively exchange with third parties, this has no impact on the implementation status of new technologies.

In the context of Industrie 4.0, local followers seem to be more euphoric about the benefits of it. Global pioneers more likely expect higher benefits from Industrie 4.0 and digitalisation. However, in the case of pioneers, expectations generally appear to be somewhat more cautious and therefore more realistic with regard to direct effects.

Conclusion

There is a lack of consistent studies on new technologies in the coordination environment of manufacturing companies. At the same time, there is great uncertainty among companies as to the meaningful application of new technologies. The findings in this article are drawn from an exhaustive study of the Swiss manufacturing industry.

Furthermore, a data analysis regarding new technologies to improve the coordination of sites was conducted.

Rather digital technologies are being considered to improve coordination than hardware-based technologies. Particularly global companies are working on the implementation of such technologies. However, this raises further questions as to whether global companies are able to demonstrate a higher implementation status due to their idiosyncratic resources or whether other criteria are decisive. An important finding is that global pioneers distribute responsibility within the network and thus assign a higher degree of autonomy to individual sites. This can increase performance per se. Further research must be carried out on digitalisation, autonomy, and its effects on performance.

In summary, the research contributes to reveal the status quo of technologies improving the coordination of sites. Furthermore, it shows differences between local and global acting manufacturing companies and those who have already managed to achieve a high implementation status such as companies with a low implementation status.

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Data transfer in maintenance outsourcing relationships: The case of the Dutch public infrastructures

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Abstract

Despite the increasing amounts of data generated by disruptive technologies, such as smart sensors, the use of this data in condition-based monitoring of critical infrastructural assets is still at its infancy. One main challenge is the exchange of data between owners of critical infrastructures assets, and their maintenance contractors. Our case analyses reveal three root causes of lack of data sharing: 1) a mismatch between contract specification (i.e., provisions) and contract evaluation (i.e., KPIs); 2) ineffective incentive schemes (i.e., tied to the wrong provisions or lacking salience); 3) a lack of contractual flexibility to accommodate and facilitate data sharing.

Keywords: outsourcing, data-driven innovations, condition-based maintenance

Introduction

Neglecting to maintain critical infrastructures (such as roads, railways and waterways) can lead to catastrophic failures with widespread economic and social consequences (Frangopol and Liu, 2007). A recent example is the collapse of the Morandi bridge near Genua, Italy, in 2018 that resulted in 43 deaths and forced around 600 people to leave their demolished homes (Valkenet, 2018). The sheer scale of this disaster caused the Italian government to critically review road owners' licenses to operate, and to oblige them to make their maintenance regimes available to both the government and the general public. Another less tragic, but nevertheless impactful, example is the partial closing of the Merwede bridge in the Netherlands, in 2016, after visual inspections revealed severe signs of saturation leading to a ban of heavy vehicles on the bridge (Van Baarle, 2016). One of the reasons for lagging maintenance is that information management at most infrastructure works is insufficient to inform the responsible organisation (in time) about the state of its infrastructural works. This critical assessment of maintenance decisions in relation to missing information coincides

with the introduction of several disruptive technologies. Disruptive technologies, such as Internet of Things (IoT) devices, big data analytics, smart sensors, and cloud computing urges organisations to re-think the management of their supply chains (Harris et al., 2015). Employing these technologies allows for productivity increases, costs reductions, and quality improvements (Bălan, 2018). At the same time, these technologies also result in a massive increase in data from which valuable information can be distilled (Queiroz and Telles, 2018).

Disruptive technologies propel 'data-driven innovations' at organisations. According to the OECD, a data-driven innovation (DDI) can be defined as "*the significant improvement of existing or development of new products, processes, organisational methods and markets arising from the dynamics generated by the use of big data*" (OECD, 2015). In the context of this study, equipping infrastructural assets such as sluices and rail tracks with smart sensors provides asset managers with data that can provide (real-time) insights into the condition of assets and upcoming maintenance needs. Combining such insights with usage data and other relevant data, such as weather conditions, enables asset managers to shift towards more advanced maintenance regimes such as Condition-Based Maintenance and Predictive Maintenance (Akkermans et al., 2016; Sakib and Wuest, 2018). These advanced regimes can ultimately lead to "*improved availability of installations, reduction of failure costs and lower costs over the entire life cycle*" (Van de Kerkhof et al., 2018).

Asset managers of infrastructural networks have not adopted disruptive technologies in their asset management practices on a large scale yet (Van de Kerkhof et al., 2018). Their effective use is especially complicated due to the fact that public organisations, responsible for infrastructural networks, increasingly outsource maintenance activities to maintenance contractors. Even if asset managers would equip all their assets with disruptive technologies, those investments will not yield any benefits if the contractors fail to act upon the data these technologies generate. On top of that, utilisation of the data will, in many cases, require data from both the asset owners and the contractors. Motivating both parties to transfer data in their buyer-supplier relationship requires appropriate contractual and relational conditions.

A plausible explanation may be that, at the core, asset managers and private maintenance contractors have almost opposing interests. While asset managers aim to minimise maintenance, to lower costs and increase the availability of their assets, private contractors want to perform as much maintenance as possible, to increase their profits. Agency theory identifies this as a 'goal conflict' and suggests that goal alignment may be achieved through the use of outcome-based contracts (Eisenhardt, 1989). We build on the premise that under such contracts, suppliers will be stimulated to innovate with the aim of making their service delivery more effective and/or efficient (Sumo et al., 2016). Disruptive technologies provide important means to suppliers to achieve such innovations. Hence, it is counter-intuitive that even with outcome-based contracts, disruptive technologies are only used to a limited extent.

The aim of this paper is to determine appropriate contractual and relational conditions that can stimulate data transfers between asset owners and their contractors, as well as innovation, to enable the use of CBM in an outsourcing situation. To attain our goal, we frame our research in agency theory (Eisenhardt, 1989) and analyse the findings from four cases that involve maintenance outsourcing contracts and the introduction of disruptive technologies. Three cases are taken from an executive agency of the Dutch Ministry for Infrastructure and Water Management, responsible for roads and waterways, and one case comes from an unlisted public limited company responsible for railways.

Our theoretical contributions are twofold. First we add to the literature on performance-based contracting by highlighting how such contracts can stimulate both parties to share and

enrich data, as well as innovative behaviour. We aim to lower potential barriers and (further) enhance potential enablers. Second, studying the impact of increasing information (generated by disruptive technologies) on principal-agent relationships in a supply chain context constitutes an important contribution to the supply chain management literature (Waller and Fawcett, 2013). For managers, this paper enhances their understanding on how the use of data for the purpose of enhanced maintenance can effectively be accounted for in contracts.

The remainder of this paper is organised as follows: in the following section, we briefly review extant literature on maintenance outsourcing, and elaborate on the influence of disruptive technologies. We then turn to the notion of outcome-based contracting to develop a framework on how contractors may be stimulated to share data and to innovate. Next, we explain our research methodology before turning to our findings. This paper ends with conclusions, implications, limitations, and future research opportunities.

Theoretical background

The impact of disruptive technologies on maintenance

The maintenance literature roughly distinguishes between two types of maintenance policies: corrective and preventive (Irawan et al., 2017; Jardine et al., 2006; Tsang, 1995). A corrective maintenance policy implies that maintenance only commences after a failure occurred and/or an asset broke down (Tsang, 1995). In contrast, under a preventive maintenance policy, maintenance is ideally performed before a failure occurs, thereby preventing unexpected disruptions (Irawan, et al. 2017). Condition-based maintenance (CBM) can be considered as an example of a preventive maintenance policy, where asset managers collect data on the actual condition of assets and perform maintenance only if there is evidence of an impending failure (Jardine et al., 2006). CBM can help asset managers identify imminent problems, their nature, the time until they manifest, and where exactly (i.e.: in which specific component) they are about to occur (Tsang, 1995), thereby significantly reducing maintenance costs while increasing asset availability (Jardine et al., 1995).

The notion of CBM is not new at all. However, this concept regained significant relevance after the 2010s when disruptive technologies emerged that provided asset managers with novel ways to collect, store, analyse, and interpret condition data with respect to their assets (Sakib and Wuest, 2018). Disruptive technologies such as (smart) sensors allow the cost-efficient, real-time collection of condition data, in contrast to more costly and periodic methods such as visual inspections. As such, these technologies can support the elements of a CBM program: data acquisition, data processing and maintenance decision making (Jardine et al., 2006). For example, smart sensors can support the acquisition of condition data, while IoT devices and cloud computing can help speed up processing this data. Finally, (big) data analytics can help asset managers in decision making processes with respect to maintenance activities. Ultimately, big data analytics may increase the transparency and availability of information, enabling a constant monitoring of real-time data on the actual condition of assets and tracking performed maintenance activities (Kache and Seuring, 2017).

Asset manager-maintenance contractor outsourcing relationships

Many organisations increasingly outsource maintenance activities to specialist maintenance providers (Ulloa et al., 2018). Implementing disruptive technologies to establish a CBM program hence also concerns maintenance contractors. This implies that contractors are often the ones to leverage available data for the purpose of more effective maintenance. Outcome-based, or performance-based, contracts offer an attractive way to achieve just this, as such

contracts allow for the inclusion of appropriate incentive schemes that will lead agents to pursue the outcomes for which they are rewarded (Eisenhardt, 1989). On top of that, performance-based contracts have been suggested to foster supplier-led innovation: "*...partner-initiated, proactive undertakings that take place within the context of a specific inter-organisational relationship, either in collaboration with, but in any case for, a focal organisation, that result in new or improved ways of delivering transactions*" (Sumo et al., 2016). Hence, we expect that under performance-based contracts, maintenance contractors are automatically incentivised to leverage data for the purpose of more effective maintenance.

In order to stimulate contractors to act in the best interest of the contracting party, an appropriate incentive scheme must be designed and enforced. The extent to which a scheme is effective is likely to be contingent on the proportionality of bonus and penalty elements (Selviaridis and Van der Valk, 2019), in combination with the specifications these incentives are tied to. In most situations, this will involve a mix of behavioural-based and outcome-based incentives, tailored to a specific situation, motivating the agent to act in the principal's best interest (Halldorsson et al., 2007). Finally, not only the explicit aspects of the contract, the formal and often legally binding agreements of the contract, should be considered. Also the implicit aspects, the social agreements made between the principal and the agent, should be acknowledged when trying to identify the most appropriate contract design.

Based on the insights we gained from the literature, we defined the following four a-priori constructs (Barratt et al., 2011) to guide our exploratory data collection and analysis: 1) the mix of provisions included in the contract (behaviour-based or outcome-based), 2) the incentive scheme specified in the contract, 3) the degree of data-sharing between asset owner and contractor, and 4) performance outcomes. We consider data sharing to be an intermediate performance outcome that will in turn enhance availability. Hence, we posit data sharing to be a mediator between contractual characteristics and performance. Note that our study is qualitative in nature, and hence can only provide a first validation of this conceptual model.

Research methodology

This study focuses on two organisations that are active in the Dutch public infrastructures sector: Rijkswaterstaat (hereafter: RWS) and ProRail. Both organisations aim to smarten the maintenance of critical assets by introducing disruptive technologies and analysing condition data. Since both organisations outsource their maintenance activities to private maintenance contractors, they need to stimulate their contractors to aim for the same goal. Up until now, four cases, three at RWS and one at ProRail, were mature enough to be analysed in this paper. Refining processes with respect to cases at ProRail are still in progress. Nonetheless we found enough interesting insights to compare a more general case from ProRail with three refined cases from RWS. A short overview of each of the four cases can be found in Table 1.

RWS has a national contract management department, but also strong regional sub departments (responsible for the infrastructural assets in their region), each with their own contracts and their own ideas about (smart) maintenance. In order to align all initiatives and outsourcing contracts, the organisation started the 'vital' assets program: a program with several pilots, involving assets that play a pivotal role in either the waterways or flood-preventing water systems, to determine a national standard with respect to how asset management can be smartened. In these pilots, RWS aims to collaborate with the contractors and stimulate them to help realise smart maintenance for the assets they maintain to ensure a higher availability of RWS' overall network. In consultation with RWS, three pilots have been selected as our research cases, which are denoted by 'Case E', 'Case K' and 'Case Y'.

ProRail recently started with a national 'datalab' to investigate the possibility of predicting railroad switch failures. Failing switches lead a lower availability of (a specific part of) their railroad system. Although it was initially intended for their own railroad network control centre, ProRail found that predicting switch failures can also be used by their regional departments and maintenance contractors to predict maintenance needs of these switches more accurately. This in turn helps to plan maintenance activities on the most useful timeslot, just before a failure actually occurs. The current challenge is to find a way to incorporate this innovation in contracts that foster collaboration towards smart maintenance. The 'general' case from ProRail is denoted by 'Case P'.

Table 1 - Overview of the case studies

Case E	Case K
• 5 year contract (two 1 year extensions possible) • Primarily based on performance-based metrics with some descriptions of 'desired' behaviour • All data regarding assets is owned by RWS	• 5 year contract (two 1 year extensions possible) • 'Desired' activities are described in contract • Contract specifies the data to be collected by contractor and contractor receives remuneration for delivering data • All data regarding assets is owned by RWS
Case Y	**Case P**
• 5 year contract (two 1 year extensions possible) • Combination of performance-based metrics and descriptions of 'desired' activities • Contract specifies the data to be collected by contractor and contractor receives remuneration for delivering data • All data regarding assets is owned by RWS	• 5 year contract • Combination of performance-based metrics and descriptions 'desired' activities • Contract does not specify the data to be collected nor shared by contractor • Data generated by contractor with respect to assets remains under ownership by contractor

Data collection so far included 20 interviews (15 at RWS and 5 at ProRail) with employees who are actively involved with the maintenance of critical assets (e.g.: asset managers, incident managers) and/or maintenance-relevant data (e.g.: data managers, data scientists), as well as with the employees that are involved with drawing up the maintenance contracts (e.g.: purchasers, contract managers). Moreover, to date, a total of 20 documents from RWS have been analysed, including excerpts of actual contracts, documents that described RWS' vision on smart maintenance, project documents, and official press releases. Visiting 'vital' assets at RWS enhanced our understanding of maintenance regimes in context. Finally, direct observations were made by the researchers of meetings between RWS and their contractors during which the progress of running projects was discussed. Collecting data from different sources allows us to perform data triangulation in order to enhance the validity of the collected data and the resulting evaluation of cases (Yin, 2013).

The quality and rigour of the case studies was ensured by applying specific criteria and measures that address construct validity, internal validity, external validity and reliability issues (Yin, 2013). Data coding and analysis was conducted manually and much in parallel with data collection following recommendations by Barratt et al. (2011). Data coding initially focussed on key constructs, but increasingly included additional themes and codes as they emerged from the interviews (e.g.: to what extent the case companies should specify and manage 'desired' behaviour from their contractors). Initially, open codes (e.g.: "key performance indicator", "bonus/penalty scheme" and "data sharing") were assigned to the interview transcripts and collected documents. Next, these were grouped into higher-order

categories (e.g.: "contract type" and "incentive schemes") using axial coding procedures. Overall, data analysis was an iterative process with codes being refined by moving back and forth between data, the analytical framework and the cross-case analysis.

Preliminary findings

As our within-case and our cross-case analyses are still ongoing, this section presents some of our preliminary findings. First, the three cases at RWS are described in terms of the four a-priori constructs identified earlier. Subsequently, also the case from ProRail is described in terms of the same four a-priori constructs. A comparison between the key findings from RWS and the key findings from ProRail can be found in Table 2.

RWS

Contractual provisions – Analysing the empirical data from all three cases, it became apparent that no standard is being used regarding contracts. Rather, each regional sub department uses its own personalised contracts. In Case E for example, even though they call it a 'performance-based' contract, in reality it still contains a lot of prescribed activities: "*We named prior generations performance-based, but they were actually prescriptive and full of obligations*" – Senior Consultant Asset Management. The same is true for the contract in Case K. In contrast, the contract in Case Y has a more balanced mix between performance-based metrics and prescriptions of 'desired' behaviour: "*The last couples of years we focus more on performance, but in the beginning we focused more on behaviour. We evaluated the contractors' behaviour and addressed inconsistencies. Nowadays, we focus more on performance and performance scores*" – Contract Manager. In all three cases, interviewees indicated that currently all contracts lack flexibility: "*If you include broad terms in contracts, there is more room for innovative solutions*" – Senior Consultant Asset Management.

Incentive schemes – Our empirical data suggests that there is a discrepancy between the performance as requested in the contract, on which incentives are based, and the performance that RWS actually would like to see from their contractors. For example, in Case E, an interviewee recalled a situation where a contractor was incentivised to stall its response to a failure in order to collect a higher reward: "*What also happens: the contractor should fix minor failures itself, but if the damage is larger, the contractor is paid extra. The contractor is then enticed to wait*" – Senior Consultant Asset Management. Also in the other two cases contractors are incentivised to respond reactively to failures while RWS actually wants that their contractors take preventive measures. On top of that, the height of the penalties, that are intended to prevent undesired outcomes, is not appropriate. Case Y provides a striking example of this: "*We do penalise them* [the contractors], *but sometimes the amount of the penalty is much lower than the costs that they can save by not performing their task*" – Incident Manager. In some situations it is cheaper for contractors to not spend money on maintaining assets and paying the penalty, than actually perform the maintenance task.

Data-sharing – Our empirical data suggests that, in general, it is fairly easy for RWS to share data with its contractors regarding maintenance activities and the actual condition of assets. RWS pays its contractors to collect data for them and share it on fixed intervals: "*That information is simply our property* […] *It is our property, because we paid for it*" – Contract Manager. However, RWS employees are, on average, not fully satisfied with the way how data is shared. An interviewee from Case Y indicated: "*This is where it goes fundamentally wrong… the contractor sends us a .pdf file with which we cannot do anything. You cannot edit such documents*" – Senior Consultant Asset Management. In addition to this, there is a

big difference between the different regional sub departments with respect to their ability to actually process the data they receive from contractors. While Case K involves a regional sub department that can be seen as a forerunner with respect to processing data, Case E provides an example of a regional sub department where data processing is still in its infancy.

Performance outcomes – In all three cases, the current contract designs do not lead to the desired performance outcomes. The current contracts include extensive descriptions that contractors tend to follow meticulously as evidenced by the following example from Case Y: "*And if something needs to be adapted unexpectedly* [at an asset], *then they check the contract and indicate that it is not prescribed. And if it really needs to be fixed, then they ask prices… if this task was offered on an open market place, it would have been three times as cheap*" – Incident Manager. Put differently, contractors mainly focus on tasks that are being prescribed RWS in the contracts and do not display any initiative by themselves. Furthermore, it is fairly difficult for RWS to incorporate new innovations during a contract period. In all three cases, there was a (loud) call for more flexible contracts: "*Nowadays, you cannot afford to not be flexible at all. Everything is changing, and changing fast…*" – Contract Manager.

ProRail

Contractual provisions – Analysis of the data collected on 'Case P' leads us to conclude that ProRail made a conscious choice to move towards performance-based contracts: "*Obviously, we switched from prescribing what a contractor should do towards performance-based maintenance*" – Project Manager. However, a contract manager at ProRail pointed out that in some cases, prescriptions of 'desired' activities are still needed: "*If we are dealing with safety for example, we prescribe fairly strictly what a safe railroad switch is.*" Even though ProRail aims to evaluate contractors based on their performance, in some specific cases they also prescribe maintenance activities to ensure safety requirements are met. Although ProRail is fairly satisfied with their current contracts, one inhibiting factor is the lack of flexibility. "*I think that, currently, we have drawn up reasonably good contracts, but sometimes we do get stuck… since we ask for specific activities in contracts we cannot ask for additional things that fall outside of what has been contracted*" – Project Manager. Mainly due to European regulations regarding public procurement, ProRail is not allowed to significantly change the initial outsourcing request based on which the current contractor won the contract.

Incentive schemes – In order to stimulate innovation, one measure that ProRail has taken in its contracts is including a monetary incentive. Before a contract period starts, ProRail and the contractor jointly determine the number of malfunctions that may occur during a specific time period at a specific asset. Each additional malfunction in that time period leads to a financial penalty for the contractor, while each malfunction less than the maximum leads to a financial bonus. According to a contract manager, this financial bonus is high enough to stimulate innovation: "*The bonus is high enough to, for example, equip railroad switches with a (new) type of switch counter*". Put differently, the financial bonus is believed to be high enough to cover the investment the contractor needs to make to implement an innovation that can lower the number of malfunctions. Nevertheless, in practice some improvements are still needed: *"Sometimes it looks like* [in practice] *that they* [the contractor] *already hit the requirements for a bonus at the end of November, for example, and is not further stimulated to further improve performance during the rest of the year*" – Project Manager.

Data-sharing – Currently, there is almost no data sharing between ProRail and the current contractors with respect to maintenance and/or condition data. This is mainly due to the fact that they did not include any clauses regarding data (sharing) in the current contracts, making

it difficult to ask for data: "*We have asked data regarding 100 railroad switches and in the end we only received data on 15 of them*" – Project Manager. For new contracts, ProRail will start with including clauses in which they ask for specific data from contractors: "*They made new definitions regarding assets and components, and now they ask in new contracts: you* [the contractor] *have to provide feedback on whether you performed maintenance activities and on which components these activities have taken place*" – Data Scientist.

Performance outcomes – The latest contracts used by ProRail are partially capable of aligning the intended performance and the actual outcome achieved by the contractor: "*Since we began with performance-based contracts, you do see a decent increase in innovativeness.* […]. *The number of railroad switch malfunctions decreased by 2/3s as compared to 10 years ago*" – Contract Manager. Since the introduction of financial stimuli in their contracts, ProRail sees increases in innovativeness at their contractors resulting in a steady decline in malfunctions. However, with respect to sharing information regarding the condition of assets, the current contracts do not help a lot yet: "*Currently, we say: it* [the assets] *has to perform! Thus, if it performs, it is good. However, I believe that we are changing our minds with respect to this, because we also want to know what exactly happened*" – Project Manager.

Table 2 – Comparison between RWS and ProRail

Key Construct	RWS	ProRail
Contractual provisions	Performance-based clauses mixed with prescriptive behaviour. Mainly prescriptions of behaviour.	Performance-based clauses with prescriptive maintenance tasks to ensure safety requirements are met.
Incentive schemes	Incentives motivate passive behaviour Incentives motivate solving incident instead of lowering number of incidents.	Incentives for contractors are somewhat linked to the ultimate goal of ProRail (less malfunctions, higher availability).
Data-sharing	No issues with sharing maintenance data, RWS pays for and owns the data, as outlined in maintenance contracts.	ProRail does not share maintenance data with its contractors. No contractual agreements yet present.
Performance outcomes	Desired performance not attained; no substantial improvement of availability.	Desired performance with respect to availability is generally attained. ProRail's information needs not met.

Discussion and conclusion

The purpose of this study was to enhance our understanding of how contractual and relational conditions can stimulate data transfers between asset owners and their contractors, as well as innovation, in order to enable CBM. In this paper, we analysed four cases from two Dutch infrastructural organisations to determine how their current contractual and relational conditions can or cannot stimulate data transfers and innovation.

Our preliminary analyses lead to three main findings. First, the rigidity of current contracts seem to inhibit both the introduction of new innovations, as well as making adjustments to specifications regarding data sharing. Both RWS and ProRail are clearly struggling with stimulating the sharing of data by and with contractors, and with stimulating the introduction of new innovations. The problem here does not reside in the willingness of either party to start implementation or sharing, but in the rigid design of the contracts. When new and proven technologies become available, both case companies cannot directly capitalise on these since they are dependent on their contractors. Because current contracts cannot be changed during the contract period, it is fairly expensive to quickly adopt new technologies. Stimulating data sharing by and with contractors is also problematic for both RWS and ProRail: the rigid

contracts do not allow changes to the agreements made in the past, and the clauses that are currently used are either underdeveloped or non-existent. Both case companies need to wait until the next contract period to include new requirements with respect to data sharing. More flexible contracts will facilitate efficient data sharing and can kick start the implementation of proven technologies. This finding resonates with the notion of contracts having a coordination function (Schepker et al., 2014), meaning that the contract is not static, but subject to change following changing requirements and circumstances.

Second, current contract designs do not seem to be conducive to achieve the overall objectives of the contracting party. Especially in the three cases at RWS we see that, on the one hand, they clearly aim to smarten the maintenance of their critical assets, while on the other hand, we see that they are currently utilising contracts, which include both performance-based elements and highly detailed prescriptions that ultimately results in passive behaviour by contractors. Although previous studies have acknowledge that most contracts should contain a mix of performance-based and behaviour-based elements (e.g., Halldorsson et al., 2007), the prescriptive elements in the RWS cases seem to overshadow the performance-based elements, leading contractors to stick to prescriptions to avoid being penalised for deviating behaviour. In contrast, ProRail's case provided evidence that if you have a good mix of performance-based and behaviour-based elements in your contracts, it can indeed help align the overall objectives of the contracting party and the contractors. This demonstrates the importance of considering the detailed design of contracts in joint with the clarity and overall purpose of the contract (Selviaridis and Van der Valk, 2019).

Third, and related to the point above, also the incentive schemes adopted in contracts do not always have the desired effects. At RWS, contractors are rewarded for meeting specific response times in case of failures. Thus, in order to collect a bonus, an asset must first fail while RWS actually wants to achieve the highest availability possible for its assets. Thus, the incentive schemes are not linked to the objectives RWS ultimately tries to achieve. ProRail, on the other hand, incentivises its contractors in such a way that they get a bonus when they have less failures than a specific base line. Less failures in turn leads to a higher availability of ProRail's network. The incentive schemes are thus better aligned with the objectives ProRail ultimately aims to achieve. Stimuli in contracts should furthermore be proportional to the efforts required to achieve performance targets (Selviaridis and Van der Valk, 2019). The three cases at RWS show that in the presence of mild penalties, the costs of the efforts required to avoid the penalties outweigh the penalty itself. Hence, contractors will accept the occasional penalty leading to more frequent incidents or lower than desired performance.

The findings discussed here should be interpreted with care, as indeed they are very preliminary in nature. Data collection, as well as analyses, are currently ongoing, and may lead to more nuanced findings regarding how contractors may be incentivised to share data and implement disruptive technologies. The mix of cases from the two case companies is also not ideal yet. Expanding our study with additional cases at ProRail, will further enhance our understanding and provide a stronger basis for a cross-case analysis between the RWS and ProRail. Future studies should also more explicitly address aspects of relational governance. Our preliminary findings suggest that the trust levels between our case companies and their contractors is (extremely) low. Contractors follow contracts meticulously and they are mainly focused on short-term gains. This inhibits the building of trust and leads to inefficiencies during the contract period that are very costly.

This paper presents our first thoughts. We are hopeful that our work will pave the way for further empirical research in this area, by us and by others.

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Operations Innovation

Operations innovation adoption within the legal service sector

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Abstract
This paper discusses how innovation can be effectively applied into the legal sector for increasing its productivity and performance efficiency. Fifty-three semi-structured interviews were conducted with legal professionals worldwide to explore their day-to-day challenges and identify the barriers that hinder innovation application into the legal sector. This qualitative study identifies six key themes, each with a number of different dimensions and expressions, as the result of a systematic thematic analysis examining the raw interviewees' responses. Our results suggest that the traditional culture and the resistance to new technology adoption are the primary reasons for slow innovation in the legal sector.

Keywords: Legal firms, Efficiency, Innovation

Introduction
Legal firms face difficulties on how to manage their business model and adapt to the rapidly changing technology and customer expectations (Giannakis et al., 2018). Additionally, the deregulation of the legal service sector in 2007 and the demise of legal aid have been the forces driving many legal firms on the verge of bankruptcy or to productivity declines (Susskind, 2017). Similarly, legal firms undergo pressures due to the entrants of new competitive businesses such as the accounting firms and the online based legal suppliers promising for faster and cost-effective legal services (Gottschalk, 2002). In addition, still ongoing discussions about Brexit consequences are preventing mostly large legal firms from expansion opportunities and others by changing their recruitment practices due to uncertainty in the qualifications and overall regulations (Hellwig, 2017).

Nonetheless, the legal industry still makes a vital contribution to the worldwide economy, with the UK legal sector generating around ten percent of the global market for legal services, second only to the USA (The Law Society of England and Wales, 2016; Hellwig, 2017). Actions need to be taken for revitalising the sector that can optimise legal business procedures, which nowadays may be somewhat dysfunctional or unorthodox. The professional service sector is characterised by a high knowledge intensity, a high professionalised workforce and a low capital intensity (Von Nordenflycht, 2010); thus, knowledge transfer from other professional disciplines and innovation implementation can be a way forward for improving the sector.

Innovation as a concept can have multiple meanings across different industries. Slack et al. (2016, p.110) argued that innovation of a product or service is about anything new and unique happening to the company. Rothaermeler (2015) describes innovation as *"the successful introduction of a new product, process, or business model that can lead to a powerful driver in the competitive processes"*. More specifically, from an operations management perspective innovation is about the transformation of a new idea into practice for the means of creating value for the customer. This paper considers innovation implementation as a process change or modernization of the legal service sector.

Theoretical perspective

The resource based view supports the theoretical backbone of the study for developing a framework for legal firms to adopt innovation. Resources that are valuable, unique, and difficult to imitate can provide the basis for firms' competitive advantages (Barney, 2001). For this project the authors adopt the term '*resources'* as the activities that the senior managers are responsible to manage and control, the operations within the legal firms, but also the lawyers. Tacit knowledge that lies among these resources is the key asset for a firm's competitive advantage (Michalakopoulou et al., 2017) and it can be transferred through team-work, organisational processes and communication (Fu, 2013).

Stakeholder theory is also being employed to support the theoretical perspective of the study. When there should be a change within a business environment, the views of the company's stakeholders have to be taken into account. In particular, for performance improvement all the stakeholders of a firm should have the same objectives. Stakeholders are not only the people that are taking the decisions but also the people that they are going to be affected by them (Jensen, 2001). Stakeholders are defined as the *"organisations, groups, and individuals that can affect or are affected by a firm's actions"* (Rothaermel, 2015, p. 11). For the legal firms there are internal and external stakeholders that can have an impact on the working environment of the legal professionals. For example, internally these are the legal personnel i.e. the partners, the lawyers at all levels and the IT department; these are considered the most valuable internal stakeholders of a legal firm. Furthermore, the owners and the shareholders of the legal firm are those who are the decision makers and the strategy developers. Externally, the regulatory bodies and the government are the institutions influencing the business model governing the legal firms. Last but not least, the clients are the key external stakeholders to whom legal firms deliver value through their services. Finally, the IT suppliers are providing law firms the merchandise i.e. templates and documents to run their business. All these stakeholders are interconnected as changes in their 'behaviour' are direct or indirect affecting the legal firms' performance.

Literature review

Innovation for the professional services can be referred here as the entrance of new technological tools, the effective management of employees and the transformation of

employees' knowledge into services (Love et al., 2011). From an operations management perspective, the application of those innovative aspects in association with operational management techniques such as Lean thinking may lead to a process change and to a competitive edge in the workplace.

Love et al. (2011) characterised *service* as a *"heterogeneous collection of activities that includes business, professional services and consumer services"*. Additionally, *service* is the *"combination of the service delivery and the experiences received by the customer"* (Johnston et al., 2012, pp. 15-17). Others (Roper et al., 2016; Desyllas et al., 2018) focusing on innovation in the legal sector stated that innovation is considered when firms employ *"a process change"* or specifically *"improved services or new improved ways of delivering legal services"*.

Technology adoption is considered as a key innovation element that can lead firms to a competitive advantage. Firms opt for adopting the newest technologies and products to leverage over the highly competitive market (Zaefarian et al., 2017). Although there is a vast selection of technological tools that can help lawyers optimise their work, most law firms are resistant to innovative ways of working. The reasons behind it, is something that this research study is looking to examine.

The culture of the firm and the management of the human factor play an important role for the encouragement of the adoption of new technological tools and techniques. The human element is considered as an additional factor that needs to be taken into consideration for the decision-making, the design and the implementation of operations and innovative approaches within an organisation. Managers should pay particular attention to nurture social capital as a pathway to realise the true value of technology implementation (Wu et al., 2018). This is line with Chichkanov et al. (2019) research on 519 Russian knowledge-intensive business services. They argued that the human factor has a significant influence on the diffusion of technological innovations. Overall, for the lawyers, it is argued that the term innovation emphasises their continuous journey of adaptation, evolution and improvement (Destefano, 2018).

Lean thinking is a philosophy, originally coming from the Japanese manufacturing industry, which has been employed worldwide in various industries as an apparatus to reduce wastes and improve business operations. Companies in the service sector like the healthcare (D'Andreamatteo, et al., 2015; Burgess and Radnor, 2013) and other knowledge-intensive businesses (Suárez-Barraza et al., 2012) adapted the Lean principles to increase their productivity and performance efficiency. Often, it is argued that for the successful implementation of those operations management techniques, the understanding of the importance of the human element plays a significant role (Hines et al., 2004).

Thus, the aim of this study is to explore how synergies among innovative approaches such as lean and technology practices can be integrated and operationalised within law firms can lead to a competitive advantage in the workplace.

Methodology

The work presented in this paper is the qualitative part of a mixed-method study that also includes a legal professional survey. The study reported herein has a primarily exploratory character and is based on a thorough thematic analysis examining raw interview data collected through fifty-three in-depth semi-structured interviews with legal professionals working in legal firms around the world. The sample consists of both law academics and legal practitioners including lawyers and paralegal personnel; all the interviewees had experience in working within a legal firm in the UK or abroad. More specifically the respondents were law academics, firm partners, associate solicitors, attorneys/lawyers,

trainee solicitors, legal IT experts, in-house lawyers, barristers and legal administrators. The academic sample included heads of Law schools, senior lecturers in law and law students. Twelve interviewees of this group had the role of the academic and the qualified but not practicing solicitor at the moment. This twin professional background of these interviewees potentially adds value to the research as they could identify in a broader way the challenges of the legal sector since they have faced these themselves in their previous role; actually for some of them these were some of the reasons that led them to change their career path and pick an academic post.

The analysis of the qualitative phase follows a theory-driven thematic analysis approach as described by Braun and Clarke's (2006) six-step framework for analysing the qualitative data gathered from the semi-structured interviews. Through thematic analysis the researcher can *"identify, organise, analyse and report the finding patterns-the themes"* in the data corpus (Braun and Clarke, 2006, p.4).

Findings

The qualitative results of the study were organised, managed and analysed using the NVivo11 software. From the thematic analysis, the researcher extracted six main themes and each of them with a number of different dimensions, based on the patterns of the interviewees' responses; these are summarised in the table 1 below.

In general, the majority of the participants suggested that there are many problems which mostly arise from the legal profession's heterogeneous and complicated nature. They also identified that there is a need for operational improvements within their legal firms. Additionally, it seems that the legal service sector lacks innovation contrary to other services sectors like the accounting industry. The resistance of service professionals to adopt innovation might be among the reasons for that. For instance, the poor management of employees and the inherent 'traditional' culture of the law sector emerged as key challenges. The slow adoption of the technological advancements and the resistance to change were two other potential reasons for the lack of innovation into the legal sector.

Table 1: Thematic analysis

THEMES	Human Factor and Culture	Client and Market	Technology	Organisational Transitions	Legal Processes	Education

The first key theme according to the table 1 is the human factor and culture that provides an insight into the barriers that legal professionals are facing within their working environment. It is a common fact that the legal profession has a distinctive and typical culture that someone can find it difficult to easily integrate within. Most interviewees supported that if there is to be change, the profession has to go through a cultural and attitudinal change. *"The profession is running historical; the recruitment criteria are often similar as those were in the past rather than adapted to the today's requirements, because they (senior managers) want to recruit and work with people like them"* (barrister in commercial law, 9years of experience). Another respondent having long experience working as a head manager for a large law firm expressed that law firms are operating conservatively in comparison to other professions like the academic one. Although it is evident that most law firms are embracing the new technological tools focusing on

keeping up with the new trends, their traditional and outdated thinking keeps legal employees in the past.

Technology was also an important theme that legal experts were constantly referring to. For instance, most of the respondents supported the view that although technological tools can help the legal profession with the document and case management, it can also impose security risks. Cybersecurity was identified as a significant theme that all senior professionals are often concerned about as they are dealing with clients' confidential information and large amount of money. The lawyers' worries have increased after the 2017 cyber-attack to a global large firm operating in the UK, strict regulations are being in place. For instance, according to another legal professional *"with technology in place there is a risk of hacking and security issues; who can ensure specific access to legal document?"* (Solicitor and academic in commercial law, 6years of experience).

Some of the respondents employed in senior position within the legal firms argued that training of the employees on the new technological developments could potentially tackle the resistance on technology adoption. *"Technology for me it has been really, really helpful. I mean I am not an IT freak, so at first it may seem a little bit difficult to, but it is not eventually and you get used to that but since I have trained and learnt how to use these new facilities, it is much better"* (in-house lawyer in commercial and litigation law, 14years of experience).

Moreover, another theme identified were the competitiveness in the market and the clients' constantly changing needs. Due to the competitive environment and the need to satisfy the customer, lawyers have to work relentlessly to meet their deadlines and achieve a good deal for their firm. *"There is a lot of pressure to increase your billable hours. You have targets, and you have got to try to hit those targets and bill a certain amount per year"* (in-house lawyer in commercial and litigation law, 10years of experience). Another consequence of competition in the legal market, is that law firms are hesitant to invest in human resources by recruiting senior law personnel as they used to do in the past. Similarly, the interviewee supported that it is evident that legal firms are in a period of reducing or not increasing their personnel for the means of decreasing their costs. *"Some firms have made redundancies and cost cutting for trying to optimise their operations"* (in-house lawyer in commercial and litigation law, 10years of experience). In terms of the customer lawyer interface, clients as part of the market are playing an important role to law firms' prosperity and it is a factor that can drive change. All respondents working in private legal firms argued that they value their customers, by focusing on satisfying them and respond to their requests. For example, face-to-face interaction is often in forefront. *"We are interacting with our clients probably via email or through Skype, or on the telephone. However, we are mostly focusing on whatever method is available and it is convenient to the client"* (managing director/ shareholder in family law, 20years of experience). However, communication between lawyers and customers is not running smoothly with problems arising often due to the lack of understanding of the lawyer's role. *"Clients sometimes do not a full understand of what it is going on and this has to do with the fact that they are not experts, they are not lawyers and we have to explain to them the situation in the simplest way possible"* (in-house corporate and commercial lawyer, 10years of experience).

The fourth theme identified refers to the political implications impacted on the legal profession. As legal multinational companies operate under strict regulations and laws in the UK, a change on them, such as Brexit, can have a considerable impact on them in various ways. The legal professionals' of this study argued that it is still unknown of what law firms will have to do to comply with the new regulations. *"It is still uncertain of what will happen with the Brexit. I believe that people are scared, law firms are trying to move*

their head offices in Ireland, a lot of solicitors are trying to qualify in Ireland to keep being a European lawyer" (trainee solicitor and part-time student, 2years of experience).

Last but not least, the complexity of legal processes were mentioned from the legal specialists as a key challenge of the dearth of efficiency in the legal firms. The efficiency is strongly associated with the complexity nature of each legal transaction. For instance, for long transactions like mergers and acquisitions a team of lawyers is needed to secure the deal; that means more time and effort and resource allocation for the client's legal case completion. For instance, *"on average the time delivery for our corporate transactions it takes from three to four months. So it is quite a long process, but I do not think that it can become shorter and as a matter of fact"* (partner/ head in financial law, 14years of experience).

Finally, academic education was identified as another theme that has an impact on the legal firms' recruitment policies and performance. Another respondent working as a family attorney in a niche law firm in the USA emphasised the lack of skills of the trainee solicitors entering law firms. *"There are a lot of newer attorneys that do not necessarily have the experience and skills to enter the sector. However, most of them know how to use online marketing to appear to be experienced and well regarded" (*attorney in family law, 8years of experience). That means that academic institutions do not necessarily equip their law students with the required skills to enter the workplace as early career lawyers.

To conclude, the thematic analysis provided evidence of the challenges that the legal professionals are facing in their working environment mostly focusing on the highly competitive market and the fast developing technology.

Conclusion

This paper contributes by presenting an in-depth explanation about the challenges that legal professionals are facing within the legal firms and highlighting the lack of empirical research into the investigation of how innovative approaches such as technology and the Based on our findings we strongly recommend that where the legal profession operates in a way not as effective, robust or technologically informed as it should, problems should not be ignored; problems should be solved. Lean thinking is a well-established path to higher quality, improved operational performance, increased timeliness and greater respect for the people who provide the services. It can improve legal processes and result in rigorous corporate legal transactions and to a competitive advantage over their competitors in the workplace. Lean is a tool that could enhance innovation and technology adoption and skill enhancement.

Further research focuses on a quantitative survey examining insights on innovation adoption by legal firms' professionals by addressing questions highlighted by the qualitative work. This is a complementary research looking to eventually produce results that could be easier to generalise into a wider context.

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The role of unmanned aerial vehicles in mapping and search and rescue in response to natural disasters

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Abstract

This paper intends to present the implications of deploying UAVs in assisting mapping and search and rescue in immediate response to natural disasters. For doing so, empirical data has been collected from three organizations with real deployment experience. Evaluation framework (Piotrowicz & Irani, 2010) have been used to classify the impacts. Findings indicate that on strategic level, intangible and non-financial benefits, challenges and risks dominate whereas on tactical and operational level, tangible and non-financial impacts outnumber. Considering these impacts, the study identifies areas for improvement. Moreover, it modifies and extends the evaluation framework for use in humanitarian sector.

Keywords: Unmanned aerial vehicles, mapping, search and rescue

Introduction

Every year, sudden onset natural disasters cause deaths, causalities and often result in significant economic and financial losses (Shavarani & Vizvari, 2018). For international NGOs and aid organizations, these disasters restrict their ability to access the affected areas and collect up to date information about the situation (Haavisto et al., 2016; Erdelj et al., 2017). Since first 72 hours are crucial for searching victims post disaster, therefore collecting accurate and timely geospatial information becomes critical for coordinating rescue operation and delivering need based response. Several studies indicate the usefulness of mini and micro Unmanned Aerial Vehicles (UAVs) in bridging knowledge gaps in immediate response phase and enhancing data collection and information sharing capabilities of first responders and humanitarian organizations (Sakr et al., 2016). While each methodology has different impacts, this research intends to present the benefits, challenges and risks of the using UAVs in disaster response, particularly in mapping and search and rescue.

Evaluation Framework

Since UAVs can be used to strengthen the capabilities of Geographic Information System (GIS) by collecting and transmitting remotely sensed spatial data, therefore we decided

to use evaluation framework (Piotrowicz & Irani, 2010) to identify and classify implications of the use of UAVs in disaster response. This framework takes into account the technology related flexibility and can be used to present impacts that cannot be measured through conventional evaluation techniques (e.g. cost benefit analysis).

For this research, we have the modified dimensions of framework to incorporate unique characteristics of humanitarian sector and our research aim. The dimensions of this framework are explained below.

Strategic, tactical and operational impacts

Strategic impacts are linked with the objectives of organization and represent the long term impacts. They affect performance on tactical and operational levels (Gunasekaran et al., 2001). In case of humanitarian organizations, these impacts can be affected by the time and socio-political and economic conditions of the country in which disaster strikes (Pettit & Beresford, 2009). Tactical impacts are linked with resource, process and task requirements and affect medium (short terms) success of project. Operational impacts represent requirements that must be fulfilled on daily basis for successful completion of a project (Gunasekaran et al., 2001).

Impact characteristics

Impacts experienced at each level can be categorized based on the extent to which they can be measured indirectly or directly (Gunasekaran et al., 2001). Tangible (T) impacts can be experienced and measured in a direct manner whereas intangible (INT) impacts cannot be assessed directly (Piotrowicz & Irani, 2010). Tangible and intangible impacts may indicate financial (F), or non- financial (NF) repercussions of innovation decisions (Gunasekaran et al., 2001).

Balanced Scorecard (BSC) dimensions

Piotrowicz & Irani (2010) have used BSC dimensions to present distribution of benefits in areas such as financial, internal business processes, customers and learning and growth (Kaplan and Norton, 1996). Due to immense importance of donors and beneficiaries in humanitarian sector, several humanitarian organizations consider them as their customers. Donors provide funds and influence humanitarian decision making (Beamon & Balcik, 2008) therefore, we chose them as customers. As the main objective of humanitarian organizations is to save lives and reduce suffering of victims, their main responsibility is also towards beneficiaries (Beamon & Balcik, 2008). Thus, we also regarded beneficiaries as customers.

Unmanned aerial vehicles (UAVs)

UAVs are aerial vehicles without passengers and crew onboard. They can be dispatched autonomously or semi-autonomously to perform sensory operations (Sakr et al., 2016). In this research, we aim to analyze the implications of micro and mini UAVs because they are preferred for use in disaster response from regulatory point of view due to their size and weight (OCHA, 2014). The maximum take-off weight of mini UAV is less than 30 kg whereas that for micro UAV is less than 5 kg (Bendea et al., 2008; Giordan et al., 2018). Several humanitarian organizations and emergency management organizations such as International Organization for Migration (IOM), World Bank and Greater Manchester Fire Rescue Service (GMFRS) have used them (both fixed wing and multi-rotor) for mapping and search and rescue in immediate response to disasters (Soesilo et

al., 2016). Mini and micro UAVs can easily be transported to disaster site and perform challenging tasks such as search and rescue (SAR) (Tanzi et al., 2014; OCHA, 2014).

They are more affordable to use for mapping and SAR operations compared to other types such as High Altitude, Long Endurance (HALE) and Medium Altitude, Long Endurance (MALE). Small rotary wing UAVs cost around US$2,000, whereas high endurance fixed wing models costs around US$130,000,000 (Tatham et al., 2017). DJI's phantom (multi-rotor UAV) costs around €500-€1500 and MikroKopter's ARF OktoXL 6S12 (multi-rotor UAV) costs approximately €6,500 for mapping. Fixed wing UAVs (for mapping) range from €10,000 (Danoffice IT's Cumulus 1) to €20,000 (SenseFly's eBee). The cost of UAVs for live feeds during SAR can range from €42,000 (Microdrones' MD4-1000) to €40,000 (Sky-Watch's Huggin X1). These cost variations are due to brand, type of UAV (fixed wing or multi-rotor) and sensors used (Soesilo et al., 2016).

Limited endurance of mini UAVs (<2 hours) and micro UAVs (around 1 hour) affect their ability to fly longer (Bendea et al., 2008) and support SAR and mapping operations without a charging arrangement or extra capacity. Their limited payload capacity restrict their capacity to carry the number and type of sensors and cameras. However, the development of miniaturized and custom designed thermal sensors as well as multi and hyper spectral cameras have enhanced usefulness of these platforms (Giordan et al., 2018).

Mapping and SAR challenges in immediate response phase

Immediate response to disaster involves multi-dimensional activities to reduce disaster impact, save lives and prevent further damage. Despite the critical need to rescue victims and provide relief, humanitarian organizations have to face significant challenges in conducting immediate response activities, particularly with first 72 hours. This is because disasters most often damage physical infrastructure and cut off affected areas (Haavisto et al., 2016). Inaccessibility to affected locations coupled with inaccurate understanding of situation limit the ability of humanitarian organizations and first responders to collect up to date spatial data. Most often in response phase, humanitarian organizations are receiving information from deployed assets and reports from the community. The collected information is sometimes inaccurate or incomplete (Griffin, 2014).

Benefits of UAV assisted mapping and SAR

The availability of accurate and up to date information is critical for rescuing victims and providing relief (Griffin, 2014). In this regard, images or live video feeds streamed by mini and micro UAVs from disaster site can improve situational awareness of humanitarian actors (Shakhatreh et al., 2018). These videos can also increase the flexibility of first responders in improvising SAR operation (Tanzi et al., 2014); thereby improving SAR time efficiency (Shakhatreh et al., 2018). Sending data acquisition plan to satellites and collecting data from them takes several days whereas UAVs can be deployed on demand for multiple observations of disaster affected area. Mini and micro UAVs carrying IR camera and LiDAR can be quickly dispatched to scan the disaster affected site and collect data even during night time and adverse weather conditions (Shakhatreh et al., 2018). This can improve mapping time efficiency (Nedjati et al., 2016). UAV based images can be used to create maps and other information products (such as DTM and DSM) which can be used to conduct risk assessment, damage assessment and plan need based relief efforts efficiently (Hashemi-Beni et al., 2018). Their use can also reduce the overall response time (Tanzi et al., 2014). Up to date UAV based spatial data

can strengthen GIS and can be used to improve other immediate response activities (Gomez & Purdie, 2016).

Autonomous mini and micro UAVs can reduce operating costs of UAVs because these vehicles are less costly as compared to helicopters and airplanes (Soesilo et al., 2016). Low cost and off the shelf sensors and cameras have also reduced unit cost of these vehicles (Sakr et al.,, 2016). Moreover, autonomous systems reduce the need of trained pilots to operate the vehicles and decrease the total manpower required to perform UAV based mapping. Micro and mini UAVs can also enhance victim detection and mapping accuracy. As compared to other remote sensing platforms such as airplanes, helicopters and satellite, mini and micro UAVs can fly at low altitudes (30-150 meters) and capture high resolution images from different angles (Soesilo et al., 2016). Sensors carried by these vehicles allow them to locate and detect victims with accuracy (Tanzi et al., 2014). UAVs as a platform can overcome coverage issues due to atmospheric conditions (such as cloud cover and dust whirls) (Soesilo et al., 2016).

Deployment risks and challenges in disaster response

Regulations present a major challenge in deploying UAVs for disaster response (Gomez & Purdie, 2016; Shakhatreh et al., 2018). Every country has different regulations and several countries in which humanitarian organizations operate do not have UAV laws (OCHA, 2014; Tatham et al., 2017). Compliance with local regulations is necessary for operationalizing the technology in a safe manner. However, the lack of UAV laws can raise the level of uncertainty regarding their use in disaster response. Since UAVs can collect, store and transmit significant amount of big data, their use has raised concerns regarding data security and privacy of victims (Tatham et al., 2017). This data upon leaking or hijacking can lead to intrusive monitoring of people and observed areas and can also cause personal harm to people (Erdelj et al., 2017). In addition, UAVs have a negative image due to their prior association with the military and their use in modern warfare. For humanitarian organizations, such an image becomes a critical issue that must be managed to retain their image as an independent and impartial entity (OCHA, 2014).

Mini and micro UAVs are sensitive to heavy rains and strong winds (Shakhatreh et al., 2018). Such weather conditions can change the pre-determined flight path; thereby, affecting the coverage of observation area (Shakhatreh et al., 2018). UAV based operations required highly trained pilots and technical staff available, particularly within first 48 hours (Soesilo et al., 2016). In addition, integrating UAVs as a supplementary tool requires significant costly preparations beforehand to ensure timely results. UAV based operations also demand managing (or overcoming) long data processing and energy constraints (Shakhatreh et al., 2018). In case of UAV based SAR, managing coordination between technical team and first responders or humanitarian staff is critical for ensuring success of operation. Lack of clarity about roles and priorities can reduce the possibility to find victims in time and save lives (Soesilo et al., 2016). While the technology is still evolving, technical risks such as limited communication range, need for robust collision avoidance solutions, use of low cost and risky off the shelf components and unexpected sensor failure present challenges related to public safety (Erdelj et al., 2017).

Methodology

Empirical data has been collected from a purposeful sample of three humanitarian organizations (HOA, HOB and HOC) with actual deployment experience in disaster response. HOA and HOC are based in Central and Southern Europe respectively. HOB is based in North America. Multi-case study design has been used to enhance generalizability of findings and compare implications across cases. Constructivism

paradigm have been used to guide research process, data collection and data reporting. Altogether 3 skype based individual interviews have been conducted from 3 respondents in humanitarian industry using an interview guide. All respondents are UAV experts who have used the technology and have participated in real deployment experience of case organizations. Apart from the interviews, written communication in the form of UN reports, documents published on websites of case organizations and previous studies were used for data triangulation.

Findings

Humanitarian Organization A (HOA)

HOA use UAVs as a supplementary tool for mapping only. It uses satellites, on ground team with COBO (Company Owned/Business Only) phone or tablet with GPS and UAVs for collecting spatial data and supporting GIS analysis. Before implementing UAVs, HOA considered cost comparisons between satellites and UAVs, frequency and resolution of observations required, and finance. In addition, an assessment of best tools in terms of days or duration of project was also made. The report was first submitted to the program manager and then to the mission manager in Haiti. After gaining approval, HOA collaborated with a private company named SenseFly to source micro- UAVs and software. After receiving field validation reports from teams on ground, HOA conducted test flight with UNOSAT in the aftermath of Hurricane Sandy (2012). To make sense of spatial data, HOA collaborated with Pix4D and converted raw data or images into accurate 2D maps (orthomosaic) and 3D models (DEMs). For digitizing images and conducting GIS analysis, HOA hired a specialized team from Open Street Map (OSM). It then reduced the size of each UAV based imagery and maps (<50 Megabytes) and shared this information freely (open source) through humanitarian data exchange (HDX platform) and OSM with relevant stakeholders (volunteers, local government, humanitarian partners and civil protection bodies).

UAVs showed advantages during first deployment as it provided the data faster (29th October) than satellite (2nd November). Cost wise UAVs gave a more detailed overview as compared to satellites on km^2 basis. Upon realizing benefits from this experience, HOA began developing in house UAV capacity. It sourced more vehicles, servers and formed a specialized team in house. Later it deployed UAVs in response to Hurricane Matthew (2016) to verify satellite data, improve situational awareness, collect baseline data to identify hurricane pattern and support damage assessment and plan response (in terms of NFI and food distribution). The respondent mentioned that UAV based operations are challenging because the technology can be deployed only if the Government requests and allows their use. Their use also requires considering and complying with laws regarding data management (storage, filter information and processing). Moreover, cases in which Government receives reports of misuse of UAV sourced data, improvising the situation becomes problematic.

Humanitarian Organization B (HOB)

HOB use UAVs as a complementary tool for mapping only. HOB does not replace satellite, manned aviation assets or ground based surveys with UAVs. It uses them for data triangulation or bridging knowledge gaps. HOB prefers to use UAVs for direct live feeds or improve situational awareness of an area when satellite images are inadequate. UAVs provide high resolution images (1.5 to 10 cm) that are accurately geo-referenced. These vehicles are used when HOB has the capacity to use the technology in terms of

funds, vehicles and technical staff available. UAV are preferred for small scale (10 km) localized assessments as compared to ground based survey. An aerial image sourced from UAV can be cheap as compared to satellite images. Moreover, UAVs provide flexibility to HOB for on demand and efficient mapping. However, the preparation for UAV based operations can be very costly in terms of acquiring the technology, permits and developing or hiring technical staff. Regulations for UAVs are more restrictive than satellites in terms of data management and use of vehicle. If preparations are not done before deploying UAVs in immediate response then, UAV based response can take long time. Even with preparations done, data processing stage can be significantly time consuming if HOB is covering large areas with UAVs. Thus, with 72 hours, it is hard to conclude that UAVs can be effective in delivering the maps. It can be useful with 72 hours provided the vehicle streams live video feeds to the team. Furthermore, the use of UAVs requires collaborating with the technical team or technology providers on site. Challenges and risks mentioned by the respondent deals with ethical implications (such as privacy of victims, data protection and management), lack of uniform standards, long processing time (e.g. 3-4 days to map 10 square kilometers), harsh weather conditions, overhyped product capabilities, costly preparations, lack of experience of technology providers in emergencies and regulatory restrictions. She mentioned that some countries do not even have UAV regulations and several do not have streamlined processes to gain approval for UAV, pilot and operator. It usually takes several weeks to go through several registration processes and certifications.

Humanitarian Organization C (HOC)

HOC has been using UAVs as a supplementary tool for mapping and improving visibility of national partners at lower costs. However, it has been supporting local Governments, National Disaster Management Organizations (NDMOs) and first responders in SAR by prepositioning lower cost UAVs ($2000/ UAV) and localizing skillsets through training programs. For mapping, HOC has prepositioned equipment at six regional bureaus (Panama, Bangkok, Cairo, Johannesburg, Nairobi and Dubai). It has been conducting capacity building workshops for HOC personnel, cluster partners and the Government. For localizing UAVs, HOC is working with civil aviation authorities to get clearance.

Before deployment, HOC defined expectations at programme level in each country of operation. Decision to use the technology was based on the comparative analysis of the end product price vs methodology. End product price was measured on project or unit cost basis. For mapping HOC analyzed cost effectiveness of UAVs i.e. it compared quality and accuracy vs cost per hectare of land.

HOC have used UAVs in Philippines after Typhoon Haiyan (2013) to map out millions of damaged coconut trees and to support efforts to enable reuse of farmer lands. In Columbia, HOC used UAVs to track displaced population in the aftermath of Hurricane Irma (2017). In Mozambique, it mapped 14000 km^2 of River Delta (2018) to assess damages in the aftermath of floods (2018). In response to Hurricane Maria (2017) in Dominica, HOC used UAVs to support Government and rescue teams. For map generation, HOC use LiDAR, photogrammetry software and high processing power computers to create orthomosaics, Digital Surface Models (DSMs) and Digital Elevation Models (DEMs). It then freely shares the generated information products with national partners to improve situational awareness. HOC use micro UAVs (less than 1kg) and sensors such as Near Term Digital Radio (NTDR) and Unreal Development Kit (UDK) camera for thermal imagery. For observing large areas (e.g. 500 hectares), HOC use fixed wing UAVs. The benefits reported by the respondent include workload reduction,

improvement in inter-agency coordination and information sharing and strengthening GIS. UAVs improved mapping and SAR accuracy, flexibility and capabilities. The challenges and risks that HOC reported include ensuring the appropriate equipment (UAV) for use, retention of technical knowledge and staff, timely communicating with civil aviation authorities for safe operations and assuring safe operations across the cluster.

Discussion

Table 1 & Table 2 presents classification of reported benefits, challenges and risks based on the framework dimensions (Piotrowicz & Irani, 2010). Majority of the reported benefits can be categorized as strategic and operational whereas most of the challenges and risks can be classified as strategic and tactical. On strategic level, UAVs mostly improve: inter-agency coordination and information sharing and other immediate response activities. These findings are in line with previous research (Gomez & Purdue, 2016; Soesilo et al., 2016). On tactical level, UAVs can reduce map procurement costs (HOA, HOB & HOC) and improve GIS data collection and information system (HOA & HOC) on organizational (HOA) and multi-agency level (HOC). These findings are supported by previous studies analyzing the impact on intra organization (Sakr et al., 2016) and inter-organization level (Soesilo et al., 2016). On operational level, UAVs can be used to enhance capabilities and accuracy of mapping (HOA, HOB and HOC) and SAR operation (HOC). All these findings are similar to observations made in previous studies (Nedjati et al., 2016). On strategic level, the main challenges and risks mentioned by all cases include concerns regarding: regulations and data protection. Limited resource capacity, lack of deployment preparedness and data management were found common challenges and risks among several cases on tactical level. On operational level, technical team dependence, long processing time, and weather conditions can be categorized as main challenges and risks. These findings have been confirmed by previous studies (Bendea et al., 2008; Erdelj et al., 2017). We found some new challenges and risks such as retaining technical knowledge and staff, monitoring risk and assuring safety at multi-agency level, dependency on agency request and gaining approval internally. On strategic level, intangible and nonfinancial benefits, challenges and risks were found dominant. Majority of benefits, challenges and risks on tactical and operational levels were identified as tangible and non-financial in nature. We found donor and learn and growth as main improvement areas in all organizations. Moreover, findings revealed learn & growth, internal process and beneficiary as the areas that require the most attention to reduce risks and overcome challenges.

Conclusion

Findings have revealed the difficulty in measuring benefits, risks, and challenges for humanitarian organizations on strategic level. Most of the implications on strategic level (such as improvement in inter-agency coordination and information sharing and regulations) are intangible and non-financial in nature. Although their impact is difficult to measure, these outcomes can greatly impact the performance of humanitarian organizations in immediate response. On tactical and operational level, tangible and non-financial impacts dominate tangible and financial as well as intangible and non-financial for all organizations. Evaluation framework enabled us to indicate intangible and non-financial implications of UAV assisted response. These impacts cannot be captured by conventional evaluation techniques (e.g. cost-benefit analysis) and operational measures.

Table 1 – UAV deployment challenges and risks-HOA, HOB and HOC

	Balanced Scorecard dimensions				
Levels	**Donor**	**Beneficiary**	**Internal process**	**Learn and growth**	**Financial**
Strategic	Improve other immediate response operations (INT, NF)	Improve other immediate response operations (INT, NF)		Improve other immediate response operations (INT, NF) Improve inter-agency coordination and communication (INT, NF)	
Tactical					
			Improve map procurement process (T, NF)	Strengthen GIS , proactive assessment and planning (NF, INT) Accurate and on demand information products (T,NF)	Reduce map procurement costs (T, F)
Operational					
	Enhance mapping accuracy (T, NF) Increase mapping time efficiency (T, NF) Enhance mapping capabilities (INT, NF) Improve situational awareness (INT, NF)	Improve situational awareness (INT, NF) Reduce waiting time (T, NF)	Reduce waiting time (T, NF) Increase mapping flexibility (NF, INT) Autonomous systems streamline workflows (NF, T)	Improve situational awareness on organization and multi-agency level (INT, NF) Enhance mapping accuracy (T, NF) Reduce personnel workload (INT, NF) Enhance mapping capabilities (INT, NF)	Increase cost effectiveness and efficiency (T, F)

Table 2 – UAV deployment challenges and risks-HOA, HOB and HOC

	Balanced Scorecard dimensions				
Levels	**Donor**	**Beneficiary**	**Internal process**	**Learn and growth**	**Financial**
Strategic	Data protection and privacy (INT, NF) Regulation and authorizations (INT, NF-F)	Regulation and authorizations (INT, NF-F) Data protection and privacy (INT, NF) Public safety (INT, NF)	Regulation and authorizations (INT, NF-F)	Overhyped capabilities of UAVs (INT, NF)	Costly preparations (INT, F) Regulation and authorizations (INT, F-NF)
Tactical					
	Data management (INT, NF)	Data management (INT, NF)	Data management (INT, NF) Dependency on Government and agency request (T, NF) Limited resource capacity (NF-F, T)	Data management (INT, NF) Gaining approval internally(T, NF) Resource preparation and prepositioning (T, NF-F) Monitoring and assuring safety measures on cluster level (T, NF) Retention of technical staff and knowledge (T, NF)	Limited resource capacity (NF-F, T) Resource preparation and prepositioning (T, NF-F)
Operational					
		Weather conditions (NF, T)	Limited availability of trained staff (T, NF) Weather conditions (NF, T)		Limited budget for operation (T, F)

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Decision making on risky innovative production investments

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Abstract
Radical manufacturing technology innovations (RMTI) involve the introduction of new technologies in the firm's production processes. They represent especially challenging production investment decisions, due to inherent high risks and uncertainties. Firms' approaches to RMTI decision making are insufficiently understood. We explore the nature of RMTI decision making processes in nine RMTI projects from three manufacturing firms. The findings reveal slight differences compared to typical investment processes and organizations' different approaches for guiding the decision making.

Keywords: radical innovation, manufacturing technology, investment decision

Introduction
Radical manufacturing technology innovations (RMTI) mean the development of the production process through a radical shift in the core production technology and related practices. They involve the introduction of new-to-the firm production equipment and enable big benefits such as targeting of new markets, creation of new products, and savings (Oke et al., 2007; Reichstein and Salter, 2006; Keupp and Gassmann, 2013; Maine et al., 2014). They require significant investments from the manufacturing firm and can be risky. This study deals with decision making concerning these risky innovative production investments.

The front end process for RMTI includes a search for alternative technologies and suppliers, idea selection, and further investigation to prepare a business case for enabling an informed decision for the investment (Frishammar et al., 2013). As compared to regular equipment investment proposals, decision making on RMTI investment proposals presents a greater challenge due to various risks and uncertainty. Radical innovations are not completely known and well understood in the beginning, and they will require learning and development during the innovation process (Von Hippel and Tyre, 1995). Existing literature does not comprehensively cover decision making in such a context: whether to invest in an RMTI proposal or not, and how to assess the investment options. Manufacturing firms will face various dilemmas concerning the risks and potential benefits from the RMTI, and regarding the internal capabilities and external support available, during their decision making.

Therefore, the purpose of this paper is to explore manufacturing firms' practices in analyzing and deciding innovative production investments at the front end of RMTI. The main research question is: how do manufacturing firms evaluate and decide RMTI investment proposals? The focus is on radical innovations in the core production process, and incremental and peripheral innovations as well as product innovations are purposely excluded.

Literature review

Radical manufacturing technology innovations as risky production investments

Radical technological innovations deal with the introduction of a technology that is radically novel and different from the previous technology it may be displacing (Harborne et al., 2007). Radical manufacturing technology innovations (RMTI) cover such innovations within the core production technology and process (Chaoji and Martinsuo, 2016, forthcoming). While discussion on advanced manufacturing technologies typically focuses on the technological innovation itself, RMTI imply changes more broadly including the supply, delivery and manufacturing processes and related ways of working. For example, change from subtractive to additive manufacturing could be considered as RMTI. RMTI do not cover innovations in non-core or peripheral production processes such as production quality control and monitoring (Bessant, 1982), or innovations in other than manufacturing operations such as material purchase processes (Parikh and Joshi, 2005).

Radicalness implies novelty at the level of the adopting manufacturing firm, and in some cases the novelty may be true also for the equipment supplier firm and the industry more broadly (Chaoji and Martinsuo, forthcoming). RMTI may require using non proven equipment and technologies, and therefore have greater uncertainty than other types of innovations. The overall creation process (development and implementation) for RMTI starts with activities related to idea search, selection and refinement (Kurkkio et al., 2011). Following the decision to invest in the development of the actual production equipment and its technology, the back end process involves the detailed engineering, construction, installation and production trials (Lager and Frishammar, 2010). A recent study has mapped the different types of RMTI processes and reveals differences based on the degree of novelty particularly at the front end of RMTI (Chaoji & Martinsuo, forthcoming).

The focus in this paper is on the decision making concerning RMTI as risky production investments at the front end of the innovation. Due to their centrality as part of the firm's production process, RMTI investments can be considered as strategic and long-term oriented. The objective of the front end of innovation is to reduce uncertainties and unknowns about the RMTI idea to enable 'informed' decision making (Frishammar et al., 2013). However, some extent of unknowns are present at the decision making as the innovation is not completely known and well understood until its pilot implementation as part of the project itself.

Decision making in operations management

Decision making involves the identification and selection from alternative options, and research on decision making suggests various pathways to choosing among alternative options and their potential impacts (Cook et al., 2007). Decision making can be structured, formal comparison and analysis of the alternatives using, e.g., multiple criteria decision analysis methods (e.g. Ting, 2008). Also, it may be intuitive, unstructured and based on a person's experiences without systematic analyses of all alternatives (Tello et al., 2010; Kammerlander and Ganter, 2015). Furthermore, decision making in an industrial context

is influenced by organizational processes and contexts, raising questions regarding the role of individuals making decisions versus organizational procedures and contexts influencing their decision making (Tello et al., 2010; Leiblein et al., 2002).

Accordingly, decision making can be perceived as a rational process involving the consideration of all possible alternatives, or it can be considered as boundedly rational where individuals consider such alternatives that are practically feasible (Turpin and Marais, 2004), leading to the selection of one possible best option. Research acknowledges that decision making is a behavioural process, wherein the outcome is considered to be linked with the individual involved, for example their previous experiences, values etc. (Evans et al., 2013). Within studies from the behavioural paradigm, the political view observes decision making as a social process of interactions between individuals from different interest groups, each group trying to maximize their gains and interests from the decision (Turpin and Marais, 2004).

Decision making on RMTI investments

There has been considerable research on decision making on selection of advanced manufacturing technologies, and both rational and behavioural paradigms have been covered. A large number of studies have concentrated on decision making support formulae and systems (e.g. Sambasivarao and Deshmukh, 1997; Chan et al., 2006; Osman and Cengiz, 2005). The dominant view perceives decision making on RMTI investment proposals to be a rational team-level decision making process comprising three stages: 1. Search for alternatives, 2. Screening alternatives and collecting facts, and 3. Comparing the alternatives in a team, to prioritize them and choose the best alternative (Baines, 2004; Farooq and O'Brien, 2010; Ordoobadi, 2012).

Manufacturing investment decisions are considered as challenging due to the presence of multiple criteria that need to be optimized in selecting the best technology (e.g. Chan et al., 2006; Iakymenko et al., 2016). In addition to economic criteria, strategic needs and risks have been shown to be important attributes in making the decision to invest (e.g. Chan et al., 2006; Iakymenko et al., 2016; Meredith and Hill, 1987; Farooq and O'Brien, 2010; Kakati, 1997; Stading et al., 2001). Some studies also highlight the role of previous experiences, intuitions in such decision making (e.g. Evans et al., 2013), and have described the challenges related to conflicts in interest groups in multi-department or cross-functional teams involved in investment planning teams (e.g. Ordoobadi, 2012; Choudhury et al., 2006; Lefley, 2018).

Research method

A multiple embedded case study has been conducted to identify how RMTI investment proposals are evaluated and decided in practice. The selected three manufacturing firms are active innovators: they have had multiple successful RMTI projects in the past 15 years. The companies are from different industries and portray differences in their strategies for RMTI. Within each firm, three RMTI projects were discussed, totalling 9 projects. 17 expert interviews (totaling 27 hours of recorded interview data) were held with managers involved in the evaluation and decision making processes, covering nine different RMTI projects, three in each firm. Table 1 includes background information on the companies, their RMTI projects, and the interview data.

Table 1 – Characteristics of companies, RMTI projects in them, and interview data.

	Firm A	Firm B	Firm C
Range of firm sizes (in turnover MEUR)	>50 MEUR	>1 BEUR	>2 BEUR

Size	Small (<500 employees)	Medium (about 1000 employees, part of a larger corporation)	Large (>5000 employees, part of a larger corporation)
Industry	High-tech raw material industry	Process industry	Assembled products industry
Market position	Niche market leader, among top 10 global firms	Market leader, among top global firms	Market leader, among top global firms
Nr. of interviewees	5	7	5
RMTI projects covered in the analysis	A1: New tolerance A2: Feature replacement A3: Higher performance	B1: Novel process B2: Energy alternative B3: Waste reduction	C1: Novel approach C2: Automation C3: Speeding up
Job positions of interviewees (examples)	Sr. Process Engineer; Process engineering manager, Sr. VP, Products	Sr. VP, Production; Sr. VP. Business Development; Plant Manager; Project Manager	Production Systems Development Manager; Sr. R&D Engineer; Manufacturing Manager
Total duration of recorded interview data	467 min (approx. 8 hours)	562 min (approx. 9 hours)	580 min (approx. 9 hours)

The interview outline included questions on timeframe, activities, events, people involved, search process, evaluation and selection process in the early period of the RMTI project before the investment decision was made. The interviewees were selected by key informants of the projects, due to their participation in the innovation front end. Interviews were arranged in meeting rooms in company premises, were recorded and transcribed. Separate interviews were arranged with all participants. Promise regarding confidentiality of information regarding names of firms, interviewees and the technology involved or product specific information was given.

We analyze what was known and unknown concerning the RMTI project and the business environment, and what were the key factors for decision makers generally in the firm's decision making. Also we explore the exceptions concerning the specific RMTI project, compared to regular investment decisions. We analyzed the data for the nature of the decision making process, including its activities, the use of systematic and formal practices versus intuitive and unstructured practices. The data was coded to identify the role of individuals, organizational processes, risks inherent in RMTI investment proposals and the key justification criteria and motivations for the decision. The projects were the unit of analysis, and observations were compared across the 9 projects to arrive at the findings.

Results

RMTI decision making process: Deciding on the technology and implementation concept
Typical decision making on investment involves: 1. Search for alternatives, 2. Screening them and collecting facts, 3. Comparing alternatives in the team and deciding. According to the interviewees, RMTI decision making goes through these three stages, but actually covers two choices in a sequence: technology choice and implementation concept choice.

Typically, there are no known technology alternatives to an existing process for RMTI. The search for technology alternatives appeared in the interviews often as an ongoing long period when the managers engaged in discussions about the need to find an alternate technology or process. Some interviewees told about specific small exploratory projects

as part of the search, to assess or test any potential technologies. In project A1, the firm made a decision to start a technology survey project to find an alternate technology. Typically, during this long ongoing period of active interest in finding alternate technology, the technology choice became clear. This involved either conclusive validation tests, sample pieces made (e.g. projects A1, A2), or depth of technical expertise that was accumulated during ongoing technological research. Typically, there was often one technology that was clearly selected for further investigation, and one of the reasons for this was lack of any other potential fit. For example, an interviewee explained the technology selection at the end of technology survey project in project A1 as follows: "*reasons for the selection were, well quite simple. First of all some of the processes were not capable so they were easy to drop out. Some were horribly expensive, so by order of magnitude too expensive or too low in capacity to be realistically useful. So we had basically two realistic options. And then the manufacturer of that one tool gave us the very clear message that they're not going to sell tool outside Japan. So that left us with one technology!*". Similar clear selection of one potential technology was visible in other projects too. For example, an interviewee explained about project B3: "*I think every second year in our company has been some kind of, small studies done how to handle these questions. But in those cases (this idea) has never raised up. ….it was only possible way to handle it. And Mr. (project head) was very eager, to make those studies to final end and then he was very happy that okay now we can handle this, biggest problem what (industry name) mill ever have had*".

Once a technology idea was obtained, the firms began to investigate this specific technology and gather data to understand its fit and feasibility to their unique needs. This largely included a search for possible suppliers and gathering information about their equipment concepts and implementation concepts for the technology in the firm's process. The facts regarding implementation ideas gathered through implementation plans from suppliers and discussions with suppliers, their previous experiences with the technology and existing industrial users of the technology were then typically evaluated by internal technical experts for evaluating their feasibility and comprehensive impact e.g. on own processes, products and customers' production processes. Figure 1 illustrates the sequential decision making process for RMTI.

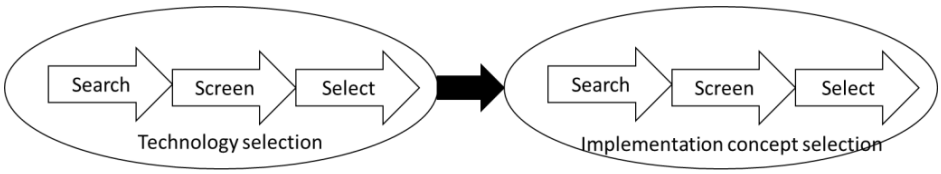

Figure 1 – Decision making process in case of RMTI ideas

Overall, RMTI investment proposal evaluation and decision making in the studied projects appears as a logical, team-based process involving the search, screening and selection of the production technology solution. A lot of effort had to be put to the early search and screening, due to the lack of existing ready-made technological solutions. Also the evaluation of the appropriateness of the screened new technology for the purpose of the firm appeared as technically demanding. The selection of the technology and/or the implementation concept was experienced by the interviewees as natural, and it emerged to decision makers through the screening process quite clearly. In many projects, there was only one viable alternative in the end since others got eliminated during the review, and the final decision making was therefore very straightforward.

Role of organizational processes versus individuals in the decision making

All three firms had some processes in place, to support the RMTI decision making. The alignment of investments with the firm's strategic goals was evidently important. Decision making and related evaluations were linked with key customers' needs, product technology roadmaps, and the procedures for investment projects. The organizations had rather rational team-level mechanisms and processes in place, guiding the search and contacting of suppliers, asking for proposals, discussing the proposals in teams, and evaluating them based on explicit criteria.

Despite the rational decision processes, also individual persons had a clear influence on the decisions. Individuals stood out in their contributions particularly during the search for ideas, moving in the right direction, and selecting the right direction among alternatives. Here the persons' depth of technical expertise was valuable. As an interviewee summarized: *"And we have, lucky to have, quite capable personnel to even have an idea what direction we have to take and what kind of tooling we would need to accomplish".* The suitable technology idea sometimes emerged through serendipity, chance events and conversations with the right people or visiting the right firms, and coming across breakthrough ideas and information in other ongoing research. For example, as the interviewee in project B3 summarized how they came across the technology idea: *"In real life there, wasn't any other possibilities to solve. I was lucky to, meet a, partly retired fellow!"*

Risks and managing them in RMTI decision making

RMTI involve piloting of a new technology in the production processes of the firm, and in some projects also piloting prototype equipment and unproven technologies. Thus, technological and commercial risks and uncertainties are inherent to RMTI. We analyzed the reasons for firms to accept technical risks in the RMTI projects. Two primary factors guided the firms' risk-tolerance toward non-familiar, non-proven technologies: strategic need or target, and the investment project replacing a bad old technology.

Strategic need refers to a burning need for the new technology. For example in one project, the key customer started such a new product development program that required components with much higher accuracy, and this implied shifting to tolerance levels beyond the capacity of the focal firm's existing processes. Therefore, finding a new technology for the manufacturing process became quite urgent. As the interviewee explained: *"Because this customer is identified as one of our key customers and this was clearly a very very important project for them, we saw this that it is not the right time to calculate that well there are big risks…".* Strategic targets stem from strategic goals and development priorities: the firms had annual plans and three to five-year technology roadmaps to renew existing capabilities, meet product roadmaps, anticipate stringent regulations, and finally, expand markets.

Replacing outdated or inefficient technology and renewing production capability was a necessity for firms when there was already a commercial justification available. Managers in the investment planning team of some of the RMTI projects wanted to maximize the return on investment. Either they saw that the current technology would not be sustainable for a longer time, or it was already outdated, compared to competition or customer needs. By elimination, there is just the radical choice of renewing the technology completely, as an interviewee explained: *"I think the drive was that the other option was just bad.. we have kind of two options here, the bad old one and the risky new one".* In all projects, the alternatives available were scarce, in terms of how many alternate technologies they knew, and how many alternate suppliers were available. The three firms differed in terms of the business context, and it affected the technology

possibilities. The nature of the product and industry segment implied for some projects the unavailability of any mainstream equipment suppliers for their production, and the need to develop and build the equipment needed.

Risks typically present in RMTI proposals at the time of decision making were technical risks due to equipment being a prototype for the equipment supplier firm and pilot trial in exact industrial context of the manufacturing firm. There was also uncertainty about production economics parameters such as speed of production, anticipated volumes, and therefore unit costs, and other product quality parameters. In some projects where RMTI were linked to launching a new product with better specifications, the demand volumes expected in the near future were uncertain, except for demand from key customers.

The measures that gave confidence in taking the above risks included confidence in technology choice, for example interviewee in projct A2 commented "*the test runs that were implemented at the supplier side were rather conclusive…we were quite convinced that yes it makes a very nice edge. So it meets our expectation in that regard (performance on the key parameter for switching to new technology*)". Confidence in the equipment supplier firm's capability and commitment to the needed development work was also an important enabler of accepting the technical risks and uncertainty. The confidence was based on previous successful projects with the supplier, or was based on critical review of the supplier's technical capabilities and strategic interest in this RMTI project. A related aspect was confidence in the plans for implementation. In project A3, a consultant was employed specially for support in the decision on supplier and implementation concept selection: "*we used the services of a former employee who is nowadays a consultant…and he was kind of challenging the suppliers' designs and calculations and expectations and material selections, if for no other reason then at least for the reason of making them make it double sure that they know what they are saying*". In cases where the RMTI project would impact the quality of product, an important confidence generating factor was involvement and positive feedback of key customer(s).

There were also projects where technical failures occurred eventually after the investment decision was made (projects A2, B2), and these were present where firms went ahead only based on their confidence in the supplier firm, and internally were not sure about the implementation plans specific to this project prepared by the supplier. For example, as interviewee in project B2 reflected: *"But now afterwards I have to say that, there was problems in the process because they have not made this kind of project earlier… this valuation and how we are making the decision is very important in these kind of situations that, there is some technological risk and in that case there was the technological risk, but we believe that this equipment supplier it has supplied us many kind of equipment and so on, and they have done then very well. But in this case, there was problems in the project management."*

Investment justification criteria

Strategic needs and targets were drivers of initiating the technology search and evaluation processes in most cases. However, these were not sufficient criteria to justify the decision to invest. As the Sr. VP of products involved in project A1 elaborated: "*For in this case we, the strategical drive for the better layer tolerance was clear. It was coming almost by nature from the fact that this was the most important parameter our customers are looking for. That's what we always talk about with the customers, then we need to move forward. So that was clear. By the time we were narrowing down the technologies and it was clear that there's not going to be a cheap solution, a cheap solution which we could just adapt for our all production so that our all production could change from .3 to .2. It might have*

led to the conclusion that let's not do it…0.1 would be a product which opens up completely new markets and therefore that was for me and for the decision to seek board's approval it was very important that this technology actually enabled the jump all the way to .1". Thus, higher benefit than merely satisfying the strategic targets with which the technology search was begun, such as new product, new markets, added economic savings were needed to justify the decision to invest. There was often need for additional pressure, triggers for starting the investment pre-engineering phase once the technology had been identified, such as scope for an investment project (need for additional capacity) in a production mill (project B1, A2), or pressure from key customer to start the development (project A1). Satisfying regular investment justification criteria, such as payback period, integration with existing processes, economic unit costs of production, were also calculated, and there was thus thorough consideration of the impact of the investment.

Besides enough reasons to invest in new technology, enough confidence in technology, equipment supplier firm were also important for justifying the investment proposal. The risks were present, but there was good confidence in taking them. This also highlights the characteristic of uncertainty that is present to the end in RMTI investment proposal, to the point of making decision. As Sr. VP of business development involved in project B1 explained, "*when you have made the research and investigations as long as it's possible, then you just have to make the business case and then either choose or not so, we looked at far as you can, and we thought that there is more to gain*."

Discussion and conclusions

The present study explored decision making practices in manufacturing firms on RMTI investment proposals. For this purpose, we gathered data on events and activities in the front end of nine RMTI projects from three manufacturing firms. The firms belong to different industries and are of different sizes. In studying three projects per firm we intended to discover if decision making on risky innovative production investments follows typical patterns, for example, in terms of the key enablers for the decision. We further analyzed the nature of decision making process in RMTI, as a type of radical innovation.

The findings reveal that the early phases of technology identification and evaluation were technically demanding, and the final phase of selection of technology was often easier due to lack of many comparable alternatives. This is contrary to the dominant focus in previous studies on the problem of selection from among technology alternatives (e.g. Ordoobadi, 2012; Chan et al., 2006).

Strategic needs and risks were observed to play an important role as motivation and justification for the decision making, thus supporting findings from previous research regarding high relevance of strategic needs in justification of advanced manufacturing technology (e.g. Chan et al., 2006; Iakymenko et al., 2016).

Organizational process for investment projects was utilized in the studied cases, and at times organizational process for new product development projects within product research and development team was also used in the early period. The projects were thus driven by organizational processes and team-based decision making practices were used. However, role of individuals was observed in picking right direction for search for technology solutions. This is in line with observations in previous research focusing on radical technologies, where individuals impact how radical technologies capture attention in organizations (e.g. Kammerlander and Ganter, 2015).

The topic of decision making on radical process innovation ideas has been less understood in previous research, and the study thus contributes to call for further

empirical research in manufacturing firms on processes for developing ideas and concepts for radical process innovations (Kurkkio et al., 2011; Frishammar et al., 2016). This study also expands previous knowledge on the creation of RMTI, from the perspective of manufacturing firms (e.g. Reichstein and Salter, 2006; Keupp and Gassmann, 2013). The findings open up decision making in context of risky innovative production investments and illustrate where RMTI projects are similar to and different from regular investment projects. The results have implications for practice, in terms of providing a framework for supporting management of decision making in these high risk, high benefit investments for manufacturing firms.

Limitations of the research include the small sample of RMTI projects and some topics in decision making research, e.g. political process, are not visible in these projects. Also, the use of decision making systems, e.g. IT based systems, in decision making on RMTI remains a question mark since the projects have not provided any evidence on their use. Further research is encouraged concerning other decisions in the RMTI projects besides the investment decision, including possible cancellations, changes, and reorientations. Also, exploring the prioritization and negotiation processes taking place in firms' management teams concerning RMTI projects could be an interesting avenue for further research. Furthermore, the managers' ways to acquire information and, thereby, reduce the uncertainty in RMTI investments could be studied further.

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Industry 4.0 Maturity Models: A bibliometric study of scientific articles from 2001 to 2018.

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Abstract
The aim of this article is to present the scientific production over the last two decades with regard to the terms Industry 4.0 and Maturity and to introduce a new concept of maturity. A bibliometric study focusing on the key words Industry 4.0 and Maturity is conducted and main journals, authors, countries and trends of maturity models are analysed. Based on the analysis, a new concept for measuring maturity to evaluate a company's readiness for Industry 4.0 is introduced. The assessment enables companies to systematically increase the quality of their transformation by providing insights about their readiness level.

Keywords: Bibliometric Study, Industry 4.0, Maturity

Introduction
New technologies, the demands of the markets and the emergence of new business models have influenced and transformed production processes since the beginning of the industrialization (Zhong et al., 2017). The Fourth Industrial Revolution establishes a new paradigm for production systems. Central concepts to this new paradigm are among others: Big Data, Cloud Computing, Artificial Intelligence, Industrial Internet of Things (IIoT), and Cyber Security (Jazdi, 2014). The term Industry 4.0, which refers to the Fourth

Industrial Revolution, was derived from the German term “Industrie 4.0” and first presented at the Hannover Fair in 2011. It denotes the high technology project of the Federal Ministry of Education and Research of the German Government, with the aim of increasing the automation of local production systems (Lee, 2015). The number of publications on the Web of Science platform, that used the term Industry 4.0 between 2001 and 2018 increased exponentially in the last years, 98 publications in the year of 2012 for a total of 1389 publications in 2017, a leap of approximately 1417%. There is wide agreement that companies must have a certain degree of maturity in order to engage in an Industry 4.0 environment (Canetta, 2018; Unterhofer, 2018). That is, they must fulfil a set of requirements to be able to apply technologies and skills to further develop towards the vision of Industry 4.0. Maturity models serve scientific and practical purposes. From the scientific point of view, these models help in gathering information about the current state of the company and its strategies for Industry 4.0. From a practical point of view, maturity models enable companies to evaluate themselves within an Industry 4.0 context (Schumacher et al, 2016).

The purpose of this article is to present a bibliometric analysis of scientific publications containing the terms "Industry 4.0" and "Maturity" which were published from 2001 to 2018. Main journals, publications, authors, countries as well as trends of maturity models in the context of Industry 4.0 were identified. Based on the analysis of existing maturity models, a new concept for measuring companies’ Industry 4.0 Readiness is introduced.

Methodology

The methodology used in this study follows protocols for research, classification and bibliometric analysis (Weitzel, 2006). Currently, there are several databases that use bibliometric indicators and provide a bibliometric analysis of scientific production. Two of the most common platforms among them are the Web of Science (WoS) and the Elsevier Scopus (Scopus) platform. The data presented in this study was obtained through a bibliometric research of these two platforms. Table 1 presents the keywords, the number of total publications containing the keywords and the number of publications related to the objective of this article.

Table 1 - Keywords used and number of publications in WoS and Scopus platforms

Keywords	WoS		Scopus	
	No. of total publications	No. of related publications	No. of total publications	No. of related publications
Industry 4.0 and Maturity	37	20	43	26
Advanced Manufacturing and Maturity	83	12	85	19
Digital Transformation and Maturity	41	19	77	24

Results

The number of publications on the Scopus platform using the term Industry 4.0 in relation to the term Maturity, rose drastically in the last years from 2015 (1 publication) to 2018 (49 publications), as can be seen in Figure 1.

Another highlight is the countries that generated these publications. Leading is Germany with 7 publications in WoS and 12 in Scopus. This aligns with our expectation since Germany is the nation that initially launched the term Industry 4.0. In third place is Brazil with 4 publications in WoS and Scopus. Austria, Sweden, England, China, USA, Finland, France, Ireland, Italy, Spain, Switzerland, Taiwan and Turkey appear in sequence. Brazil stands out in second place in the WoS and third in the Scopus ranking.

This is mainly related to the high degree of industrialization in the central and southern regions of Brazil. These regions are characterized by a large number of German immigrants and researchers who completed part of their studies in Germany. Several researches and studies have been carried out in Brazil in recent years with the objective of evaluating the local productive matrix and looking for ways to make it more efficient by using Industry 4.0 technologies, i.e. the maturity evaluation tool developed by the National Industrial Learning Service - SENAI / CNI (Loureiro, 2016) or the work conducted by the Brazilian Industrial Development Agency – ABDI (Gadelha, 2012).

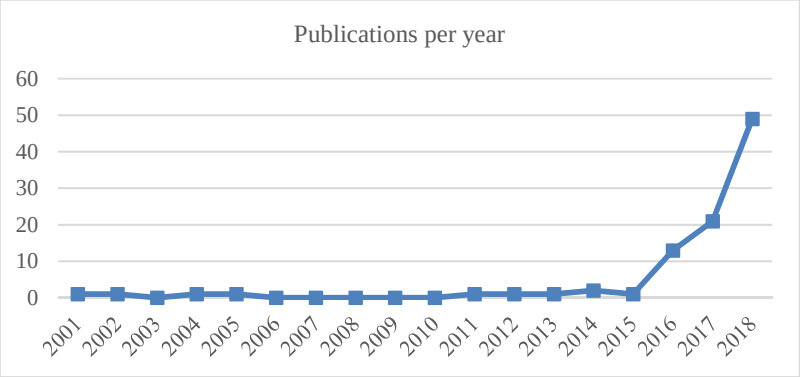

Figure 1 - Number of publications per year containing the terms Industry 4.0 and Maturity (Scopus)

In Table 2 the main sources of the publications were listed and classified according to their SCImago Journal Rank (SJR) and the H-Index. The SJR evaluates and ranks scientific periodicals according to the quantity of their citations in a three year period after the publication of the editions, to the origin of citations as well as to the logic of citations (Falagas, 2008). The H-Index expresses the journal's number of articles (*h*) that have received at least h citations. It quantifies the journal's scientific productivity and scientific impact and it is also applicable to authors (SCImago, 2007).

Table 2- Main sources and their impact factors

Source	SJR	H-Index
Journal of Industrial Engineering and Management	0.21	16
International Journal of Logistics Management	0.71	60
International Journal of Production Research	1.43	107
Independent Journal of Management & Production	-	-
Journal of Industrial and Production Engineering	0.47	21
Logforum – Scientific Journal of Logistics	-	-
Technological Forecasting and Social Change	1.38	86
Research-Technology Management	0.72	55

In addition to the main sources presented in Table 2, the IEEE 2018 International Conference on Engineering, Technology and Innovation (ICE/ITMC) published four articles. This confirms that the examined topic is currently discussed in the scientific community. The Vienna University of Technology in Austria ranks first regarding the amount of generated publications among institutions (three publications) (see Table 3). Among Brazilian institutions the Federal University of Santa Catarina-UFSC stands out with two publications. It is important to note that different institutions work together through the collaboration of several authors, which leads to differences between the

number of publications and the respective number of institutions. The WoS and Scopus platform provide the most cited keywords, within the set of analysed papers, after inserting the terms Industry 4.0 and Maturity. As expected, the most frequent keyword is Industry 4.0 with 13 quotes in WoS and 14 quotes in Scopus. The keyword Maturity Model appears in sequence with 7 quotes in WoS and 13 quotes in Scopus. Other keywords cited are Digitization, Digital Transformation, Smart Factory, Internet of Things and Learning Factory, among others.

Seven maturity models, identified in the bibliometric research, were further analysed. Additionally, four other models (PwC, Acatech, IMPULS and Rockwell Automation) were included in the analysis. The results are provided in Table 3.

Table 3 - Maturity models

Author	Year	Name	Dimensions	Maturity Levels
Parkinson, B; Rockwell Automation, Inc.	2014	Rockwell Automation	-	5 levels: Evaluation, Updated and Safe Network, Available and Structured Data, Analytics, Collaboration
VDMA, RWTH Aachen, IW Consult	2015	IMPULS	6 dimensions: Strategy and Organization, Smart Factory, Smart Operations, Smart Products, Service Oriented Data, Employees	6 levels: Layman, Beginner, Intermediate, Experienced, Specialist, Expert, High Performance
Geissbauer, R.; Vedso, J.; Schrauf, S.	2016	PwC	7 dimensions: Business, Products and Services, Value Chain Integration, Data Analysis, Agile IT Architecture, Compliance and Security, Organization and Culture	4 levels: Beginner, Vertical Integrator, Horizontal Collaboration, Digital Specialist
Schumacher, A.; Erol, S.; Sihn, W.	2016		9 dimensions: Strategy, Leadership, Customers, Products, Operations, Culture, People, Governance and Technology	5 levels: 1 = not implemented to 5 = fully implemented
Ganzarain, J.; Errasti, N.;	2016		3 stages: Envision 4.0, Enable 4.0, Enact 4.0	5 levels: Initial, Managed, Defined, Transformation, Detailed Business Model
Leyh, C.; Schäffer, T.; Bley, K.; Forstenhäusler. S.;	2016	SIMMI 4.0	4 dimensions: Vertical Integration, Horizontal, Digital Development, Technology Crossing	5 stages of digitalisation: Basic, Cross, Horizontal and Vertical, Total
Schuh, G.; Anderl, R.; Gausemeier, J.; Hompel, M.; Wahlster, W.	2017	ACATECH	4 dimensions: Resources, Information Systems, Culture, Organizational Structure	6 levels: Computerization, Connectivity, Visibility, Transparency, Predictive Capability, Adaptability
De Carolis, A.; Macchi, M., Zegri, E.; Terzi, S.;	2017	DREAMY	4 dimensions: Processes, Control and Monitoring, Technology and Organization	5 levels: Initial, Managed, Defined, Integrated and Interoperated, Digitally Oriented
Gökalp, E., Şener, U., Eren, P.E.	2017		5 dimensions: Asset Management, Data Governance, Application Management, Process Transformation, Organizational Alignment	6 levels: Incomplete, Realized, Managed, Stabilized, Predictive, Optimized

Canetta, L; Barni, A; Montini, E.	2018		5 dimensions: Strategy, Processes, Products and Services, Technologies, Human Resources	4 levels: Absence, Beginner, Intermediate, Experienced
Sjodin, DR; Parida, V.; Leksell, M.; Petrovic, A.	2018		3 dimensions: People, Processes, Technologies	4 levels: Connected Technologies, Structured Data Collection and Sharing, Real-time Process Analysis and Optimization, Intelligent and Predictive Manufacturing

Rockwell Automation (Automation, 2014), which has partnered with other major technology companies such as Microsoft, Cisco and Panduit, presents a five-stage model of measures and best practices for changing technology and culture with the objective of developing a connected company. In a study commissioned by the IMPULS Foundation of the German Engineering Federation (VDMA) (Lichtblau, 2015), carried out by IW Consult and the Institute for Industrial Management at RWTH Aachen University, a maturity model was developed including six key dimensions, each of which is defined on a six-level scale. Four of the six dimensions presented coincide with the necessary capabilities as required for Industry 4.0: smart factory, smart products, smart operations, and data-driven services. According to the model, the level of maturity of a given dimension is defined by the lower level of maturity of the respective areas of interest that compose it. In addition, according to the level of maturity obtained by the model, organizations can be classified into three types: “Newcomers” (level 0 and 1) companies that have done either nothing or very little to deal with Industry 4.0, “Learners” (level 2) companies that have already taken first steps in implanting Industry 4.0, and “Leaders” (level 3 and up) companies that are already well in the way to implementing Industry 4.0, representing the benchmark group. The PwC Model (Geissbauer, 2016) is based on seven dimensions of digital capabilities, involving business, products and services, value chain integration, data analysis, agile IT architecture, compliance and security, organization and culture. Four levels of maturity are presented: beginner, vertical integrator, horizontal collaborator and digital specialist. Ganzarain (2016) proposes a process model consisting of tool oriented sub-models aiming at vision, strategy and construction of actions. A 5-level scale is defined for each model. The maturity model for System Integration (SIMMI 4.0) by Leyh (2016) allows companies to classify their own IT systems with respect to the Industry 4.0 landscape. It consists of five stages of maturity. Each stage represents a corresponding level of maturity for Industry 4.0 and is divided into four dimensions that represent different areas of the company (vertical, horizontal, digital development and technology crossing). In Schumacher (2016) a model based on 62 items of maturity is developed with respect to technology and organization. These items are grouped into nine company dimensions, each being evaluated within five levels of maturity. The model was then applied in case studies.

According to the ACATECH (German Academy of Science and Engineering), being 4.0 means generating data knowledge to transform the company into an agile, learning organization, allowing rapid decision making and flexible adaptation of processes in all business areas. The ACATECH has developed a maturity model, which includes four key perspectives of an organization: resources, information systems, organizational structure and organizational culture. Each of these perspectives are assessed at six levels of maturity (Schuh, 2017). In the study called DREAMY (De Carolis, 2017), five major areas are initially structured: design and engineering, production management, quality

management, maintenance management and logistics management. Based on these areas, five levels of maturity are defined: initial, managed, defined, integrated and interoperated as well as digitally oriented. In order to evaluate the digital capacity of an organization, not only technologies in use are considered. Instead, the digital capacity is evaluated by four dimensions: processes, control and monitoring, technology and organization. In Gökalp (2017) a maturity model for Industry 4.0 based on ISO/IEC 15504 is presented (also known as SPICE; Software Process Improvement and Capability Determination). The model is built on five dimensions and six levels of maturity. Canetta (2018) developed a model based on 36 questions divided into five areas: strategy, processes, products and services, technology and human resources. Based on the questions four different levels of maturity are derived: absence, beginner, intermediate, and experienced. As a result, a radar-type graph is generated and the mean of the company's general maturity level, based on the five dimensions, is calculated. In Sjödin (2018) five case studies are analysed and the challenges and key steps required to implement a smart factory are identified. A model is then built based on three principles: people, introduction of agile processes and configuration of modular technologies. These principles are classified into four maturity levels. The benefits of implementing a smart factory are analysed as well, which are the following: greater process efficiency, lower operating costs, higher product quality as well as greater safety and sustainability.

Readiness: A New Concept for Maturity

The previously introduced maturity models imply to get a holistic view of a company by evaluating various dimensions of it (apart from Leyh (2016) which primarily focuses on the IT-Systems of a company). There is a common understanding that maturity regarding Industry 4.0 cannot be based on one dimension alone, hence several dimensions are introduced. Depending on the model, the focus of the dimensions varies. Overall, two main dimensions can be identified, namely an enabler dimension and a technology dimension (see Table 4). Based on the characteristics of these dimensions, the maturity level regarding Industry 4.0 is evaluated. Thus, in current models, maturity appears to be considered as an outcome instead of an independent dimension.

Table 4 – Enabler dimension and technology dimension in maturity models

Enabler	Source	Technology	Source
Strategy and Organization	Lichtblau, 2015	Technology	Schumacher, 2016
Strategy, Leadership, Culture	Schumacher, 2016	Digital Development, Technology Crossing	Leyh, 2016
Organization and Culture	Geissbauer, 2016	Data Analysis, Agile IT Infrastructure	Geissbauer, 2016
Processes, Organization	De Carolis, 2017	Control and Monitoring, Technology	De Carolis, 2017
Organizational Alignment	Gökalp, 2017	Information Systems	Schuh, 2017
Culture, Organizational Structure	Schuh, 2017	Products and Services, Technology	Canetta, 2018
Strategy, Processes, Human Resources	Canetta, 2018	Technologies	Sjödin, 2018

In our experience, companies often fall short in their Industry 4.0 approach since they may have the necessary enablers and technology but lack in their maturity. Maturity is the necessary path to achieve the improvement of organizational processes, within a set of specific areas (following the Capability Maturity Model (1986)). Enablers of maturity models describe generic dimensions of organizations which are not related to technology. For example, a company can have a culture which is open to change and use new technologies, but is unaware about the improvement path in specific areas of the company and comes short in its Industry 4.0 approach. Therefore, we introduce a new concept for evaluating how prepared a company is to engage in an Industry 4.0 environment. Our

approach follows the idea of Schumacher (2016) who enhanced the technology focus of maturity models with organizational aspects to get a more detailed assessment of a company's Industry 4.0 maturity. Similar our concept augments current maturity models which were focused on enablers and technology with maturity itself. We call this concept Industry 4.0 Readiness. Industry 4.0 Readiness takes into account the dimensions of enablers, technology as well as maturity of a company and shows how ready a company is to engage in an Industry 4.0 environment. For each dimension of the concept four different levels are set. The lowest level refers to a company which is not yet ready with regard to the respective dimension. The highest level implies that a company is fully ready to engage in an Industry 4.0 environment. However, there are no levels to Readiness itself. The different dimensions (enablers, technology and maturity) set up a three-dimensional Industry 4.0-Readiness space in which a company is categorised (see Figure 3).

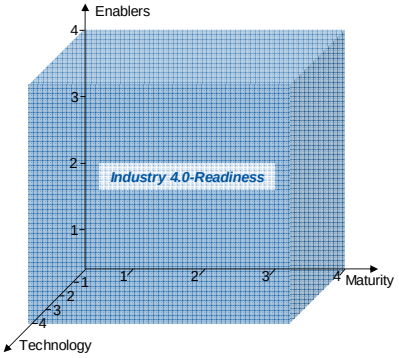

Figure 3 - Industry 4.0-Readiness space

In the following, the three dimensions and the proposed variables of these dimensions will be presented. The variables were chosen based on their relevance in the scientific literature. Whereas, numerous variables of enablers and technology could be found based on the literature analysis conducted in part III, variables for maturity were elaborated on the basis of the Capability Maturity Model Integration (CMMI).

Enablers

Enablers for Readiness are differentiated into the following three variables (following (Schumacher, 2016; De Carolis, 2017; Leyh, 2016)):

- Organizational Culture
- Business Model
- Human Resources

These variables were chosen based on the enablers mentioned in Table 3. However, the enablers in the maturity models differ in their granularity (i.e. Organizational Alignment (Leyh, 2016) compared to Strategy, Leadership, and Culture (Schumacher, 2016)). Therefore, we aggregated them into variables with a similar level of granularity. Organizational Culture refers to people's shared basic assumptions about transformation at all levels of the company. How strategy, market perspective and value constellation benefit a company in its readiness will be assessed by the variable Business Model. Lastly, Human Resources point at the digital and data literacy of employees and their strategic development.

Technology

The technology dimension is of great importance and at the centre of discussion of the scientific community (Schneider, 2018). Instead of specific technologies Industry 4.0

design principles based on Bücker (2016) and technology components of the aforementioned maturity models were chosen in order to consider ongoing technology developments. Additionally, contributions from the authors´ practical consulting experiences were taken into account. The following variables have been included:

- Interconnection
- Information Transparency
- Decentralized Decisions
- Technical Assistance
- Network-based Production

Interconnection refers to the connection of all members of an organization in the Industry 4.0 era. Objects as well as people are connected. Information Transparency is based on the collection of data from the connected objects and people in real time. Linking this data to digitalized models makes it possible to create a virtual copy of the physical world. Hence, all objects and people have access to all relevant data. Therefore, they are empowered to make informed Decentralized Decisions on their own (with respect to the company's overall goal) as autonomous as possible. Technical Assistance refers to the idea of supporting humans in accomplishing their increasingly complex work in organizations. The last variable, Network-based Production comprises technologies like additive manufacturing, which enable not only the main manufacturer to produce the whole product or parts of it, but various actors in the value chain as well, even if an actor is the final consumer himself.

Maturity

According to Kohlegger, (2009, p. 59), *"a maturity model conceptually represents phases of quantitative or qualitative enhancement of the capacity changes of a maturing element to evaluate its advances in relation to defined focus areas"*. The capability of a process is defined as competencies, or sets of actions and know-how, applied by an organization, which are subordinated to coordinated activities and make use of the organization's assets. In the Capability Maturity Model (CMM), a methodology created in 1986 to improve organizational processes and capabilities in managing the development, acquisition and maintenance of software products and services, the maturity concept is classified as the necessary path to achieve the improvement of organizational processes, within a set of areas, called levels of maturity. In Chrissis (2006) the Software Engineering Institute expanded the CMM concept to add hardware integration giving form to CMMI as a guideline for process integration and product improvement. The original proposal of CMMI encompasses four bodies of knowledge: systems engineering, software engineering, integrated product and process development, and supplier sourcing. Our concept adapts this approach to Schuh (2017) and takes into account that new business models are produced under consideration of product-service systems (PSS) (Tukker, 2017). Considering the three-dimensional model presented in Figure 3, the maturity of an organization, as observed in the models presented in Table 3, should be assessed by analysing four areas:

- Product-Service Development
- Production
- Logistics
- Marketing and Sales

Product-service Development addresses the effort to meet customer requirements that

are currently based on customization and product-service systems. Production and Logistics are the main value adding chains in manufacturing companies and must be structured in a systematic way. Marketing and sales have to be integrated into production planning and control as well as sales and distribution planning to realize the potential of technologies and enablers of Industry 4.0.

Conclusion

Summary

Maturity is a concept, which offers important solutions to companies from a competitive point of view in face of the fast and changing environment of Industry 4.0. This bibliometric study analysed a total of 168 publications on the Web of Science and the Elsevier Scopus platform. Initially, the terms Industry 4.0, Advanced Manufacturing and Digital Transformation were combined with the term Maturity to identify scientific publications ranging from the year 2001 to 2018. A total of 20 publications that deal with the topic of interest were identified. Based on the analysis of these publications, a drastic increase in scientific publications in 2017 could be observed with Germany and Brazil being one of the main contributors. Out of the 20 publications seven publications introduced a maturity model for Industry 4.0. Additionally, four more practice oriented publications covering maturity models were identified. These models evaluate the maturity of a company regarding Industry 4.0 on the basis of different enablers and technology dimensions of a company. They do not target maturity as dimension on its own. Addressing this gap, a new concept for maturity is introduced. The main difference of the concept to previous models and concepts is that maturity is no longer seen as a dependent dimension and, thus, as outcome of a company's enablers and technologies. Instead, the concept introduces Industry 4.0 Readiness consisting of three different dimensions, namely enablers, technology and maturity itself. The Industry 4.0 Readiness is assessed by diagnosing the level of the company in each of the three dimensions.

Limitations and Outlook

The newly introduced concept for maturity still has its limitations. First, despite the fact that the variables and levels of the concept's dimensions were carefully selected, there is the possibility that they are too generic or not of practical relevance for companies. If a variable is too generic, an accurate assessment of the variable is difficult. If a level is too generic, there is not a clear distinction between the levels of a dimension. Hence, a valid and reliable assessment of the Readiness of a company becomes challenging. Therefore, the variables have to be tested regarding their practicability and level of detail and adjusted accordingly. In order to address this point, a focus group with industry experts is planned. Within the focus group, the dimensions and variables of the concept are discussed, evaluated and updated. Second, the concept lacks operationalisation. For the operationalisation of the concept, a situational judgement test will be developed. Consequently, for each variable a situational description will be defined. Furthermore, the situational descriptions are discussed within a focus group of experts and revised. Third, the concept is based on the existing literature and therefore mainly of theoretical nature. Since maturity models fulfil a practical as well as a scientific purpose, the practical purpose needs to be validated. For the practical validation of the concept, it is intended to pre-test the operationalized concept with Brazilian and German companies to show the practical applicability and possible deficits. The results of the pre-test are used to update the concept and apply it in practice. Based on its application in practice, the model will be evaluated regarding its practical usefulness.

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Digital process innovation and financial performance: An event study

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Abstract

Digital process innovation—defined as the use of digital technology for process innovation—has recently become a new orientation of manufacturing companies to solve operational problems; however, the actual impact of digital process innovation is still unclear. In this research, we study the actual effect of digital process innovation on organizational performance. We further examine whether the impact of digital process innovation is strengthened if manufacturing firms increase their absorptive capability and their slack resource. This research provides valuable insights into how to effectively implement the strategy of digital process innovation.

Keywords: Digital process innovation, Absorptive capacity, Slack resource

Introduction

Operational problems, such as high-volume inventory, continuously increasing operational cost, operational inefficiency, are usually the concerns of the conventional manufacturing process (e.g., Boston Consulting Group, 2014; Kearney, 2016). Recently, digital process innovation—defined as the use of digital technology for process innovation—has become a new orientation of manufacturing companies to solve such kind of operational problems and has demonstrated its effectiveness. Taking GE Company (d'Aveni, 2015) as an example, it adopted digital technology in the production mode transformation of an engine from the assembly of twenty separate cast parts into direct production of one piece. This saves 75% of the operational cost. Nevertheless, there are some other concerns towards the effect of digitized operational processes. For instance, more energy is required in three-dimensional printing than in the traditional injection molding (Chen et al., 2015). Thus, the actual impact of digital process innovation is still unclear.

In this research, we study the actual impact of digital process innovation on organizational performance. We further investigate operational factors that may exert significant bearing on digital process innovation to enhance a firm's performance. Specifically, we examine that the impact of digital process innovation is strengthened if manufacturing firms increase their knowledge absorptive capability and their slack resource.

Theoretical Background and Hypothesis Development

Digital process innovation enables firms to promptly and accurately identify customer requirements and preferences and to offer customized even new products that, in turn, better meet customer individual requirements (Armenakis and Harris, 2009; Ye et al., 2007; Judge et al., 2009). This may result in increasing firms' performance. Hence, we hypothesize that the adoption of digital process innovation can improve a firm's performance, as shown below.

Hypothesis 1: Digital process innovation enhances organizational performance.

Operational absorptive capacity is referred to the capability of an organization's operational units to obtain, assimilate and exploit knowledge from external source (Patel et al., 2012). In a company, when its operating unit has absorptive capacity, the unit is more likely to have the ability and flexibility to obtain, assimilate and exploit the information provided by external parties and required for the implementation of digital process innovation, leading to higher organizational performance. Therefore, we hypothesize:

Hypothesis 2: Absorptive capacity of a firm positively moderates the relationship between digital process innovation and organizational performance.

Slack resource is defined as the buffer resource, in excess of the minimum necessary resources for a firm's daily operation, for coping with environmental uncertainty (Nohria and Gulati 1996). Companies with slack resource are likely to have buffer resource as safeguard to present the risk imposed while implementing digital process innovation, leading to enhanced organizational performance. Thus, we have the following hypothesis.

Hypothesis 3: Slack resource of a firm positively moderates the relationship between digital process innovation and organizational performance.

Methodology

We conducted a longitudinal event study to test the effect of digital process innovation on organizational performance. We focus on manufacturing companies that are publicly listed firms in the Mainland China. Driven by the recent China's policies such as Made in China 2025 and internet plus manufacturing action (China Daily, 2016), many manufacturing companies have gradually adopted and even have fully implemented the strategy of digital process innovation. Hence, manufacturing companies in the Mainland China are the most proper setting to conduct this study.

We consider digital process innovation as a firm's official launch of digital innovation initiative for its manufacturing process. Accordingly, we collected the

announcements about the adoption of digital process innovation from Factiva and Wisenews using keywords, for example digital platform, digital channel, digital manufacturing, intelligent manufacturing, additive manufacturing, and three-dimensional or 3D printing. Return on asset is regarded as the performance outcome of the firm. R&D intensity as a proxy for absorptive capability while slack resource is based on inventory level.

Finally, we obtained the relevant announcements from a sample of 168 firms. For these sampled firms, we collected data on return on asset, absorptive capacity and slack resource from the China Stock Market and Accounting Research databases.

Data Analysis and Results

We employed the approach of longitudinal event study to test the causal relationship between digital process innovation strategy and organizational performance. The results show that digital process innovation has a long-term effect on the performance of manufacturing companies. Subsequently, we conducted the ordinary least squares regression to examine the potential moderating effects of absorptive capacity and slack resource on the association among digital process innovation strategy and firm performance. The findings demonstrate that absorptive capacity and slack resource strengthen the effect of digital process innovation on firm's performance.

Discussion and Conclusion

This research reveals the real impact of digital process innovation on organizational performance in the manufacturing domain and explores the factors to enhance such impact. Specifically, it fills up the gap how to effectively implement the strategy of digital process innovation. This research also provides useful guideline for effective implementation of digital process innovation by considering a firm's internal absorptive capacity and slack resource.

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Collaborative innovation in the public sector to manage GNSS CORS technology in Thailand

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Abstract

Organisations require effective access to disruptive technology management including a generation of a culture of continuous innovation. Therefore, the open innovation paradigm has been established as a theoretical base for managing innovation in the enterprises and public sectors. In order to handle the independent ownership and management of GNSS CORS technology complexity in Thailand at the national level, collaborative innovation has arisen for building and refining the creative ideas and sharing internal resources and external knowledge. Moreover, stakeholder theory is deployed to consider the role-plays and the power of each of the partners over an inter-organisational collaboration.

Keywords: GNSS CORS, Collaborative innovation, Public sector

Introduction

Public and private organisations in sectors such as health care, construction and logistics that require satellite data for ensuring target locations are faced with a proliferation of positioning applications. Continuously Operating Reference Stations (CORS) constitutes one of the technologies designed as a supplement to Global Navigation Satellite System (GNSS) signals to improve positioning precision (GPS.GOV, 2017). Effectively implementing this land-based augmentation system has presented difficulties for countries such as Thailand. In particular, independent ownership and management of the GNSS CORS network has led to problems of duplication and overinvestment and the lack of facility sharing has adverse effects on the budgetary requirements of individual CORS users.

To resolve such complications in the management of GNSS CORS technology in Thailand requires the adoption of technological innovation in the public sector. To this

end, the various Thai government agencies involved have developed a form of collaborative innovation. But this must take account of the different levels of power among the CORS licence holders based on their number of assets and major missions. The present paper analyses key issues surrounding innovation management with respect to GNSS reference networks from the perspective of the open innovation paradigm, with a particular focus on collaborative innovation and stakeholder engagement.

Theoretical Background

Open innovation

The term 'open innovation' was coined in 2003 by Chesbrough in his seminal book, since then open innovation has become a term synonymous with modern approaches to innovation (Cassiman and Valentini, 2016). Essentially open innovation means that the innovation process is permeable, meaning that "there are many ways for ideas to flow into the process, and many ways for it to flow out into the market" (Chesbrough, 2006). This understanding that innovation transpires across the boundaries of individual firms and involves many actors linked together in formal and informal innovation activities has resulted in Chesbrough (2003) distinguishing open innovation from the traditional closed model of innovation. Closed innovation is based on the premise that investment in R&D results in technological discoveries that advance into new products and services, which increase profits that are then reinvested into the development of further new technologies, all in a process controlled and managed by a single firm. Conversely, within open innovation this process is opened up with ideas and technologies being developed externally to the firm. What also occurs is the spinout of ideas, technologies and business models from the open innovation activities to other firms who perhaps create new ventures.

Since 2003 a plethora of studies have emerged on the topic of open innovation. While we agree with Huizingh (2011), who highlights that innovation has very rarely been 'closed', there is no denying the increased focus on more complex forms of innovating with multiple actors, across organisational boundaries. What we see in the literature is the use of 'open innovation' as an umbrella term, with other forms of innovation such as collaborative innovation, network innovation, co-creation, user-driven innovation, crowdsourcing all falling under the broader term of open innovation. While it is not the purpose of our paper to disentangle the knotty conceptual underpinnings of various types of openness within innovation practices, it is important to recognise the shared dimension of these concepts – namely, that innovation takes place with multiple actors and not within the confines of a single organisation.

Open innovation in the public sector; collaborative innovation

While much of the literature in this area has its roots in for-profit organisations there is a growing body of research focusing on the application of these practices of innovation in public sector organisations. There is a recognition that open and collaborative forms of innovation may support an increase in the quality and quantity of innovations in the public sector (Nambisan, 2008; Bommert, 2010), at the same time as helping to remove policy impasses and deadlocks while dealing with ever increasing complex societal problems (Torfing, 2016). It is also known that models of open and collaborative innovation cannot be directly transferred into a public sector setting due to the policy processes and cycles that determine the introduction of new policies (Mergel and Desouza, 2013). However, there is a growing literature on the development of guidelines and frameworks applying

the principles of open and collaborative innovation into the public sector (e.g. Bloch and Bugge, 2013; Brown and Osborne, 2013; Crosby et al., 2016).

In a related field, collaborative governance is defined as the inclusion of government organisations in formal discussion in order to reach agreement with respect to public policy adoption or how government resources or plans are managed (Ansell and Gash, 2008). Networked government engages all types of organisations (for and not-for profit organisations) and citizens in the system to attain relevant public goals. As a result, the concept of collaborative innovation emphasises that resources should be shared over different organisational boundaries (Moore, 2009; Bommert, 2010). Also, a cross-disciplinary approach is proposed to the collaborative work between governments in which the advanced collaborative innovation hierarchies could strengthen public innovation by instigating stable processes (Sørensen and Torfing, 2011).

Stakeholder management

A key aspect of open and collaborative innovation is the management of stakeholders to engage with innovation. This appears to be more of a challenge in public sector led collaborative innovation where IP issues are less transparent, knowledge is often more tacit and there are inherently more politics at play (Mergel and Desouza, 2013). Furthermore, the literature identifies a key consideration concerning the management of the open and collaborative innovation, which is 'who' takes ownership and responsibility for the innovation. This means that the facilitation of the collaboration is of utmost importance in the success of the collaborative innovation (Sørensen and Torfing, 2011); but there is limited theoretical or practical insight into how this facilitation can be done effectively.

A multi-stakeholder partnership (MSP) is an idea in which stakeholders, both governmental players and non-governmental players, make an effort to do something together under a win-win situation, with each actor given a clearly defined role (Simon et al., 2016). When the stakeholder-based process is applied to local government administration, the decision makers are influenced by the stakeholders who are empowered to deploy the power over their organisation (Gomes, 2006). There appears to be an element of power differential that can impact the success of the collaboration; for example, the individual managers' consideration of power and power-motivated behaviours can impact the success of the innovation (Cankar and Petkovšek, 2013). This can result in power asymmetries that can risk the operation of the collaborative innovation (Sørensen and Torfing, 2011). In order to overcome these power differentials there are traditionally five elements that underpin the collaboration concept; namely:

1. organisation,
2. associateship,
3. interaction process,
4. objective, and
5. temporal attribute.

The task of exploring the stakeholders' role needs the comprehension of the distinctiveness, the depth, area of interest, distinct portion and logic deducting of players. The requisite conditions are as follows: to obtain the arrangement of the public value that needed to be co-produced; to gain legitimacy and authorisation over the converging and diverging points: and to create the required capability of co-producing the public value, especially delivery and interconnected system capacity with a close attention to the important route, divergent resourcing, and contrasting time frames (Bryson et al., 2017).

Initial conceptual framework

This demonstrates the complexity of the areas to be considered in the setting up and management of a collaborative innovation network. Figure 1 outlines the initial conceptual framework for our study. It illustrates the key areas of importance and will provide guidance as an analytical framework for our empirical data.

Figure 1 - Initial conceptual framework

Our study into the complexity of managing the GNSS CORS system in Thailand aims to analyse how different government agencies are collaborating in terms of data gathering, data management and service distribution. Our study will also evaluate the roles played by prominent owners of GNSS network infrastructure in this collaboration.

Research Methodology

Outline of the research design

An earlier case study of interagency cooperation relating to GNSS reference station administration in Australia has shown the need to make proper allowance for the innovation capability of each participating organisation and to assign the separate key roles (Hausler and Philip, 2013; Higgins, 2008; Roberts et al., 2004; Roberts, 2009). Based on the apparent similarities, we seek to build on the Australian research findings in our own study of GNSS CORS management in Thailand. A central feature of the Australian case was the establishment of ANZLIC as the top government body in Australia and New Zealand responsible for the accessibility and usability of spatial information (ANZLIC, 2019). In Thailand, no less than nine organisations are getting involved in GNSS ground infrastructure technology, including six government agencies and three universities (Rizos and Satirapod, 2011).

Our research design is founded on a realist ontology combined with a multi-methodology approach to data gathering, including focus groups, expert interviews and in-depth case studies. In practical terms, this involves focus group interviews with six organisations who own the base stations in Thailand and expert interviews with academics from three universities, supported by simultaneous analysis of the Australian case study documentation. Our approach to data analysis is based on deductive content analysis to derive our research findings. The broad objectives and scope of our study and

somewhat convoluted nature of the research design lead to a large set of multifarious research data (Stewart et al, 1990).

The data collection phase started in the summer of 2018 and is currently ongoing. Following transcription and translation of the focus group and expert interviews, detailed content analysis is applied, and findings are compared.

Data collection methods

A focus group is a data collection method that provides large amounts of information on the perspectives and spontaneous body language from of a range of individuals about issues raised in the group interaction (Rabiee, 2004). Primary focus group data were collected from six government and public organisations that control GNSS CORS infrastructure in Thailand. The six focus groups respectively comprise the Royal Thai Survey Department (RTSD), the Department of Lands (DOL), the Department of Public Works and Town & Country Planning (DPT), the Hydro and Agro Informatics Institute (HAII, a public organisation), the Geo-Informatics and Space Technology Development Agency (GISTDA, a public organisation), and the National Institute of Metrology, Thailand (NIMT, a public agency).

Each of the focus group interviews lasted between one and three hours. They were conducted internally: the participants were invited to discuss a given topic with three to six government officers who came from the same organisation. The detailed composition of each focus group was determined based on selected criteria covering the purposive specification and multidimensional aptitude of the participants. These criteria included, for example, age range, knowledge of the study area as well as other characteristics, organisational responsibility and decision-making power. As they had been carefully selected based on these criteria, the participants were comfortable expressing their ideas to the group members and researcher (Rabiee, 2004). Additionally, some of the participants were assigned as the representatives of their specific department, in order to substitute for any important decision makers who were unavailable for the focus group interviews.

Expert interviews constituted the second data collection method employed in this study. This particular qualitative technique requires skilful participants with a specific interest and expertise in the relevant area of research. Although a powerful technique if applied in the right manner and circumstances, the choice of experts is subject to a number of constraints; in particular, proficiency in the specialised research questions but also limitations in terms of time, availability and accessibility. Such factors tend to put a strict limit on the number of the potential participants (Baker et al., 2012).

Once selected, experts are requested to attend sessions with an interviewer who raises queries relating to specific topics and records the responses (Muskat et al., 2012). In our research design, the experts were two Professors and a Lecturer from three Thai academic institutions; namely, Chulalongkorn University (CU), King Mongkut's Institute of Technology Ladkrabang (KMITL) and Kasetsart University. They are all professionals in GNSS technology and related fields of research; and they participated in semi-structured interviews lasting between one and two hours.

Data analysis methods

Data collection was immediately followed by the start of the process of data analysis. Summaries and transcriptions of the focus group and expert interviews, including nonverbal communication as well as the way in which participants used words and the tone of their voice, were made in preparations for the next steps in the analysis (Onwuegbuzie et al., 2009; Stewart et al., 1990). In a qualitative research paradigm, the

analysis aims to understand the meaning of a situation, rather than its literal truth, according to the purpose of the study. In the context of focus groups, transcribing interview data could yield many similar instances and phrases. There is then a risk that data selection and evaluation could become highly subjective. Therefore, an in-depth analysis of the interview data should be systematic, sequential, verifiable and continuous. (Krueger and Casey, 2000; Rabiee, 2004).

Content analysis is a flexible approach that can be applied to quantitative data as well as qualitative data, either in an inductive or deductive investigation. Although its very flexibility and lack of straightforward guidelines for use have sometimes caused problems for researchers applying this analysis method, it is very well suited for delicate and multifaceted context analysis. Moreover, a deductive analysis is capable of testing existing assumptions or differentiating between phenomena relating to dissimilar categories and different times (Elo and Kyngäs, 2008).

Based on our prior theoretical knowledge from the literature review, we have used our initial conceptual framework (in Figure 1) to apply deductive content analysis to the massive set of data from both the focus group interviews and expert interviews. This has been done through a systematic process, in which data consisting of the use of words, tone of voice, gestures, facial expressions and body positions have been examined in connection with the research questions. The quotes have been classified into a 'relevant category' and 'not so relevant category' and duplicate quotes have been grouped as per their similarities. The data preparation step has been repeated until all was in readiness for the data interpretation stage (Rabiee, 2004).

Findings

Outline of data analysis

After the preparation stage, we have analysed our data in accordance with the seven criteria of Krueger (1994) and Rabiee (2004); including actual words used and their meaning, context, internal consistency, frequency or extensiveness of comments, intensity of the comments, specificity of responses, and big ideas.

1. Consider the actual words used and their meaning

The word most fequently mentioned in the interviews is 'business model', which the participants considered as a framework for the collaboration. The participants seemed to believe that this word constitutes the main guideline for the direction in this collaborative project and that it will influence multifaceted factors of the cooperation, including the policy or regulation that will be adopted accordingly.

2. Consider the context

The researcher did not ask about the importance of the CORS technology. However, the participants expressed that this technology is necessary to ascertain the quality and ease of their work. Thus, the expansion of GNSS network is required. However, they are taking additional technology into account at the same time, in order to prevent obsolescence of traditional technology effect.

3. Consider the internal consistency

The individual participants' steadiness in viewpoints and position was firmly retained; the viewpoints of others rarely impacted their individual perspectives. Some changes happened solely when new information emerged from trustworthy members who are directly responsible for the matters related to that information.

4. Consider the frequency or/and extensiveness of comments

The most frequent words occurred in discussions is 'who', with reference to the context, 'who' means 'which organisation'. The questions about 'who' arose in many

instances: either who should be the project leader?, who should be the national data centre?, who should manage the central network?, who should process the CORS network?, who should provide the services?, who should take responsible for the marketing strategies?, who should deal with the private sector or foreign countries?, and who else should be able to own the CORS in Thailand?. The participants responded to the question about 'whether collaboration on GNSS CORS in Thailand should be done' that 'everyone (organisations) wants to get involved in this collaboration as it is a great opportunity to gain advantage from the shared infrastructure'. 'Many of them want to be the leader of an association; however, who is the most appropriate one?'

5. *Consider the intensity of the comments*

This stage has aimed to perceive the profound feelings of the speakers about their comments. When the directors or managers from the prominent organisations stated that they agreed with the collaboration, it means that their organisations would love to join the created community of CORS as important players and could leave the coordination once the conditions are of no further interest. Conversely, the comments from less-powerful organisations are thereunder. They have more positive feelings about this collaboration than the powerful ones.

6. *Consider the specificity of responses*

The replies from the members that related to individual experience have been considered as contradictory hypothetical situations. For instance, an officer who graduated from Japan recommended to use the Japanese business model as a guideline of the cooperative project rather than Australian business model; whereas an IT specialist commented about cell-based technology to replace or supplement the CORS technology.

7. *Find the big ideas*

Making provision for overall discussion matters requires a temporary pause to increase the ability to assess the massive amount of resources thoroughly and go through the variety of information efficiently. As a consequence of this step, the big picture of the discussion would be asserted.

Data interpretation

A preliminary interpretation of the results by manually comparing and contrasting the interview data can be summarised as follows. First, the comments in respect of the given topics reflect a considerable shift in attitudes towards the collaborative project. There are several issues that the interviewees concerned about listed below.

1. *Whether public collaborative innovation relating to GNSS technology will come into effect?*

The lack of the obliging power of the laws and regulations supporting the actions has decelerated the team forming process. Further, a change of the government could cause unpredictability and uncertainty in the policy of CORS management.

2. *Which government agency (between the one who has the maximum number of the assets and the one who has core responsibility for state surveying) should be the project leader?*

The Royal Thai Survey Department who is responsible for the national mapping was the most frequent mentioned organisation in this point. Nevertheless, the Department of Lands who have the greatest amount of CORS sites in Thailand was named as well.

3. *Which organisation should be the national data centre?*

Should the project leader be the national data centre? If yes, they would be the central unit for the CORS management in Thailand. On the other hand, the national data centre should be able to make profit or make the contract with private sector or foreign countries.

Therefore, the Royal Thai Survey Department, which is a Special Services Group of Headquarters, Royal Thai Armed Forces, might not be applicable to this aspect.

4. What should be the shape of the cooperation design?

As regards the interests of the structure of the cooperation between government organisations, the regulations or an Act of Parliament to permit government authorities to share internal information with other parties had to be granted beforehand. In addition, the restrictions on resource sharing and the relationship between organisations should be clarified.

5. What business model should be selected?

They need to judge between Japanese business model and Australian business model (or other business model) which one is the most pertinent to be followed?

6. What technology should be installed for the overall network configuration?

Multiple type of hardware and software have been established, the configuration for the central network need to be chosen in advance. Once the data streaming start, the network setting should be ready to go as well.

Second, the interviewees demonstrated the strong desires for concrete out-turns with respect to rational doubts that are mentioned above. The following are crucial needs they pointed out.

1. *Regulations or policies*

They greatly desired the effective regulations or policies for inter-organisational cooperation so that each organisation is allocated a suitable role.

2. Authority

An appropriate authority is demanded of each office. In order to the flexibility and possibility in working on this project together, particular authority should be given to specific collaboration members. Therefore, they will know the extent of their legitimate rights in performing tasks or duties and protect them from any charge and trial as the result of proceeding with the plan under the government policies.

Contribution

The ultimate goal of our research is to support the adoption of the policy framework for strengthening the GNSS CORS collaborative innovation in Thailand. This will include the development of a viable business model to formulate budgetary guidance and resolve budgetary issues.

From a theoretical perspective, our research contributes to a better understanding of the roles that each of the stakeholders should play in a collaborative innovation effort, taking account of their different levels of power and interest. Collaborative innovation holds considerable promise in breaking individual policy deadlocks, minimising system-wide investment costs and improving public service quality. However, Bommert's (2010) contention still holds: there is an urgent need for empirical research, typically in the form of in-depth case studies, to substantiate such potential benefits. Our research aims to make an original contribution to fulfilling this need.

Conclusion

The study of GNSS CORS technology management in Thailand is now under way to establish a final stage of analysis and interpretation which are an extremely time-consuming process due to a huge amount of data. After that, we will endeavour to adopt the policy framework for this technology management which require a great thoroughness. Therefore, the relation between the cooperative government organisation and the power of stakeholders should be identified precisely prior to the policy adoption. However, the vital role of political leadership, politicians, and politics that influence

public value production in the society are greatly significant to take into account (Bryson et al., 2017). As a result, further study would extend to focus on the political power issues that could impact the GNSS CORS collaboration management in Thailand.

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Operations Management in Regional Economies

Dynamic capabilities in micro and small enterprises: Evidence from developing countries

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Abstract

Micro and small enterprises in developing countries are a source of employment and poverty alleviation but have low survival rates. This contrasted picture hints to the paramount importance of dynamic capabilities, which enable firms' sustainable performance. Research on dynamic capabilities, however, is scarce. Because dynamic capabilities depend on managers' actions, we focus on dynamic managerial capabilities, namely human capital and social capital, and their relationship with financial performance. Using secondary data, we analyzed 2340 Peruvian micro and small enterprises. We found that human capital is positively related to financial performance, and mediates the relationship between social capital and financial performance.

Keywords: Dynamic managerial capabilities, Micro and small enterprises, Developing countries

Introduction

Small-and medium-sized enterprises (SMEs) are key players in the sustainable growth of most economies. In developing countries, SMEs contribute to up to 45% of total employment and 33% of GDP (OECD, 2017). Recent research has contributed to the understanding of SMEs' efforts to improve their operations and the consequent impact on performance (e.g. Lagacé and Bourgault, 2003, Matthews et al., 2017). However, significantly less attention has been paid to micro and small enterprises (the smallest firms in terms of number of employees and annual turnover). These are especially important for the production ecosystems of developing nations, such as Latin American countries, in which MYPEs (which stands for micro and small enterprises in Spanish) represent the vast majority of firms, and a rich source of employment, poverty alleviation, and economic dynamism (International Labour Organization, 2016, Maksimov et al., 2017).

Unfortunately, many MYPEs struggle to sustain their operations over time. Among the most common reasons for business failure, low profitability occupies the first rank (Global Entrepreneurship Monitor, 2018). This hints to the utmost importance of productivity (Krishnan, 2013). While many micro and small enterprises focus on marketing practices to increase their sales and respond to market needs (Danis et al., 2009), it seems that they pay a lot less attention to the management of their operations. Generally, the development of capabilities is relegated to the background. If existent, this development process is usually unstructured, and sometimes unintentional. However, this view is a rather oversimplification of the MYPE's potential. It is possible that MYPEs have different capabilities and use different processes to build them compared to large enterprises (Arend, 2014). Yet, we argue that capabilities that are *dynamic* are important in the sense that they allow MYPEs to deal with the typical constraints of developing countries, also known as institutional voids.

The managerial perspective of *dynamic capabilities* proposes that these capabilities are driven by top managers (Salvato and Rerup, 2011). Given the small size and entrepreneurial origins of MYPEs, owner-managers are undoubtedly the key actors for capability development (Matthews et al., 2017, Eikelenboom and De Jong, 2018). In line with this managerial perspective, we focus on the study of dynamic *managerial* capabilities. Dynamic managerial capabilities are "the capabilities with which *managers* build, integrate, and reconfigure organizational resources and competences" (Adner and Helfat, 2003: 1012, emphasis added), and have been proven to be crucial in large enterprises (Ambrosini and Bowman, 2009, Helfat and Martin, 2015). Thus, our research question is the following: *What is the impact of dynamic managerial capabilities on financial performance in MYPEs in emerging economies?* To respond to it, we conduct a quantitative study using secondary data from Peruvian MYPEs.

Current research focuses on the role of the environment, e.g. institutional voids and market characteristics, thereby implying a deterministic stand. Our goal is rather to unveil how owner-managers actively and purposefully invest in themselves to develop their MYPE's dynamic capabilities. We contribute to the literature on dynamic capabilities and society in general by offering a basis to create successful training programs aiming to support MYPE managers' skills.

Theoretical background and hypotheses development

While only a few studies focus on the *operational capabilities* of SMEs usually in developed countries, a lot fewer on *dynamic capabilities* of MYPEs in developing countries. The body of literature has focused on the heterogeneity of SME's operational capabilities and their impact on performance (e.g., Wolff and Pett, 2006). Empirical evidence shows that what works for large companies does not always work for micro and small companies (Cagliano et al., 2001, Arend, 2014). We can translate this argument to the level of dynamic capabilities. Dynamic capabilities are at higher-level of abstraction (Helfat and Winter, 2011) for they allow firms to adapt operational routines and capabilities to the dynamic environment (Eisenhardt and Martin, 2000). It is plausible, for example, that MYPEs are reluctant to invest in continually adapting to the environment since it implies obtaining financing and using resources to perform "less urgent things." As Krishnan (2013: 1441) points out: "some entrepreneurs even consider 'process' a bad word in their companies due to the organizational rigidity, inertia, and bloat associated with them." Owner-managers that think like this indicates that they lack an operations management (OM) view. A profound negative implication is that these owner-managers would not prioritize the MYPE's continuous improvement

infrastructure, and consequently hinder the materialization of a dynamic capability (Matthews et al., 2017, Anand et al., 2009). Furthermore, the environmental characteristics of developing countries shape the need for dynamic capabilities (Meyer and Peng, 2015). Prasad and Tata (2009), for example, argue that a supportive political/legal system, access to financing resources, information management, and establishment of inter-organizational linkages increases the quality levels of Indian micro-enterprises. Yet, managers' endeavors to make the best use of the available resources and capabilities as well as managers' interpretations (Adner and Helfat, 2003, Helfat and Martin, 2015) are key enablers of dynamic capabilities.

Thus, due to the key role of managerial intervention for the concretization of dynamic capabilities (Helfat and Martin, 2015), we study *dynamic managerial capabilities*, "the capabilities with which managers build, integrate, and reconfigure organizational resources and competences" (Adner and Helfat, 2003: 1012). We focus on two core underpinnings of dynamic managerial capabilities: human capital and social capital.

Managerial human capital

Managerial human capital refers to knowledge, education, experience, and skills (Helfat and Martin, 2015). Human capital improves productivity by, first, improving the marginal productivity of other organizational resources, and second, affecting the amount and type of investments in physical and labour resources (Bruhn et al., 2010). Using a meta-analysis, Jiang et al. (2012) confirm the pivotal role of human capital for increasing operational outcomes. However, most of the literature has focused on human capital in large firms in developed countries. Following the framework of Ployhart and Moliterno (2011), we consider two forms of human capital: generic and specific knowledge.

First, *generic managerial knowledge* is acquired mainly through education. Education fosters managers' ability to process complex situations and make faster decisions (Wally and Baum, 1994). Education also forms a basis for openness to new experiences and innovation (Barker and Mueller, 2002). This generic knowledge provides the constituent skills that can be applied in different situations, such as problem solving and social intelligence (Ployhart and Moliterno, 2011). Because of their great mobility, managers can transfer them across industries and firms (Bailey and Helfat, 2003).

In the case of MYPEs, they are usually led by entrepreneurs. And entrepreneurs' education is positively related to business success (Robinson and Sexton, 1994) and profit (Bosma et al., 2004, Honig, 2001). Although Lee and Tsang (2001) found that education only supports venture growth in large enterprises, we argue that in the context of developing economies, the owner-managers' educational background creates a competitive difference. Our argument follows Unger et al. (2011) in that heterogeneity and scarcity of educational resources in these countries mean that highly educated managers are better prepared to face environmental constraints and identify opportunities.

H1. Managerial generic knowledge is positively associated with financial performance of MYPEs in developing countries.

Second, *specific managerial knowledge* is the knowledge and skills that are specific to the tasks of the manager (Unger et al., 2011). In that sense, the performance of manufacturing MYPEs is dependent on managers' skills in OM. Because of our interest in dynamic capabilities related to the MYPE's OM, we chose to represent managers' specific knowledge as the aggregate knowledge regarding practices to improve (quality management) and innovate. We also include managers' knowledge on information and communication technologies (ICT) since small enterprises heavily rely on them to operate efficiently (OECD, 2017). In fact, these three types of specific knowledge encompass the

most commonly reported growth-impeding constraints on the contribution of the operations function in SMEs (Clegg, 2018).

While in developed countries *quality management practices* are taken for granted, in developing countries, managers may be more skeptical about the benefits of implementing them. Due to lack of information regarding quality along the supply chain and difficult access to economic resources, MYPEs in developing countries may show low levels of quality (Prasad and Tata, 2009). Furthermore, it is possible that owner-managers see quality as a threat. Quality training may be elusive for those with little management background or time. Making operations transparent, through quality management practices, may also frighten owner-managers that rely on informal mechanisms and bureaucratic corruptive influence (Mersha, 1997). The managers who take the big step to acquire knowledge of quality practices are thus creating a source of differentiation (Chandler and McEvoy, 2000), not only supporting better quality products but also developing elaborated and proactive plans, and, consequently, superior performance (Frese et al., 2007).

Knowledge of *innovation practices*, such as development of new or better products, services, and processes, represents the second type of specific knowledge. Empirical evidence in large firms categorically states that innovation has a positive impact on financial performance. On the one hand, MYPEs have few resources to continuously renovate their products or sustain a large-scale research and development operation. On the other hand, because of their size, inherent flexibility, and less bureaucratic organization, they have an enormous potential to capitalize in innovation practices (Qian, 2002, Honig, 2001). We expect that owner-managers who are highly skilled at innovating can accurately sense new opportunities and reconfigure their MYPE's resources.

Knowledge of *ICT* represents a third type of specific knowledge. Although this ICT knowledge may marginally affect the development of dynamic capabilities in large enterprises, they allow MYPE owner-managers to reinforce the corporate image, offer timely information, and assist consumers (Nieto and Fernández, 2005). Many positive outcomes arise from this presence in the virtual world. First, knowledge in ICT simply reduces unnecessary paperwork and presents the MYPE to the world. Second, MYPEs benefit from a constant inflow/outflow of data that may foster formal knowledge storage (e.g. standard operating procedures, sales catalogues, quality reports). Third, MYPEs have direct access to different sources to support timely and informed decision-making (Wales et al., 2013, Agarwal and Selen, 2009). Finally, training in e-commerce allows managers to reduce costs by facilitating the MYPE's integration with business partners (Wales et al., 2013).

Overall, we posit that the managers' accumulated capital specific to the management of their MYPEs' operations shapes how they develop, modify and reconfigure their MYPE's capabilities.

H2. Managerial specific knowledge is positively associated with financial performance of MYPEs in developing countries.

Drawing upon the model of Ployhart and Moliterno (2011), we hypothesize that generic knowledge facilitates the development of specific knowledge. The idea is that other enterprises may copy the owner-manager's generic knowledge—for example, hiring an equally capable person. Context-generic forms of human capital facilitate the adaptation and assimilation of specific-context forms. Managers with a high level of education may have higher attention capabilities, be more selective in the knowledge to assimilate, and accurately invest in the type of specific knowledge they need. Therefore, managers create a unique distinctive source of capability when they use their general

knowledge to acquire easily and selectively the specific knowledge provided in managerial training. We argue that when specific knowledge, supported by generic knowledge is applied to the particular context of the MYPE, a unique human capital becomes a dynamic capability, which in turn concretizes in financial gains.

H3. Managerial specific knowledge mediates the relationship between generic knowledge and financial performance of MYPEs in developing countries.

Managerial social capital

Managerial social capital refers to "goodwill derived from relationships, both formal and informal, that managers have with others and can use to obtain resources and information" (Helfat and Martin, 2015: 1286). Social capital is at the basis of dynamic capabilities (Blyler and Coff, 2003). It fosters the search and acquisition for resources by taking advantage of social ties, for example, in the form of referrals to investors or other stakeholders (Shane and Cable, 2002). In developing countries, informal mechanisms, such as the use of personal networks, are privileged to counterbalance the cumbersome political and economic context. Strong ties help managers to compensate for the lack of governmental support, and access to reliable information (Stam et al., 2014). Also, entrepreneurs belonging to business networks or who are "politically connected" can enhance their performance by seizing capability-building opportunities and accessing public-sector resources (Armanios et al., 2017, Bosma et al., 2004, Acquaah, 2007).

H4. Managerial social capital is positively associated with financial performance of MYPEs in developing countries.

We also advance that managerial social capital increases specific knowledge (human capital). Through social networks, owner-managers are influenced by others' knowledge and experiences (Helfat and Martin, 2015). This may translate in an increased motivation to invest in new knowledge either to deepen what they have learned from their peers or to gain status. Consequently, we expect that specific knowledge mediate the relationship between managerial social capital and financial performance.

H5. Managerial specific knowledge mediates the relationship between managerial social capital and financial performance of MYPEs in developing countries.

Method

Research context and sample

Peru is our research setting where MYPEs represent around 99% of companies of which 20.1% are in the manufacturing sector (Global Entrepreneurship Monitor, 2018). Moreover, Peru ranks among the top five economies with the highest "entrepreneurial spirit index," and 7.4% of Peruvians are owner-managers of established businesses (with more than 3.5 years in operation). In 2008, the Peruvian government enacted a legislative decree approving a law to promote the competitiveness, formalization and development of MYPEs, and the access to decent employment. Other initiatives, such a labour regime for MYPEs and national training programs, and new organizations' efforts to support the MYPEs' development, make of Peru an ideal context of study.

We use data from a secondary source comprising results of a survey conducted by the National Institute of Statistics and Information Technology (INEI, 2013). The data was collected through interviews between August and September 2013. The population was composed of MYPEs—according to the definition of local authorities, annual sales between 20 and 1700 tax units (1 tax unit=3650 Peruvian Soles)—in the manufacturing sector. The survey includes 2515 responses (response rate=83.2%). Non-responses originated from buildings not found, activities not studied, rejection, definite closing, or

absence. Additionally, we discarded other responses for two reasons. First, because we focus on *managerial* capabilities, we discarded responses in which the informant was the accountant or the administrative assistant. Second, we did not include two responses of MYPEs with more than 100 employees because it is not considered a MYPE per the Peruvian definition. We ended up with 2340 usable responses. The MYPEs in the sample represent different manufacturing sectors (apparel=31.4%, metal products except from machinery and equipment=27 %, furniture=15.9 %, leather and related products=15.5 %, wood and cork products including straw and plaiting materials=6.1 %, food (dairy and cacao products)=2.1 %, other manufacturing industries=2 %) and geographic regions (Lima=38.5, Arequipa=22.2%, La Libertad=13.5 %, Lambayeque=6.1 %, Junín=6.0, Cusco=3.5 %, others=10.3 %).

Measures

To measure the dependent variable, financial performance, we use the value added of the MYPE calculated as the costs of inputs to production and the price of output. The respondents provide the main entries of their profit and loss statements for 2012. Regarding the independent variables, we measure the core underpinnings of dynamic managerial capabilities of the respondent, the owner-manager or a top manager. Human capital includes two measures. First, generic managerial knowledge as the last education level attained in a 10-item-scale (from 1=none to 10=completed university education). Second, specific managerial knowledge as a formative index of the total hours of training and mentorship received in 2012, regarding quality management practices (quality management systems, 5S, Kaizen, ISO 9000, and good manufacturing practices), ICT (web design, e-commerce with suppliers and customers, online banking, online transactions with public organizations, social networks, and basic computing skills), and innovation practices (practices to develop new or better products, services, and processes in the firm and the supply chain). We measure social capital as the frequency of participation in meetings of business associations (from 1=weekly to 6=annual). We use the logarithmic transformations due to the right-skewed data distribution.

We include several control variables, including characteristics of the respondent (age and gender), and the enterprise (logarithmic transformation of the MYPE's years of operation). Given that macro level factors may also affect financial performance, we consider two environmental variables, munificence and dynamism. We use the value added of each industry sector between 2007 and 2011 available in the INEI database. We replicate the calculation as in prior studies suing time as the independent variable in the regression of growth (Castrogiovanni, 2002). So, munificence equals to the regression slope coefficient divided by the mean value, and dynamism to the standard error of the regression slope coefficient divided by the mean value. To control for knowledge in the shop floor, we include the natural logarithm of the total hours of technical training received by the employees in 2012.

Results

The means, standard deviations, and correlations are available upon request. We used ordinary least squares regression to test the direct effects proposed in H1, H2, and H4 (Table 1). Human capital, in its two forms was positively associated with financial performance supporting H1 and H2. Social capital, however, was negatively associated with financial performance and the effects were not strong enough to be significant. H4 is not supported.

To test the mediation effects in H3 and H5, in line with Rungtusanatham et al. (2014), we ran Hayes (2013)'s PROCESS model 4 for SPSS with 95% bias-corrected confidence intervals and 10000 bootstrap subsamples. The bootstrapping method has been proven as more reliable than the traditional Baron and Kenny method (Ta et al., 2018). If the confidence intervals do not contain a value of zero, significant mediation is evident (Hayes, 2013). In support of H3, the results confirm that managerial generic knowledge was associated with financial performance, mediated by managerial specific knowledge (*indirect effect*=2011.7, *SE*=794.42, 95% CI=605.32 to 3682.39; *direct effect*=30310.78, *SE*=3454.21, 95% CI=23537.13 to 37084.43; *total effect*=32322.48, *SE*=3419.78, 95% CI=25616.35 to 39028.61). In support of H5, we found that managerial social capital was associated with financial performance mainly through the investment in managerial specific knowledge (*indirect effect*=11343.2, *SE*=4675.76, 95% CI=3184.3 to 21418.51; *direct effect*=-935.05, *SE*=17494.74, 95% CI=-35241.93 to 33371.83; *total effect*=10408.15, *SE*=17266.93, 95% CI=-23452 to 44268.3).

Table 1 – Ordinary least square regression for financial performance

Variables	**b**	**Std. error (*SE*)**	***p***	**95% Confidence interval (CI)**
Main effects:				
Human capital				
Managerial generic knowledge	52664.81	14319.65	< 0.001	24584.22 – 80745.40
Managerial specific knowledge	30310.78	3454.21	< 0.001	23537.13 – 37084.43
Social capital	-935.05	17494.74	0.96	-35241.93 – 33371.83
Control variables:				
Gender	2422.37	14090.69	0.86	-25209.24 – 30053.98
Age	674.00	635.88	0.29	-572.952 – 1920.96
Munificence	457000.47	237385.50	0.05	-8508.38 – 922509.32
Dynamism	508892.74	633880.14	0.42	-734135.22 – 1751920.69
Firm age	48358.92	10504.31	< 0.001	27760.139 – 68957.70
Technical training	3295.18	4426.98	0.46	-5386.05 – 11976.41
Constant	-271373.40	49576.61		

Discussion

We contribute to the literature on OM in micro and small enterprises. Our study attempts to integrate views from OM, Entrepreneurship, and Human Resources Management by using the dynamic capability perspective. Our argument is that in such small firms, functions overlap and the owner-managers are in the spotlight. They decide every step of the MYPE so any heterogeneity in practices, capabilities, and performance depends on their own capabilities. In adopting this "human" angle, we complement prior works that focus on the effect of operational capabilities on performance (e.g., Cagliano et al., 2001).

We also contribute to the literature on OM in developing countries that has largely emphasized the role of the environment (e.g., Prasad and Tata, 2009). Our findings show that the individual level that is investments in managerial knowledge of the management of the MYPE's operations is fundamental. This suggests that the effects of new improvements or innovations at the organizational level (MYPE's dynamic capabilities) is affected by the capability of the owners or managers to bring the knowledge to the MYPE through their own instruction efforts (dynamic managerial capabilities).

Overall, we contribute by bringing the individual back into the conversation of dynamic capabilities. In that regard, we show that dynamic capabilities could help

MYPEs to overcome the obstacles along the growth path identified by Clegg (2018). Our results demonstrate that human capital provides the main underpinnings of dynamic managerial capabilities that result in increased financial performance. In that sense, our results echo those in the literature on large firms in which top managers' capabilities are the key actors. Notably, MYPEs in developing countries highly rely on their owner-managers. A possible explanation is that human capital is scarce in developing countries. The Peruvian index of expenditure on public education (as a percentage of GDP) was 2.6 in 2012—compared to the top country, Norway with an index of 6.9. Knowledge and skills are thus very valuable assets. The significance of human capital in our study, as well as its mediating role, has a profound practical implication for developing countries: a need for both educational policies and training resources to support entrepreneurs to manage their operations. Although many countries are investing strongly in *entrepreneurship* education and training, which has an effect on starting or growing a business (Martin et al., 2013), this may be not enough. Our results suggest that investing in *OM* education and training determines performance of the business in the long term.

Furthermore, our results are congruent with previous literature that highlights the key role of informal mechanisms to counterbalance institutional voids in developing countries (Stam et al., 2014). Although we did not find support for a relationship between managerial social capital and financial performance, we did find that specific human capital mediates this relationship. This implies that personal connections may increase the opportunities to access new knowledge related to the MYPE's OM, which in turn increases financial performance. In large enterprises, connections with supply chain partners have been proved important; in MYPEs, other types of networks, such as business groups, may matter equally or more. The direct effect of managerial social capital in our sample is, however, negative. Although not strong enough to be significant, this indicates that the sole reliance on associating with peers may not be beneficial for MYPEs likely because of limited resources and time.

Conclusion

We tested the relationship between dynamic managerial capabilities and financial performance of Peruvian MYPEs. The Peruvian context is representative of Latin American countries in terms of entrepreneurial spirit, as well as economical, cultural, and political context. Nonetheless, cross-country research can shed more light into the different successful combinations of dynamic managerial capabilities. We acknowledge that our analysis is limited by the available data. We encourage the study of other variables such as different types of education, training, and social capital. We conclude that MYPEs are key players in developing economies yet neglected so far in the OM research agenda. In this study, we explicitly consider the interconnections of three core underpinnings of dynamic managerial capabilities—human capital, the knowledge of operations management (managerial specific knowledge) and the managerial generic knowledge, and social capital. Our results support the positive impact of dynamic managerial capabilities on financial performance for MYPEs in a developing country.

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A classification of deception in operations and supply chain management: A case study of deception in Australian souvenir markets

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Abstract

Sustainability concepts inform business considerations of production and procurement in order to satisfy consumer demands for ethical products. Drawing on the Deception Impact Model, the aim is to understand the severity of deception, implementation of socially sustainable practices, and impact on consumers by examining a case in the Indigenous art Australian souvenir industry. It found where a firm decouples from socially sustainable practices the result, a form of deception, negatively impacts ethically motivated consumers. The paper highlights where Indigenous people should be involved in the development chain to avoid infringing on human rights as it relates to commodification of culture.

Keywords: Social Sustainability, Ethical Practice, Deception, Indigenous Art

Introduction

The growing consumer desire to make ethical purchases necessitates firms to become more transparent in their production and procurement processes. Sustainability concepts, which include social, environmental, and economic dimensions, are ways in which business can consider the production and procurement in order to satisfy

consumer demands for ethical products. Likewise, the sustainability dimensions are a lens in which to examine operational processes to understand where practices decouple from what is legally and socially accepted in the provision of goods and services.

Sustainability issues transform the competitive environment for business (Longoni and Cagliano, 2015). There are various reasons for the private sector to demonstrate sustainability practices in their operations and behaviour. For example, the recent shift within the sustainable development paradigm has seen the private sector take a more prominent role alongside civil society and governments in addressing issues facing inclusive global growth and development (Scheyvens et al., 2016). Beyond contributing to global aspirations for sustainable development, economies can be achieved through environmentally sustainable operational practices, such as waste reduction and energy conservation. These savings can be amplified across a supply chain through coordination with upstream and downstream partners (Gupta and Benson, 2011) and assist in achieving a positive long-term performance of individual companies and their supply chain (Ahi and Searcy, 2015).

When considering sustainability within a supply chain context financial returns are not the only benefits for a network of firms working together to compete in the industry. Supply chain partners also have an interest in understanding each other's processes in order to ensure they are satisfying the needs of stakeholders in both legal and social aspects. The reason is to uphold legal obligations and avoid broader scrutiny by society.

Despite the benefits of practising sustainability in business processes, there are many instances of firms decoupling from strategic sustainability goals during implementation at the operational level. This paper uses the case of the Australian souvenir industry to illustrate where a firm decouples from socially sustainable practices in the production and procurement of low-cost souvenirs featuring stylised designs representative of the culture of Indigenous people. The result of the decoupling, a form of deception, negatively impacts consumers who are motivated to make ethical purchases. In addition to upholding the rights of Aboriginal and Torres Strait Islander people to protect and commodify their culture as a fundamental concept of Indigenous human rights.

This case has been chosen to illustrate deceptive practices as it has been recently highlighted within a Federal Government Inquiry (the Inquiry) and subsequent report (the Report) and legal proceedings brought before the Australian courts prosecuting a well-known souvenir distributor (the Distributor) mislabeling products to deceive consumers who are concerned with making ethical souvenir purchases. Further, this case highlights the role of social sustainability in business to protect human rights as it relates to the cultural dimension. Reasons for this will be outlined.

To understand deception in this context and understand where operational processes decouple from sustainability objectives happen, the Deception Impact Model (DIM) by (Hammadi et al., 2018) is utilised. The DIM connects three dimensions to provide an understanding and positioning of a firm's practices and impacts regarding severity of deception, implementation of sustainability practices and, impact on customers and other stakeholders.

There are differing attitudes and values towards the commodification of culture to produce souvenir product influencing what is classified as 'authentic' or 'fake' product. It is not the aim of this paper to classify or debate authenticity concepts, rather demonstrate the implementation (or lack) of social sustainability concepts in the production and sale of souvenir products featuring designs representative of Indigenous culture, and their subsequent impacts on operations management, supply chains, consumers and stakeholders. The term *inauthentic* will be used in reference to objects or products that do not engage Indigenous people in the design for the purpose of providing clarity and consistency.

The aim of this paper is to highlight where operations management and supply chain concepts can add value to society - particularly with respect to developing Indigenous Australian enterprises which are a valuable mode of sustainable development in remote regions. The paper provides a background to unsustainable practices, then discusses the concept of culture within a human rights framework and how it relates to the social sustainability in the Australian souvenir industry. The legal proceedings brought before the Distributor are examined using the DIM framework to understand the severity of the Distributor's deception. The Distributor's development chain is then examined to understand the degree to which the firms are implementing socially sustainable practices from an operations management and supply chain perspective. Finally, the impact of consumers and other stakeholders is considered to position the Distributor in relation to the implementation of social sustainability practices.

Background

Historical factors also demonstrate a lack of internal culture towards social sustainability among distributors and retailers with the issue of deception relating to inauthentic products within the Australian souvenir supply chain having been addressed in 2003 prior to the Distributor case in 2018. The Australian Competition and Consumer Commission brought action against Australian Icon Products Pty Ltd (AIP) for engaging "in conduct likely to mislead or deceive consumers" due to making claims that souvenirs were hand-painted by Indigenous Australians (NSW Government, 2007). Under Australian consumer law, "consumers are entitled to receive goods that match their description". The ACCC alleged Australian Aboriginal Art Pty Ltd (AAA) mislabelled products claiming they were 'Australian Aboriginal Art', 'Aboriginal Art' and/or 'Authentic, made by Aboriginal artists or artists of Aboriginal descent' despite not employing Indigenous people in the production process (NSW Government, 2007). The 2003 and 2004 cases demonstrate broader public awareness of deceptive practices by souvenir wholesalers in the form of mislabelling products. Despite this awareness, the production and sale of goods to retailers with misleading labels continued.

Recently in Australia, the Arts Law Centre of Australia revealed the widespread use of deception in the souvenir industry through an advocacy campaign. The campaign, known as *Fake Art Harms Culture,* highlighted the pervasiveness of merchandise available at tourism retailers, which presented as Indigenous cultural souvenirs appeared

ambiguous in provenance (Indigenous Art Code, 2019). One of the aims of the *Fake Art Harms Culture* campaign was to draw awareness to products whereby culture is commodified, often with inappropriate designs and materials, to create a product for a specific market. The advocacy campaign led to the Federal Australian Government undertaking an official *Inquiry into the growing presence of inauthentic Aboriginal and Torres Strait Islander 'style' art and craft products and merchandise for sale across Australia* (Inquiry) and a final report (Report) into the findings was published in 2018 (Australian Government, 2018).

Additionally, in 2018, the Australian Competition and Consumer Commission (ACCC) launched legal proceedings against a souvenir distributor finding the firm in breach of labelling laws (Australian Competition and Consumer Commission, 2018). The ACCC case demonstrates a legal mechanism (i.e. consumer law) in which incorrectly labelled souvenirs representing Indigenous culture assist in protecting consumers from making unethical purchases.

Despite consumer law providing protections for consumers in this context, Australian law does not extend to the "underlying idea or information that is put into a work" or a "style or method of art" such as dot painting techniques synonymous with Indigenous culture. Therefore, there are limited legal mechanisms in place to prevent a product being produced that references an Indigenous story or artistic style associated with a culture or specific nation (Artists in the Black, 2019). The commodification of Indigenous cultures to produce and sell souvenirs, without having an overt connection to an Indigenous person is not legally prohibited, and are termed 'inauthentic' for the purposes of clarity. Thus, as evidenced by the 2018 Distributor case, producers, wholesaler, and retailers of souvenirs continue to engage in deception.

Social sustainability: Culture as an aspect of human rights

While social sustainability is becoming an increasing concern of business (Mani and Gunasekaran, 2018), there is ambiguity regarding the social sustainability dimension and what it encapsulates (Ajmal et al., 2018). Cultural and ethical issues have been overlooked compared to factors related to legislative compliance, and the hierarchy of factors enabling social sustainability has not been clearly established (Mani et al., 2014).

A dimension of social sustainability is the rights of Indigenous people. The *United Nations Declaration on the Rights of Indigenous Peoples* protects Indigenous people's "right to maintain, control, protect and develop their cultural heritage" and "to maintain, control, protect and develop their intellectual property over such cultural heritage"; the "right to the dignity and diversity of their cultures"; further advance their economic and social conditions including employment (Australian Human Rights Commission, 2012).

Supply chain management research has been limited in considering the interrelationships between sustainability issues (Gimenez et al., 2012). The three sustainability pillars are ubiquitous in our understanding of sustainability, however, their distinction as separate dimensions is conceptually fuzzy (Kuhlman and Farrington, 2010). There has been a stronger focus on addressing economic and environmental

dimensions of sustainability in business, while the social aspect has not been well developed (Ajmal et al., 2018). As a concept of social sustainability, upholding the rights of Indigenous people demonstrates the convergence of positive social and economic development outcomes.

The *Declaration* highlights the role of culture, cultural heritage, and intellectual property as fundamental to the rights of Indigenous people. A successful example of Indigenous Australians engaging in enterprise and using culture as a means of advancing economic and social conditions is Indigenous art centres. Art centres have become important institutions in remote Australia as they provide people with access to the mainstream art market where only a limited opportunity for economic inclusion exists, and in some instances, represent the only non-welfare form of income available to Indigenous people (Seet et al., 2018). Art centres are also linked to the overall wellbeing of Indigenous people and broader communities by generating positive psychological and emotional impacts (Allain, 2011).

Despite the success of art centres in facilitating cultural production for the art market, commercialisation of culture can lead to conflicting priorities between producers and consumers within the souvenir industry. Indigenous artisans producing handcrafted goods according to cultural protocols (e.g. use of a specific material or production technique) for tourist markets may not be able to price a product to fit the requirements of consumers seeking a low-cost travel memento (Guttentag, 2009). Thus, non-Indigenous firms with capabilities to produce low-cost products, and without legal obligations to follow cultural protocols, are free to appropriate elements or styles of Indigenous culture to meet consumer demands (Guttentag, 2009). In this instance, the non-Indigenous producers are able to exploit the legal environment and take away opportunities for Indigenous people to advance their economic and social conditions through the commodification of culture and intellectual property. The example of non-Indigenous firms participating in the market under these conditions illustrates how firms can engage in socially unsustainable practices in the production of inauthentic goods within the souvenir industry.

Severity of the Distributor's deception

The relationship between social sustainability and the production of authentic souvenirs has been established as an aspect of human rights. Examining levels of deception is one of the three interrelated factors proposed by DIM to determine the degree to which a business is delivering on sustainability objectives from a supply chain perspective. In the case of the Distributor who was prosecuted by the ACCC, the DIM framework provides a basis for understanding the severity of deception. In a supply chain context, deception can occur between buyer-supplier or organisation-consumer. Deception is the gap between actual claims, practices and outcomes of those practices.

The development of nomenclature for deception relating to sustainability within supply chain literature demonstrates its prevalent in contemporary business. Green-washing and blue-washing (Dadush, 2018) describes the practice of misleading

consumers by misrepresenting the degree to which a product or service is environmentally (green) or socially (blue) sustainable.

The Australian Federal Court found the Distributor in breach of Australian Consumer Law over misrepresenting souvenirs featuring Indigenous style designs as being hand painted by Indigenous people (Australian Competition and Consumer Commission, 2018). The products at the centre of the case were represented to be 'associated with Australian Aboriginal Art' and using words in the labels including 'Aboriginal Art, 'genuine', and 'Australia' (Australian Competition and Consumer Commission, 2018). Several products were featured in the case including loose boomerangs, boxed boomerangs, bullroarers, didgeridoos and message stones. Some of the products featured designs licenced by an Indigenous artist. However, the products examined in this case that were in breach of labelling laws were manufactured in Indonesia with designs the firm procured from Internet sources (Federal Court of Australia, 2018).

Blue-washing is applicable to this case as the Distributor made claims on particular products to infer a connection to Indigenous people and local products that do not exist in that form. The deception not only impacts consumers but also the buyers (retailers). When using the DIM model (Figure 1) to investigate the deception, consider the inauthentic supply chain in the Donald Trump quadrant as the supplier deceives with low sustainable impact yet are liked for the low price. The change to the authentic responsible supply chain can risk failure as consumers may not like the increased price despite having an authentic product and thus have made an ethical purchase. However, it is most likely that it shifts to influencer with an outcome being the partial loss of consumers, triggering a new concept/idea being marketed for its sustainability, with a final shift towards maturity. Note though, Robin Hood is a possibility if both supply chains collaborate and find a solution to be authentic and to keep the price in an acceptable price range.

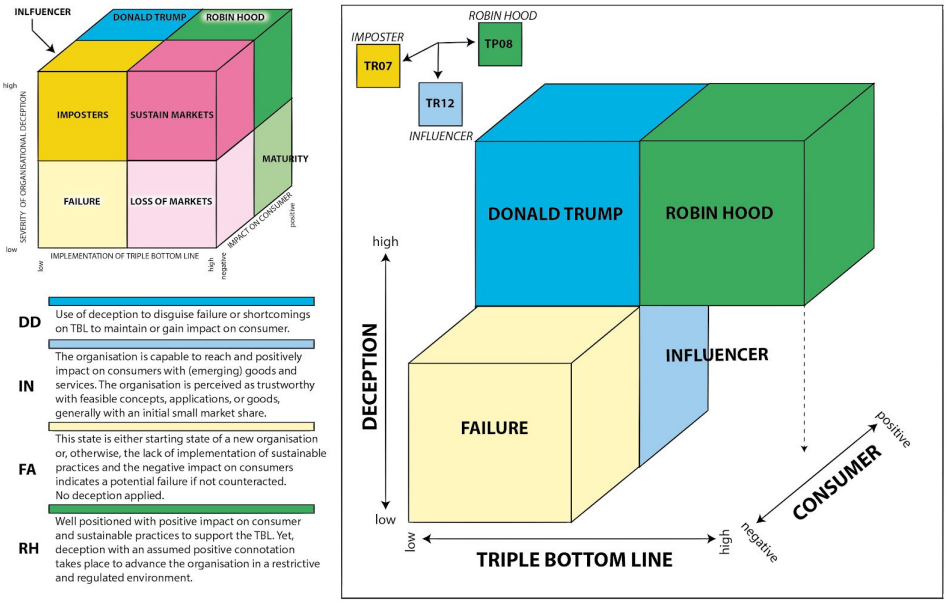

Figure 1: Deception Impact Model (DIM). See also Hammadi et al. (2018)

Implementation of sustainability practices

The sustainability orientation of an organisation is significant and is based on sustainability practices to achieve sustainability goals. The DIM proposes a firm's sustainability orientation on a spectrum between compliance with standards or legal obligations through to internal firm culture. The spectrum has been developed through Goldsmith and Samson's (2005) four categories of sustainability practices: compliance, conformance, performance, and transformation. Compliance and conformance are on one end of the spectrum, considered a reactive approach to sustainability implementation, and are demonstrated by firms who will only do what is necessary within a particular industry (Goldsmith and Samson, 2005). The DIM proposes the impact of this reactive orientation as an indicator of low implementation of sustainability.

To operationalise this impact in the context of the Australian souvenir market, the Distributor's development chain was examined. A strategic business activity is new product development (Hilletofth and Ericsson, 2010), with the intersection of product development with the supply chain known as the development chain (Primus, 2017). Attributes of products and the supply chain process can be aligned by firms to increase competitiveness (Morita et al., 2018) and thus, influence operations processes.

Two key elements of the development chain are 'planning and design' and 'sourcing' activities, with product architecture (planning and design phase) connected to the attributes of products. Within souvenir purchasing Revilla and Dodd (2003) found "appearance/utility, traditional characteristics and certification, rarity, local production and low cost" as factors impacting purchases. The Distributor sourced Indigenous symbols from the internet to be incorporated into souvenir products to give the products a particular appearance that would be attractive to customers (e.g. traditional characteristics). Labelling and packaging also inferred local production.

Design sourcing is the primary activity in which the Distributor decouples from human rights within the social sustainability dimension. This represents a key stage during the development chain where a firm can go beyond legal requirements, and ethically source a cultural element which will return positive benefits to Indigenous people, while satisfying product architecture requirements, thus supporting the human rights of Indigenous people to protect, maintain, and control their cultural heritage.

Make or buy decisions is another dimension of the planning and design phase, and supplier selection falls under sourcing activities. A factor influencing souvenir purchases is price. Research has found that price-orientated operations strategy models are less likely to compliment social and environmental sustainability aims (Longoni and Cagliano, 2015). The products considered in this case are at the lower end of the market and there is evidence that the Distributor outsourced production of souvenirs to Indonesia (Federal Court of Australia, 2018). Offshoring production of Indigenous style souvenirs may not result in decoupling from social sustainability as a discrete activity. However, combined with a decision to not include Indigenous people in the design of

the product combined with mislabeling statements on the product's packaging demonstrates a low commitment to social sustainability.

Consumers and other stakeholders

Within souvenir purchasing there are a variety of customer motivations "including workmanship, sensuous appreciation, cultural linkage and ease of handling" (Hu and Hong, 2007, p. 123). As consumers become more aware of products and manufacturing processes, firms are driven to address sustainability concerns (Mani et al., 2014). Despite customer trends, retailers need to consider balancing the demands of customers who are interested in sustainability, while also guarding against potential loss of market share and sales resulting from sustainable practices (Wilson, 2015).

Within the DIM, organisations able to accomplish positive impacts on consumers, despite relying on deception, are considered to be at the high end a deception severity spectrum. Retailers who knowingly procure products such as those discussed in the Distributors development chain, that disregard the cultural aspect of human rights, and are also priced at the lower end of the market, can satisfy price conscious consumers who are not motivated by ethical purchases. Due to the nature of competitive environments, buyers and suppliers on the supply chain may be motivated to align competitive priorities and have a low commitment to social sustainability. A challenge for business in the operationalisation of sustainable practices is reconciling traditional operations management models that focus on price, markets, and capability, to fit sustainability aims (Longoni and Cagliano, 2015). An internal 'reactive' culture towards social sustainability, which relies on maintaining minimum compliance with regulatory requirements, demonstrates the low commitment of those Australian souvenir supply chains to address human rights issues.

Conversely, authenticity is also a dimension motivating souvenir purchasing. Authenticity is considered a social construct, and consumer perceptions of authenticity is shaped by the "social and cultural conditions under which the product was produced" (Littrell et al., 1993, p. 200). It is not the aim to classify which product attributes constitute an authentic Indigenous souvenir product. However, this concept is important when souvenir producers mislabel products and engage in blue-washing as consumers seeking authenticity are at a disadvantage when making an ethical purchasing decision. This is also relevant in a buyer-supplier context as retailers may also be deceived if they are seeking to supply ethical products.

Conclusion ideas

Applying the DIM, this paper contributes to the understanding of product development and supply chain decisions within the Australian souvenir industry with regards to Indigenous art. When examining the Distributors development chain it was revealed that a critical stage in which a firm decoupled from social sustainability practices occurred in the procurement decision supporting a product's architecture. The paper highlights where Indigenous people should be involved in the development chain for

other non-Indigenous firms selling like-for-like products so as to avoid infringing on human rights as it relates to commodification of culture.

For Indigenous organisations and individual artists, seeking to enter the souvenir industry as a means of economic participation and inclusion, the paper provides an understanding of why specific techniques (such as offshoring) are used to satisfy customer purchase requirements, conversely impacting social sustainability. Additionally, for existing firms within the souvenir industry seeking to satisfy the market for ethical products, the research highlights where deception and decoupling from social sustainability relating to human rights and the cultural paradigm can occur from a production perspective.

Here, we addressed the gap in supply chain and operations management knowledge Indigenous producers face when participating in souvenir markets as established in the Report. Finally, the research contributes to the understanding of cultural paradigms within commodification contexts, as they relate to social sustainability as a concept.

Acknowledgments

The authors acknowledge Aboriginal and Torres Strait Islander peoples as the traditional owners of Australia, and pay respects to elders past, present, and emerging. The term *Indigenous* is used in reference to the cultures of both Aboriginal and Torres Strait Islander people throughout this paper.

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The protagonism of Cash & Carry in the supply chain in Brazil: fashion or trend?

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Abstract

New formats of retail stores continue to emerge, in order to better meet the needs of consumers. In Brazil, the Cash & Carry format occupied a leading position due to the high growth in number of stores and billing volume. This research aimed to characterize the value chain of the Cash & Carry format in Brazil, in comparison to the traditional physical stores in search of the justification for this phenomenon. Through a documentary research, the ten largest retail chains of the country and their brands of physical stores and wholesale stores were analysed, in order to construct the presented models.

Keywords: Supply Chain Management; Cash & Carry; Value Chain

Introduction

Retail organizations are diverse and new forms continue to emerge so that consumers can now buy goods and services in a wide variety of stores (Da Conceição, 2018). The idea of cash & carry, better known as "Cash & Carry" in Brazil, came into being in Europe and was more developed in the United States from 1980 onwards. The idea came from the following understanding: having a store capable of bringing the desired product to small retailers or objective consumers, without offering any services but with a more robust mix of products (Napoleão, 2017).

According to Abad (2016) and Napoleão (2017), Brazilian families has preferred the "Cash & Carry" to the supermarket and hypermarket. This research aims to characterize the chain of values and the format Cash & Carry, demonstrating the main advantages obtained by this business model in comparison to the traditional physical retail that justify its recent rise and its impacts in the retail supply chain in Brazil. The contribution of the results obtained here derives from the example of this operation in an emerging country.

Literature Review

Chain of Values For an examination of the activities performed and the way they interact, for a broad approach and identification of the main process flows of the company, the chain of values can be introduced as a systematic tool for such an evaluation.

According to Porter (1990: 31): The value chain disaggregates a company into its strategically important activities so that it can understand cost behavior and existing and potential sources of differentiation. A company gains competitive advantage by performing these strategically important activities at a cheaper or better way than the competition.

The performance of the value chain represents a process of differentiation between companies and their processes and the establishment of competitive advantages. Figure 1 illustrates the value chain model proposed by Porter (1990).

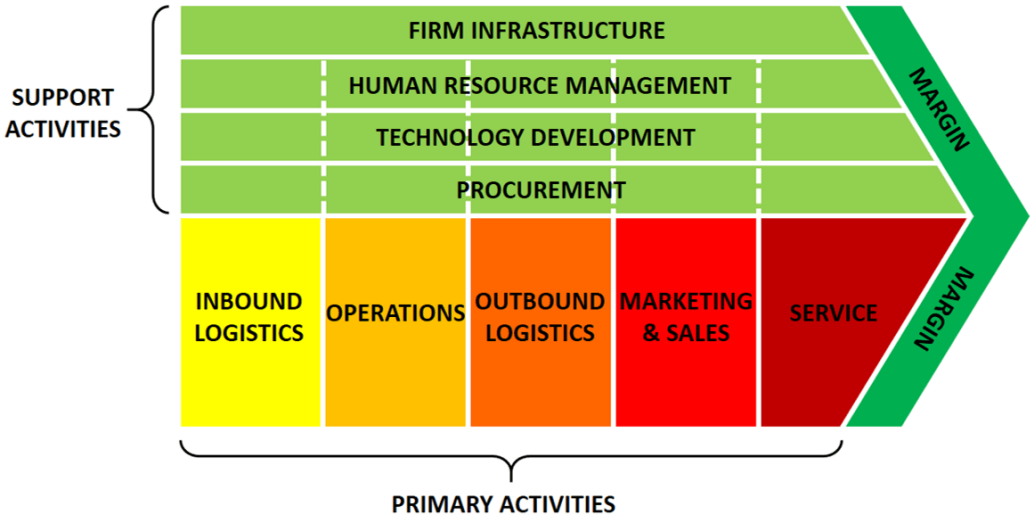

Figure 1 – Value Chain Model, Porter (1990)

Primary activities are those involved in the physical creation of the product and its sale and transfer to the buyer, as well as after-sales service. In any company, primary activities can be divided into five generic categories: (1) internal logistics: the activities associated with the receipt, storage and distribution of inputs in the product, such as material handling, warehousing, inventory control, fleet scheduling, vehicles and return to suppliers; (2) operations: the activities associated with the transformation of the inputs into the final product, such as working with machines, packaging, assembly, equipment maintenance, testing, printing and production operations; (3) external logistics: the activities associated with the collection, storage and physical distribution of the product to buyers, such as storage of finished products, material handling, delivery vehicle operations, order processing and programming; (4) marketing and sales: these are the activities associated with providing a means by which buyers can buy the product and induce them to do so, such as advertising, promotion, sales force, quotation, channel selection, channel relationships and pricing; and (5) technical assistance: these are activities associated with the provision of service to enhance or maintain the value of the product, such as installation, repair, training, parts supply and product adjustment.

Support activities can be divided into four generic categories. Like the primary activities, each category of support activities can be divided into a series of activities of

value that are distinct and specific to a particular company. The generic categories of support activities are:

(1) acquisition: refers to the function of purchasing inputs used in the company's value chain, not to the purchased inputs themselves. Inputs purchased include raw materials, supplies and other consumer items, as well as assets such as machinery, laboratory equipment, office equipment and buildings. Although these acquired inputs are commonly associated with primary activities, they are present in each value activity, including supporting activities;

(2) technology development: it consists of several activities that can be broadly grouped together in efforts to perfect the product and process. The development of technology related to the product and its characteristics can support the entire production chain;

(3) human resource management: consists of activities involved in the recruitment, hiring, training, development and compensation of all types of personnel. Human resource management affects competitive advantage in any company, through its role in determining qualifications and the cost of hiring and training; and

(4) company infrastructure: consists of a number of activities, including general management, planning, finance, accounting, legal, government affairs and quality management. Infrastructure, unlike other support activities, generally supports the entire production chain and not just individual activities.

Porter (1990) relates an advantage to value creation, that is, the competitive advantage arises from the value that a company can create for its buyers and that exceeds the cost of manufacturing the company and provides the difference between a firm's offer and that of others.

From the evolution of Supply Chain to Cash & Carry

When looking to analyse the dynamics and structure of the chain of supermarkets, it is necessary, at first, to understand some basic concepts that guide the actions of the products and services that are in networks. The need to understand the performance scenario is fundamental for assertive and optimized decision making throughout the chain.

By understanding the organizations and the ways that these are instituted, it becomes perceptible to understand the dynamics and structure of the business and therefore outline the strategies needed to gain competitiveness. The understanding of economic reality requires interpretations that are based on a systemic environment, which involves not only the parts, but the whole and their interrelations (Capra & Jakobsen, 2017).

Antonialli et al. (2016) infer that it is emphasized as the importance of studies on productive chains requires evaluations of both economic and technical operations throughout the stages of production and consumption of goods, ranging from (organizational, institutional, consumer) environments that permeate the production chain, essential for the construction of the competitive advantage of the chain (Antonialli et al, 2016).

Although dynamics is different from that of the Supermarket Supply Chain, these studies converge to the same point, being applied to all sectors, which are the structures of their respective chains (Zylbersztajn, 2005). By using the concepts of chains, production systems and coordinated subsystems, the expansion of volumes of empirical research volumes, both national and international, was evident from the 1980s to the present day. Whether in agro-industrial systems or in any other organization, they all employ the concept of continuous production steps, from the raw material to the finished product, in order to guide their analysis (Andrade, 2015).

The supply chain, according to the Supply Chain Council (2002), infers that "the supply chain covers all efforts involved in the production and delivery of an end product from the vendor supplier to the customer's customer" (Machline, 2011). Thus, typical transactions and the influence of institutional and organizational environments (which are defined as determinants of competitiveness) are common to all chains, regardless of the theoretical conceptualization (Zylbersztajn, 2000).

This relationship between supplier, producer and client creates and models the organizational and institutional environment, from which it is intrinsically linked to the cultural environment and the consumer environment, as shown in figure 1. Thus, the Supply Chain can be understood as the "main cell" in all production dynamics of products or services goods, since each chain link is affected, directly or indirectly, by any actions that affect one of its agents.

When we turn the perspective to retailing in the dynamism of information and interpersonal relations, new approaches emerge not only in the academic environment, but also in the commercial relations and the Cash & Carry is one of those results coming from the modifications in the organizational and institutional environments, as mentioned above.

Cash & Carry

According to Oliveira, Lima-Filho and Watanabe (2013), it is understood as Cash & Carry being the format of store known in Brazil for being a mixed operation of wholesale and retail, of which its actions are intended to serve preferentially, purchase (Silva, 2017).

In addition, it is important to note that the quality of the food service is not limited to the food service sector. According to Broud (2016) and Levy (2000), Cash & Carry is understood to be: The "Cash & Carry" is a phenomenon nowadays, mainly in Brazil, this model joins features of wholesale retail and aims to provide products with lower prices to the client to offer good services. This model does not have a refined structure, the design is low cost and its focus is on "pay and carry" (Broud, 2016; Levy, 2000).

Napoleão (2017) advocates that over the years, the development of this type of business has brought from new purchasing systems to adoption of new practices, such as the agglomeration of additional services added to the physical structure of the store, and in this way, it is possible offer not only cheaper products, but also, better quality services whose situation ends up adding more value to the enterprise.

Methodology

This work, in terms of its concept, is characterized as qualitative, through documentary analysis as scientific articles, as well as reports of specialized journals in the field, descriptive-exploratory. This infers that this type of research seeks to understand a reality that has not yet been studied, in which one can describe how the phenomena related to it occur (Gomes, 2006; Reis, 2018).

Pimentel (2001), shows us that studies based on documents as primordial material, be they bibliographic reviews or historiographical research, extract from them all the analysis, organize them and interpret them according to the objectives of the proposed research, giving them the specific treatment in order to corroborate with the object of study (Pimentel, 2001). Garcia Gutierrez (1984) apud Junior, Medeiros & Augusta (2017), reflects on documentary analysis as "all recognition and study that is made of a document, requiring an identification of the physical characteristics, which would be the form, and the intellectuals, the content". These elements corroborate the establishment of the best method to organize all the "information" expressed in the document (JUNIOR, Medeiros & Augusta, 2017).

It was applied in this work the analysis of documents such as scientific articles, books and reports in magazines or nationally recognized electronic sites that dealt with the theme of evolution and modification in the structures and dynamics of the retail chain and seek to understand what the current panorama of the transition traditional market of the hyper and supermarkets for the recent cards.

As a study delimitation, we opted to work on the analysis with the top 10 retail chains in Brazil's supermarket or hypermarket sector, according to the Brazilian Retail and Consumer Society (Sbvc, 2017). From the list obtained, company flags were tabulated in a spreadsheet and classified according to their size and sales format (small retail, super / hypermarkets, cash backs, etc.). In order to obtain a broad analysis specifically of the cash cards, the analysis of the discount cards that make up the Brazilian Association of Wholesale Carriers (Abaas, 2017) was included in the analysis. Below, the table 1 presents the flags chosen for the analysis.

Table 1: Retailers chosen for analysis

Flag *or* Brand	**Type**	**Flag or Brand**	**Type**
Carrefour	Super/Hyper	Assaí Atacadista	Cash & Carry
Pão de Açúcar	Super/Hyper	Atacadão	Cash & Carry
Extra	Super/Hyper	Comercial Esperança	Cash & Carry
Wallmart	Super/Hyper	Makro	Cash & Carry
G. Barbosa	Super/Hyper	Mart Minas	Cash & Carry
Prezunic	Super/Hyper	Maxxi Atacado	Cash & Carry
Bretas	Super/Hyper	Roldão Atacadista	Cash & Carry
Perini	Super/Hyper	Spani Atacadista	Cash & Carry
Dia%	Super/Hyper	Tenda Atacado	Cash & Carry
Smart Supermercados	Super/Hyper	Fort Atacadista	Cash & Carry
Super Muffato	Super/Hyper	Villefort Atacadista	Cash & Carry
Big	Super/Hyper	Carrefour Bairro	Small retail
Bompreço	Super/Hyper	Carrefour Express	Small retail
Mercadorama	Super/Hyper	Pão de Açúcar minuto	Small retail
Comper Supermercados	Super/Hyper	Extra mini mercado	Small retail
Supermercados BH	Super/Hyper	Todo dia	Small retail

From the choice of the sample, the electronic websites and news related to the respective flags were searched and the data obtained were classified in a spreadsheet, so that the specific characteristics of each company were allocated according to each activity of the value chain. Then, the data collected and classified were submitted to content analysis according to Bardin (1977), and the content analysis categorization was based on Porter's value chain proposal (1990).

Findings and Discussion

In analyzing the Brazilian retail supply chain over the last decades, it is notorious to realize that there has been a restructuring between distribution channels both among internal and external agents and, therefore, shaping the structure and dynamics of the latter. With this, several consumers have migrated their shopping environment, but mostly inserted in the super / hyper format for the retail and small retail formats.

This fact can be evidenced when it is observed that the largest retail groups operating in Brazil started to enter this market more intensively over the years, especially in the

infrastructure and locality models of their stores. To better elucidate this phenomenon, the section will be presented in three stages. The first presents the comparisons of traditional retail value chains versus the retail value chain. Subsequently, the traditional structure of the Brazilian retail chain is presented, followed by the characterization of the chain after the rise.

The retail versus retail chain of value - Traditional structure of the retail chain in Brazil
The Cash & Carry in Brazil, although recent, presents a highly dynamic and increasingly comprehensive structure. The distribution channels between the suppliers of inputs, products or services to the final customer, generate impacts at all levels of the chain.

The more complex and long the relationships between the agents that feed the chain, the more financial and managerial resources will be needed, and this is the dynamics of the traditional retail model in Brazil, where the acquisition, inventory, distribution and sale management of products of the supermarkets, presents in its great majority, like an extensive and pushed system. Figure 1 summarizes the distribution channels of the products in the traditional retail markets in Brazil.

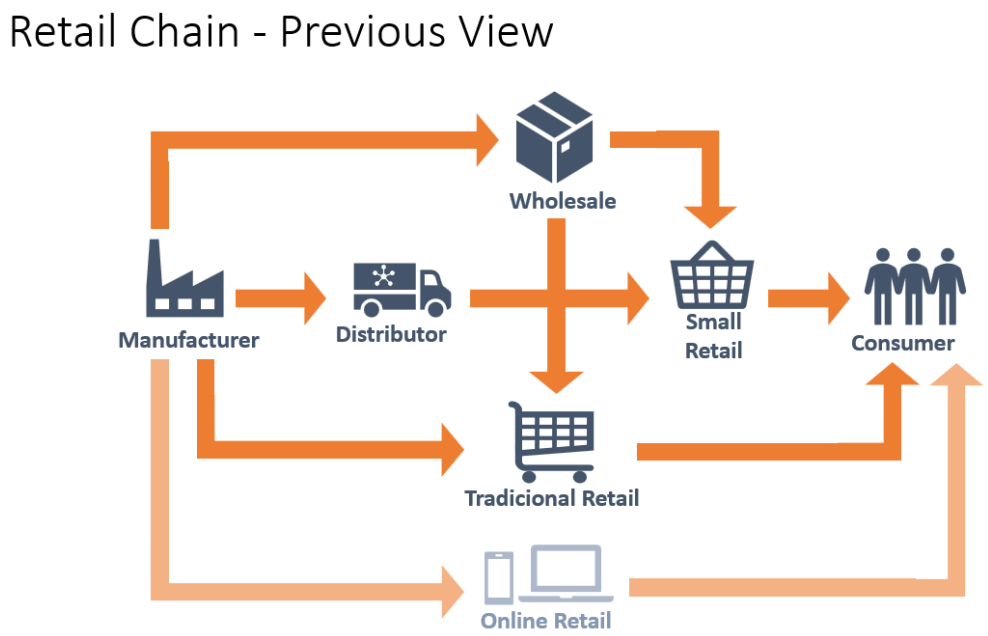

Figure 1 - Traditional structure of the retail chain in Brazil – By Authors

In this model, the product manufacturer presents itself not only as the one who produces a particular product, but also becomes a stockist (in this case, stockist would means the manufacturer as being the maintainer of the products in its own physical structure for later distribution) and sometimes acts as a distributor to the wholesale or traditional retailer. The Wholesale in turn supplies the small retailers that make the products available to customers, replacing them from time to time. The same happens with traditional retail, where the products are stored at the disposal of the final customer. In this model, the interfaces between the links in the supply chain show an increase in the final cost of the product, since each agent must receive a value for transportation, inventory and / or resale of the products to final customers.

Losses, low optimization of inventory management and costs, is recurrent in this type of marketing. Sometimes this commonly used structure has certain barriers that raise costs throughout the chain, as explained above. Linked to this favor, chain coordination

becomes fragile because it has several links between agents, which, due to the complexity of coordination conditioned to the various factors, can generate countless losses due to the organizational environment that this chain is inserted.

In addition, the operational costs of the distribution operations mean that the products that reach the end of the chain have an additional level of intermediation and consequently an added value that ultimately increases the final price of the product to the final consumer.

Current structure of the retail chain in Brazil

At Cash & Carry sector, dynamics and coordination of the chain become leaner, with the optimization of the distribution and storage of products. In the meantime, it is worth stressing with the performance of the chain is more dynamic, both the product outputs and the search for these products by the end customer. This coordination of the chain reinforces the considerations of the Value Chain proposed by Porter (1990) and demonstrate the impacts that the operations both internal and external, modify the organizational and institutional environment of the retail chain as a whole.

Thus, stores denominated Cash & Carry become the link between the manufacturer and final consumer, presenting not only as a retail store, but also as a wholesale center and as a Distribution Center (CD - It would be inferred that it is a warehouse whose purpose is to manage the inventory of goods in the fixed distribution (Abralog, 2016; Do Nascimento et al., 2018).). This changes the whole structure of internal logistics, operations and supplier, vendor and consumer relations. In this sense, Cash & Carry is a protagonist in relation to the position in the supply chain, since it occupies in a concentrated and strategic way, a new location in the structure of the chain. Figure 2 demonstrates the Chain Supply Chain and its structural arrangement differentiated from the traditional chain.

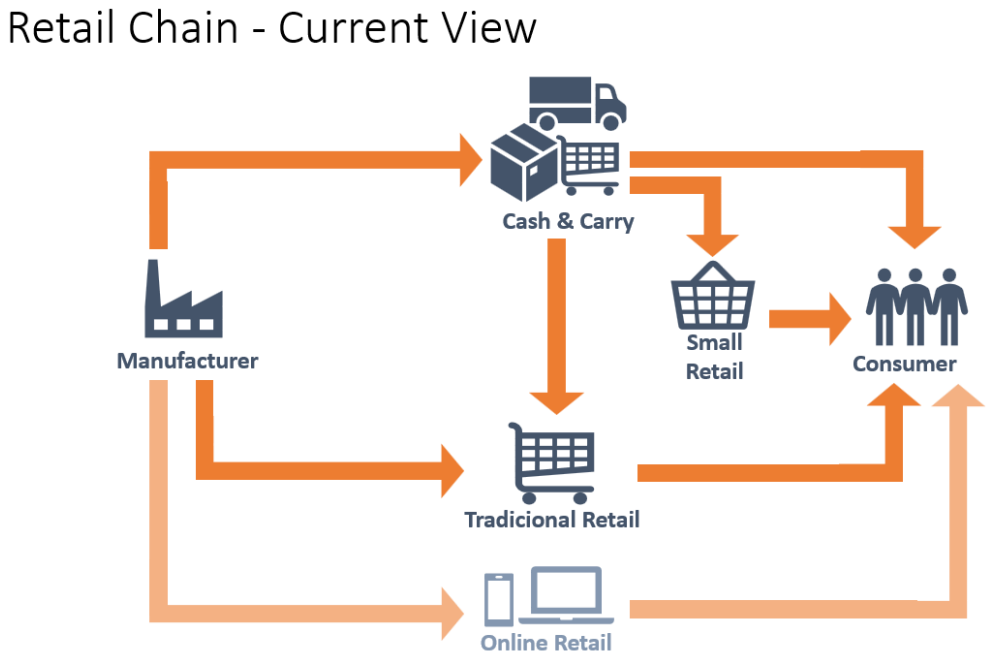

Figure 1 - Current structure of the retail chain in Brazil – By Authors

Notorious is the concentration of the agents under a single player that are nets of Cash & Carry. These, in turn, have the following characteristics: 1) attacked; 2) Retail and 3)

Distribution Center for himself as well as the small and medium retailers of the surrounding region. This explains the growth of this type of commercialization in recent years in Brazil, since in addition to reducing the costs of maintenance, personnel and charges with CD's, the cash cards provide a greater mix of products in a single structure and increase the capillarity of distribution of the products.

In addition to providing support to small retailers, the final consumer is also impacted by the quantity / price ratio, where more quantity, lower price than the cash cards provide and corroborates for the maintenance of small retail stores with quick purchases in small quantities and (which does not, on certain occasions, also exempt the consumer from purchasing small quantities in the card in certain situations or preferential).

This new arrangement solidifies the trend of the expansion of the Cash & Carry in Brazil, because it meets the assumptions of the Brazilian consumer (be it the final or internal consumer of the chain), which is the question of price. As the prices are better in the wholesale account, one can then refute, at first, that the card is a fad, but a new business model that emerges to consolidate over time.

Delimitations and Suggestions

This research was limited to a brief illustrative analysis of the structure and dynamics of the supply chain in Brazil, since the incipient studies are about this topic in depth and, thus, propose new perspectives and considerations about the Cash & Carry Brazilian. However, the limitation was only limited to some academic articles available and also focused on specialized magazines in Brazilian wholesale and retail.

As a suggestion for future research, it is the search for correlating international and national articles (if there is one) to understand the coordination of this chain and the economic, financial and social impacts that the attack provides to the region in which it is installed, such as employ ability, cost and inventory, logistic cost, among other determinants. Moreover, the authors of this work sought to demonstrate the Cash & Carry chain as a whole in its physical structure, but without neglecting or omitting, as shown in figures 2 and 3, the profound changes that online retailing causes and will cause in retail as a everything.

Thus, it is suggested that further studies are about what impacts online retailing can impact on the retail strategies, as well as, to understand the dynamics of Online Retail Supply Chain in the interfaces between supplier and buyer, restructuring the organizational and institutional environment of retail trade.

Conclusions

Cash & Carry, although widespread around the world for more than two decades, presents substantial growth in Brazil only from 2012 to the present day. However, the Brazilian retail sector is not in line with this expansion, since only large groups started to emerge for this new modality that is Cash & Carry. The perception of traditional retailers needs to be reviewed and, above all, studied and disseminated in their planning and management strategies so that there is no disappearance of traditional retails or even the bankruptcy of several of these, due to a strong and massive competition resulting from credit cards.

Since the Brazilian consumer is more closely linked to the prices of the products, the Cash & Carrys appear as an innovative and comprehensive business model, providing a more balanced inventory management between a push-pull management, since the latter occurs more strongly in the traditional retail. This leads to a reduction in the costs and concentration of the products in the own cards that not only replenish their stores in their gondolas, but also have their own stock at the same time, as well as serving as a CD for small retailers, that is, an anchor for other people in the chain.

This all leads to a reduction in costs and optimization of transactions across all interfaces, which today, is a matter of survival of most businesses. Thus, the exponential growth of Brazilian cash loans is more like a market trend than just fad or punctual actions of large corporations. The dynamics of the current relations are getting faster and faster and adapting to the new trends is and will be, in most cases, the threshold between the success or failure of the cash advance in Brazil.

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Are Quick and Dirty the Characteristics of Chinese Manufacturing Systems?

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Abstract

This paper seeks to review the Chinese manufacturing evolutions in the last 40 years and explore what the characteristics of its industrial systems could be. We recognise that the traditional industrialisation model and industrial systems have made China the largest manufacturing country in the world. However it has also brought the nation to the tipping point where its very success could potentially destroy its own and the world. The paper concludes by proposing that the new generation of operations and manufacturing strategies need to learn from the evolution of Chinese manufacturing and explore un-conventional strategic and system solutions.

Keywords: New Manufacturing Strategy, Chinese Industrialisation, and Industrial Systems

Introduction

China started its economic reform by introducing the open-door and market policies in the late 1970s. It has achieved the GDP (Gross Domestic Product) annual growth about 10% continuously in the previous 30 years although it slowed down to 7-8% in the last five years. The industrialisation made China the largest manufacturing nation in the world in 2012, the second largest GDP country in 2013, and possibly the largest GDP PPP (purchasing power parity) country in the last year. However, the dark side of the industrial developments has gradually been exposed and caused global concerns, including environmental pollutions in water, soil, and air; fast increases of CO2 emission speeding up climate changes; all kinds of natural resource limitations potentially constraining manufacturing growth in the future; and social welfare systems lagged behind triggering society unrest risks.

This paper seeks to explore and explain what Chinese manufacturing developments in the last 40 years can inspire and challenge many management disciplines. The paper believes the classical management model and industrial systems have brought China not only to the largest manufacturing nation but also to the tipping point where its success can destroy its achievements and even the world. Therefore, it recognises the new generation of operations and manufacturing strategies have to learn from the Chinese manufacturing experiences and explore new type of strategic and system solutions.

Literature Review

This paper reviews literature in the following three areas: the concept of industrial systems, Production and Operations Management regarding China in relation to design – operations improvement, and how Chinese industrialisation urgently requires an integration of

environmental and social sustainability concerns in the era of Anthropocene. First proposed by Paul Crutzen and Eugene Stoermer (2000) to denote the present time interval in which many important geological processes and conditions have been, and continue to be, profoundly affected by human activities.

Industrial Systems

The concept of industrial systems is evolving with the pace of economic, technological and social development. In 1980s-1990s, industrial systems initially refer to networks of relationships among firms (J. Johanson & Mattsson, 1987; Jan Johanson & Mattsson, 1987), when researchers began to realise the importance of viewing business activities from the network perspective since coordination and cooperation becomes very crucial to organizations' survival in the fierce market competition (J. F. Moore, 1996; J. Moore, 1993).

Later, the concept of industrial systems is further developed by the Royal Academy of Engineering, who defined industrial systems in a report as "the context, resources, activities, processes, actors, and interdependencies that support the creation and delivery of products and services" (The Royal Academy of Engineering, 2012). This report suggests that a system thinking to gain a holistic understanding of industrial systems is of vital importance for different stakeholders within the system to capture value.

Another report contends that, except for the value perspective, sustainable issues should also be among the main concerns towards the research of industrial systems (Institute for Manufacturing, 2009). Despite the fact that there are already several definitions of industrial systems among different researchers, we argue that current concepts are not straightforward and comprehensive enough to capture the essentials of industrial systems. We, therefore, propose the following working definition of industrial systems: "An industrial system refers to a complex input-output transformation process."

Production and Operations Management regarding China

Production and operations management research within the Chinese context has been growing and the topics range from strategy through policy issues to supply chain/network management (Jiang, Frazier, & Heiser, 2007). These China-related research do address the differences from traditional research based on Western countries under the Chinese context, such as how Chinese companies with different ownership structures differ in operations management and technological capabilities (Pyke, Farley, & Robb, 2002), how organizational culture in the east and west differs and its impacts upon organizational performances (Naor, Linderman, & Schroeder, 2010) and how buyer-supplier relationships should be governed through transactional and relational mechanisms (Liu, Luo, & Liu, 2009).

There are also a few researchers investigating how well the Chinese manufacturing system performs when introducing established manufacturing practices such as Kaizen (Aoki, 2008) and Lean operations (Taj & Morosan, 2011), and compare the performance to that of Japanese companies. In general, scholars do agree that operations and supply chain management issues are very important to Chinese companies (Robb, Xie, & Arthanari, 2008).

Despite the fact that researchers have noticed the significant growth of Chinese manufacturing, there are few literatures explicitly investigating the distinctive characteristics and mechanisms of Chinese manufacturing which are potentially very different from that of traditional Western countries or Japan. Also, many researches have been focused on joint-venture activities, which would inevitably be affected by their foreign investors. Supply chain

management issues in China, though quite mature in Western context, still lack comprehensive elaboration and investigation, which is also a growing trend of future research.

Sustainable industrialisation development in China in the era of Anthropocene
In recent years sustainable development has gained increasing attention in the domain of operations management. Scholars called for an integration of environmental and social sustainability priorities in operations strategies (Longoni & Cagliano, 2015). Most notable efforts and suggestions are in the form of "lean sustainability" (Piercy & Rich, 2015) and "environmental management practices" (Simpson and Robert, 2014).

During the recent years as China transformed from a developing economy into the world's largest manufacturing nation, it has become an important research phenomenon. Alongside the economic growth as the rest of the world comes to terms with China's increasing political power. When it comes to Chinese industrialisation and its consequences, there is limited research in the POM discipline.

In social science there are some efforts directed to how Chinese innovate. Many refer to innovation in China using the term proposed by Christensen (1997) as "disruptive innovation". Some also use terms such as "cost innovations" (Williamson 2010), "secondary innovation" (Ni and Wu, 2000) and "frugal innovation" (Economist 2010: Zeschky et. al, 2011). Disruptive innovation allows firms to offer products with superior customer value at low costs (Brown and Hagel 2005; London and Hart 2004: in Zeschky et. al, 2011). Kash (2010) points out that Chinese innovation tends to be more incremental and process driven, as learning usually occurs within the connected network and the hierarchical structure of the society often encumbers product innovation or technology breakthrough.

Yin Yang embodies duality, unity in diversity, change, and harmony, offering a holistic approach to problem-solving (Li, 1998, 2008, 2011: in Fang, 2012). To the best of our knowledge little research has been done to apply Yin Yang thinking to explore Chinese innovation.

Overall there is a gap in consolidating existing knowledge and research to update the POM society about Chinese industrialisation and the environmental and social challenges China face. Therefore we endeavour to start the exploration with this paper, in the hope to stimulate a conversation, and to invite more research into this very timely topic. As we live in a globalised world, China's concerns will soon become the world's challenge.

In summary, the following diagram seeks to link the above theoretical reviews with some general understandings about Chinese industrial achievements. The diagram highlights that management research community has not got enough attention and detailed observation in Chinese manufacturing evolutions (Figure 1). Consequently, we need to explore the following three main aspects of Chinese manufacturing.

Research Design and Data Collection
Based on the literature review and research gap analysis in the last section and Figure 1, the fundamental research question can be defined as the following – "Can Chinese new industrial systems cope with the future development requirements?" The research question implies further detailed explorations in three key areas:

1) Understanding Chinese manufacturing developments and the industrial systems in the last 40 years during the economic reforms;
2) Explaining and identifying the characteristics of the Chinese industrial systems and manufacturing evolutionary process – the drivers, triggers, and transformations;

3) Identifying future external requirements and capability gaps of Chinese industrial systems to cope with the future development.

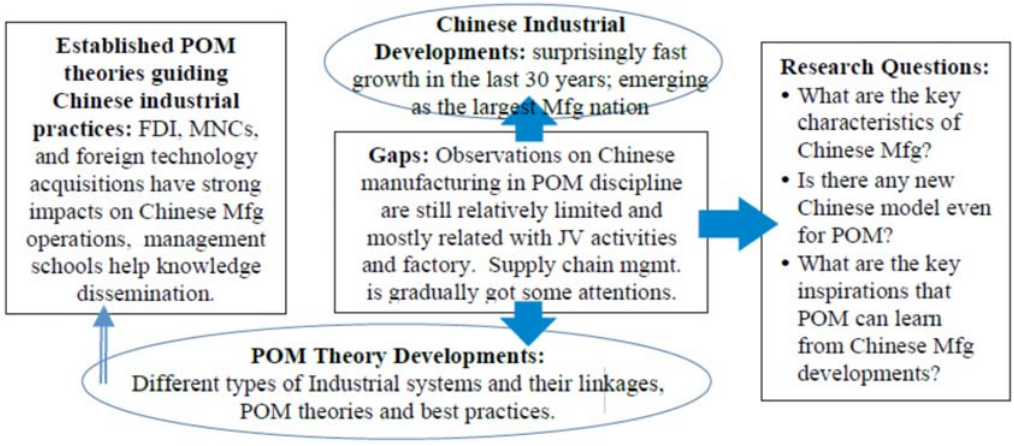

Figure 1: Research Literature Review, Gap Identification and Questions

The research question and related exploration areas are massive but timely in order to understanding Chinese manufacturing and its implications to industry and academia, especially for POM society. In order to comprehensively capture the picture of the Chinese manufacturing evolution, the following research design is proposed and discussed as Figure 2 illustrates. Considering 30 years Chinese radical industrialisations, multiple industrial data sources and combined pictures about different levels of Chinese industrial systems are necessary. Besides exhaustive secondary data collection through published academic papers and industrial reports, the first hand longitudinal and accumulative observations from the collaborations with Chinese industry and academic institutions have provided most insightful observations and narratives of Chinese industrial developments. From the middle of 1990s, systematic PhD research projects and theses have been dedicated to Chinese industrialisations and continuously upgrading. The Figure 2 illustrates the research project and its aims, predicted outcomes and research process.

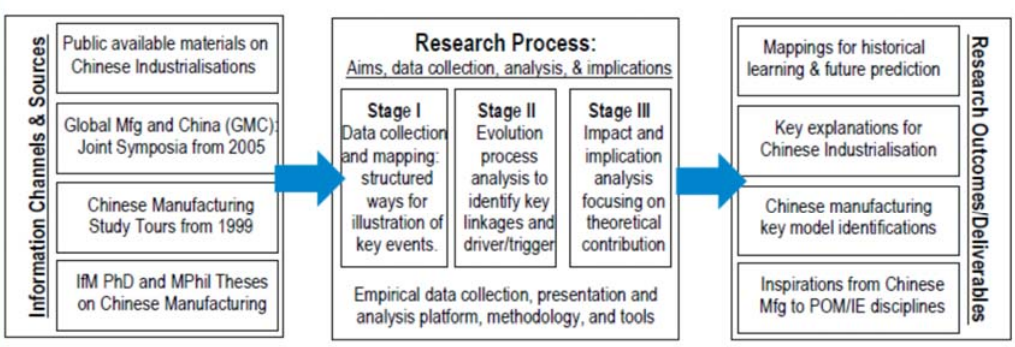

Figure 2: Research strategy and process for exploring the Chinese

The research process as demonstrated in the above Figure 2 includes three main stages after research design – empirical data collection and mapping; key industrial development explanation and key milestone identifications; and theoretical implication and impact through the key event analysis. Technology roadmap approach developed by Phaar and his colleagues (2011) are adopted in the Research Stage I in order to systematically present the data and identify the linkages between the main events and interacted institutions. Checkland's soft system think approach (1999) is implemented in key milestone identification and event linkage analysis.

Research Findings

Based on the research data and analysis, three main research findings are identified:

Chinese manufacturing evolutionary map:

Figure 3 illustrates Chinese manufacturing development in the last 40 years. It seeks to capture the most significant events and driving forces as well as the consequences. According to the data analysis, the Chinese industrialisation can be divided into the following three phases.

1) Up to 1980s - "Accumulation" period
   At the time China has just started the Economic Reform, the state controlled planning means there was a shortage of almost all consumer products. State Owned Enterprises (SOEs) reform started during this time to adapt to market demand. With the establishment of special Economic Development Zones, China started to attract foreign investments, particularly into the coastal cities. Economy in townships also started to develop as local private firms in hired "Sunday engineers" who were employees to help with knowledge transfer to gain faster technology dissemination. Zhejiang private firm cluster as well as the Dongguan contractual manufacturing model emerged. It is the period where both knowledge and fixed assets were accumulated in preparation for transforming China's manufacturing.
2) 1990s – "Transformation" period
   SOE reform continues with re-structuring and resources transfer into private enterprises. More and more multinational companies and other foreign investments took place to facilitate the formation of manufacturing bases in Pearl River Delta (PRD), Yangtze River Delta (YRD), Zhujiang River Delta (ZRD), Shandong Peninsula, Beijing (BJ) and Tianjin (TJ) region. Labour intensive and consumer goods industries start to gain momentum.
3) 2000s - "World Factory" period
   SOE reform continues across national level while the central government continue to nurture new industries like automobile and telecommunication to fuel further economic growth. Infrastructure projects and Western region development plans also helped with the continued double digits GDP growth.
4) 2010 to present – " Post World's Financial Crisis" period
   China emerged as the world's largest manufacturing base. Chinese companies start globalisation journey. Central government encourages innovation at the national level in an effort to transform Chinese manufacturing from labour intensive, "catching up" to potentially "overtaking". Environmental concerns become major challenge of the China model. Globally the so-called "Beijing Consensus" and newly re-emerged powerhouse caused concerns and debates on Chinese development and industrialisation models.

In summary, Chinese manufacturing and its industrial systems have demonstrated "quick and dirty" characteristics in its fast growth. The quick part is the formation and reconfiguration of the resources into new industrial systems while the dirty part is its poor quality and pollutions.

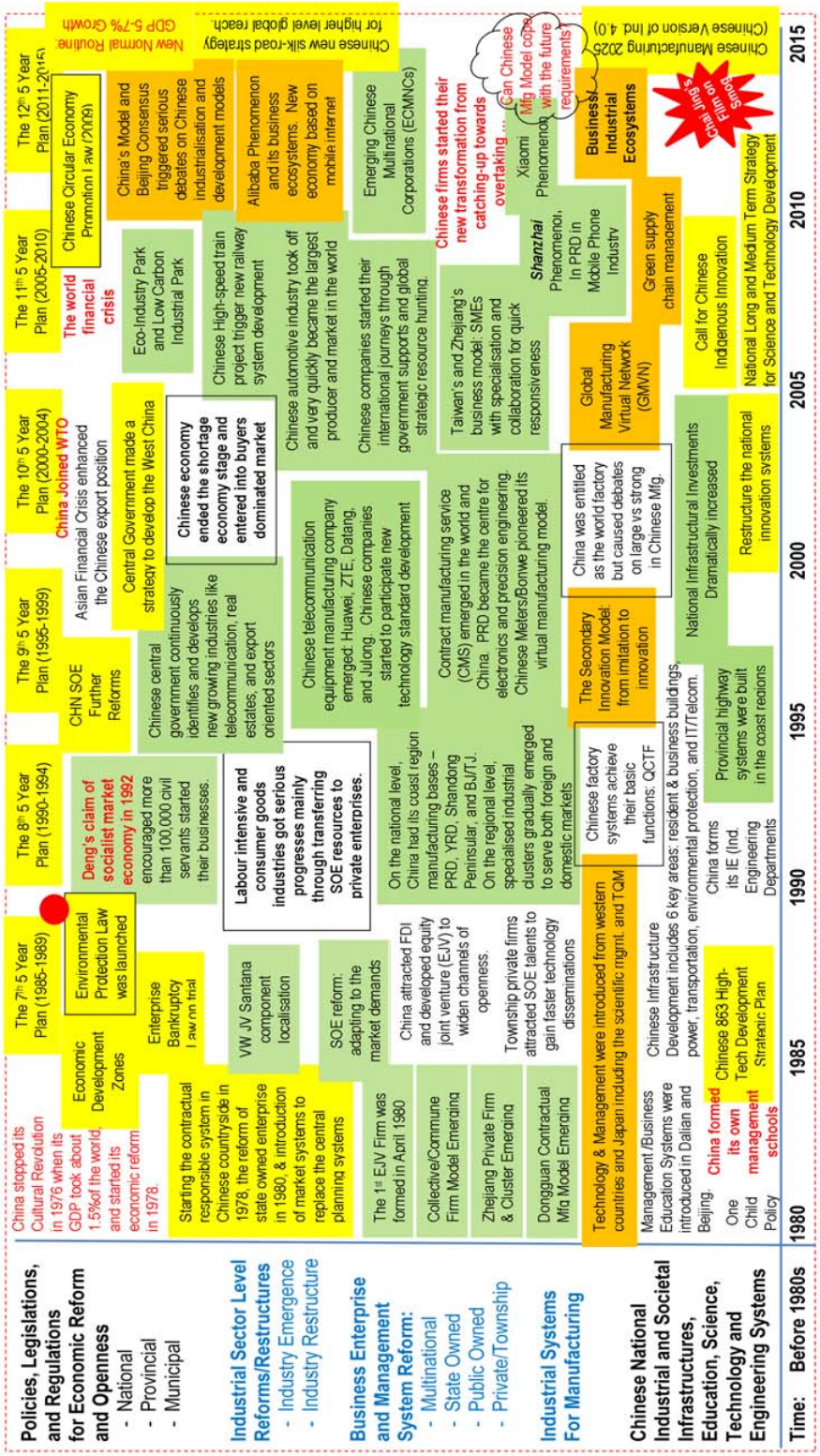

Figure 3. Chinese Manufacturing Developments and Industrial Evolutions

Reasons why Chinese manufacturing can grow so fast
Based on the evolutionary mapping, the paper recognises the following key factors making Chinese manufacturing industry outstanding from an economic standard perspective:

- Good ambidexterity capabilities dealing with the shift between market and planned economies, different requirements of rural and urban markets, complex supply and demand relationships, as well as FDI (foreign direct investment) dependency and indigenous innovation.
- Dynamic balance of industrial systems on all levels from basic work units, factories, enterprises to regions, sectors/industries, and the whole nation. So much has happened that one could say that the only constant is change. Economic reforms and radical transformations are deeply embedded in the majority of Chinese people's life.
- Pursuing prosperity through hardworking and dedication are deep-rooted Chinese cultural traits. Also they believe in the importance of education, regardless of rural or urban Chinese. This has generated a large number of educated and skilled labours that formed the foundation of the rapid development of Chinese manufacturing. The economic reform policy frees up the long suppressed entrepreneurship and enhances the traditional spirit. It forms a solid foundation for industrialisation.

What are the negative impact of Chinese manufacturing industry
Chinese industrial systems' problems are mainly caused by its successes:

- The dedication has changed into desperation that single-mindedly pursues economic performance. GDP indicator and material achievements have emerged as the most important driver for growth. Such focus has caused significant environmental and societal issues.
- The dedication has also propelled the whole China to learn from the advanced nations through benchmarking, duplication and imitation. But Chinese manufacturing ignores its own problem solving capabilities, sometimes even fail to acknowledge that there were problems.
- Because of the fast growth and radical changes, Chinese industrial systems lack of systematic review and rationalised redesign. Lack of interactions between industry and academia fail to integrate good practices into systems or processes.

Inspirations from Chinese Industrialisation
We propose that the evolution of Chinese manufacturing can provide inspiration and insights to the POM discipline and community. In particular it highlights the following interesting trends:

New industrial systems:

- Transformation: a major POM task may be to transform from the current "design - operation - improvement" process towards a more radical design and reconfiguration one.
- The boundaries have been changed: it requires not only input-output transformation and value-creation systems, but also industrial ecosystems that enable value-creation system to be easily reconfigured.
- New perspectives: the individualistic corporation/firm view is no longer enough; what we need is a holistic, ecosystem perspective that takes into account of stakeholders in the whole community - clusters, regions, nations, and the whole world.

Can existing thinking cope with the future requirements?

- We need to adopt new industrial design principle: not only competitive advantages but also more "resource based view" orientation – by more appreciating the intrinsic value embedded within the resource and strategically cascading its full potentials – new RBV 2.0.
- Industrial symbiosis and circular economy may provide a better model for POM
- Constructive ambiguity: learning from the Chinese government in how it directed China and Chinese manufacturing, a Yin Yang thinking inspired strategy may enable us to navigate the ever changing and ever complex world of the future.

Inspiration for management discipline may include the following:

- Adopt a holistic/ecosystem perspective when seeking solutions to management current challenges, as the world is becoming more and more connected, a form based individualistic view may no longer be sufficient as manufacturing is becoming ever complex effort of collaboration.
- Strategic ambidexterity: learn to adopt the Yin-Yang thinking, particularly in the form of balancing seemingly opposite forces dynamically can be a very powerful management tool.
- Chinese innovation models, such as Alibaba and Xiaomi, may offer solutions to liberate and leverage current resource constrains and inspire management research community.

Conclusions

It can be recognised the key characteristics of Chinese manufacturing systems and operations management as "Quick and Dirty". The quick response and fast reconfiguration of social resources into industrial systems are the strengths. But the dirty operations cause serious wastes, pollutions, and damages to the society and the world. For China and the rest of the emerging economies to improve and live the Western way of life is clearly not sustainable. Even though China has achieved incredible growth in its economy, it was primarily based on a low wage, export driven model, at the cost of deprivation and degradation of the environment. Today China stands at a crossroad. To avoid any disasters going forward it needs to change its goal from only seeking short-term economic growth and profit to a more sustainable form.

Chinese manufacturing at a tipping point. Clearly the current Chinese industrial systems cannot cope with the future requirements. The profit driven growth focus needs to be transformed to high value added manufacturing. Besides the manufacturers, all other key stakeholders must also participate to enable the transformation. Government agencies need to support and direct manufacturing towards a sustainable and environmentally friendly system; consumers need to be educated with the awareness and supported by the manufacturers to ensure the products are consumed efficiently throughout its life cycle.

Finding a solution for China may help the rest of the developing nations, as well as helping the entire earth to restore its original balance. As it is no longer a problem that China needs to solve on its own. If the environmental concerns (air pollution, global warming, water supply just to name a few) as well as social issues won't be given enough attention and addressed effectively in the near future, soon the rest of the world would suffer the dire consequences together with China.

Is the current Chinese industrial systems can cope with the future requirements? No, of course! However, it is no longer a Chinese problem, but it has emerged as the whole human beings' challenges. We need to face it together.

Acknowledgement
This paper is a long-term research outcome. During the time, we received many supports from both internal research centres and educational programmes at IfM and many collaborators in China, especially Zhejinag University Management School and our joint research centre there. Most recently, our research has also received the European 7th Framework Programme research grant – Europe-China High Value Engineering Network (EC-HVEN 295130). We are also grateful for the great contribution and assistance given to us so generously by our friends from the industry.

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Does Logistics Clustering Promote Regional Economic Growth?
The Case of China's Yangtze River Economic Belt

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Abstract

This paper analyzes the mechanism of how logistics clustering promotes the regional economic growth in China's Yangtze River Economic Belt. Based the panel data of 2000-2016, the author empirically studied the spatial heterogeneity of logistics clusters and their positive effects on the regional economic growth by introducing the location entropy index into Cobb-Douglas production function. The results show that logistics clustering can significantly promote the regional economic development, but there is spatial differences between the three sub-regions in the Yangtze River Economic Belt.

Keywords： Yangtze River Economic Belt, Logistics clusters, Regional economic growth

Introduction

In recent years, the importance of clustering of industrial activities to regional economic growth is well recognized by researchers following Marshall's industrial cluster theory (Chhetri et al., 2014; Rivera et al., 2016; Kumar et al., 2017; Hylton and Ross, 2018). According to Porter (1980), industry cluster is defined as geographic concentrations of interconnected companies and institutions in a particular field, which compete and cooperate. Sheffi (2012) pointed out that logistics cluster is a specific type of industrial cluster, which refers to the geographical concentration of: (i) firms offering logistics services, such as third party logistics service providers (3PLs), transportation carriers, warehousing companies and forwarders, (ii) the logistics functions of manufacturers and retailers, such as the distribution operations of retailers, manufacturers and distributors, and (iii) companies with logistics intensive operations (such as automobile manufacturers or bulk commodities distributors) for whom logistics is a large part of the cost (Sheffi, 2012).

Both Kadokawa (2011) and Rivera et al. (2014) illustrated the competitive advantage and network benefits of logistics clusters to the regional economic and industrial development. According to Kadokawa (2011), geographic concentration of logistics firms can have benefits through external and internal economies of scale and scope

(Kadokawa, 2011). Other benefits of logistics clusters include natural resource endowment, stable local demand and market size, rent opportunities and other opportunities such as knowledge sharing, greater specialization and supplier competition (Rosenthal and Strange, 2004; Van den Heuvel et al., 2014; Hylton and Ross, 2018).

Despite the positive evidence gained, previous studies lacked detailed examination of the mechanisms through which logistics clusters promote regional economic growth. Moreover, previous studies are largely based on developed countries and lacked enough focus on whether regional economic growth of emerging economies will also benefit from logistics clusters, given that there are major differences between developed countries in terms of infrastructure, technology development, skills level, and policy and regulations.

After 40 years of reform and opening up, China has made significant achievements in its social-economic development. Due to governmental policy support and increasing investment in infrastructures of modern logistics industry, logistics clustering is becoming an emerging phenomenon in China. However, there still a paucity of research examined how logistics clusters will benefit the regional economic growth. Questions remain to be answered: Does logistics clusters promote the regional economic growth? Are there spatial differences in different regions? And what are the possible reasons for these differences? This research attempts to answer the above questions and to provide recommendations to policy-makers and practitioners for better development of logistics cluster.

The main contribution of this paper is to examine the macro level mechanism of logistics clustering in promoting the regional economic growth in China. This finds of this paper will also help future researchers to better understand the logistics clustering in other national contexts.

Literature review

Previous research on the formation of logistics clusters is largely carried out on the basis of the framework of industrial cluster theory (1920). For example, Li (2007) emphasized the importance of trust mechanism in promoting logistics clusters. The author suggests that trust mechanism is an important driving force to promote logistics clusters. Chhetri et al. (2014) analyzed the impact of labor factors on the development of logistics clusters. The research shows significant spatial clustering of logistics employment in the western and southern corridors of Melbourne, associated spatially with manufacturing, service industry and retail hubs in those areas.

One of the important focuses of previous research has been the influence of logistics clusters on the economic growth. For instance, Rubbén et al. (2013) analysed the impetus of the logistics cluster on the economic growth of Arogon region in Spain using the input-output method. Rivera et al. (2014) analyzed the impact of logistics cluster on logistics industry development in the US. The study found that the spatial agglomeration of logistics industry in the US had a gradual upward trend, and accompanied with an increase in employment, a decrease in total cost of social logistics, a higher level of logistics services and a faster coordination of supply chains, thus promoting the development of logistics industry in the US. Kumar et al. (2017) studied the marginal contribution of logistics clustering to the regional economic growth in the US by taking advantage of spatial econometric model. The results show that logistics clustering has a positive impact on the regional economic growth and the employment promotion in the US. Hylton and

Ross (2018) further demonstrated the two-way synergistic growth relationship between logistics clustering and the regional economic growth by using data sets at the U.S. Postal Code Level.

There are a rising number of studies examining the characteristics of logistics clustering in China. For instance, Zhong (2011) analysed the logistics cluster degree of 31 provinces and municipalities in China by using the location entropy theory. The results show that there is a strong spatial correlation between China's logistics clusters in provinces and regions. Similarly, Xie et al. (2015) used the method of location entropy and spatial autocorrelation to analyze the spatial and temporal evolution characteristics of China's logistics clusters. The results show that China's logistics industry generally presents a trend of agglomerative development, with strong spatial autocorrelation and obvious spatial heterogeneity. Xu and Fang (2018) empirically tested the spatial spillover effect of logistics clusters on China's regional economic growth and its spatial difference by using spatial econometric model. The results show that the spillover effect of logistics cluster on the economic development in central China is the greatest, followed by Eastern China, but negative spillover effect was found in Western China.

Despite the research effort in the existing studies there are still major gaps in the literature. First, modern logistics is a productive service industry with high product liquidity, which means that logistics clusters have obvious spatial spillover effect, which is less focused by the previous study. Second, the impact of logistics clustering on the regional economic growth should be reflected by a range of indicators of regional economic growth, but most of the existing studies were carried out from a single indicator, and there are few studies focused on a comprehensive set of indicators of the regional economic growth. Third, the previous research mostly focused on the national or provincial level and there is a lack of research focusing on provinces and cities in a specific region.

Based on the panel data of 11 provinces and cities in China's Yangtze River Economic Belt (which is one of the most important economic development regions in China) from 2000 to 2016, this paper analyses the promoting role of logistics clusters on the regional economic growth and its spatial differences through econometric modelling.

Research framework and methods

Mechanisms of logistics clustering in promoting the regional economic growth

Nowadays, logistics industry is an important part of modern supply chains and the regional economy. The operation of logistics is typically cross-region and cross-industry. The development of logistics cluster is influenced by many factors such as resource endowment, geographical location, leading industry, economic structure, economic policy, government support, and logistics infrastructure. Logistics clusters can promote the regional economic growth by improving the efficiency of regional economic operation, promoting the development of related industries, optimizing regional industrial structure, and generating spatial spillover effect. Based on the extant literature review, the potential role of logistics clusters in the regional economic growth is shown in Figure 1.

Previous literatures (e.g., Liang, 2015; Shu, 2014; Tao, 2017; Rivera et al., 2014) found that the economies of scale and cost-saving effects brought about by logistics clustering can drive the micro-indicators (such as, manufacturing value added, regional

industrial productivity, manufacturing labour productivity, total factor productivity, logistics industry efficiency) of regional economic development into a benign direction, so as to optimize the micro-foundation of the regional economy and improve the efficiency of regional economic activities. In addition, logistics clustering can also promote the effective flow of regional economic resources, and optimize the allocation of regional logistics resources, as well as improve the efficiency of logistics industry (Yu and Wu, 2010; Chen and Zhang, 2018).

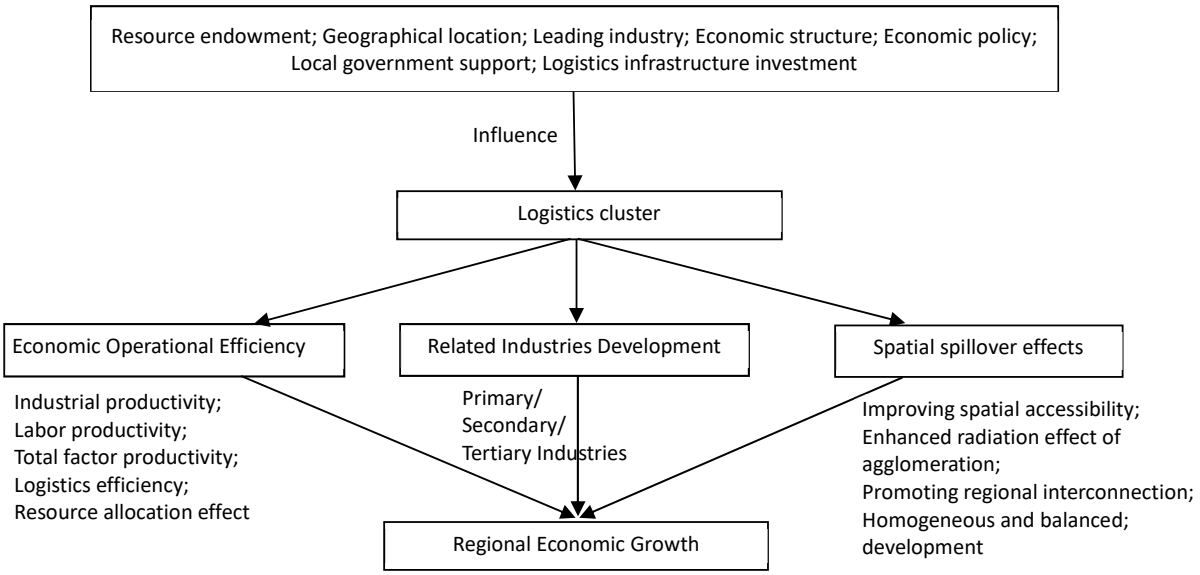

Figure 1. Potential role of logistics cluster in the regional economic growth

Selection of evaluation indicators of logistics clusters

The literature suggests that the most common approaches used to measure the degree of industrial clustering include Industry Concentration Index (ICI), Herfindahl-Hirschman Index (HHI), Location Quotient (LQ), Spatial Gini Coefficient (SGC), Ellison–Glaeser index (EG). These approaches have its advantages and disadvantages (Rivera, 2014; Chhetri, 2014; Cerina and Mureddu, 2014; Cui, 2017; Kumar, 2017; Abushaikha, 2018). In consideration of the characteristics of the logistics cluster, we choose LQ as the indicator to measure the degree of logistics clustering in China's Yangtze River Economic Belt.

LQ was first proposed and applied to location analysis by Haggett (1965) and was since widely used in economic geography and regional economics. Because LQ is based on administrative units to measure the degree of spatial clustering of industrial development, its method of calculation is simple and the data needed is more available. Therefore, LQ is considered as more suitable to measure the degree of regional logistics clustering. LQ is defined as:

$$LQ_i = \frac{\frac{e_i}{e}}{\frac{E_i}{E}} \quad (1)$$

Where, e_i is the employment number or the output of the logistics industry in region i, e is the employment number or the output of all industries in region i, E_i is the employment number or the output of logistics industry in a reference region (which

is typically the country), E is the employment number or the output of all industries in a reference region (which is typically the country).

LQ value greater than 1 suggests a higher than average share of employment or output of logistics industry in region i. The larger the value of LQ, the higher the level of logistics specialization in region i, and the higher the level of spatial clustering of the logistics industry; on the contrary, a low LQ value suggests there is a lack of specialization, and the level of logistics clustering is low.

Econometric model construction

According to the classical economic theory, the influencing factors of total economic output include capital input, labor input, natural resources and technological conditions. Cobb-Douglas production function (expressed as $Y = AK^{\alpha}L^{\beta}$) is typically used to measure the total economic output. In order to further investigate the impact of logistics cluster on regional economic growth, we introduce the LQ (degree of logistics clustering) into the Cobb-Douglas production function on the basis of relevant research results (Pang and Liu, 2012; Rivera et al., 2014; Gong and Zhang, 2017). Therefore,

$$Y = AK^{\alpha}L^{\beta}LQ^{\gamma} \quad (2)$$

Where Y, A, K, L and LQ represent the total economic output (Y), natural resources and technological conditions (A), capital input (K), labour input (L) and logistics clustering (LQ), respectively. The parameters α, β, and γ represent the elasticity, so that $0 < \alpha, \beta, \gamma < 1$, $0 < \alpha+\beta+\gamma < 1$. By taking the natural logarithms on both sides of the formula (2), we get the formula (3):

$$LnY = LnA + \alpha LnK + \beta LnL + \gamma LnLQ \quad (3)$$

Assuming that natural resources and technological conditions remain unchanged in a short run, we can obtain the following econometric models:

$$\text{Model I:}\quad Y_{it} = \beta_0 + \beta_1 K_{it} + \beta_2 L_{it} + \beta_3 LQ_{it} + \varphi_{it} \quad (4)$$

$$\text{Model II:}\quad LnY_{it} = \beta_0 + \beta_1 LnK_{it} + \beta_2 LnL_{it} + \beta_3 LnLQ_{it} + \varphi_{it} \quad (5)$$

In order to further investigate the difference of the impact of logistics cluster on regional economic growth in different sub-regions in the Yangtze River Economic Belt, we introduce dummy variables D_1, D_2 and D_3 into formula (5) and to obtain model III:

$$\text{Model III:}\quad LnY_{it} = \beta_0 + \beta_1 LnK_{it} + \beta_2 LnL_{it} + \beta_3 LnLQ_{it} + \beta_4 D_1 LnLQ_{it} + \beta_5 D_2 LnLQ_{it} + \beta_6 D_3 LnLQ_{it} + \varphi_{it} \quad (6)$$

Where, i denotes the upstream, middle and downstream area of the Yangtze River Economic Belt, t denotes each period, β is the coefficient to be estimated, and φ is the error term; D_i is the dummy variable, so that $D_1 = 1$ denotes the downstream area, $D_1 = 0$ denotes other areas; $D_2 = 1$ denotes the middle reaches area, $D_2 = 0$ denotes other areas; $D_3 = 1$ denotes the upstream area, $D_3 = 0$ denotes other areas.

Data analysis and results

The case of China's Yangtze River Economic Belt

As part of China's regional development strategies, Yangtze River Economic Belt is one of the largest regions needed coordinated development of regional economy, which covers 9 provinces and 2 metropolitans: Shanghai, Jiangsu, Zhejiang, Anhui, Jiangxi, Hubei, Hunan, Chongqing, Sichuan, Yunnan and Guizhou. Total area of the region is about 2.05 million square kilometres, which is more than a fifth of whole China. By the

end of 2016, the region had a population of 591.4 million, which accounted for 42.77% of the total Chinese population. The regional GDP was 3,351 trillion RMB, which accounted for 45.06% of the total Chinese GDP. The added value of logistics industry in the region was 1,366 billion RMB, which accounted for 41.32% of the total national value added of 3,306 billion RMB. The high value added of the logistics industry compared with the national value added suggests that the logistics industry in the region is hugely important.

Data source and data processing

To examine the logistics clustering effect and its impact on the regional economic development, the panel data is collected from the Statistical Yearbook of the 11 provinces and metropolitans in the region over 17 years from 2000 to 2016. The main variables included GDP (Y), total investment in fixed assets (K), total number of employees (L), and location quotient coefficient of logistics industry (LQ). In the analysis, we used employment number as the basis of calculating the LQ value. Moreover, in order to eliminate the influence of price factors, CPI index is used to adjust GDP and total fixed asset investment (see Table 1 for the descriptive statistics main variables).

Table 1. Descriptive Statistics of Main Variables

Variables	Unit	Obs	Maximum	Minimum	Mean	S.D.
GDP	100 millions	187	76086.17	255.72	14117.60	13247.44
K	100 millions	187	49370.85	402.50	8935.46	9260.71
L	10 thousands	187	4860.00	771.95	3040.66	1196.82
LQ	%	187	197.75	57.36	103.22	23.61

Test Result

Eviews 9.0 software is used to process the data. F values of model I, model II and model III are tested respectively before choosing fixed-effect model or random-effect model for the panel data. The test results of F statistics of three models are respectively: F1(10, 173)=281.74, F2(10, 173)=309.62, F3(10, 170)=277.44, while the critical value of F statistics is F(10,173/170, 0.05)=6.46. Moreover, the Hauseman's test results show that the P values of the three models are all significant, thus indicating that the original hypothesis that individual effects are not related to explanatory variables is rejected at a significant level of 0.001. Based on the F-statistics and the Hauseman's test results, fixed-effect model was chosen for the parameter estimation. In addition, because the data set contains time and space in dimensions, there is potential problem of heteroscedasticity. Therefore, the White heteroscedasticity correction method is used in the least square regression , the estimated results of the model are shown in Table 2.

It can be seen from Table 2, all variables are significant for all three models, and suggesting there is no spurious regression. Regression results of model I suggest that logistics clustering (LQ) has significant impact on the regional economic growth (Y). Similarly, regression results of model II suggest that there is a significant positive correlation between logistics clustering (LnLQ) and the regional economic growth (LnY).

Table 2. Regression Results of the Impact of LQ on Regional Economic Growth

	Model Ⅰ	Model Ⅱ	Model Ⅲ
C	-1569.475（-4.170）***	-3.086（-1.843）**	-1.823（-1.057）**
K	0.279（3.101）***		

L	0.152（2.685）**		
LQ	269.785（1.294）*		
LnK		0.821（36.849）***	0.683（36.290）***
LnL		0.670（36.184）***	0.652（2.846）***
LnLQ		0.187（5.175）*	
D_1LnLQ			0.329（1.310）***
D_2LnLQ			0. 546（1.673）***
D_3LnLQ			-0.072（-0.222）*
R^2	0.955	0.959	0.961
Adjusted R^2	0.952	0.956	0.957
F statistics	281.736***	309.621***	277.443***
P values	0.000	0.000	0.000
n	187	187	187

Note：Values with ***, ** and * indicate the significant estimates at the level of 1%, 5% and 10%, respectively.

The regression results of model III suggests that the effect of logistics clustering on the economic growth of different areas – downstream, middle reaches and upstream – in the Yangtze River Economic Belt is not identical. According to the national statistics of China, downstream areas of Yantze River Economic Belt is economically most developed followed by the middle reaches area and then the upstream area. The results suggest that the differences in economic development of different sub-regions may have impact on the different promotion effects of logistics clustering on the economic development. As shown in Table 2, the regression coefficients of logistics clustering on regional economic growth in downstream, middle and upstream sub-regions are 0.329, 0.546, and -0.072, respectively. The positive regression coefficient of downstream and middle reaches area of the region indicate that logistics clustering in those sub-regions has a positive effect on the regional economic growth. The negative regression coefficient (although small in value) in upstream areas of Yangtze River Economic Belt indicates that logistics clustering in the upstream area did not promote the regional economic growth.

Robustness test

Robustness test was conducted by using the output of logistics industry instead of logistics employments to re-calculate the level of logistics clustering (LQ'), so that to test the stability of the regression results. As shown in Table 3, the regression results suggest that all coefficients are significant although at different significance levels with the original regression models, thus indicating that the results are generally stable. The regression results also shows that the logistics clustering calculated by replacing the number of logistics employments with the output of logistics industry has more significant impact on the regional economic growth (the regression coefficient increased from 0.187 to 0.466). However, there are some differences among sub-regions in terms of levels of significant impact on the regional economic growth.

Table 3. Regression Results of the Impact of LQ' on Regional Economic Growth

	Model Ⅰ	Model Ⅱ	Model Ⅲ
C	-8725.768（-4.170）***	-0.440（-0.299）*	-1.318（-0.932）*
K	1.199（19.456）***		
L	0.926（2.685）***		
LQ	174.414（0.434）*		
LNK		0.681（41.310）***	0.699（42.427）***
LNL		0.478（2.440）***	0.567（3.025）***
LNLQ		0.466（6.702）***	

D_1LNLQ			0.638（2.726）*
D_2LNLQ			0.290（1.652）***
D_3LNLQ			-0.549（-7.993）***
R^2	0.957	0.967023	0.971
Adjusted R^2	0.949	0.964545	0.968
F statistics	121.150***	390.233***	375.188***
P values	0.000	0.000	0.000
n	187	187	187

Note：Values with ***, ** and * indicate the significant estimates at the level of 1%, 5% and 10%, respectively.

The robust analysis suggests that due to different levels of economic development in sub-regions of the Yangtze River Economic Belt, the role of logistics clustering in promoting the regional economic growth is not the same. The logistics clustering (LQ') measured by logistics outputs in the developed sub-region (i.e., the downstream area) plays a more important role in promoting the regional economic growth. On the contrary, the logistics clustering measured by logistics outputs in the less developed sub-region (i.e., the middle reaches area) has weaker effects on the regional economic development. Furthermore, there is certain inhibitory effects of the logistics clustering in terms of logistics outputs in the least developed sub-region (i.e., the upstream area) on the regional economic growth.

Conclusions and implications

The existing literature lacked the empirical understanding of the relationship between logistics clustering and the regional economic development. In this study, we take China's Yangtze River Economic Belt as an example to test the promotion effects of logistics clustering on the regional economic growth.

First, logistics clustering has a significant role in promoting the regional economic growth in the Yangtze River Economic Belt. However, there is spatial differences among sub-regions (i.e., upstream, middle reaches and downstream areas), which is consistent with Cerina and Mureddu (2014)'s research. The role of logistics clustering in promoting regional economic growth is not identical among sub-regions. One of the reasons behind such difference is the uneven economic development in those sub-regions. Generally speaking, logistics clustering (in terms of logistics employment) in the middle reaches area followed by the upstream area contribute most significantly to the regional economic growth. Such contributing role is much weaker in less developed sub-regions (i.e., upstream area) and even being negative.

Second, based on the robustness test, the logistics clustering (measured by logistics industry outputs) has shown a more significant impact on the regional economic growth, which indicates that industry clustering on the basis of value added has a greater impact on the regional economic growth than that of the logistics clustering in employment. Again, due to the uneven economic development among sub-regions in the Yangtze River Economic Belt, logistics clustering has shown differences in promoting the economic development of sub-regions. What we found is that logistics clustering in terms of logistics outputs in the less developed sub-region (i.e., the upstream area) has a negative effect on the regional economic growth.

These findings deserve attention from policy makers when promoting logistics clustering in different sub-regions. First, the economic contribution of logistics clustering needs to be recognized. Policy-makers should focus on strengthening clustered development of the logistics industry given that it has significant impact on the integration

and the optimization of logistics resources in the region, and subsequently on the regional economic growth. To enable logistics clustering, the accumulation and the investment in human capital, logistics infrastructure, ICT infrastructure, and improvement of the interconnectedness of roads within the region are essential.

Second, policy makers should also realize that contributions of logistics clustering differs across regions. According to Cerina and Mureddu (2014), industry clustering is not always good for the economic growth. For instance, the regional economic growth will not benefit from the logistics clustering from the upstream area of the Yangtze River Economic Belt. Because although logistics clustering improves sector efficiency and optimization, but it may reduce the total employment numbers and total investment in the wider society in that sub-region. Given this sub-region has lower average skills levels and is more labour intensive, and has a higher need of general investment rather than focused investment, the economic contribution of the logistics clustering will be reduced. Therefore, policy-makers should formulate suitable policies according to local conditions, local economic development levels, status of leading industries, geographical conditions, quality of logistics practitioners, and the technological level in the region.

Third, while providing policy support, the regional government should avoid over-intervention, since the logistics clustering would inevitably be realized by the participation of logistics enterprises. Therefore, direct administrative intervention should be minimized to optimize the business environment and to improve the engagement of logistics enterprises.

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The supply chain through direct trade in agribusiness coffee: a look at the perspective of its agents

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Abstract

The main objective of this study is investigate how the new model of coffee trade, known as Direct Trade Coffee has increased worldwide and how it has changed the supply chain in coffee trade. Through interviews by multiple-case method, the agents of supply chain coffee as producers, roasters and cafeterias demonstrated your perceptions in trade production, distribution and selling specialty coffee. The Transition Cost theory was used to understand how large the asymmetric information, opportunism and limited rationality impacts the supply chain value overall. This study is value to support the understanding of short and more fair coffee negotiate.

Keywords: Supply Chain**;** Direct Trade Coffee; International Trade

Introduction

In an increasingly dynamic and integrated economy, which information is constantly permeability in the agro-industry sectors, the informational symmetry and economic development of both producers and roasters are put in the agenda, requiring a rational and behavioral analysis of their agents. Factors such as negotiation, contracts and mutual relationship between sellers and buyers, begin to reconfigure the coffee production chain, peculiarly the specialty coffees (special or gourmet ones).

This article aims to demonstrate the new trend that has grown worldwide in the supply chain of specialty coffee market known as *Direct Trade*. This new model aims not only to shorten the supply chain's coffee, but also seeks to increase the relationships between the agents since the coffee producer to the final consumer changing, in this way, the traditional supply chain's coffee. Although studies about *Direct Trade* in coffee agribusiness have grown in the last decades, especially in the last few years linked to research on the Third Wave of Coffee, which is focused on specialty coffees, there are still, few studies that try to understand the supply chain of *Direct Trade* at coffee trade as a whole.

Therefore, this article sought to deepen an understanding the impression of this theme through face-to-face interviews with the agents involved in the coffee supply chain as producer and roasters and/or cafeterias in Brazil and abroad. It was evident through this research that Direct Trade is a trend in the specialty coffee market, but its similarity with the principles of coffee certification and requires further studies would be developed to consolidate the shortening of the coffee supply chain and optimize the aggregation of value of all links in the coffee chain.

Literature Review

Theoretical Background

Global coffee consumption has increased considerably in recent years. Brazil is the largest producer of coffee in the world and the second in consumption. A range of coffee varieties arises dynamically, requiring the coffee sector methods and actions aimed not only at increasing production but also at analysing the impacts these increases have on the environment, people and the economy (Silva, 2006).

The coffee certifications as FairTrade, UTZ Certified, RainForest Alliance Certified appear with the objective to certifying producers that, throughout the production, have to fulfil environmental and social standards, characterizing to be a specialty coffee, although this is not an affirmative condition that they will be able to obtain a quality coffee (Pinhero, Nagai, 2014).

On the other hand, the demand for specialty coffees has altered the dynamics of the global market, as buyers are investing directly in coffee growers, taking risk instead of facing future market price volatility. Certified coffees have been a trend in recent decades and the causes of their growth are the benefits that certifications bring. High prices paid to coffee growers, openings to new markets, maximization of production longevity and valorization of labor routines are the "flagship" of Certifications (Guimarães, 2016).

In order to optimize the process between growers and roasters, a new model of coffee bargaining arises, with the objective of paying a "real fair price" to the coffee grower in the acquisition of a higher quality coffee. Direct Trade is a business model that aims at a direct trade relationship between the coffee grower and / or roasters, eliminating the so-called "negotiators", reducing operating costs and retaining the coffee farmer to the buyer (Counterculture Coffee, 2015).

Thus, in the coffee market, paradoxically, there is a great demand for the consumption of specialty coffees, but the supply of quality grains which are produced in a sustainable manner is below the conventional market, despite its consumption of rapid growth, especially in developed countries.

The Waves Coffee

Direct Trade is most faced to specialty(and gourmet) coffees and also, presents in part, as an extension of coffee certification as FairTrade, RainForest and UTZ Certified, etc. but

works in a short supply chain and more direct relationship between agents, as it is concerned with offering superior quality coffees, unique and exclusive, with the characteristic soft drink with high added value, with 'traceability' and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization local infrastructure and the community as a whole, with school construction, support for workers, empowerment of coffee growers, gender equality, among other actions that make up the premises of certifications. To clarify further the results, Borrella, Mataix and Carrasco-Gallego (2015) and Guimarães (2016), explain the Waves Coffee.

The first wave of coffee is attributed to the expressive increase and worldwide dissemination of beverage consumption, especially in the late nineteenth and early twentieth centuries. More specifically in the United States of America, this movement gained momentum with the Great Depression and World War II, requiring minimal time and effort in its preparation. (Reis, 2018; Guimarães, 2016).

The second wave arises when, introducing the new concepts of roasting, in order to reach certain beverage profiles and the consistency of the supply, as well as new notions of origin, recognizing that this, at country level, influenced the quality and some characteristics of the grains (Andrade et al., 2015; Guimarães, 2016).

The third wave appeared in the mid-90s, when only specialty coffees and grains of the Arabica species were used, as well as the vaporization of its numerous aromatic and flavor notes, highly influenced by its origin of production, Thus, coffee goes through a process of total "decommoditization", being considered as a complex, exclusive and seasonal product and compared to other specialty products (Reis, 2018).

The Direct Trade as the State of the Art of Supply Chain Coffee

The traditional Supply Chain Management (SCM) has many agents which are linked each other in the whole chain. Mentzer et al. (2001), infers that SCM can be understand as "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole" Mentzer et al. (2001).

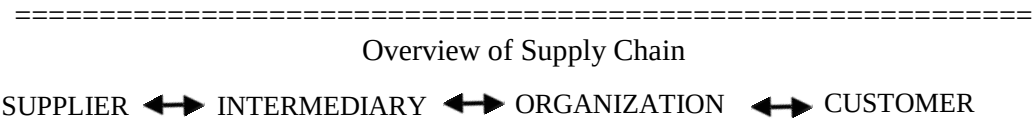

Figure 1 – The Supply Chain – Mentzer et al (2001), adapted.

Below, the figure 1 shows the complexity of SCM as a pipeline, proposed by Mentzer (2001). At this model it is clear that there are innumerable intermediary agents and in the coffee chain it is not different, being these intermediaries: cooperatives, associations, brokers, exporters, roasters and coffee shops.

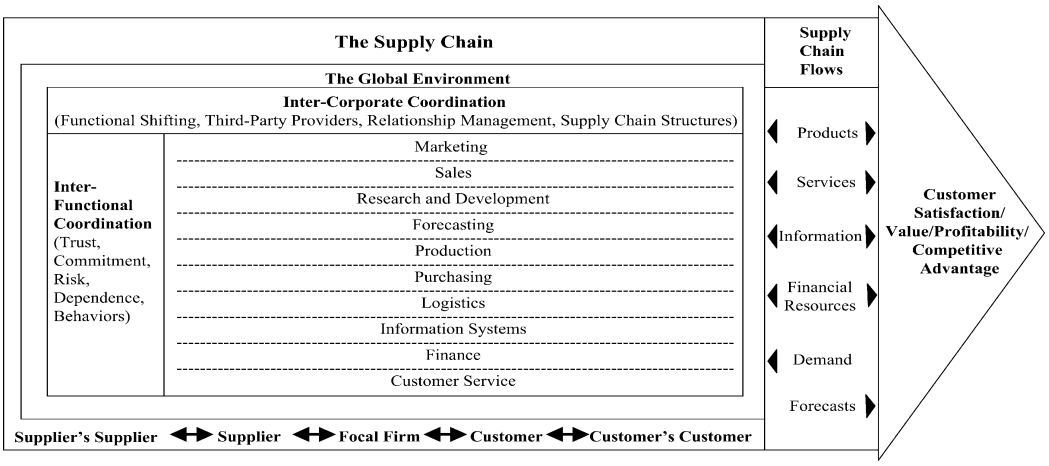

Figure 2 – The traditional Supply Chain Extended – Mentzer et al (2001)

Severins (2015) infers that the traditional supply chain of coffee typically contains seven levels: growing, harvesting, hulling, drying and packing, bulking, blending and roasting. The entire SCM coffee is further extended by several intermediaries, including global transporters as well as exporters and retailers.

The State of the Art of Direct Trade is how the whole chain is shorter and with this, the considerable reduction of costs with the intermediaries along the whole chain, which in turn, allows higher financial gains for the producers and coffee shops. For Badiyan-Eyford (2013), Direct Trade arises because of a strong tendency to offer quality coffees to the market with a close relationship between producers. For this type of trading, there are no pre-designed templates, nor standard terminology.

Direct Trade presents itself as a relationship of stability, trust and equality between the roaster / cafeteria and the producer (Brown, 2012), which is increasingly valued and highlighted in the marketing of the final product. The actors in this chain would thus share their knowledge and work together in a coordinated way in order to optimize the supply chain, increase the quality and supply of specialty grains *or* beans, as well as "empower" coffee growers and, above all, reduce costs along the chain.

Assumptions of Transaction Cost Economics

In order to obtain an analysis of transactions between agents within a business network, or more specifically, in order to develop this research on coffee agribusiness, we have the Transaction Cost Economics. Transaction Cost Economics, also known as ECT, was developed by Ronald Coase in 1937, when it was published in The Nature of the Firm (Langlois, Foss, 1999, Thielmann, 2013).

Silva Filho (2006) highlights the main factors in the transactions: (i) the limited rationality of agents, which prevents them from taking, over time, decisions that maximize well-being; (ii) the opportunistic behavior of the agents, which motivates them to act in order to obtain benefits at the expense of other agents with which they are related; (iii) the asymmetry of information, which implies unequal access of the agents to the information pertinent to the exchange made by them, preventing it from being given in the most advantageous manner from the point of view of society.

Methodology

For this research, it was characterized as qualitative with a descriptive-exploratory character and it was adopted the study of multiple cases, to understand the behaviors of the coffee agents that act in the direct form of commercialization and to explore what the risks and advantages in the relations between the agents (Labuschagne, 2003; Yin, 2014). In this way, an attempt was made to offer a description of the environment in which the agents are inserted and how their behaviors affect the structure of the chain of acquisition of coffee and the relationships with the coffee growers.

Case selection

Agents were chosen that act directly in the direct trade of coffee in each chain link. For this, a non-probabilistic sample was used as sampling (Yin, 2001). Sample convenience was used because, for Miles, Huberman and Saldãa (2013), such sampling is only targeted to agents that meet the requirements of the study in question. As this research aims to understand how agents act to reduce costs between buyers and sellers of coffees, known as chain intermediaries, seven agents in total were interviewed.

As it assumes that each agent via Direct Trade has a mutual relationship between each link in the chain, the focus on each was delimited in the search for possible asymmetries of information, opportunism of some agent or limited rationality of one or several agents. If any of these actions prevails between the negotiations, it will modify the structure and dynamics of direct trade, weaken mutual trust between the parties and strengthen opportunism.

Interviews

The interviews were semi-structured and have basic questions that are supported by theories and hypotheses that are interrelated to the research theme (Triviños, 1987, p.146). The interviews took place in Brazil and in the United States, among producers of specialty coffees, roasters and coffee shops.

The choice of the seven interviewees is justified by the following considerations: a) search of the perspectives of the agents participating in the governance structures in the coffee chain; b) the need to understand the practices of international agents; c) to confront or find "gaps" between what is said and practiced among the agents; d) the search for the design of a non-active agent in the direct trade of coffee. These interviews allowed the agents' visions to be intercalated, generating results (or lack thereof) that could respond to the research objective in line with the theory of transaction costs.

Data collect

In this stage, Yin's (2001, p. 81) propositions that highlight how the interviewing skills for case studies: 21 questions were followed; knowing how to listen to the interviewees' positions, identifying the interviewee's keywords and effective components; to be flexible and make adaptations to better enjoy the moments of the interview; have extensive knowledge of the issues contained in the interview script and seek to be impartial during their performance.

Initially, contact was established with some coffee shops, roasters, both in Brazil and abroad, and coffee growers from the southern region of the State of Minas Gerais, in order to conduct the interviews. The interviews were recorded and later transcribed in the data analysis stage. In addition to the recordings, annotations of topics considered were taken, and the reductions were made from larger sentences to smaller sentences until reaching the main points of the research (Miles, Huberman and Saldãa, 2013).

There were seven interviews in all, with the managers, directors and coffee growers involved in the practice of Direct Trade Coffee. This stage was based on an elaborate

interview script, considering the theoretical propositions of the Transaction Cost Economy and its impacts within the coffee supply chain.

Data analysis

For the analysis of the interviews, content analysis was used. Bardin (1977) defines content analysis as being a cluster of inter locution analysis techniques, aiming to obtain, through systematic and objective techniques of exposing the content of the messages, the inference of knowledge regarding the conditions of production or receptivity of such messages.

This systematic should follow a sequence of procedures that cover pre-analysis, coding, categorization and inference. Thus, the data were compiled as follows: (i) Pre-analysis: Separation and identification of the interviewees; Separation by topic / subject from interviews; Capture of legend to identify the interviewees; (ii) Transcript of interviews; (iii) Encoding and categorization of interviewed agents: Organize and separate according to the subject of each respondent's related response - (Coffee producer = P; Roaster = T and C = Cafeteria <P1, P2, P3, P4, T1, C1, C2>); (v) Inference of the Thematic Analysis: Analyse the responses of the groups (intensity, frequency and meanings of the pertinent themes; (vi) Realization of the discussion of the results.

Findings

This research has revealed a number of important points about the relationships between agents in the supply chain via Direct Trade. Access to information and transparency in negotiations and contracts are vital for reducing information asymmetry and the opportunistic actions of agents outside of Direct Trade.

Another very important point is the need to demystify that Direct Trade is a direct purchase and sale action between producer and cafeteria (or roaster). There will always be an intermediary within the chain, whether it is an exporter for buyers from other countries or an internal transport company sale made within the producing country. Thus, the structure of Direct Trade is lean (figure 3), but does not completely eliminate the intermediates of the chain.

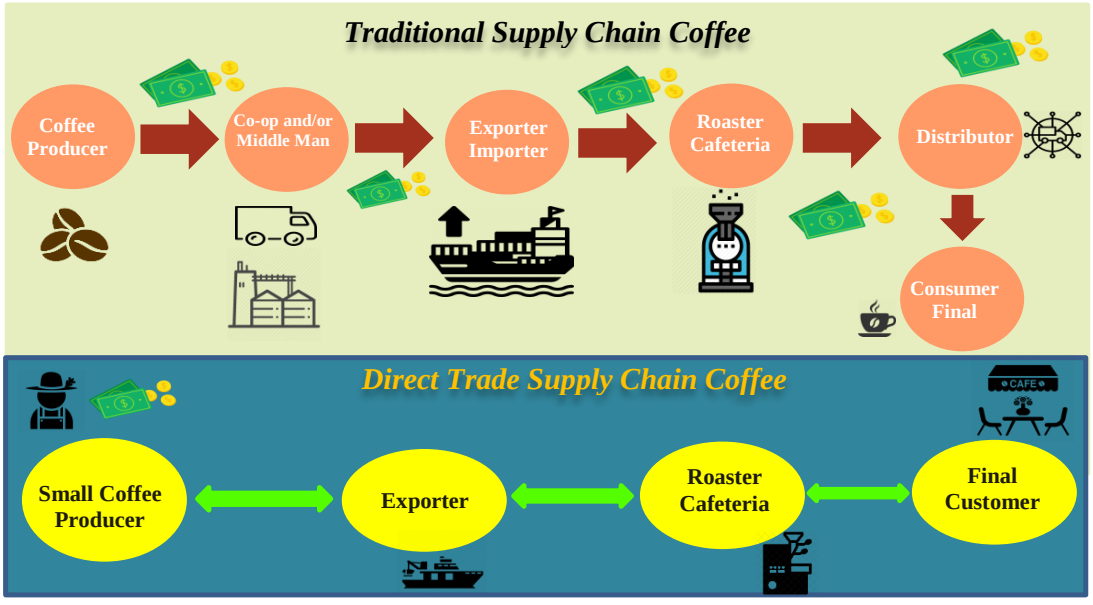

Figure 3 – Traditional versus Direct Trade Coffee Supply Chain - By Authors

The Institutional Environment, of the transactions and the behaviors of the agents
It was observed that the transactions between the agents are not clear when asked about the expectations advocated by agents. While coffee shops have argued that coffee growers receive direct attention from their sponsors, such as trainings, support and / or technical visits on their farms, whether semi-annually or annually, coffee growers, in turn, have explained that obtaining the quality of their coffees is an action derived from its own dedications and the correct management of the coffee, without, necessarily, the intervention of some agent of the roaster or cafeteria.

Limited Rationale
It was observed that all Direct Trade agents interviewed are intended to be rational about their assignments within the specialty coffee chain; but it was noted that this rationality is achieved in a non-integral way, that is, it proves to be a limited rationality, which for Williamson (1989), such rationality is an intrinsic behavior to agents. The rationality of the interviewee P2 demonstrates the limitation on the possibilities or perspectives proposed by the Interviewee T1. Although they seem simplistic perspectives on the same theme, they generate asymmetries of information in the structure of governance and loopholes so that opportunism arises and modifies the entire organizational environment.

Opportunism
It can be explained that the main opportunistic behaviors reported among coffee growers were: restriction of information, concentration of access to new markets (for coffee resale); high rates of logistic payment for the outflow of production (paid more, besides the necessary, for not having competition) and mystification of the export processes.

Asymmetry of Information
It was unanimous among the interviewees P1, P2, P3 and P4 that they were unaware of the practices adopted by the roasters or coffee shops, regarding technical visits and support in the production processes of the specialty coffees to be sold to them. This is due to the fact that, while roasters and international coffee shops are proposing to offer support (in different ways) to their peers, one can see how many coffee growers do not even know of the possibility of winning an extra prize in their coffees and, above all, increase the networks of transactions between people who offer assistance to the coffee management and the more widespread, increase the transactions with the agents of the post-harvest, which, in turn, increase the risks of opportunism in the relations.

Discussion

This research has brought significant contributions regarding the direct trade model of the direct trade model, which, in the coffee agribusiness, focused almost exclusively on the commercialization of specialty coffees, is still incipient its performance in the traditional market (commodity) or certified coffee, but in turn have shown an exponential growth in the last decades, requiring special attention to their growth.

Thus, this research identified by the theory of Transaction Cost Economics (ECT) the existing gaps, in this almost unprecedented chain of direct coffee trade, in whose organizational environment the coffee grower and roaster, because they are distinct, either in the rational model, in the geographic environment, lead to a discrepant informational asymmetry between these agents, making it clear that, while coffee shops focus on the quality of their coffees sold, coffee growers do not demonstrate knowledge about the various 'resources' made available by roasters in this segment.

The small coffee growers producing specialty coffees do not have certain information that would generate market advantages, since their rationalities are directed to the traditional coffee marketing model: 1) it produces; 2) benefits; 3) stock; 4) seeks buyers in the coffee market or sell to cooperatives; 5) sell coffee; 6) It pays the bills and what about is profit. This attitude offers the possibility of intermediaries accessing the chain and reselling specialty coffees to specific markets with a higher premium, but that is not (re) passed to the coffee grower, maintaining the same chain structure.

As for the increase in sales in the international market, it should be pointed out that in view of the difficulties reported by coffee growers in reaching the external market by themselves, as a small-medium producer, it is believed that in the domestic market, it is easier to negotiate prices, , etc., for two reasons: (1) the ease of language (communication); (2) the growing public interest in higher quality coffees (or better sensitization). The rationale for coffee export processes, as previously reported, corroborated (or corroborated), to a certain extent, the growth of the domestic market in the consumption of specialty coffees.

Conclusions

Although studies on Direct Trade in coffee agribusiness have grown in recent decades, especially in the last few years linked to research on the Third Wave, which is focused on specialty coffees, there are few studies that seek to understand this chain of direct trade as a whole.

In this way, it is possible to infer, albeit prematurely, that Direct Trade is an extension of certification, concerned with offering superior, unique and exclusive quality coffees with the characteristic soft drink with high added value, traceability and sustainability, while certifications are concerned with numerous facets within the organizational structure of the coffee chain, such as training to improve coffee quality, optimization of local infrastructure and the community as a whole, building schools, support workers, empowering coffee farmers, equality between genders, among other.

In this way, this work can be glimpsed by the theory of the Economy of the Costs of Transaction in which Direct Trade allows a structure of governance leaner than the traditional coffee agribusiness chain; reduces opportunistic actions when the information asymmetry is small, that is, when there is an efficient bilateral relationship and broadening the rationality of the agents regarding the possibilities of gains among the agents.

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Operations in the Public Sector

Can lean management practices in the operations of the universities lead to sustainability?

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Abstract

Sustainability in the educational curriculum of the higher education providers like universities has received considerable attention due to its importance in practice in most of the industry sectors. However, when it comes to having a sustainable operation in universities, limited evidence is found in both theory and practice. The few research papers that addressed the issue, did not quite address the underlying barriers by proposing effective solutions. This research aims to propose solutions to this problem by examining if lean practices would be able to facilitate environmental sustainability in the universities' operation in the UK.

Key Words: Sustainable University, Lean Management, Barriers to Sustainability

Introduction

Sustainability has been a buzzword in practice for the last couple of decades. It has also been a matter of academic interest to most of the universities in modern times. There has been a considerable shift in sustainable development in the last two three decades due to the increasing importance of policies to promote sustainability (Jorge et al., 2015). Yet, the universities often struggle to manage their sustainability targets in their own operations especially in the case of environemnatl sustaibaility. This has been documented in several studies from different parts of the world including studies in Portugal (Aleixo et al., 2018), in the UK (Robinson et al., 2018), in Poland (Kogcielniak, 2013), in Lithuania (Dagiliute and Liobikiene, 2015). The present study focues on the UK higher education providers and to the issues on the environmental sustainability of the triple bottom line framework. The rational for this is the doeumented concerns regarding the performance of many of the university's environmental sustainability issues based on People and Planet League table. Following the Data Energy Certificate release in 2017, a study was followed to identify the potential savings opportunities in the UK higher education sector. A potential £15.6 million savings opportunity was identified (Hawkins, 2017). In a report published in the Guardian (2016), only 25% of the UK based university campuses are on course to meet the carbon reduction targets by 2020 (Lightfoot, 2016). The author further mentioned-"*UK universities are helping lead the world on environmental research – but when it comes to their own back yard they appear to be falling behind.*"

This leads to the question of why the higher education sector falls behind their environmental performance. This has been mentioned in the literature including Disterheft et al. (2012), Netaji and Netaji (2013), Kogcielniak, (2014), Berchin et al. (2017), and Akins et al. (2019) where the authors highlighted the presence of certain challenges/barriers to sustainable approaches in the form some case studies. These studies highlighted the importance of cultural change, but these studies did not highlight the type of change required and the stages involved in operational improvements to achieve those changes. Some authors tried some assessment tools to offer some practical insight regarding assessment and reporting of sustainability performances, but these have limitations in terms of addressing some of the basic barriers including awareness (Lauder et al., 2015). Moreover, there has been limited evidence on how to address those challenges against achieving those sustainability targets in the university set up by improving the universities' operations. Adoption of some of the continuous improvement techniques from operations management such as lean management has been found to be improving the sustainable operations in practice in many sectors including manufacturing (Piercy and Rich, 2015). Yet, limited evidence is available when it comes to operations in universities. On this backdrop, "this research aims *at exploring and examination" if lean management principles can be implemented in universities operations to facilitate the sustainability targets to be achieved by addressing the barriers. This research will focus on the operations of the universities in Scotland in the first phase with an extension to the UK wide research in the subsequent phase. The objectives are*

Objective 1. To examine the barriers to achieving sustainability goals in universities operations in the UK.

Objective 2. To examine if the lean management principles can be applied to address those barriers and improve performance.

Literature review/Research backdrop

There is a growing body of literature on sustainability in the universities and other higher education institutions. This section presents an appraisal of extant literature considered relevant to this study, highlighting key themes and theoretical propositions for this research. A conceptual framework is also presented.

Sustainability Tools

A literature review shows some of the themes in the research involving sustainability issues such as tools used for sustainability measures (Li et al., 2018; Marrone et al., 2018; Algamdi et al., 2017; Berzosa 2017; Jorge et al., 2015; Lozano, 2011; Lozano, 2006), application of environmental management system (EMS) (Disterheft et al., 2012; Clarke and Kouri, 2009). Research in presenting the tools used for sustainability performance reporting has been considerably popular in the last 10-15 years. Lauder et al. (2015) presented a review of the Green Metric of the university ranking that is used for sustainability reporting in the university. In early research, Lozano (2006) presented a comparative study among the different tools used to assess and report the sustainability efforts by the universities along with some proposed modification in some of the tools such as Global Reporting Initiative (GRI), and Graphical Assessment of Sustainability in Universities (GASU). The author further extended the study to incorporate the GASU to compare the performance of the 12 universities' sustainability performance (Lozano, 2011). Townsend and Barrett (2015) used Environmentally Extended Input Output Analysis (EEIOA) in their empirical study based on the University of Leeds. The authors found this tool to be allowing the performance

comparioson between the universities. Jorge et al. (2015) proposed a multi-item quantitative tool which can be used for cross-university comparison. Alghamdi et al. (2017) examined 12 tools in sustainability in universities. Berzosa et al. (2017) conducted a comparative study with the application and application of multiple tools of sustainability applied for universities. Li et al. (2018) used the Analytical Hierarchy Process approach to propose prioritisation of the sustainability indicators in an Australian University. Marone et al. (2018) analysed and investigated the strengths and weaknesses of one of the popularly used index, the green metric index. Leon (2018) used Neighbourhood Evaluation for Sustainable Territories (NEST) tools for the environmental assessments of the University of the Basque County. Alshuwaikhat et al. (2018) proposed a model using the application of Geographical Information (GIS) tools to evaluate the sustainability related performance at the King Fahd University of Petroleum and Mineral. Alba-Hidalgo et al. (2018) proposed the definition/scope of environmental sustainability in the context of universities. The authors highlighted some of the characteristics of the tools that are used for this purpose such as STARS, SAQ (ULSF), AISHE, GASU, Green Report card, CSAF, AUA, STAUNCH, UI Green Metrics, CRUE, and USAT (MESA).

Alongside the sustainability performance reporting, the research on the application of Environmental Management System (EMS) has also been the topic of discussion in the literature. Clarke and Kouri (2009) discussed different campus EMS frameworks, their characteristics, and the drivers of implementation. Disterheft et al. (2012) conducted an empirical study on EMS development and implementation in universities across Europe. Velazquez et al. (2013) conducted a study on Sustainability Management System (SMS) implementation at the University of Sonora in Mexico to reduce the waste of water. Lo-Iacono-Ferreira et al. (2016) emphasized the importance of having an EMS for Ecological Footprint Assessment using Life Cycle Assessment. In a recent work by Omrecen et al. (2018), the authors presented a case study based on the implementation of climate strategy at the University of Gothenburg by the effective use of EMS. However, a limited insight was offered in these studies on the perceptions of the staffs and students. A study by Sammalisto et al. (2015) addressed this issue in a case study of a Swedish university. The authors addressed the perceptions of the staff members of the university on ISO14001 implementation. Other tools found such as Sustainability Management System.

Perception of Sustainability

Sammalisto et al. (2013) addressed the perceptions of the staff members by proposing a conceptual model. The author concluded with some insightful findings including variety in staff perceptions, and the importance of top management's encouragement. The importance of top management support was also highlighted in the studies of Wright (2010), Wright and Horst (2013). Nejati and Nejati (2013) proposed a scale for capturing the student perception on sustainability in the universities. Sylvestre et al. (2014) conducted an empirical study to address the perceptions of the professors of Dalhousie University by the implementation of Q-method.

Barriers to Sustainability

Despite a considerable amount of research in sustainability reporting and the tools used for sustainability in the universities, the efforts to achieve sustainability in the universities often fall short. This is mainly due to the existence of some of the barriers. This has been highlighted in few studies including Wright (2009), Wright and Horst (2013), Kogcielniak (2014), Robinson et al. (2015), Disterheft et al. (2015), Dagiliute

and Liobikiene (2015), Leal Filho et al. (2017), Alexio et al. (2018), and Akins et al. (2019). The issues identified as barriers includes financial predicament (Wright, 2009; Wright and Horst, 2013; Aleixo et al., 2018), lack of awareness/weak acknowledgement (Wright, 2009; Dagiliute and Liobikiene, 2015; Leal Filho et al., 2017; Alba-Hidalgo et al., 2018; Akins et al, 2019), resistance to change (Wright, 2009), lack of leadership/management support (Wright and Horst, 2013; Kogcielniak, 2014; Leal Filho et al, 2017), type of approach adopted by policy makers/lack of support from policy makers (including Government) (Kogcielniak, 2014; Dagiliute and Liobikiene, 2015; Robinson et al., 2015; Leal Filho et al., 2017; Aleixo et al., 2018). In addition, authors including Vieira et al. (2018) discussed barriers to the EMS implemementation in the university set up. Vieira et al. (2018) conducted the study in the Brazilian higher education sector.

One of the key internal issues has been identified as the barrier was the lack of top management support in some of the above studies in the last paragraph. A top-down approach to entail the goals and objectives of the sutainability has been recommended as a proposed requirement in the studies including Wright and Horst (2009), and Kogcielniak (2014). However, some counterintuitive evidence has also been documented such as Dagiliute and Liobikiene (2015) the existence of a top-down approach in their study in the Lituanian universities. The authors extended this as a possibly due to external barriers including government support and frequent policy changes. This has been highlighted in some other studies such as well to be having a significant impact on the clarity on the sustainability goals at the workplace among the higher education providers (Kogcielniak, 2014; Robinson et al., 2015; Leal Filho et al., 2017; Aleixo et al., 2018). In fact in the study by Robinson et al. (2015), the authors identified a need for setting a realistic and achievable carbon reduction target to be set in place.

There are certain limitations are in existence in the above studies such as

- Many of the studies were conducted in specific geographic locations such as Canadian universities (Wright, 2009), Portugese universities (Aleixo et al., 2018), Polish univeristies (Kogcielniak, 2014), Lithuanian universities (Dagiliute and Liobikiene, 2015), Brazilian universities (Vieira et al., 2018). Li et al. (2018) highlighted the geographical differences may have implications on the results to be changing form case to case.
- A need for a more exploratory investigation with a different group of stakeholders (Wright and horst, 2013; Disterheft et al., 2015; Leal Filho et al., 2017);
- A need for identifying solutions/ways to overcome the barriers (Filho et al., 2018).

Earlier, this research highlighted the importance of the problems of poor environmental performance and related flak being drawn towards the universities in the UK. This has motivated the present research to aim at conducting an exploratory study and identifying if any proposed solution can be offered to address some of the barriers.

Problems of environmental sustainability can be improved by imporoving the practices of operations within the organisation. Some well known continuous improvement practices such as Lean operational practices have been identified as one of the key facilitators towards environmental sustainability in manufacturing sctor in some early researches by Florida, (1996), and Corbett and Klassen (2005): “lean is green”. In fact, this mantra was the theme of a literature review of Garza-Reyes (2015). Authors including Hughes et al. (2012) highlighted the importance of lean practice with the focus on “doing more with less being used/spent”. Simpson and Power (2005) found the similarity between the practices that support lean manufacturing and environmental performance. This type of overlap between lean and sustainable practices has been

identified in the study of Cabral et al. (2012) where the author found the environmental waste reduction from lean tool implementation. According to Piercy and Rich (2015), one of the key limitations of the majority of these previous research topics was the focus on the relationship between lean practice and environmental sutainability only. In their research, the authors showed far stretching benefits that could be derived from lean practice towards sustainability in the UK based manufacturing sector. In recent research by Halldosson et al. (2018) reiteretaed the potential for integrating the principles of lean mangagement and sustainability initiatives. The authors further supported the findings of Piercy and Rich (2015) on the need for exploring the potential benefits of lean practices beyond environmental sustainability to other forms of sustainability that can be derived from the triple bottom line.

Despite its proven success in many other sctors including manufacturing, the application of lean management practice in higher education's own operation has been quite limited. Thomas et al. (2015) argued that higher education institutions (HEI) in the UK are quite slower to adopt the lean practice and derive the necessary benefits. Balzer et al. (2014) highlighted some of the factors as a facilitator including institutional readiness, leadership, awareness, understanding, support, and a favourable culture or the associated changes towards it. Similar was the finidng by Anthony et al. (2012) where the authors highlighted some additional critical success factors of successful implementation of lean six-sigma such as support from top management, effective communication, strategic and visionary leadership, and a favourable culture. This research has identified some of the similar key facilitators/success factors in the case of achieving sustainability by the universities. In fact, Balzer et al. (2014) highlighted based on some previous research by Balzer (2010), the amount of paper cost reduction upro 92% in facilities and management work orders in University of Central Okahoma. Based on these observations and the growing concern in terms of league table performance and the follow up implications, our research focuses on the aim highlighted in the introduction section.

Design/Methodology/Approach

The objectives of this research aimed to understand the barriers of sustainability in the operations of the higher education sector in the UK. This was followed with the exploration and examination of some of the solutions using the concepts of continuous improvement such as lean management techniques. According to Creswell (1998), when the phenomenon of interest is its early stage with a lack of understanding around the theories, qualitative exploration is more appropriate. On the contrary, the well defined phenomenon may render a need for the quantitative investigation. The research methods adopted in similar research are quite diverse including qualitative methods such as in-depth interviews (Wright, 2009; Wright and Horst, 2013), semi-structured interviews (Disterheft et al. 2015; Aleixo et al., 2018), and qualitative case study (Akins et al., 2019). In the study of Leal Filho et al. (2017) used survey methods to gather qualitative and quantitative data in respective phases to conduct a mixed method research study. Scondaruy data based research was also found in some literature including Robinson et al. (2015). To select an effective methodology foir this study, a set of literature on methodological discussion in operations management and related fields such as supply chain management were referred including merediuth et al. (1989), Craighead et al. (2007), Boyer and Swink (2008), and Golicic and Davies (2012). The framework poroposed by Meredith et al. (1989) (Please see fig 1.) was found to be the appropriate starting point for this reasacrh as it allowed the current research to cater the three elemenst of research paradigm: Ontology, Epistemology, and Methodology

(Denzina and Lincon, 1994, Frankel et al., 2005). The vertical dimension of the framework represents the epistemological elements where as the other dimension explains how the reality exists (Meredith et al., 1989).
Although, the concepts of sustainability are not new, given the present research context, the concepts are relatively in its earlyy days (Jorge et al, 2015). The objectives of this research require an understanding of the way people perceive, behave and react to the changes that are brought about by the incorporation of the priniciples/strategies required to achieve sustainable goals. Thus, this research adopted qualitative methods. The intension of the researcher of the present research is to interpret people's perception. Considering these elements, this research adopted semi-structured interviews with the university academics/non-academic staff members and the policy makers including the top management. In phase 1 of this study, the interviews will be condcueted with the above mentioned participants from Scottish Universities. Then a preliminary analysis will be conducted. This is expected to be followed by the UK wide sampling.

Natural ⟷ Artificial

Rational ↕ Existential

	DIRECT OBSERVATION	PEOPLE'S PERCEPTIONS	ARTIFICIAL RECONSTRUCTION
AXIOMATIC			• THEOREMS/LOGIC/REASONING • NORMATIVE MODELLING • DESCRIPTIVE MODELLING
LOGICAL POSITIVIST	• FIELD STUDIES • FIELD EXPERIMENTS	• STRUCTURED INTERVIEW • SURVEY RESEARCH	• PHYSICAL MODELLING • LABORATORY EXPERIMENTS • SIMULATION
INTERPRETIVE	• ACTION RESEARCH • CASE STUDIES	• HISTORICAL ANALYSIS • DELPHI METHODS • INTENSIVE INTERVIEWS • EXPERT PANNEL	• CONCEPTUAL MODELLING • HERMENEUTICS
CRITICAL THEORY		• INTROSPECTIVE REFLECTION	

Figure 1 – Framework for research method (Source: Meredith et al. (1989))

Relevance/Contribution
The literature review section of this research highlighted how the research about sustainability and lean management in the operation of the higher education sector is in

their early stage. Similar is the case in practice as well as highlighted in the form of docuemnetd problems with certain league table performance in the UK higher education sector. On this backdrop, the present research is expected to contribute to the theoretical knowledge especially identifying the barriers of achieving environmental sustainability and proposing some conceptual solutions with the help of lean management principles. Recent trends including plastic free society, requirements of less energy consumption in public sector premises, and less consumption of paper are some of the modern day challenges modern day universities face including the Scottish universities. Moreover, wider issues including challenges including a change in geopolitical changes, tighter budget, societal changes including poverty, and increasing tuition fee are also posing challenges in terms of the sustainable performance of the universities in the UK. However, often the universities do struggle to set out an optimal policy with respect to sustainability performance. Hence, the present research is expected to contribute to the generation of ideas to have an effective policy by having a more efficient operation in the universities for Scotland with a further expectation to generate future research ideas for UK wide.

Discussions and Conclusions

This research is expecting to find a similar set of barriers including lack of awareness, financial constraints, lack of stakeholder engagement, and resistance to changes. It is expected to be found that the lean management principles to be having a positive impact on achieving the sustainability targets of the university by addressing the barriers. There are some counter-intuitive resulst were shown in an earlier study by Rothenberg et al. (2001) in manufacturing set up where the authors found some negative relation between the lean practices and sustainability in certain particular cases. However, this research ahs shown a great deal of litetaure has found a positive relation between the implementation of lean practices and achieving sustainability in manufacturing. In fact, the authors including Anthony et al. (2012) even argued that the non-applicability of lean practices in a non-manufacturing sector like higher education is a misconception. Thus, this research is expecting to generate new ideas as a solution to overcome some of the barriers toward achieving environmental sustainability in the higher education sector in the UK.

A possible limitation would be some of the barriers of sustainability would be quite external in nature and proposing a solution would either require a longitudinal study over time. Another possible limitation that would emerge would be the applicability within the specific geographical situation. This problem has been highlighted in some of the research papers cited in the literature review. This study is expected to set the basic foundation solution approaches/concepts which could be extended in future research to offer more genaralisable solutions. In addition, future research could also take into consideration the other dimensions triple bottom line i.e. social and economical sustainability.

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A location model for cultural facilities based on spatial analysis

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Abstract

Clusters of cultural facilities such as museums and galleries create synergies with positive results for the public. Public institutions are the main builders and operators of cultural facilities, and equity for residents is a major criterion in site selection. This study proposes to solve the public cultural facilities location problem using a spatial analysis based on the 1ocal Moran's *I* statistic for efficiency and the gravity model for equity. This model provides an objective method to locate a cultural facility. Local governments can use this model to avoid unnecessary social conflicts that often occur in locating a cultural facility.

Keywords: Location model, Spatial information, Public cultural facilities

General instructions

With the remarkable growth of cultural tourism, cultural facilities have become high added-value assets that attract domestic and foreign tourists to a society. Compared to public service facilities like hospitals and schools, cultural facilities are visited by people of their own independent and free will. In this context, research on the locations of cultural facilities needs to consider different factors than that on general public facilities. Clusters of cultural facilities such as museums, art galleries, and cultural centers create synergies that have a positive effect on the public. Public institutions are the main builders and operators of cultural facilities, and equity for residents is a major criterion in site selection.

Most studies on the location-allocation of cultural facilities have focused on defining the factors that are taken into account (Shim, 2005; Park & Kim, 2009; Markusen & Gadwa, 2010; Kong, 2018). If mathematical modeling is developed on the basis of the factors defined in previous studies, it is possible to identify candidate locations more systematically and objectively. However, it is hard to find such research among the analytical studies on the locations of cultural facilities.

Since Alfred Weber's study in 1909, a variety of mathematical location models have been developed (Brandeau & Chiu, 1989; Current et al., 1990). Efficiency and equity are the traditional priorities in a location problem for public facilities (McAllister, 1976;

Mayhew & Leonardi, 1982). The objective functions in these prior studies minimize the spatial distribution of facilities for equity and maximize the coverage of service demands for efficiency, under a given budget constraint. Some subsequent studies address the problem using an optimal location model with a minimum travel distance and maximum coverage area (Morrill & Symons, 1977; Smith et al., 2013). Khodaparasti et al. (2016) suggest a more realistic measure of equity based on the Gini coefficient of the Lorenz curve and use data envelopment analysis to find an alternative with high efficiency, small inputs, and great outputs. These previous studies do not consider the complicated interactions between the demand and the candidate locations. Thus, they cannot consider the cluster effect, which greatly increases the efficiency of a new cultural facility.

This study proposes using spatial analysis to solve the cultural facility location problem based on the 1ocal Moran's *I* statistic for efficiency (Anselin, 1995; Yuan et al., 2018) and the gravity model formula for equity (Guagliardo, 2004; Xing et al., 2018). The local Moran's *I* statistic measures the correlations of candidate locations with various demand levels, which are then used to determine their cluster levels with a statistical test. The gravity formula is used to capture the degrees of alienation for candidate locations, which depends on how far away a location is from existing cultural facilities based on accessibility.

When a cultural facility is located in an area in which similar facilities are already situated and there is or will be a strong cultural image, it is reasonable to expect that such a facility leads local culture and produces a neighborhood ripple effect through interaction with the existent facilities. If a P-median model is applied to minimize travel cost, it is possible to define a factory site or a commercial district as a final candidate. In this case, the location of a cultural facility is unlikely to cause any economic or cultural ripple effect. To measure the location equity of cultural facilities, it is possible to use the Coverage model. However, this model fails to provide information on the degree of relative inequality and tries to get closest to the point with the longest demand, meaning that the demanders living in the center can be isolated. Given these aspects, the local Moran's *I* (Anselin, 1995; Builes-Jaramillo & Lotero, 2018) and Gravity model (Joseph & Bantock, 1982; Guagliardo, 2004; Kiran et al., 2018), can become good alternatives to classical location models because they enable analyzing spatial information to allocate a cultural facility location.

To identify the optimal location for a cultural facility, this study proposes an optimal location model with a bi-criteria objective function that is capable of measuring facility agglomeration with the use of the local Moran's *I* model and regional equity with the use of the Gravity model. The optimal location of this model is drawn by the Pareto optimal set (Kalyanmoy, 2001; Cheaitou et al., 2018) and the Top-K (Chaudhuri & Gravano, 1999) algorithm.

To confirm the effectiveness of the proposed optimal location model, we measured the agglomeration and equity of cultural facilities for 85 public cultural facilities (i.e., museums, art museums, art centers, local culture centers, and culture houses) in 424 districts in Seoul, Korea based on data from the National Culture-based Facility Survey published by the Ministry of Culture, Sports and Tourism in 2017. In our analysis of Seoul's 424 districts, we found areas where the agglomeration of facilities is valid and quantified the equity between the districts to derive optimal locations for new facilities.

Literature review

Most studies on the location of public facilities have focused on location models for hospitals considering efficiency and equity (Wang, 2012; Smith et al., 2013; Khodaparasti et al., 2016; Zhang et al., 2016). Location efficiency was measured with the P-median

model and equity with the Coverage model. Smith et al. (2013) revealed that two objective functions had a trade-off relation with each other with the use of the P-median model and Coverage model when assessing optimal hospital locations. Based on the relative locations of population centers in any geographical area, some improvement of equity may be achieved with little loss of efficiency. Therefore, it was proved that this model made it possible to identify a point that satisfied both efficiency and equity.

For the efficiency of cultural facilities, influence is more important than size. It is likely that the influence of a cultural facility is connected to its neighboring facilities. A place in which similar facilities are gathered together can experience enhanced differentiation and uniqueness, and thereby find it easy to secure visitors. The local Moran's *I* can analyze the agglomeration or distribution of similar facilities in a geographical area. Feng & Ji (2011) classified the commercial facilities located in Shanghai into 16 types and measured the agglomeration and distribution of each facility type with the use of the local Moran's *I*. Their results showed that businesses that require interpersonal contact are concentrated in the interior of the city, while businesses that depend on heavy resources like transportation and construction are located at the outskirts. In addition, the local Moran's *I* was applied to research on the spatial inconsistency between the distribution and potential demand of public facilities like medical facilities or bicycle facilities (Rybarczyk & Wu, 2010; Yin et al., 2018).

The Gravity model measures the potential accessibility of facilities to the local population in a particular area. To measure the distance between a facility and a demand point, a Euclidean distance is usually employed. However, recent studies introduced models that consider travel distance by vehicle or walking. These models can reflect more realistic accessibility than linear distance-based models (Chang & Liao, 2011). With the use of the Gravity model, the equity of 12 public facilities, including schools and parks, was analyzed. The results showed that public facilities were mainly distributed centrally and had high accessibility. This indicates that a non-central area experiences inequality in its geographical separation level. The analysis results indicate that national policies have paid more attention to the requirements of residents living in central areas and have ignored minor opinions until now (Tsou et al., 2005; Lou & Qi, 2009)

In reality, location-allocation decisions take various objectives including cost, accessibility, and demand into consideration. To design a model, it is possible to give a different weight value to each objective function depending on its significance and thereby produce different optimal locations. These optimal locations of the multi-objective function are identified in the form of a Pareto front. Since this method provides a set of optimal candidates, rather than a single optimal location, a decision-maker is able to select the most proper location according to subjective preference or quantitative decision criteria (Zhang et al., 2016; Neema & Ohgai, 2010).

Methodology

The notations are as follows.

Index

h, i, j, q: location units (districts or candidate districts for locating a new facility)

k: existing cultural facilities

Data

x_i: number of existing cultural facilities in location i
$\bar{x}$: average number of existing cultural facilities in the area
d_{ik}: distance from location i to existing facility k
v_k: potential demand for existing facility k
s_k: capacity of existing facility k
n: number of all locations

$$w_{ij}=\begin{cases}1, \text{ if location } i \text{ adjunct to location } j\\ 0, \text{ otherwise}\end{cases}$$

In formula (1) below, I_i measures the efficiency of location i. The formula is used to measure the proximity tendency of locations with similar cultural facilities. Note that w_{ij} becomes 1 if location i and location j are adjacent, and otherwise 0. In formula (2), A_i captures the equity of location i. It measures the spatial accessibility of a location based on how closely located all cultural facilities are from the location. In formula (3) as a constraint, P_i is the p-value of the local Moran's I of location i. If the value is 0.05 or less, it is interpreted that the agglomeration level of the location is statistically significant at the level of 95% (Lee et al., 2015). P-values for I_i statistics are calculated with the use of normal distribution. Formulas (4) and (5) are used to calculate the mean and variance for location i, respectively. Z[I_i] statistics can be calculated in formula (6) (Anselin, 1995; Lee et al., 2015).

Decision variables
I_i: local Moran's I index
A_i: equity level of location i
P_i: p-value of the correlation coefficient of location i

$$\text{OBJ1: } Max.\ I_i = \frac{(x_i-\bar{x})}{\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}} \sum_{j\neq i}^{n} w_{ij} \frac{(x_j-\bar{x})}{\sqrt{\frac{\sum_{i=1}^{n}(x_i-\bar{x})^2}{n-1}}} \quad (1)$$

$$\text{OBJ2: } Min.\ A_i = \sum_k \frac{S_k}{d_{ik}V_k} \quad (2)$$

s.t.

$$P_i \leq 0.05 \qquad \forall i, \quad (3)$$

$$\mathrm{E}[I_i] = -\frac{\sum_{j=1}^{n} w_{ij}}{n-1} \qquad \forall i, \quad (4)$$

$$\mathrm{V}[I_i] = \frac{w_{i(2)}\,(n-b_2)}{n-1} + \frac{2w_{i(kh)}\,(2b_2-n)}{(n-1)(n-2)} - \frac{w_i^2}{(n-1)^2} \qquad \forall i, \quad (5)$$

$$\mathrm{Z}[I_i] = \frac{I_i - E[I_i]}{\sqrt{V[I_i]}} \qquad \forall i, \quad (6)$$

with $b_2=m_4/m_2^2$, $m_4=\sum_i z_i^4/n$ as the fourth moment, $w_{i(2)}=\sum_{j\neq i} w_{ij}^2$, and $2w_{i(qh)}=\sum_{q\neq i}\sum_{h\neq i} w_{iq}\, w_{ih}$, $z_i=(x_i-\bar{x})/\sqrt{\sum_{i=1}^{n}(x_i-x)^2/n-1}$, $h,j,q\neq i$.

A solution of a multi-objective model can be drawn with the dominance concept. If the location $X^{(1)}$ is better for all objective functions than $X^{(2)}$ or is strictly better for at least one objective function, it is fair to say that $X^{(1)}$ dominates $X^{(2)}$. In the multi-objective model, the Top-K selection query is the algorithm that determines the order of priority of the Pareto optimal set. This algorithm makes the Pareto optimal set arrayed by the order of locations closest to the objective function (Chaudhuri & Gravano, 1999).

Experimental analysis

The public cultural facilities used in this study are 85 public cultural facilities in Seoul that are listed in the National Culture-based Facility Survey published by the Ministry of Culture, Sports and Tourism in 2017. They consist of museums, art museums, art centers, local culture centers, and culture houses. The types of public cultural facilities in Seoul, their positions, and their sizes, which are all provided by the National Culture-based Facility Survey, were used for the analysis. In Seoul, there are 424 districts of administration. The maps and coordinates of the Seoul administrative districts were offered by Statistics Korea in the format of shapefiles. In terms of the population in each district, the 2018 demographic statistic data of Statistics Korea was used.

For the local Moran's *I* analysis, a neighboring area was defined as an area that shares a boundary at a 2.5km radius from the center of the administration. Table 1 shows the 18 districts that have a statistically significant agglomeration of cultural facilities among the 424 districts of administration. I_i statistics are recommended to be analyzed with the result of standardization. This is because it is more accurate to compare relative agglomeration by estimating the I_i value of frequency distribution, rather than using its absolute value, and because the Z[*I*] value makes it possible to make clear interpretations in terms of statistical significance (Lee et al., 2015).

Table 1 – local Moran's I index for public facilities in Seoul

No.	ID	I_i	Z [I_i]	$P(P < 0.05)$
1	1101053	7.330	19.786	0.000
2	1101054	4.057	9.235	0.000
3	1101057	1.405	3.513	0.000
4	1101058	2.405	5.478	0.000
5	1101060	3.405	8.502	0.000
6	1101061	8.404	20.976	0.000
7	1101063	4.442	11.992	0.000
8	1101067	0.905	2.265	0.011
9	1101072	2.405	6.007	0.000
10	1102052	4.281	10.689	0.000
11	1102054	0.905	2.265	0.011
12	1102060	2.405	5.478	0.000
13	1102068	1.405	3.513	0.000
14	1103065	1.205	2.748	0.000
15	1104054	0.905	2.265	0.011
16	1112051	5.404	10.990	0.000
17	1112059	1.905	4.760	0.000

18	1113066	2.415	6.524	0.000

Table 2 presents the results of the Gravity model analysis of districts and public cultural facilities. The locations are districts that secured the significance of the local Moran's *I* index in Table 1. The standard deviation of the Gravity model values in Table 2 is 0.33, which means that there is no large difference between them.

Table 2 – Gravity model index for public cultural facilities in Seoul

No.	ID	A_i	Mean	S.D
1	1101053	0.211	0.159	0.033
2	1101054	0.149		
3	1101057	0.234		
4	1101058	0.220		
5	1101060	0.167		
6	1101061	0.150		
7	1101063	0.124		
8	1101067	0.128		
9	1101072	0.170		
10	1102052	0.174		
11	1102054	0.155		
12	1102060	0.135		
13	1102068	0.161		
14	1103065	0.114		
15	1104054	0.116		
16	1112051	0.148		
17	1112059	0.169		
18	1113066	0.145		

To find optimal locations from the bi-criteria function, this study extracts a Pareto optimal set and uses Top-K to list the locations in the Pareto optimal set by the order of solutions closest to the ideal point. The solution results are presented in Figure 1. As shown in Figure 1, the four solutions identified are placed at the very front of the graph and dominate other solutions.

Figure 2 below illustrates part of the results. The left and right figures show the distribution of existing cultural facilities in Seoul and the four candidate locations color-coded by rank, respectively. The district with ID 1101061 selected as the optimal location has public facilities located far from its center, low equity, and public cultural facilities established in its neighboring districts. Therefore, it is found that the district is the best in terms of residents' equity and interaction with neighboring facilities.

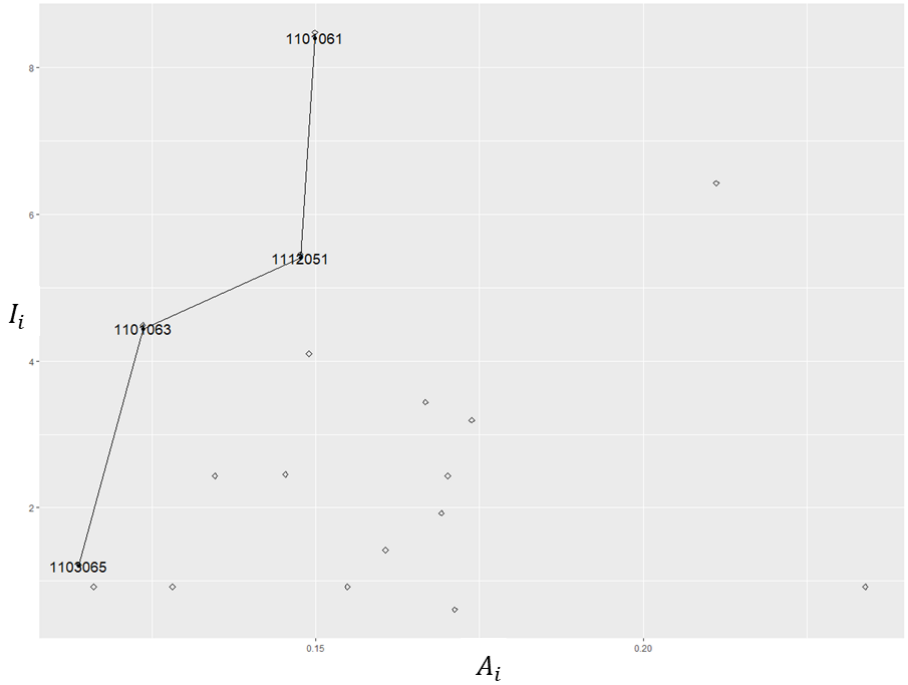


Figure 1 – Pareto Optimal set of cultural facilities

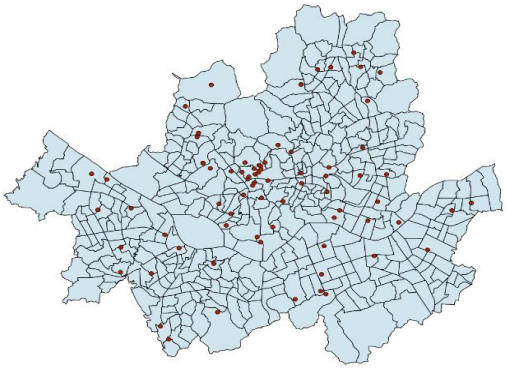
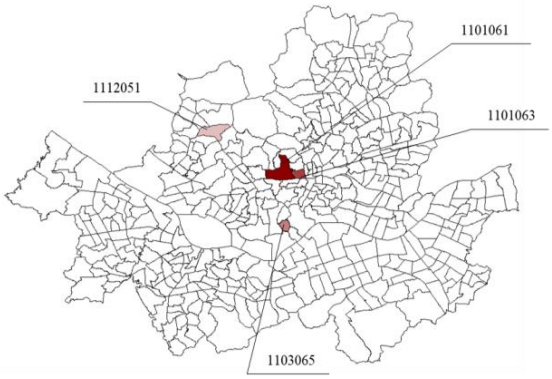
Locations of existing facilities	Optimal locations
	

Figure 2 – Optimal location for cultural facilities

Conclusion

This study proposed an optimal location model for cultural facilities that addresses their social roles in various fields, including urban regeneration and welfare. Given that recent studies on locations of cultural facilities mostly focused on defining the main factors, this study, which proposed a mathematical model in the consensus of quantitative research results, contributed to widening the range of research on the locations of cultural facilities. A quantitative approach based on a mathematical model can ensure the clarity and objectivity of the analysis and shorten decision-making times. In addition, since it takes the distribution of existing facilities into account, it is likely to complement the administrative system of the present government that focuses on the construction of new

facilities. The location models proposed in previous studies made use of multi-objective functions to find optimal locations and thereby identified a Pareto optimal set to gain a set of flat solutions. The model proposed in this study used Top-K, a type of scoring algorithm, to make the solutions arrayed by the ranking of the solutions closest to the objective function, and thereby aimed to provide additional useful information to a final decision-maker.

The location model proposed in this study can be used for the analysis of various kinds of locations other than for cultural facilities. For example, to find a proper agricultural plot, this model can identify a district that has a spatial agglomeration of the same crops and high accessibility to sales districts. It is possible to infer that a place with high agglomeration is equipped with the proper climate and soil conditions for the crops, and high accessibility to sales places can save on the cost of transporting agricultural products.

The proposed model can measure the efficiency of a location and its equity on the basis of accessibility in consideration of facility relations. In follow-up research, land price and proximity to neighboring tourist attractions will be additionally considered. Most public facilities are constructed within limited budgets, meaning that land price can become a critical variable. If there are famous tourist attractions around cultural facilities, it will likely increase visits to the cultural facilities and establish a strategy of urban development in connection with the tourist sites.

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Digitalisation in the public sector: A job mining perspective

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Abstract

The digital revolution will significantly transform organisations, their strategies, processes and needed competencies. As the central German provider for e-recruiting in the public sector, the online job portal *Interamt* provides a unique database that documents the current personnel requirements of public institutions. We summarise a snapshot of current digitalisation-related recruitment in Germany by applying text mining algorithms and statistical analyses to 800 web-crawled job postings. Our results show that public institutions are not recruiting next-generation IT experts but rather focus on current, more modest digitalisation steps. We recommend directions for further research and job market analyses.

Keywords: Job Market, Text Mining, Public Service Operations Management

Introduction

Public sector operations are massively challenged by the digitalisation. New products and services have to be developed and new expectations from citizens and organisations arise (Dunleavy *et al.*, 2006). The management of change and transformation are of major importance, including process management and technological innovation (Benner and Tushman, 2003). Many jobs through all industries will be significantly transformed or replaced by digital technologies soon. Frey and Osborne (2017) did not specifically focus on the public sector, but summarise for the overall economy that 47% of all jobs in the USA could be replaced by intelligent robots or software in the next 10 to 20 years. This development is also rapidly increasing the demand for highly qualified work. But there are also many chances connected to digitalisation. In the past years, especially organisations with in IT-intensive or highly competitive industries could benefit from the adoption of big data and analytics (Müller *et al.*, 2018) as major elements of digitalisation. Digitalisation in the public sector is not only about performance and efficiency. Customer requirements and ways of contact between the citizens/customers and public institutions are also significantly changing (Lindgren *et al.*, 2019).

Most of previous research focuses on the potential of digitalisation and on describing the future. We are taking a closer look on the current situation. The term digitalisation and its idea grew in the last decade (Dunleavy *et al.*, 2006). We are taking a job market perspective to summarise current digitalisation trends and answer the following research question:

Which conclusions can be drawn from analysing currently advertised positions in German public sector institutions regarding their digitalisation efforts?

While parts of this article include topics from information systems research, it also contributes to the domain of public service operations management, which is a rather underrepresented research field (Radnor *et al.*, 2016). Text mining as a method for big data analysis also represents an innovative and growing method for operations management research (Cohen, 2018; Guha and Kumar, 2018). We present the first large-scale analysis of public sector digitalisation jobs in Germany and thereby follow the literature about the resource-based view on organisations and their operations strategy (Coates and McDermott, 2002; Paiva *et al.*, 2008). We are building theory about the current personnel management of public organisations and their digital transformation strategies and contribute to current developments of evolving operations research in the era of big data (Feng and Shanthikumar, 2018).

Research Background

In public discussions nowadays, digitalisation could be replaced by the term *digital revolution*, comprising all aspects of transforming life and work into a more digital environment. In the academic literature, Legner *et al.* (2017) define it as follows:

"*While digitisation puts emphasis on digital technologies, the term digitalisation has been coined to describe the manifold sociotechnical phenomena and processes of adopting and using these technologies in broader individual, organisational, and societal contexts.*"

Researchers use various search terms when looking for digitalisation topics. Buer *et al.* (2018) selected terms like "industry 4.0", "smart factory", "cyber physical system", "big data". Most of these terms have a manufacturing context and will not be equally useful in the context of public administration.

The analysis of competencies related to information technology (IT) has a long history (Todd *et al.*, 1995; Bassellier *et al.*, 2001; Murawski and Bick, 2017). To use text mining technology though, has only been popular (and technically easier) for the last ten years. In the field of technology and processes, some job mining articles already analysed profiles. Müller *et al.* (2016) created competency profiles for business process management professionals and Kregel *et al.* (2019) for lean professionals. Examples for IT-related analyses are the comparison of business intelligence skills with big data skills (Debortoli *et al.*, 2014) and the analysis of digital competencies in lean-related job profiles (Kregel and Ogonek, 2018). As the public sector is known to be text-intensive, research about text mining in this domain is particularly recommended (Hollibaugh, 2019).

Due to the sharp increase of available online data in recent years, the task of extracting the most relevant information has become a novel and evolving process. As a result of this data push, job portals and websites that are very domain-specific, have experienced an increase in scope, quality, and performance. Their advantage for both jobseekers and employers is the concentration of domain-specific jobs. Given the increasing relevance of the topic of digitalisation and respective skill shortages in public sector institutions, these data collections provide a great opportunity to study current digitalisation-related recruiting.

Research Process and Methodology

We crawled and analysed job advertisements from the website *Interamt*, which claims to be the largest job exchange platform for German public services. About 50,000 ads per year come from federal, state or local level institutions. Typical job providers are ministries, state offices, city governments and associations.

We used a Robotic Process Automation (RPA) software bot to crawl the website frequently for several months to receive all job ads matching the search term *digi**. These search results therefore include words like digital, digitise, and digitalisation in various meanings and contexts. We did not use classical web crawling, as the *Interamt* website used internal frames and did not provide an individual page address for each job posting. The RPA bot was developed to simulate human access to the websites to avoid being locked out by technical bot detection functionalities. The website's structure and source code significantly changed several times during the data collection period so that we needed to reconfigure the bot accordingly.

The collection of the raw job posting data was followed by several data processing steps as well as qualitative research workshops where we discussed, categorised and clustered data properties. The following Figure 1 summarises the elements of our research process and is divided into the job analytics flow addressing the data processing, and the researcher workshop flow representing the researchers' influence on the data analysis and the respective results.

The *research workshops* were used to set goals and steer the quantitative job analysis. First, the crawled jobs in a raw form were sighted to discuss the general data base and identify typical reoccurring contents. We decided to form four main job categories for a coding of all crawled postings. More details are given in the results section. At the end of the job analytics flow, the researchers again had to sight the processed data especially for the topic modelling to discuss and summarise the main findings of the data-driven research steps.

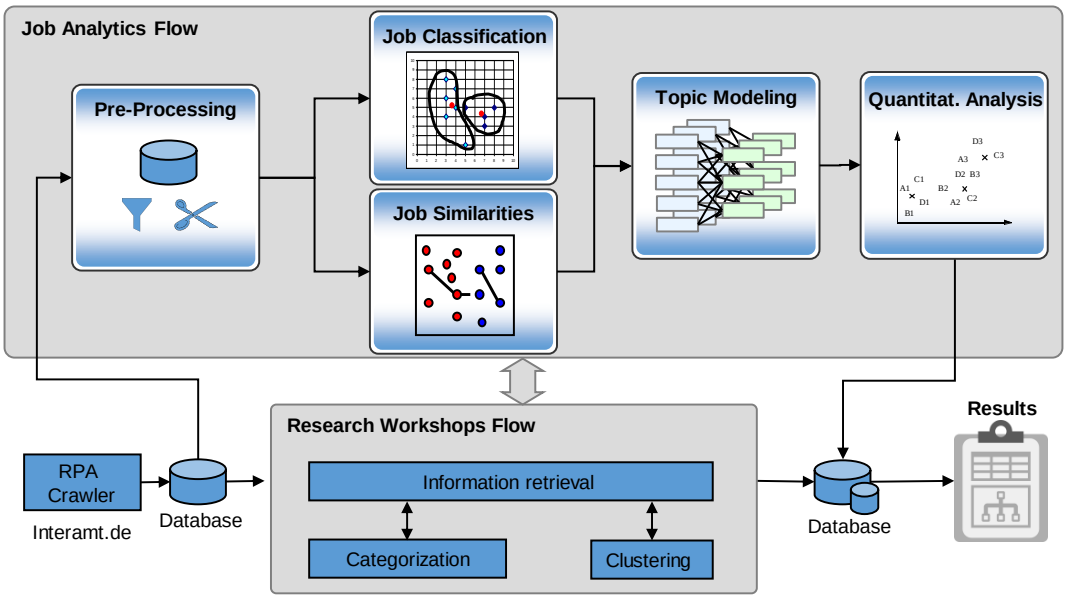

Figure 1 – Research process and methodology

The *pre-processing* of the raw data builds the typical first step of a big data analysis. Here, the categorisation, cleansing and allocation of the individual job advertisements of the data set is a necessary condition for effective use of our data-driven research approach.

Using raw and unedited job ads for modelling could lead to incorrect results. In our research process, an analysis was required to extract structured information from partially structured or unstructured job advertisements. This included the correction of missing values, job advertisement normalisation, and discretisation, and text pre-processing to remove and replace embedded characters that may affect the analysis content.

The elimination of irrelevant *stop words* also took place in the pre-processing step. We aimed on reducing text corpus of terms that occur frequently but are not adding to the informative value. In the German job advertisements, these are mainly articles, pronouns and some adjectives. For this processing step we created an extensive stop word list containing 897 terms, covering about 40-50% of the total text content.

During a research workshop, we decided to *manually categorise* all job ads into four disjunct groups. The allocation was executed manually by assistants following a written set of rules. All job information was transformed into the following elements: Job ID, check for duplicates, check for relevance, job posting organisation, job tasks, job requirements, "nice to have" requirements, job title, minimum pay scale group, maximum pay scale group.

We also applied categorisation algorithms. In our research design, we considered the k-nearest neighbours algorithm and Naive-Bayes, which have been intensively discussed in the literature (Smith *et al.*, 2002; Islam *et al.*, 2007). Both variants were examined for their suitability for job classification. The probabilistic classifiers summarise terms of the same frequency, since otherwise inquiries deliver only general results. Due to the summary, the classifier has an average frequency of occurrence and can therefore be regarded as a suitable attribute for the individual class descriptions. In order to use frequently occurring terms for classification, compound terms consisting of several individual terms are formed. This makes them more specific and produces better results. If the words are evenly distributed across the job advertisements, it can be concluded that very frequently occurring words are not suitable for classifying job assignments. This is because they appear in almost every job assignment, making it impossible to distinguish between them. At the same time, some words occur so rarely that they are not certified to be separable. Following these considerations, only words that occur with medium frequency are left for classification. Especially challenging for the classification of job advertisements is to find the correct threshold values for differentiation.

Job similarities were the object of investigation in our next step. We used the clustering of job advertisements to quickly find similar ads and a macrostructure for our job collection. We also used this to detect possible duplicates. In contrast to the previous classification, clustering does not use a predefined set of terms or taxonomies used to group job ads. Instead, groups are created based on job characteristics that are found in the set of documents. We applied hierarchical clustering techniques, which clustering groups of job ads according to a similarity measure in a tree structure. Instead of finding only one cluster that best matches a job advertisement, hierarchical cluster algorithms group the job advertisement iteratively into larger clusters. At the beginning, each job ad is arranged in its own cluster, which represents a leaf in a cluster tree. In the next step, two clusters that are as similar as possible are combined. This process continues until all small clusters are finally assigned to a single large cluster of all job advertisements.

Our next step was *topic modelling*, a method with rising popularity in research in the last years (Schmiedel *et al.*, 2019). Topic modelling describes a group of statistical procedures which allow conclusions to be drawn about the thematic structure of the individual job advertisement in the collection of advertisements. Algorithms also determine the thematic relevance of the respective job advertisements. In contrast to keyword tools, the topic modelling used does not only reveal keywords and topics that

appear in the job advertisements. Rather, it shows us the semantic relevance and context of words and phrases. In this step, we apply the Latent Dirichlet Allocation (LDA) topic modelling technique (Blei *et al.*, 2003) to domain-centred job data along with other feature engineering methods to define characteristics of a job posting and a requested job profile. We chose the LDA algorithm, because it can generate higher-dimensional topics than other common algorithms (Masada *et al.*, 2008). The algorithm is based on a repeated random selection of text segments, each of which captures the statistical clustering of word groups within these segments. The algorithm thus calculates the topics of the text collection, the topic portions in the individual texts and which words belong to the respective topics. Our design is natural language controlled, enriched with n-grams and latent topics as features. Several techniques such as latent semantic indexing, natural language processing, and semantic matching are performed on the job data.

The similarity value is then calculated and further normalised by min-max transformations. In this way, a similarity matrix is obtained, which determines the proximity of a digit* display to a range of values. The system of job capture and processing mentioned in this paper is therefore inspired by the necessity to use text mining algorithms to explore different needs for personnel within the public administration - by means of job advertisements - through a constructive mechanism on their relevant content contribution to the concept of digitalisation. This not only enables accurate and relevant information filtering, but also reduces time and human effort throughout the process.

Results

After a first pre-processing and duplicate removal, we could analyse 800 job ads crawled by the RPA bot from the *Interamt* website. More than half of them (432) describe jobs far away from shaping digitalisation activities. Instead, those ads only use *digi** randomly for describing secondary information technology (IT) aspects of current jobs. Examples for those hits are sentences like: “combine classical marketing activities with digital marketing activities”, “file management of the audit office is completely digitalised, experience in Word and Excel is required”, and “the ability to meet the requirements of modern digitalisation, e.g. become acquainted with new IT systems”. In some cases, the term only described application processing or similar side aspects: “Please note that your application will be digitised for internal processing”.

The content analysis of the remaining hits resulted in three major job categories. Ads could be categorised as addressing IT specialists, IT generalists, and project managers without specific IT skills. A qualitative manual analysis of the job ads showed that IT specialists typically create and implement digitalisation concepts and advise managers and employee regarding new technologies. IT generalists have a stronger focus on maintaining IT infrastructure and systems and to assist employees with digitalisation-related requests. The category of project managers without specific IT skills is needed for the general management of digital transformation, change, and process improvement.

Since we described our method and research path to our findings in the last section in detail, we will focus on five modelled topics identified by the introduced algorithms. The originally German data tables have been translated into English for this article.

The first modelled topic summarises terms related to flexible time management and home office (see Table 1). The effects of digitalisation on work organisation are inconsistent and sometimes contradictory in our data. Overall, it is becoming apparent that digitalisation within the public administration is leading to a disentanglement, more flexible and decentral of work. This results in new demands on the communication, cooperation and management of employees. A distinction can be made between internal and external work flexibility. External flexibility is reflected in the creation of jobs

outside full-time work for an indefinite period. This includes fixed-term employment contracts (52.70% of all cases) and various forms of part-time work (87.41%). This type of internal project economy is most common in the areas of general local government, construction and housing, transport and economic development. This change has an impact on the qualification requirements, the function-related task structures and activities of the employees as well as the organisation of work, on the one hand as a structuring of tasks and activities based on the division of labour in horizontal and hierarchical terms.

Table 1 – Modelled topic "Flexible Time Management / Home Office"

TOPIC: Flexible Time Management / Home Office		
ORDER: 11	**COHERENCE**: 0.984	**FREQ**: 1455
KEYWORDS: Home office; teleworking place; teleworking; teleworking; free; teleworking; work environment; flexible; personal responsibility; motivation; alternating teleworking; flexible work environment; free time management; alternating teleworking; flexible work environment; free time management;		

The future and performance of the public administration therefore do not necessarily require specific expertise. This is because the core competencies of many classic administrative professions are shifting more and more into breadth in the future and are also becoming detached from the classic job profiles. For example, the job advertisements very often demand considerable new- and further- qualification affinity. As the changes in job profiles are assumed to increase in the future, a continuous professional development gains importance (see Table 2).

Table 2 – Modelled topic "Professional Development"

TOPIC: Professional Development		
ORDER: 24	**COHERENCE**: 0.286	**FREQ**: 198
KEYWORDS: Professional development; diverse; possibilities; corresponding; participation; corresponding professional development; individual support with your wish; participation in internal professional development; diverse possibilities for professional development; readiness for professional development;		

The next modelled topic has a high overlap with the previous topic. Not only technical skills are listed in the job ads, also human abilities are formulated clearly. The ability to guide and coordinate, critical thinking and persuasiveness are just as much in demand as communication skills at various hierarchical levels, resilience, flexibility, problem-solving skills and emotional intelligence. We summarise this topic with "initiative (Table 3), as independency and autonomy of employees are highlighted.

Table 3 – Modelled topic "Initiative"

TOPIC: Initiative		
ORDER: 40	**COHERENCE**: 0.297	**FREQ**: 673
KEYWORDS: Way of working; personal initiative; high personal resilience; capacity for teamwork; service orientation; distinct; independent; autonomous; independent action; structured; cooperation; commitment; high measurement; high measurement of ownership; ownership responsibility; high load capability; independent method of working; high application; high commitment; high measurement of responsibility; high measurement of self-responsibility; high measurement of owner initiative; owner responsibility of work; high strength; self-responsibility; high responsibility; high commitment; high measurement of responsibility; self-responsibility and own responsibility;		

Communication skills are a standard element in many job ads of different sectors. In the analysed set of digi* jobs though, a focus lies on virtual communication (Table 4). Communication and collaboration systems are a classical element of information systems research for many years and it is not surprise, that they also form a key element of digitalisation-related recruiting. Requirements amongst others list cooperation, leadership, virtual teams, and teamwork as important terms of this topic.

Table 4 – Modelled topic "Virtual Communication"

TOPIC: Virtual Communication		
ORDER: 13	**COHERENCE**: 0.458	**FREQ**: 783
KEYWORDS: Virtual; contact; personal; cooperation; communication skills; analytical; teams; information; leadership; conceptual; internal; application; communication; team; skills; communication skills; collaboration; ability; teamwork; analytical skills; conceptual skills; analytical and conceptual skills; analytical skills as well as communication skills; application of internal platforms; functioning virtual communication; ability to communicate clearly; leadership in virtual teams; colleagues information; contact and communication technology; contact and communication live communication; personal communication; text-based communication tools; virtual teamwork; virtual collaboration; virtual collaboration and communication; virtual teams; collaboration and communication; pronounced analytical; teamwork; pronounced analytical and conceptual skills; cooperation with different stakeholders; organisational and analytical skills;		

Before starting the data processing and statistical analyses, we discussed which technologies we expected to find in the data. In a literature review about digital technologies affecting the public sector, we identified the following developments amongst others: Artificial intelligence and machine learning specialists (Nam and Pardo, 2011), big data and process automation experts (Kim *et al.*, 2014), user experience and human-machine interaction designers, (Gil-Garcia *et al.*, 2014), information security analysts, robotics engineers and blockchain specialists (Swan, 2015). Our evaluation indicates that there is still no significant demand for many completely new specialist roles. However, employers underscore the importance of skills to understand and analyse problems (Table 5). Combined with professional development (Table 2), this brings the opportunity to develop specialised knowledge after the recruitment.

Table 5 – Modelled topic "Understand Complex Issues"

TOPIC: Understand Complex Issues		
ORDER: 14	**COHERENCE**: 0.212	**FREQ**: 218
KEYWORDS: Issues; complex; ability; complex; familiarise; complex issues; grasp quickly; analytical skills; conceptual skills; analytical and conceptual skills; virtual teams; analytical skills as well as;		

Discussion and Conclusion

According to our analysis, the public administrative culture faces major challenges. The concept of digitalisation is determined above all by the closely interwoven IT investment decisions of the public sector, the amount of available information, the dynamic development of policy fields and technological change. The digitisation requirements of the administration are developing at a rapid pace, making flexibility and lifelong learning the most important factors for its modernisation. Derived from the job advertisements, the personnel policy of the public administration formulates the requirements in this context as efficient processes, networked procedures and proactive behaviour.

Thus, workflows and standards do not change visibly. New IT procedures are taken into account, also in order to make work easier in the future. This not only serves the employees, but also leads to a high communication orientation to external parties. The use of IT procedures, in turn, is intended to influence quantitative and qualitative job planning in many areas through faster and cross-departmental processes. The new employees should support and implement these changes and should therefore be able to implement the new requirements in a targeted manner, usually in a project context. At the same time, it is clear that personnel should participate in and contribute to change. To this end, particularly the intensified personnel development was identified. It includes continuing education, training, supervision and coaching. But there is also a clear need to create an open administrative culture in which staff are encouraged to get involved as their engagement and commitment is wanted and needed.

At the same time, most of the ads can be summarised showing a trend for supporting and accompanying digitalisation. However, the majority of postings does not describe a very concrete or pioneering role or mindset. It could be the case, that the most innovative impulses and changes are given in Germany by expert groups and central agencies. Most of the analysed institutions seem to follow trends, role models / pilot institutions, or simply laws and regulations. In summary, our results leave two major ways for interpretation. The data analysis shows that German public sector institutions either do not actively plan far ahead and do not seem to have a clear vision and strategy for digitalisation-related recruiting. Or they intentionally recruit for a short-term vision and are in an early stage of digitalisation where the identified key developments are known but more modest steps must be taken first.

Limitations and Further Research

Our research of course has its limitations. We only interpreted a snapshot of job postings between November 2018 and March 2019 from one single platform representing public sector jobs in Germany. Also, text mining methods would be more effective, if much more data would be available. Furthermore, more detailed job profiles are possible, if the data set would be more homogenous. These limitations leave a lot of space for future research.

The method and its details leave many possibilities for modifications in the future. Although knowledge discovery was applied quite early in the history of computer science, text mining has received a boost in the era of social networks and employment websites. Job Mining has thus become a central field of research. While studying the related literature, the research challenges such as information overload, correct model choosing to represent the found knowledge, content economy, use of RPA technology, etc. represent an innovation for job mining. As a result of these new developments, topic modelling algorithms were the most interesting research area and especially all application areas led to a mixture of classical data mining and topic modelling algorithms.

No research branch is currently working in this area of public administration with content-based analysis on such data stock. But there is potential for further improvement through machine learning and natural language processing techniques. Kobayashi *et al.* (2018) suggested LDA as the best decision to use topic modelling, especially when exploring larger text collections in the areas of employee satisfaction, performance motivation, leadership and communication quality, and their interrelationships and possible adjustments. The non-parametric machine learning algorithms proposed by (Rosa and Ebecken, 2003) essentially use genetic algorithms in combination with a k-nearest neighbours approach in the context of the assignment of text content. González-Briones *et al.* (2019) and some years before Lu *et al.* (2013) proposed a case-based and

agency-based recommendation system for job seekers and recruiters. It uses a hybrid approach that combines content-based recommendations and machine learning for natural language processing approaches to improve result accuracy and provide a more accurate information extraction. They control two models based on probabilistic hybrid information extraction by combining machine-selected job segments based on latent features of individual preference.

In the future, we could also continue our study by interviewing recruiting specialists of public institutions, discuss our findings and their view on digitalisation-related recruiting. Interesting could also be to narrow the data set down and look for specific job titles like digitalisation project manager or big data analyst do analyse their requirements and remits. Researchers could also take the digitalisation job mining on to other countries. How are the open positions in countries characterised, which are known for their comparably mature digitalisation status? Another intriguing idea could be to transform the *Interamt* analysis into a longitudinal study. This would allow to regularly compare different snapshots e.g. once per year with each other to identify changes and trends in public sector jobs related to digitalisation. Another aspect is the comparison of public sector recruiting with the private sector. Analysing the differences and communalities regarding in their digitalisation efforts leaves many opportunities for future research.

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Identifying Knowledge Management Toolkits in Greek Public Organizations

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Abstract

The purpose of this research is the clarification of Knowledge Management (KM) definition and the alignment of KM-tools with KM-Processes under the experience of the Greek public sector. The KM-tools emerged from relevant literature and semi-structured interviews were projected into each of the four KM-processes (K-creation, K-storage, K-dissemination, and K-application) in order to map the way they were used in each phase of KM-lifecycle. This research provides: a) novel theoretical insight in combining KM-tools with KM-processes in the public sector and b) a practical "roadmap" of KM for public sector executives.

Keywords: Knowledge Management (KM), KM-Tools, Public Sector

Introduction

We live in a society, where Knowledge is the most important strategic resource for an organization (Drucker, 1993) and its management has become an intriguing, though complex research issue (Allameh et al., 2011), with a variety of KM definitions and KM-processes emerging. Despite that, most researchers and practitioners regard (Anand & Singh, 2011; Alavi & Leidner, 2001) KM as a the process of K-creation, K-storage, K-dissemination, and K-application.

Early KM publications focused mainly in the private sector but in recent years, there is a burgeoning interest in the public sector as well (Seba & Rowley, 2010; Singh Sandhu et al., 2011; Luen & Al-Hawamdeh, 2001), where KM-based actions like benchlearning, aim to modernize and improve public services (Sotirakou & Zeppou, 2004). Aligning with this, the European public sector employs a self-assessment and quality improvement tool, namely the Common Assessment Framework (CAF) (Vakalopoulou et al., 2013), which encompasses the KM process. This implies the production of new knowledge which should be managed for enhancing organizational performance (Linderman et al., 2004). Besides the fact there is a proliferation of such models and a growth of prescriptive publications the practical problem of KM's effectiveness (Ragab & Arisha, 2013; Massingham, 2014) is yet to be considered. Thus this gap between theoretical and practical endeavours is the motivation for this research which identifies KM-toolkits and studies the way they are used in the Greek public sector.

By drawing on existing literature, KM definition and KM processes are clarified and synthesized, becoming the background for the production of KM-Toolkits which are aligned with KM-processes. The case under study includes team members that applied CAF in the Greek public sector. Specifically, seven public sector executives, from different public sector organizations, accepted our invitation and participated in this research. Data collection tools include: semi-structured interviews, observation and documents, which are analyzed to capture the KM-tools applied at each CAF KM-process. As a result: a) a novel theoretical insight is provided as it the first time that researchers collocate KM-tools with KM-processes in the public sector and b) a basic "roadmap" of CAF KM for engaged public sector executives is developed.

The paper proceeds as follows: synthesis of KM definition and KM processes, presentation of KM-tools, short CAF presentation from a KM view, description of research methodology, presentation of research findings, discussion of findings and conclusion.

Knowledge Management (KM) Definitions & KM-Processes

Since KM is a complex concept in social science there will be a discussion of several KM definitions in order to synthesize a presentative one, that we will be used in this research. Many authors (Obeidat et al., 2016; Quintas et al., 1997; Bhatt, 2001; Anand & Singh, 2011; Bhatt et al., 2005; Gold et al., 2001) regard KM as: process, activity, set of activities, strategy, knowledge flow, and dimension. Despite, the different terms used, most researchers commit to same conceptualizations. Mishra and Bhaskar (2011) set a logical connection among them, claiming that "existing conceptual research in KM field identifies a dynamic set of activities, called KM processes, which improve organizational knowledge flows". Besides, the majority of researchers (Obeidat et al., 2016, Quintas et al., 1997; Bhatt, 2001; Anand & Singh, 2011; Bhatt et al., 2005) accept

the term "process" in KM definitions. Therefore, this research employs the term "process", aligning with the explanation of Mishra and Bhaskar (2011).

The description of the processes characterizes most definitions of KM. Nonaka's seminal work set the foundations for KM by developing the SECI Model which describes in a spiral way different patterns of interaction between tacit (uncodified) and explicit (codified) knowledge: 1 Socialization (tacit knowledge converts into tacit knowledge), 2. Externalization (tacit knowledge converts into explicit knowledge), 3. Combination (explicit knowledge converts into explicit knowledge), and 4. Internalization (explicit knowledge converts into tacit knowledge) (Nonaka, 1994; Honarpour et al., 2017). Since then several initiatives focus on defining KM. Nonaka and Takeuchi (1995) describe KM as the systematic process of K-creation, K-storing, and K-dissemination, whereas the majority of researchers (Alavi & Leidner, 2001; Mishra & Bhaskar 2011; Gold et al., 2001; Bhatt, 2001) pertain K-application as a generative process to KM. All these processes are parts of a continuous KM-cycle, functioning complementary and/or alternatively and they could be categorized as: K-creation (knowledge identification, capture, acquisition, and creation), K-storage (knowledge in tacit form may be codified in an understandable form to the extent possible), K-dissemination (K-sharing K-transfer both explicit and implicit form), and K-application (application and use of knowledge in the organization value-adding process) (Anand& Singh, 2011).

Besides the description of processes, there are also enablers and results informing the definitions of KM in literature. With respect to enablers thee important resources are widely accepted among various researchers: right knowledge, right people and right time (O'Dell & Grayson, 1998). These critical factors facilitate and enhance the K-flow so as to improve organizational performance (O'Dell & Grayson, 1998; Du Plessis, 2007; Kamara et al., 2002; Martensson, 2000), increase productivity (Eschenfelder et al., 1998), create value for organizations (Yew Wong & Aspinwall, 2004) and enhance innovation (Dayan & Evans, 2006; Martensson, 2000). Combining all the above, KM might be defined as: a continuous cyclical process of K-creation, K-storage, K-dissemination, and K-application, in which right knowledge flows in right people at the right time in order to improve organizational performance (Figure 1).

KM-Tools

KM tools are regarded as methods, techniques, and practices, used by organizations in order to manage their knowledge. Merono-Cerdan et al. (2007) divide KM-tools in Technological and Non-Technological. KM Technological Tools are: decision support technologies, groupware, social network services, knowledge bases, digital document management, intranet, wikis (Honarpour et al.,2017; Merono-Cerdan et al., 2007). KM non-Technological tools are: spontaneous knowledge transfer initiative, informal talk room, training, mentoring, learning before doing, teams, community of practice, knowledge café, brainstorming, after action review, storytelling, knowledge repositories (Honarpour et al.,2017; Merono-Cerdan et al., 2007). In addition, leadership, case study and benchmarking methodology could be viewed as IT-free KM-tools. Extant literature is abounding with publications recognizing and describing KM-tools (Merono-Cedan et al., 2007; Massingham, 2014) but limited attempts combine them with KM-processes (Alavi & Leidner, 2001; Alavi & Tiwana, 2003) whereas in the public sector there is a gap of such studies.

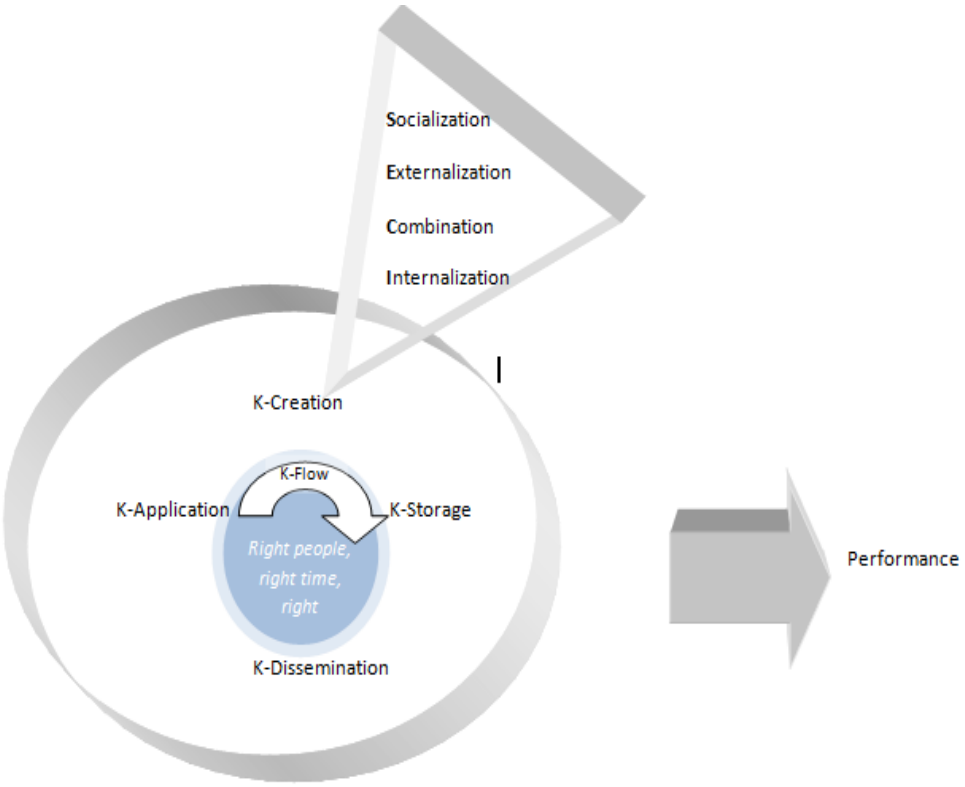

Figure 1: KM definition model

Linking the common assessment framework implementation with KM

CAF is a self-assessment tool, which is influenced by European Framework of Quality Management (EFQM) and Speyer Standard, promoting public sector change and improvement of quality and productivity. It was introduced in European organizations in 2000, whereas in Greece applications started from 2007 onwards (Vakalopoulou et al., 2013). This model includes 9 criteria with the 28 sub-criteria. For each criterion and sub-criterion a structured questionnaire is used in a 5-point Likert scale and appropriate documentation is required to justify choices. This phase is followed by an action plan development that aims to improve low scores in criteria by continuously applying the Deming cycle (**P**lan-**D**o-**C**heck-**A**ct). Usually, benchmarking facilitates action plan production and the whole CAF process provides learning and innovation feedbacks to organizations.

CAF is strongly connected with KM. Firstly, in this model, there is a sub-criterion referring to KM, which gives the opportunity to organizations to assess their KM-process and develop relevant improvement plans. Secondly, CAF implementation favors the production of new explicit organizational Knowledge, initiating the KM-process. Thirdly, KM like CAF is a continuous process. Moreover, the key methodology (Benchmarking/Benchlearning) used in CAF, is a KM-tool that could create, store, disseminate and leverage knowledge. Furthermore, KM facilitates innovation and learning (Dayan & Evans, 2006; Martensson, 2000), two aspects found also in the CAF model. Therefore, CAF applications are a means for studying KM.

Methodology and methods used

The purpose of this research is the alignment of KM-tools with KM-processes under the experience of the Greek public sector. To achieve our purpose the case in question concerns the CAF public sector community (25 members), which employs the CAF model, as a TQM-KM practice. Therefore, interviewees are Greek public sector executives, members of CAF cross functional teams, who were invited by email to contribute their experience. KM-tools drawn from relevant literature were identified through the use of semi-structured, open-ended interviews, observation, and documents. In addition, the latter methods where employed in order to investigate "What" and "How" KM-tools (namely KM-toolkits) are used in each KM-process.

Specifically, we received ten responses from CAF community members. Three out of ten organizations denied contributing in our research because of time deficit and leadership denial. Presumably, seven Greek public sector organizations participated (referred as organization H, R, D, M, MA, MB and MC). With respect to semi-structured interviews, participants were contacted by emailing them the interview protocol and an informed consent form, which reassured their confidentiality and anonymity. Interviews conducted from September 15 to November 15, 2018, in person (by visiting executives in their workplaces) were tape recorded in Greek. The interview protocol consisted of open-ended questions, mainly because the KM term is not widely known in the Greek public sector. Six questions were asked by interviewers with the same sequence to all respondents, covering the following main topics: a. motives for K-creation (CAF), b. What and How KM tools were used at: K-creation, K-storage, K-dissemination, and K-application, c. Which organizational factors facilitated and procrastinated the KM-process iteration. Besides the interviewer, a second researcher (observer) was listening carefully the interviewee, keeping detailed notices regarding body-language, layout, place, equipment, communication with other staff. Furthermore, participants sent us minutes of meetings, training manuals, presentations and reports produced and used during CAF implementation.

Findings

Motivations for starting the K-creation are different among organizations (see Table 1).

Table 1: Motives for starting the KM process

Organization (s)	Motive(s)
M	Greek National Quality Award; National Legislation (Law 3230/2004); Organization's need for Quality and Productivity Improvement
MA, MB and D	National Legislation (Law 3230/2004)
MC, and R	Organization's need for Quality and Productivity Improvement
H	Organization's need for Quality and Productivity Improvement; Transparency

During CAF implementation, specific KM-tools were applied by project teams at each KM-process. Specifically, during the K-creation process the following tools were employed: Brainstorming, Regular Planned Meetings, IT, Interviews with peers, Training (internal or/and external). Moreover, during the K-storage process Technology Platforms, Data-Bases, and Minutes of meetings were used. The K-dissemination process included the use of Discussion, Data Base, Emails, Teleconferences, face to face planned meetings, Benchmarking, Formal Events and Notifications, and Minutes of meetings (planned). Finally, the K-application process contained the use of IT, After Action Review, and Pilot application.

With reference to the way that the KM-tools were used in CAF KM-process, two dimensions are considered: CAF team formation and activities.

With respect to team formation, all organizations, apart from R and H, developed the CAF team by using a top down process. In this process, Leadership requested from middle managers, through a free participation process, to build a cross functional team. However, two out of seven organizations (R and H) had set specific participation criteria, such as: communication skills, good knowledge of department processes, and IT skills. All CAF cross functional teams consisted of 5-6 members, who were assigned, after discussion, roles and duties during the first meeting. Due to daily workload, time restrictions, tiredness, resources deficit and cultural aspects, mainly 2-3 team members were totally engaged in most organizations where as the rest of them were partially involved. Organization MA and MB team members collaborated exceptionally and were fully engaged in the project, regardless of the abovementioned restrictions.

As far as CAF activities are concerned, the following ones took place at CAF teams under study: training, planned and informal meetings, data collection and documentation, benchmarking and after action reviews. Training is a critical first step, in which a team-coordinator was trained from a public sector body responsible for training public employees and then disseminated the knowledge gained to the rest of the team. Then, members planned meetings regularly to discuss their findings and make proposals for project's progress. Additionally, interviews or/and questionnaires were used to capture departmental knowledge of each process complemented with adequate and justifiable documentation provision. For the development of action plans benchmarking was used in five out of seven members with the following types: a) historical self-comparison of performance indicators (organizations MA, MB, M, R and H) and b) studying and adapting best practices (only organization H). Five out of seven members (organizations MA, MB, M, R and H) continued applying the CAF cycle, while the rest of them stopped in the report creation phase, without completing the After Action Review.

Regarding the organizational context that enabled and restricted the KM iterative process, a number of factors emerged through the interviews. CAF team members that applied it perpetually highlighted the following factors as process facilitators: strong leadership commitment, appropriate training, problem awareness and solving skills, team-building, trust, and compliance with legislation. For example, one team member stated that: "[project] success for me is the teambuilding and trust developed between team members that made those meetings joyful", whereas another supported that: "leadership was a critical factor in scheduling and problem solving" and a third one claimed that "my training by EKDDA [Greek public sector body responsible for training public employees] was very useful in understanding the whole CAF process". A forth member confirmed: "legislation compliance triggered the continuous

implementation of CAF". Furthermore, there are various barriers limiting CAF KM-process iteration. For example, one team member claimed that: "it was politically decided to close down the organization". Another team explained: "resources deficit (Human Resources, Time, and Money) paused CAF perpetual cycle" and complemented that: "...there was no leadership commitment but just a response to political requirements and political needs fulfilment". Consequently, the abovementioned organizational factors influenced the KM-process continuation.

Discussion

According to interviewees, Greek public sector is currently characterized by bureaucracy, inflexibility, intensive legislative limitations, resource deficit, and change resistance. However, governments systematically try to modernize public organizations based on European standards. Therefore, they introduce tools, such as CAF either in a compulsory or motivational way. CAF implementation in our case synthesized context-specific dynamics where KM-tools were activated in each KM- process. From a KM view the CAF's basic goal is the transformation of tacit and explicit knowledge into new organizational explicit knowledge. This explicit Knowledge is the motive for the next KM-process through After Action Review (K-application), where members use their tacit and organization explicit knowledge to achieve the above-mentioned goal, iteratively. In our case, during the K-creation process, teams planned Meetings regularly, where tacit knowledge converted into explicit through minutes of meetings, Brainstorming, Interviews with peers, and Benchmarking. This explicit knowledge became the documentation used for the CAF report. In the phase of K-dissemination, tacit knowledge converted into tacit knowledge through informal Discussions, Teleconferences, and face-to-face meetings. This tacit knowledge was codified to explicit knowledge through minutes of meetings and Data Bases. E-mail, Formal Events and Notifications were communication tools that disseminated explicit knowledge to the organization. Presumably, figure 2 illustrates the "roadmap" of CAF mediated KM which public executives could utilize in their organizations.

With respect to Greek public sector culture, motives identified in this study could trigger under specific conditions different KM iteration results. For example, when CAF community focused on sole national legislation compliance, then the KM-process lost its spiral form and K-application was completed without After Action Review. In this case tacit and explicit knowledge was transformed into new explicit knowledge (CAF Report) that remained unused and unexploited within Data Bases or/and Minutes of Meetings. This motive was reinforced by weak leadership commitment and public sector restrictions (in people, time and money). In addition, when the motives of legislation compliance, Quality & Productivity Improvement and Quality Award winning coexisted, then KM was continuously implemented, resulting in citizen satisfaction and Quality Management interest. Finally, when the only motive was Quality & Productivity Improvement but political conditions changed the organization's structure, then the KM-process was suspended. In sum, CAF community's motives played a critical role in the KM spiral form, altering its result according to specific conditions.

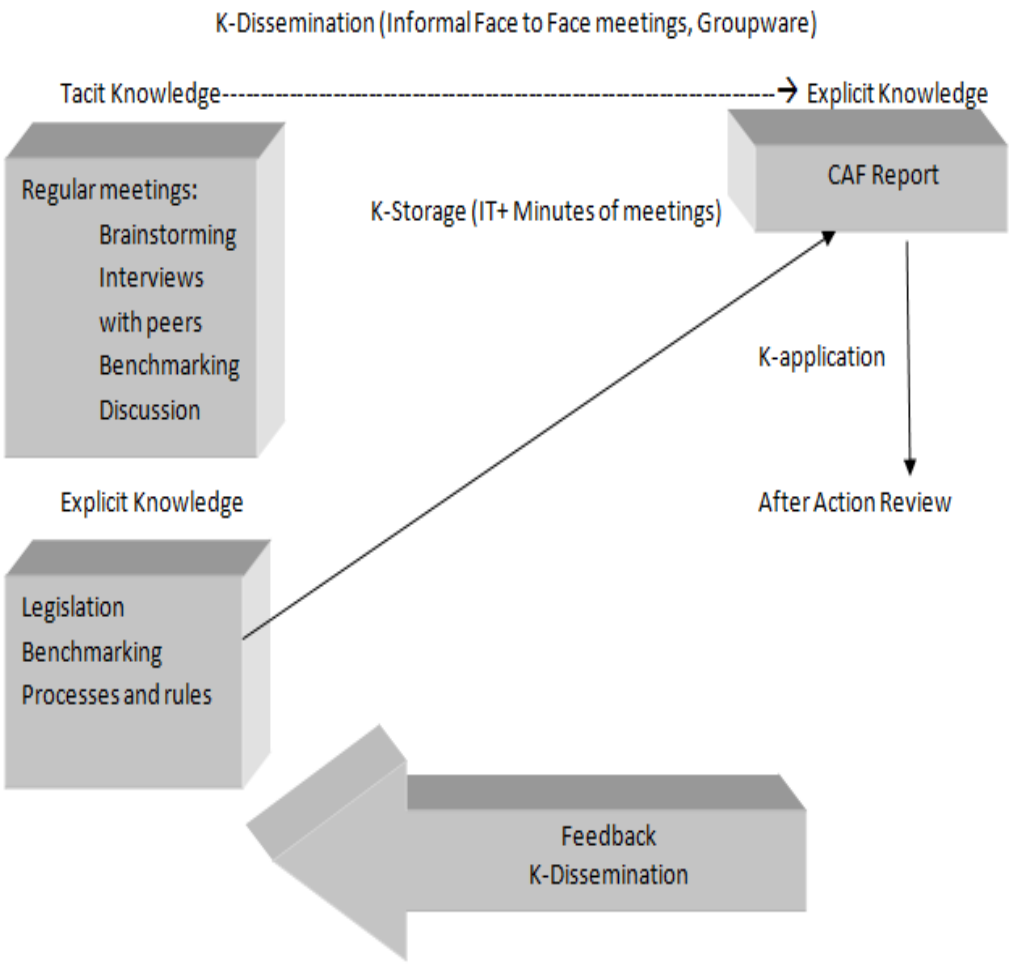

Figure 2: Roadmap of KM implementation through CAF

Conclusion

Consequently, from a KM view, CAF aims in the continuous creation of new organizational explicit knowledge (CAF report) through the conversion of team's tacit and explicit knowledge. In this framework KM-tools at each KM-process could be used in order to achieve the CAF goal (see Figure 2). Despite the fact that the abovementioned roadmap is a basic first point of KM, its critical factor is its processual iteration. Enablers of KM found in this study are: leadership commitment, teambuilding, trust, and training. However, barriers, such as daily workload, resource limitations and leadership commitment deficit, limited iteration. Therefore, taking into account internal and external conditions KM-tools used at each KM-process contributed differently in KM's effectiveness.

This work is the first attempt to combine KM-tools with KM-processes in the public sector, and to provide a roadmap of CAF mediated KM that can be utilized from public sector executives. Case findings illustrate the richness of Greek public sector CAF community KM-process, but further research should be done to enhance theoretical generalizability within different public organizations around the world.

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Adding societal value through multi-agency working – challenges in practice

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Abstract

This paper examines challenges faced by public sector organisations developing multi-agency working. Organisation A was tasked with engaging multiple User Organisations in collaborations designed to increase data accuracy, data standardisation, data quantity and data sharing, in order to improve decision making and service quality. The setting was UK police, fire and ambulance services, plus other agencies (such as social services, councils and charities), aiming to reduce harm and vulnerability in society. Multiple emergency and local services were involved in piloting data visualisation apps, designed and hosted by Organisation A, from which a number of challenges were noted.

Keywords: Multi-agency working; practice; performance measurement

Introduction

This research builds upon a body of work conducted by the AIMTech Research Centre at Leeds University Business School, investigating the use of information and technology across UK police forces (Allen et al, 2017), including three national surveys on police IT infrastructure and mobile information (Allen et al, 2018[a]; Allen et al 2018[b]; Allen et al, 2018[c]). Specifically, a Delphi study conducted in 2016-17 looked at digital transformation across the police and other emergency services over five – ten years (Shaw et al, 2017; Williams et al, 2017). The Delphi study engaged senior experts from four different domains: of 'industry', 'policy', 'technology' and 'operations'. Findings were:

- Inter-agency working is considered a priority for transforming policing
- Making greater use of digitisation and standardising the use of that data is critical
- The leadership to do this, along with human resource implications are significant.

The research reported here builds upon findings from the Delphi study. An exploratory analysis was conducted of a flagship project designed to encourage and facilitate multi-agency working across UK emergency services and other agencies. The project's aim was to develop data visualisation apps across a number of operational areas, offering a unique and innovative approach to traditional multi-agency collaboration. A number of interviews across the participating organisations identified some of the early successes, challenges and in some cases, misperceptions of the project outcomes.

Literature Review and Theoretical Context

In light of the continued impact of financial austerity in the UK public sector and increasing demand placed upon diminishing resources (Financial Times, 2015), this is an unprecedented time for managing resources across the UK public sector. The desire to work more effectively across multiple organisations - to aid decision making and utilise resources more effectively - and to work 'smarter' by adopting information technologies are commonplace.

It is readily acknowledged that sharing data can support solving not only high risk but also low risk cases (some of which can place significant demands on public services by their high frequency), by helping to identify individual cases earlier and allow more timely interventions (Wate & Boulton, 2015). However, this presents challenges.

Multi-agency working is not new however; Cheminais (2009) notes that late nineteeth century initiatives existed around health and social services working to reduce poverty, reduce social exclusion, community safety and in particular, in relation to children's well-being through the Children's Act 1989. Difficulties observed were:

- a lack of information sharing across different services and agencies
- duplication of needs assessments and subsequent provision
- poor levels of co-ordination integrating activities across different agencies
- inconsistencies in levels of service provision
- unclear accountability.

Technological advances over the past twenty years such as cloud computing and other IT platforms, coupled with austerity, have yielded renewed interest in the opportunities afforded through multi-agency working. The benefits of information technologies and mobile working in helping to increase efficiencies are well documented and increasingly, the application of this across multiple organizations is also gaining recognition (Dawes, 1996; Higgins et al, 2014). Yet the barriers to *what* is shared and *how* still remain. Wate & Boulton echo this sentiment: "*For many years organisations that are or may become involved in safeguarding vulnerable people have found sharing information problematic to achieve*." (Wate & Boulton, 2015, p.194).

Yang & Maxwell (2011) provide a literature review of information sharing in public organisations both, interpersonally, intra-organisationally and inter-organisationally. Of primary interest here is the inter-organisational context, whereby information is shared between agencies. Their model was developed further by Karlsson et al (2017) as per Figure 1 below.

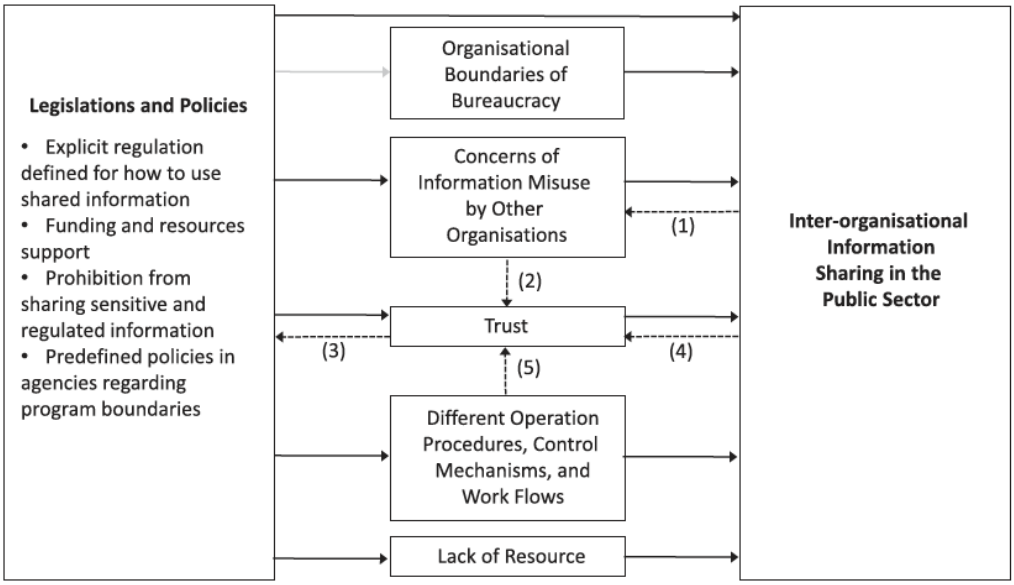

Figure 1: Karlsson et al (2017) Inter-organisational information sharing in the public sector

Karlsson et al (2017) suggest that it is often the complexity of information sharing across different organisations that causes such initiatives to fail. The numbers in the Figure above indicate the most frequent reasons for failure cited in their data. Hence, concerns of information misuse and lack of trust are primary barriers to overcome. When considering the context of this research, i.e. 1) emergency services including healthcare and 2) vulnerability, alongside 3) the recent implementation of GDPR (General Data Protection Regulation) it is hardly surprising that the relative risk-appetite for information sharing is sometimes quite cautious. A number of authors suggest that management of both the relationships between multiple agencies, and the nature of the information being shared, are required in order to facilitate rigour in the information sharing process (Karlsson et al., 2017; Higgins et al, 2014; Cuganesan et al 2017).

The case examined here investigates multi-agency working and the associated challenges, in the context of organisations with very different disciplines, historically very different ways of working, different technological infrastructures and organisational cultures, but all seeking similar aims.

For this research, a practice theory lens is adopted (Feldman & Worline, 2016; Gheradi, 2012), which considers *entwinement* (how people, actions, technologies are all inter-related), that practices are *multi-faceted in nature* (simultaneously social, discursive and material), *contextual* (where the practice is taking place and is embodied) and *temporal* (how practices develop and are improved over time) (Sandberg & Tsoukas, 2015). The research explores how practices change in the context of new opportunities to standardise and share data, and visualise this digitally to aid decision making.

Theories of practice "*locate the source of significant new patterns in how conduct is enacted, performed or produced*" (Gheradi, 2012, p. 77). Here, a practice theory lens is applied to Karlsson et al's (2017) model against the five "reshaping relationships" (Karlsson et al, p. 573) indicated in Figure 1 above.

Research context

Organisation A describes itself as providing a 'hub and spoke' model of service delivery, whereby it provides centralised services to a number of organisations (referred to as Users), in the context of individual products. These products are apps, designed to help visualise shared data in a specific operational context.

Organisation A operates over a substantial geographic region within the UK, supporting police, fire and ambulance emergency services plus a range of associated agencies, from councils and social services, to welfare agencies and charities (i.e. multiple Users). Its goal is to collaborate with these multiple agencies in order to develop an agile and data-driven approach to sharing information (Interview, 2018).

Typically, organisations would collaborate within a specific operational context and identify a need and scope for information sharing. This would then be considered and evaluated by Organisation A and a formal data sharing agreement generated. Organisation A would then design the data visualisation app, which would then be piloted, refined and ultimately hosted by Organisation A as required by the Users.

Within the evaluation activity, Organisation A advises the Users on which information is appropriate (or not) to share, issues of GDPR, data quality and data standardisation. Finally, a successful outcome for Organisation A would be acceptance of the data sharing agreement by all Users. However, for the Users, a successful outcome would manifest much later depending upon the context i.e. once the app has been operational for a number of months, possibly years.

Methodology

Adopting the practice theory lens, researchers are "*interested in understanding how [practices] are seen 'from inside', how conceptions and discussions form around the*

mode of practising a set of activities" (Gherardi, 2012, pp.2-3). The practises in question took place within a range of different organisations.

The research design was that of a case study (Yin, 2014), whereby Organisation A's work formed one individual 'case' (that of the hub, of the hub and spoke model) in order to ascertain the background, intentions and challenges to the project, and four further cases were identified by incident type. These cases were identified based upon how developed the data visualisation apps were and how embedded in practice they had become. They include: road safety; arson and anti-social behaviour; missing persons; knife crime (Figure 2).

Figure 2: Case study structure

A qualitative approach was taken in order to capture the diverse background and characteristics of each organisation. Data gathering took place primarily via semi-structured interviews, with two additional supporting focus groups. Some interviews were conducted face to face; others had to be conducted by telephone depending upon the availability of the interviewees. Interview questions were informed by a thorough review of the literature in each operational area and in accordance with a performance evaluation framework comprising forty-seven questions split into eight sections. This included:

i) background information
ii) relevant participants of the practice (i.e. those involved & their motivations)
iii) the work practices (mapping workflows and tasks, including division of labour)
iv) the motive(s) of the activity / outcomes of the practice
v) the resources utilised, e.g. technology
vi) implementation of the future app / improvement initiatives
vii) formal / informal conventions guiding behaviour and practice; and finally,
viii) multi-agency members with a shared interest in the outcome of the apps.

Interviews were conducted with domain experts within the Users and where possible, relevant staff within Organisation A too. A total of fifty-six individuals were identified, of which forty-eight interviews were completed. All data was audio recorded and transcribed. Dedoose software was utilised for coding, and a coding frame was developed between the researchers and in line with Government evaluation criteria to aid consistency of analysis. The coding frame identified categories of interest including:

Tensions and contradictions; Influence of the app technology on the area of work; and Benefits of use in terms of quantitative and qualitative outcomes. Both short term benefits (such as reductions in process time) and much longer term strategic changes to practice (such as long-term relationships developed between Users to facilitate wider collaborations) were included.

Findings

Note: all interview quotes from Organisation A are simply listed as 'interview, 2018'. Other interviews are simply quotations given the large number of interviews, from different people, in different organizations.

After approximately one year, Organisation A had established 29 data sharing agreements (Interview, 2018). This was a significant, though non-cashable achievement and due in no small part to the project manager, who had spent months establishing relationships between Organisation A and key individuals within each of the agencies. The time to develop trust and openness necessary to establish the data sharing agreements depended upon the organisation, the individual within that organisation and their relative experience of working with multiple agencies and data sharing. Certain sectors, healthcare for example, "*have a very different risk appetite*" for data sharing (Interview, 2018) and historically do not share personal data which is considered private and confidential. In other instances, such as for knife crime where much less personal information needed to be shared, establishing data sharing agreements were much easier (Interview, 2018).

Organisation A considered its work as learning-by-doing, which "*fits with that modern, agile, IT-based management style*" (Interview, 2018), the Hub is "*about pushing information to the right level in order for those people to act on that insight*", resulting in "*intelligence-led policing*" (Interview, 2018). With regard to data accuracy and quality, i.e. the information provided by the Users are beyond Organisation A's control, one interviewee suggested that there is an atmosphere of "*competition for data accuracy*" which is part of a wider cultural context in which the apps are utilised.

The performance improvements, including time and cost savings, from this project were anticipated as multi-layered in terms of activity-based and organisation-based. The complexity derives from the fact that the Organisation A's measures of success were more broadly around "*have we delivered what we said we would?*" (Interview, 2018), i.e. asking if the data visualisation apps enabled respective partners to share information in a way that aids service delivery. More extensive and longitudinal benefits are expected in line with the shorter-term gains. These comprised of individual operational process metrics such as processing times, through to Home Office measures of performance around target areas, such as reducing the number of road traffic accidents, and KPIs across individual partner organisations. Over time, the longer-term benefits will become much clearer. There were also additional unanticipated outcomes, such as the design of a data sharing agreement protocol, which would have benefit in being shared beyond this project to other multi-agency networks around the UK. A further outcome was the desire by other agencies across the UK to understand better what Organisation A was doing and to replicate its successes nationwide, share case studies and so on (Interview, 2018).

One interviewee expressed frustration at not being able to measure the impact and direct influence of the Hub inasmuch as the benefits realised by Organisation A were very different to the process improvements, cashable gains and net reductions in vulnerability experienced by User organisations. User's benefits are more quantifiable, although each User also measured different elements of performance improvement depending upon their role, such as the police compared to a welfare agency. For the Organisation A, a direct benefit of its work across partner organisations include tangible and intangible performance indicators such as:

- Increased willingness to enter in to data sharing agreements [indicative of increases in trust, greater transparency of data sharing benefits]
- Number of partners actually signed up to data sharing initiatives [quantifiable measure of the breadth of engagement in data sharing]
- Number of times data sharing protocols have been shared [indicative of the transferability of Organisation A work to other settings]
- Levels of influence on information governance, in particular through standardisation of formats and processes [indicative of transferability of good practice in data sharing in existing and new contexts]

This list is not exhaustive but illustrates other performance metrics which impact the rate of establishing new data sharing agreements.

Road Safety

This app had been running for some time and was reasonably well established. Partners expressed a desire to support activity in the area of road safety, their current levels of engagement and strategic foci differed significantly. Local authority members recognised that collaboration and reliance upon data sharing was extremely valuable. However, interviews with ambulance services offered different opinions, whereby the need to analyse road safety data and share the data they owned themselves, was not perceived necessary. This was noticed by other agencies: "*The one partner … that never seems to be around the table, and it's not just an issue with the road traffic, is health*".

Fire service interviewees presented an alternative opinion: "*from a fire service point of view, all it does is it provides … statistical evidence of what is our gut feeling anyway*."

Arson and Anti-Social Behaviour

Challenges with this operational area centred around the variety of data surrounding incidents of arson and how they are captured by the different agencies. For example, one interviewee said: *"Car fires are a problem. I think they're actually going up again at the minute, but the reasons why, you're going to look behind the reason; it's not just the incident, it's actually why, what was happening? Okay, so where was it? Was it easy to get into, what was broken into, what was stolen, what area was it in, where was it driven to when it was actually set on fire, for what reasons?"*

One interviewee also had concerns about having to double check data, which resulted in increased processing time via duplication of effort*: "Getting their information quicker and the rumours feeding into the same system would be fantastic. At the moment, I'm having to cross-reference our shelves to their shelves."* A number of interviewees expressed concerns about data potentially being misused:

> *"Depending on how they're going to gain the data protection .... Lots of data, somebody leaving, they can sell you the data, and not use it the correct way."*
>
> *"There could be resistance from other partners if they don't want to share data. Then that causes other problems and it's not useful at all to anybody."*

Missing Persons

Again, the context of missing persons cases offers high complexity, often significant vulnerability and a lot of personal data about each case. Equally, the diversity of terminology and associated data is very high. Given this, one interviewee expressed that: "*Whatever is built has to be a very, very agile product or you have to convince five local authorities to use the same terminology."* With regard to illustrating complexity, another interviewee indicated that*: "...we are seeing a lot more connections. Say, we've got 50 cases open in a month, I would say at least 20 of those are connected to each other. Boyfriend, girlfriend, family friend, uncle, cousin."*

Some frustration was also expressed with regard to the difficulty of accessing healthcare information regarding missing persons cases: *"We're entitled to that information because that's what we do. We look after people and we assess risk. We need that. Their job says, "You can't share it because it's confidential." There is a mechanism for sharing it, they just don't understand it."* An interesting observation was made by one interviewee, regarding the impact upon demand of people being reported as missing to the police: *"If our data was more easily accessible across every agency and people understood some of the risk factors at certain points, it might not ever need to come to the police",* which is hugely significant in terms of the opacity of demand that missing persons cases place upon police forces nationally.

Knife Crime

This app was the most developed and had benefitted from different agencies already working together, hence the establishing of a data sharing agreement was relatively easy. The app itself helped Users visualise the vast amounts of data much more easily; previously a simple spreadsheet had been used. The project was quite focused in terms of what it was trying to achieve and as such, a greater number of benefits were observable.

Regarding the improvements facilitated by the app, one interviewee observed: "*What the app has now allowed us to do is see everything in real time. If someone asked me "how many people on your database are open to social services? Under what categories is there a child protection?", I will be able to see that at first glance. Whereas before, I would have to sit there and have to filter everyone who isn't, everyone who is, and then*

count". Another interviewee recognised the implications for practice directly, by noting: *"this is where [the] data feeds into impact on practice. For me it's not just about having the data, it's really getting back to how we use it and I think there is not just an issue of providing data … I think there's going to be an educative part to this process that would say this is what the data is telling us, what do we need to do about it?"*

Discussion & Conclusion

This work contributes to the literature on multi-agency working, particularly within the public sector supporting harm and vulnerability reductions to society. It has explored a large-scale example of the operational, information technology and organisational cultural challenges. A practice theory lens was adopted due to the complex inter-relationship between individuals, technology and data sharing practices across multiple organisational settings.

Organisation A's work has the potential to positively influence data sharing for multi-agency working in a number of different ways. Within the current Organisation A project, the number of data sharing agreements put in place are clearly rising quickly. In addition, key outputs such as data sharing agreement protocols enable the rate of uptake of data sharing initiatives to increase beyond the Organisation A's current remit to a national setting. The sharing of good practice around establishing trust between partners, data sharing agreements etc, is proposed as an ongoing initiative beyond the original scope of the Organisation A. Much of the findings clearly relate to practices, as influenced by the "reshaping relationships" identified by Karlsson et al (2017). For example, the 'invisible' work carried out by Organisation A to establish trust through relationship building within and between agencies. The Table below indicates this further:

Table 1: Responses to Factors Inhibiting Inter-organisation data sharing

Factors from and Karlsson et al (2017)	**Counter-actions by Organisation A**
Misuse of information	Establishing protocols for setting up data sharing agreements. These can be re-used. The more they are re-used, the more agencies are likely to see them as appropriate for facilitating data sharing between agencies.
Trust	Significant time spent relationship building.
Different operation procedures, control mechanisms, work flows	Establishing standardised data formats, applying the same technology solution; creating a culture of data accuracy.

In summary, the scale and complexity of Organisation A's work captured in this report should not be underestimated, i.e. the Organisation A are striving to achieve significant innovations that, to the best of our knowledge, have not successfully been undertaken at this scale before, often working with multiple organisations across very different disciplines with very different historical ways of working, both in terms of technological infrastructure and operational culture. Shared aims however provide a cross-cutting understanding to ease these divides and provide the motivation to 'strive for

better together', that is, to improve efficiency, maximise resources, and achieve greater effectiveness of outcomes.

For the work captured in this report, it shows that despite the challenges, significant progress has been made. It is hoped this paper will contribute towards a better understanding of the challenges and opportunities of the Organisation A's work undertaken to date, and that this will support and contribute to the overall success of Organisation A's project over the longer-term.

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Demand and capacity management practices in austerity: A study across UK police forces

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Abstract

All public sector organisations within the UK have enduring a period of restricted finance. The UK's police forces are no exception, despite changing patterns of demand. This paper provides fifteen case studies of how police forces have adapted demand and capacity management strategies as a consequence. The findings show there is no standard approach to managing demand, with wide diversity in system design. A distinctive feature of police forces, unlike most other organisations, is how they adjust thresholds for dealing with demand fluctuation. There are some promising ways in which demand can be reduced without compromising quality.

Keywords: Demand, Capacity, Police

Introduction

All public services sectors are under significant financial pressure, originating after the financial crisis from 2007. In a UK context, the Police Service has experienced similar financial pressures to other public services, with a steady real-terms cut in funding from 2015 and other changes to funding from 2009 (see Elliot-Davies et al., 2016). In the period 2009-2016 the number of full-time equivalent officers fell by 14% according to the Institute for Fiscal Studies (Disney and Simpson, 2017). At the same time the patterns of demand have been under considerable change, moving away from car theft, robbery and burglary towards "white-collar crime", internet offences, sex crime and trafficking (Keene, 2012; Vinod Kumar, 2014; Boulton et al., 2017). This potentially changes the quantity and mix of skills required by forces. These problems have become more obvious in the last two year or so, leading to a series of comments in the 2017 "PEEL" review of UK policing by the Inspectorate of Constabulary (HMIC, 2018):

"[There are] *major concerns that policing is under significant stress. On occasions, that stress stretches some forces to such an extent that they risk being unable to keep people safe in some very important areas of policing… About a quarter of forces are all too often overwhelmed by the demand they face, resulting in worrying backlogs of*

emergency jobs, with officers not attending incidents promptly, including those involving vulnerable people."

Source (HMIC, 2018)

In May 2015 the national Police Chief's Council established the second phase of a project into demand management that reported back in November 2017. Amongst wide-ranging terms of reference there were the following objectives:

- To examine demand beyond recorded crime
- To examine the sources of demand data and how these could be recorded
- To identify ongoing professional good practice and set up a central repository
- To link demand to public value in terms of how the services add value
- To utilise demand forecasting models

The report contained a number of recommendations including the adoption of tools and techniques for assessing risk and prioritisation, emphasis on collaborative working, understanding internal processes to reduce waste and improve productivity and the better use of analytics.

Within the report attention was paid to defining demand, which was split into three types:

1. Public demand is equated with incidents reported by the public (but there is a need to factor in the actual resource consumption needed to meet this demand)
2. Protective demand comes from the need to provide policing cover for events, acting on intelligence or general protective patrols.
3. Internal demand is the demand for resources within policing organisations, including administrative tasks, processes and protocols.

The model that is produced to link this together is replicated in the figure below:

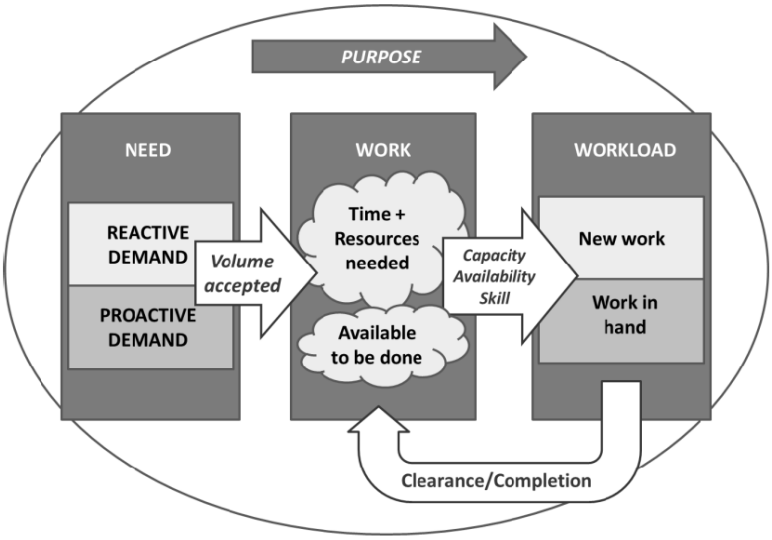

Figure 1 The NPCC representation of demand

Source: NPCC (2017)

One of the key themes of the report is to identify opportunities to reduce demand placed upon the service through a combination of selecting out demand that police do not need to attend and identifying those incidents that can be addressed through less resource

intensive solutions. An emphasis is also placed on attending incidents where those creating demand have some level of vulnerability (e.g. victims of domestic or sexual abuse).

Existing literature

In a previous paper (Walley & Jennison-Phillips, 2017) we drew attention to the perceived differences in the challenges of demand and capacity management between the public and private sectors. Literature form the private sector has long been established, with emphasis on the nature of demand in the service sector. Service demand is often instantaneous or unplanned, with seasonal and random variation (Lovelock 1992) making high utilisation a challenge. Many services also have degrees of variability that make responsiveness and flexibility necessary characteristics of service operations (Frei, 2006). The literature initially focuses on the capacity management aspects of the problem, with capacity adjustments to match demand a desirable practice (Sasser, 1976; Lovelock, 1992). Where capacity is not adjusted, demand management practices become more important. However, within the private sector there remains a desire to meet all profitable demand, so mechanisms such as price adjustments influence the timing of demand to quitter times, instead of always refusing demand when capacity limits are reached. Fitzsimmons and Fitzsimmons (2006) identify five types of demand management:

1. Reservation systems and overbooking
2. Offering complementary services that deflect demand from the core service
3. Segmenting demand so that level capacity can be better utilised by using it to deliver counter-cyclical services
4. Price incentives and price manipulation to influence the size and timing of peaks and troughs in demand
5. Promotion for off-peak times, to deflect demand away from the peak.

Within the public sector, increased demand is not usually met with an increase in revenues or resources unless there is some direct payment for service. This has significant consequences for the ways in which capacity is planned. In many cases capacity levels in the medium term are fixed and the system simply has to cope with whatever demand enters the system (Walley, 2012). Hence, public services adopt cost-centric rather than revenue-centric approaches to capacity management. Figure 2 shows how these approaches are manifested (Walley & Jennison-Phillips, 2017).

The literature on demand and capacity management within policing prior to the NPCC report (NPCC, 2017) is especially sparse. First, there are very few studies of demand for police services at all. One study (Boulton et al, 2017) highlighted the sheer diversity of the demand, with the single biggest identifiable category being concern for welfare (19% of incidents), with public nuisance (18%) and acquisitive crime (17%) also being significant. However, the biggest single category was “other” (28%), showing how the police have to deal with a wide range of rarely occurring situations. The latest crime figures from the Office for National Statistics (ONS) show that there were increases in homicides (14% increase), public order (24%) and robbery (17%). An 8% increase in knife crime has more recently become more of a topic for discussion, with a debate about the impact of the availability of police resources as a possible reason why this type of offence has become more prevalent. There is much discussion of emerging threats in policing (see Ransley and Mazerolle, 2009). The NPCC report cited previously identified 85 separate types of demand coming into police systems.

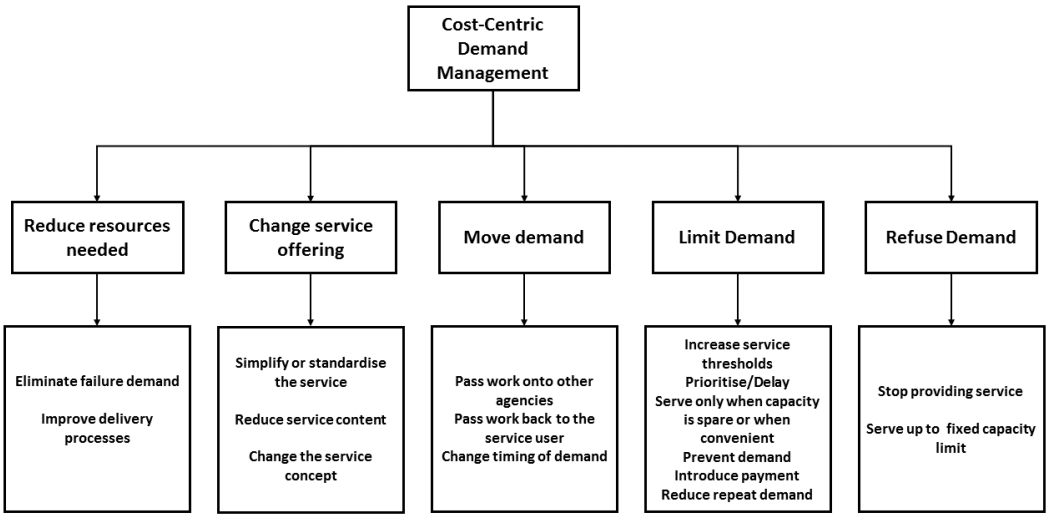

Figure 2 Cost-centric demand management practices (Walley and Jennison-Phillips, 2017)

One study has previously looked at demand and capacity management practices inside one police force, focusing mainly on custody suites (Ritchie and Walley, 2015).

Table 1 Capacity Management Strategies Observed in policing

Method	Comments
Chase demand	Assets (i.e. cells) are fixed, so in medium-term planning only adjustment of staff offers capacity change. There is limited focus on low utilization of cells, and to an extent staff. Therefore the attention to chasing demand is limited.
Increasing customer participation	In context of custody the arresting and investigating officers are the customer. The arresting officers have a specific influence on demand and throughput time. There has been awareness and engagement with arresting officers to complete all processing where possible in advance of entering the custody system.
Scheduling work shifts	A precedent has been set that although there are three shifts, these are consistent in their staffing. This is reflective of limited understanding of short term demand variability.
Creating adjustable capacity	Staff are paid both a shift and a rota allowance. However both through precedent and local affiliation the flexibility in staff assignment this is meant to provide the force is rarely used. Most of the flexibility is done through good-will agreements.
Sharing capacity	The rollout of super-custodies is meant to deliver shared capacity in terms of physical assets and staff. Further the use of 'clusters' (geographically close facilities) also provides some short-term capacity sharing. Hence capacity is shared across similar facilities more than switching resource from one type of service to another.
Using part-time staff	Part time staff have been in use for many years, and are inseparable from the full-time staff in their roles.

Source: Ritchie and Walley (2016)

Research Method

Between October 2018 and February 2019 all forces that are members of the Centre for Policing Learning and Research at the Open University were invited to participate in a study of police demand and capacity management practices. Out of twenty forces and agencies, fifteen were able to participate on the study within the timescales set. In most cases forces have been anonymised in the research, with the exception of specific cases where permission to identify them has been given. Forces have been labelled by letter (A – O) where single examples are provided.

Each force was visited for at least one day by the research team to gather the basic information. The contact centre for each forced was observed and demand entering the system tracked to establish how work entered the system from 999 and 101 calls and then processed through to dispatch. Where more detailed cases were generated a considerable amount of follow-up information was obtained after visits, including samples of demand data, performance reports from contact centres and other reports of improvement or demand reduction work.

Information was also obtained through direct discussion in structured interviews where the opinions of force officers and staff were obtained to build up a view of the perceptions of staff responsible for aspects of demand and capacity management about the situation their force is in. In most cases, officers and staff from both operational and planning roles were seen, and this allowed contrasting views to be observed. Where permission was obtained, interviews were recorded with the condition that responses were anonymised both in terms of the force and interviewee.

Of relevance to this paper, questions were asked on the following themes:

1. How well do forces and agencies understand their levels of demand?
2. Have forces changed practices involving prioritisation and response as a consequence of demand/capacity imbalances?
3. Are forces trying to reduce demand?
4. What capacity and demand management practices have been adopted across forces?

Findings

In this section we summarise the key findings across the case studies.

Demand Measurement and Forecasting

Forces generally measured the volume of calls coming into their control centres and used this to measure demand. In all but one of the forces this data collection was carried out by a variety of human interventions and automated processes. One force that had fully automated the process through a bespoke piece of software but this was used primarily as a costing tool. . It can work out the amount of demand placed on the force by an individual or business and highlight where costs are being incurred.

Forecasting of call volumes was used in all 15 forces to determine staffing levels for the control centre. These predictions had a variety of successes with one force (F) being an example of good practice in accurately predicting between 97-98% of future calls. Few forces translated this data into hard resource requirements outside of the control centre environment, especially officers needed to meet the demand and any other policing resource, such as investigative requirements. Force M was an exception as they have measured the demand across 30 different teams and created resource models to meet the demand. This has allowed force M to predict their future resource requirements. Generally forces lacked detailed understanding of demand once the call goes beyond the control room.

Call Journeys

Although there was some variation in the nature of demand across forces because some were rurally based and others were metropolitan, the basic task of meeting demand is largely the same in all forces. The call journey requires three basic steps:

1. Call handling, where calls are picked up by an operator and assessed for urgency and risk. The outcome is to reject or filter out those calls that do not need to be attended to and pass on all others graded by level of priority.
2. Dispatch, where work is allocated to available officers.
3. Attendance, where officers attend to an incident. More incidents are attended remotely now, e.g. by phone or email.

There was an unexpected amount of variation in the call journeys in each force. The variation mainly occurred through differences in the following aspects of the system design:

- The level of division or resource sharing between 999 (urgent), 101 calls (non-urgent) and dispatch.
- The number of filtering steps before dispatch, including whether or not a switchboard is used.
- The means used to assess the risk of each call.
- Thresholds for response decisions for common incident types, such shoplifting.
- The levels of one-touch or call handler resolution.
- The levels of integration between call handling and dispatch.
- The points where demand is re-graded, e.g. by dispatch
- The skill sets used within the contact centres (specialist staff, police officers etc.)
- The grading systems and response targets used
- The levels of additional back office support, such as assessment units and mental health support
- The types of response resources used, such as diary cars or booked appointments

Figures 3 and 4 show the basic flow of calls at force A and Force B:

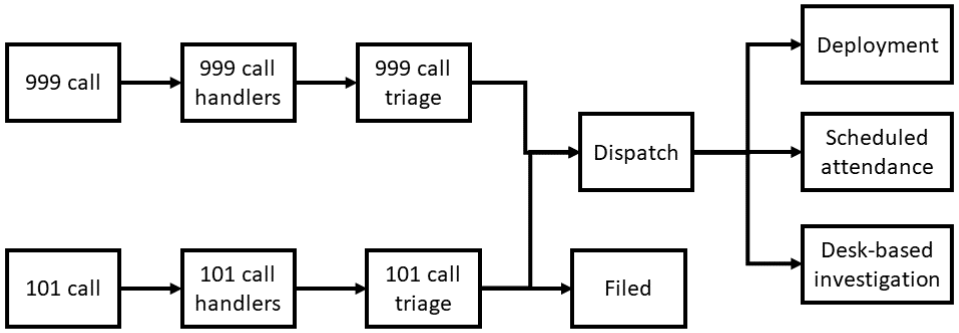

Figure 3 Call Journey at Force A

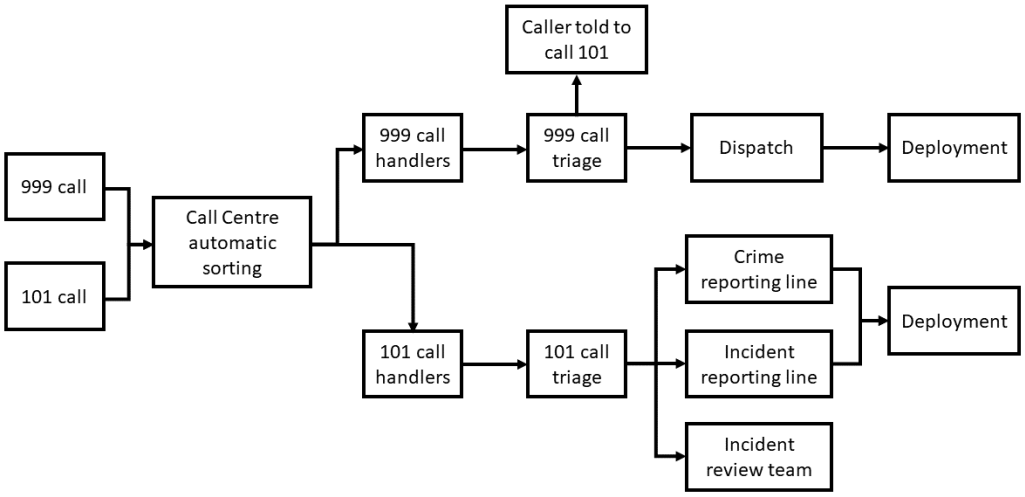

Figure 4 Call Journey at Force B

Prioritisation and Response

In all 15 forces the national decision making model was fundamental in making and justifying decisions across all ranks and departments. This changes slightly in the call centres where a method called THRIVE (threat, harm, risk, investigative opportunities, vulnerability and engagement) is predominately implemented. THRIVE has been adopted across 13 out of the 15 forces. There was evidence that all forces were simplifying their prioritisation systems, such as the number of levels of job grading, partly to improve the ways in which low-priority demand was dealt with quickly. There were clear trends towards remote resolution, where incidents would not be attended in person and would be classed as advice only. As such most forces now have just three main types of demand: urgent to be attended in person, attended soon and some form of bookable demand, such as diary car. All forces dispatched officers in a timely manner for the respective first priority category. Issues started to arise in the second category often called priority or prompt. The variety of different incidents in this category left it up to the individual dispatchers to reassess the vulnerability and risk before choosing which incidents should be dispatched to first. This problem was identified by force J, who decided to split the priority category into priority high and priority low. Hence the priority list in force J looks like this:

1. Immediate (15mins)
2. Prompt (1 hour)
3. Scheduled
4. Diary
5. Not Dealt with or closed

One of the issues that needed to be addressed in many forces was that of re-grading work where dispatch were unable to send officers within the target time. In many instances, across most forces, a call would be graded as a priority but there would not be the resource to immediately allocate to the work. There were many comments about the problem of the level of unresolved calls still being handled at any one time. In practice, once a response was going to be missed the dispatch team would re-grade the call, usually to a lower grade, including "not deal". The actual frequency of this occurrence is difficult to objectively measure, partly as there was little desire to highlight this within the control systems.

Forces reported much demand that was unnecessary or was demand that should not be the responsibility of the police. There were common problems associated with demand associated with non-police matters such as noisy neighbours, inconsiderate parking, fly tipping and other civil matters. All forces had a concept of avoidable demand even if they didn't use that specific term. The definition provided by forces was very similar. The general consensus was that avoidable demand was demand that the police shouldn't be dealing with. This definition does differ from the formal definition of avoidable demand (demand arising from behaviours that can be changed). The lack of a consistent design archetype for control centres did mean that some failure demand was generated by some of the systems in place. For example, many forces had all 101 calls arrive at a switchboard before the work was passed to call handlers in the contact centre. However the role of the switchboard varied where some merely filtered out calls that were routine contact with office staff but others deflected demand that was deemed inappropriate or unnecessary. There was also significant variation in how work passed through from call handling to dispatch.

Demand Reduction

All 15 forces have taken steps to improve their ability to manage demand or indeed reduce demand. These practices have resulted in both success and failure but demonstrate that forces are striving for improvement.

Forces have set up protocols that identify types of demand that should not be dealt with by the police. The actual topics of these protocols varies considerably. These are often incidents such as fly tipping or noise complaints that can be dealt with by another agency in a more appropriate manner. It is not the case that forces are just refusing calls for service but they are educating the public and advising them to contact one of their partners. However, the way that forces have approached this varies between blanket polices that state that they will refuse to deal with a particular call. For example, force A refuse to deal with noisy parties and lost property. By contrast, most other forces will conduct a risk assessment on the call before deciding if they will refuse deployment or not. Some forces have taken this protocol and applied it to calls for service that included a crime. This was approached in two contrasting ways displayed by force A and force B. Force A have started to only respond to shoplifting if the value of the theft is over a stated value. Force B has taken a different approach and they assess the call based on solvability factors. If there are no solvability factors and no vulnerability or risk they will not investigate the crime. Forces have also moved towards increased use of telephone resolution to close an incident in the control room and therefore prevent an officer being dispatched.

Three forces had adopted comparatively sophisticated methods of reducing failure demand (Seddon 2009; Randle and Kippin, 2014). Gloucestershire Constabulary were one of the forces that conducted an in-depth study of their unnecessary demand. They studied a sample of non-urgent demand and discovered that, for every 100 calls that could have been resolved in one contact, the demand created was 160 actual contacts. The number of contacts per incident varied quite considerably, with up to seven extra unnecessary contacts on a single incident (see Walley and Jennison-Phillips, 2018).

Capacity Strategies

All forces were able to study demand profiles broken into short (say 15 minute) blocks of calls coming into the contact centres. This did allow them to make adjustments to centre staffing levels at any particular time of day or week. A key measure for these centres is the response time for emergency calls and systems were designed to maintain good

performance in this area. (Some forces did not regularly achieve the target response time of 10 seconds for emergency calls). Forces also made attempts to meet locally-set targets for response to non-emergency calls through capacity strategies. However, these strategies were not carried through as effectively in response functions due to the underlying demand-capacity mismatch. There were capacity adjustments to cope with weekly seasonal demand fluctuation, but as one officer put it "we need to choose when we are most short of capacity". Demand management or demand deflection is still used to move demand, through the use of appointments. However, the most interesting aspect of current practice concerns the flexing of response thresholds to cope with demand at peak times. The threshold of what would be deemed a response call is adjusted, usually at dispatch, to maintain the balance between demand and resource availability. On a quieter day a less serious or urgent call may be attended. On a busy day an identical call might be graded as "not attend", re-graded as less urgent than the original call handler grade or left in the system until the incident de-escalates.

Discussion

The findings support the idea that police demand and capacity management fits within the developing theory of cost-centric demand management practices. There is work to reduce the level of resource needed to meet demand through the elimination of failure demand and through attempts to streamline processes. However, this work was seen to be the most challenging to implement as it requires system and behavioural change for it to be effective. As a consequence it was only those forces that were developing high-level demand management strategies that were taking this approach.

It is also clear that changes to the service offering are happening, usually as an emergent strategy that finds ways to reduce resource commitment to some types of demand. In particular, remote resolution through telephone advice and recording only of incidents is happening more frequently. The most significant change is where demand will not be met if there is no policing benefit – such as if attendance will not result in catching a criminal.

Another difference to existing theory comes from how systems adapt to random and seasonal demand variation. Whereas they current theory points towards chase capacity strategies that flex capacity to meet demand, in the case of policing the threshold of what they are prepared to do flexes to limit demand to what they can cope with. There is also some flexing of capacity, but this is mainly limited to the most obvious seasonal peaks and troughs. The elements of chase adjustments are part of a formal plan whereas the threshold adjustments are unplanned but happen relatively consistently when demand exceeds capacity.

All forces declared strategies to move demand from themselves to other agencies, and there was probably some naivety in the belief that demand coming to them as the "wrong place" could easily be shifted elsewhere. In practice the problem is more complex, especially where incidents involve those who are vulnerable. In such cases demand can only be met in cooperation with partner agencies, sometimes having to both deal with an incident at the same time. There was no consistent pattern in how this was achieved, with a variety of initiatives that identified specific themes of partnership working.

At the present time, one of the responses to austerity is to limit demand by simply refusing to attend demand where these is a known capacity constraint. Most of the forces had made announcements about the type of demand that they were no longer willing to deal with, including some types of lesser crime.

Conclusion

This research suggests that police forces in the UK are in a state of continuing adaptation and change with regards to the management of demand and capacity. All forces appear to share the common problem that demand outstrips their current effective capacity to attend to all demand. All forces have had to adapt their demand and capacity management practices as a response to austerity, with more sophisticated approaches to both managing demand and making adjustments to capacity. Our main conclusion is that, however, there is no one single approach that has been adopted, consistent with operations management theory. At present there is instead a wide variety of solutions that are being developed across the forces, where the theory would normally predict a more consistent response.

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Operations Planning, Scheduling and Control

Lean Supply Chain: the roles of SC partners in the Lean journey

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Abstract
Operations management literature presents a huge amount of successful cases of Lean implemented inside single organization boundaries, but few cases of Lean along supply chains. This research work aims at investigating possible reasons of why companies struggle with adopting Lean principles outside their organizations. Two potential reasons have been investigated through a simulation study: (i) unclear distribution of Lean implementation benefits along the chain and (ii) the necessity of involvement of all supply chain players for getting successful results. We focused on a sample of techniques belonging to Lean sphere: setup-time reduction, production batch size reduction and order size reduction.

Keywords: Lean supply chain, simulation

Introduction
Lean management is famous for its struggle against wastes and it has confirmed as one of the best and most profitable operations management approaches in modern era (Costa *et al.*, 2018; Tortorella *et al.*, 2018). Lean management has been wide implemented by organizations within their boundaries and great results have been achieved (Qing *et al.*, 2015). However, companies cannot survive in the market focusing on its own system only: the destiny of a producer is strictly connected to events and performances of its suppliers and of its distributors (Barnes and Liao, 2012). Even though it is clearly recognized that the application of the Lean principles to the Supply Chain level can lead to further improvements, it seems that the both the study from a theoretical point of view and the practical application of the Lean at this scale is not so simple (Staudacher and Tantardini, 2012; Rossini and Portioli, 2018). Summarizing, the need of the adoption of the Lean practices in a Supply Chain scale is stimulated by the evolution of the competition, but there are few examples of lean approach applied in SCs those are composed by operations partners belonging to different departments/firms (Cabral, Grilo and Cruz-Machado, 2012; Carvalho *et al.*, 2017; Tortorella, Miorando and Marodin, 2017). This research work aims at bridging this gap, analysing the impact of adopting Lean Management in SCP planning and providing insights about potential criticalities that obstacle the implementation of Lean in SC context. In order to achieve that, a DES

simulation study has been carried out. The paper is organised as follows. The next section reviews the literature on Lean supply chain. In the following section, the paper explains the research methodology adopted for this preliminary study and the simulation model. Then, preliminary results of the research are presented. This article ends with concluding remarks, managerial implications of the study and future research steps in Section 5.

Literature Review

Jast and Kodali (2015) defined the Supply Chain as a set of interconnected resources and processes, beginning from the raw material procurement and going on until the delivery of the final product to the consumer (Jasti and Kodali, 2015). According to them the Supply Chain Management is one of the most interesting research areas for both industry and academia. Academics made strong efforts to apply the Lean principles to a larger context, providing definitions ad interpretation keys. Anand and Kodali (2008) defined the Lean Supply Chain as "an application of Lean Manufacturing principles to Supply Chain to integrate the activities of all the stakeholders involved in the Supply Chain network and provide value to the customers by eliminating wastes" (Anand and Kodali, 2008). Hence, the core thrust of lean in supply chain (LSC) is to reduce wastes in order to create a streamlined and highly efficient system that produces at customer demand pace (Shah and Ward, 2003). Differently from single firm planning, Lean in SC needs to consider that the different links are between points those belong to different legal organizations and may be far off each other (Arif-Uz-Zaman and Ahsan, 2014). Mungan et al (2010) studied the procurement, production and delivery over a finite planning horizon for companies characterized by continuous price decrease (Mungan, Yu and Sarker, 2010). Frequent deliveries and small lots are effective to reduce the overall cost of the supply chain. An optimal lot size for raw material and manufacturing batch is determined through an efficient algorithm. Other authors analysed the impact on SC performances of adopting Lean principles in SCP: in an interesting work, Swenseth and Olson simulated continuous improvement implementation in SCP and compared it with different SCP models. Results showed that pursuing continuous improvement principle in SCP model leads to better performances in long-term than other SCP models those appears more profitable in short-term (Swenseth and Olson, 2016). A similar simulation work carried out by Rossini and Portioli Staudacher, analysed in-depth the impact of implementing Pull and Flow principles in SCP and compared it with other SCP models in a single-product SC (Rossini and Portioli, 2018). However, there is not a clear understanding of the full potential of Lean SC model in improving SC performances that appears promising but struggle in its diffusion among industry (Tortorella, Miorando and Marodin, 2017). Regarding the practical application, according to Tortorella et al. (2017), the adaptation of Lean principles to the Supply Chain level is not a simple process for two main reasons: firstly, wastes are easier to be identified at shop floor level, while at SC level the task becomes harder; secondly, managers can easily control the manufacturing processes, while to keep the control on the entire SC a huge amount of information is required form both the suppliers and customers. This research focused on the latter point, in the sense of the relationship with SC partners, attempting to explain other possible causes that lead to difficulty in Lean SC implementation. According to that, two research question have been set:

(i) How are the improvements of LSC implementation distributed along the SC?

The aim of this research question is to highlight that benefits on adopting Lean practices along the SC are not directly corresponded to who invests efforts on implementing Lean practices;

(ii) How the adoption of LSC by the different members of the SC is affecting SC final results/performances?

The aim of this research question is to show that a pervasive adoption of Lean SCP along the SC is necessary for reaching great results: when only a SC member adopts Lean SCP good results are achieved, but the potential of Lean is not fully exploited; when more SC players adopt Lean, there is integration among SC partners and synergies in results are created and effectiveness of efforts increases.

Methodology

In order to answer the research questions, a simulation study has been set. During the years SC inventory management has been studied in several ways, and many research works find out that simulation is a perfect tool for analysing quantitatively the impact of SCP on SC performances (Terzi and Cavalieri, 2004). The experiments have been carried out through discrete-events-simulations run by using the Python programming language with a strong utilization of the module Simpy.

3.1 Supply chain model

The Supply Chain is a multi-product, three-echelons Supply Chain made. Every stage is in charge of providing items to the next customer (internal or external) to feed the next production departments downstream, when they demand it. The serial supply chain is composed by three production phases (M1, M2, M3) and four buffer stocks (B1, B2, B3, B4) as presented in the figure 1.

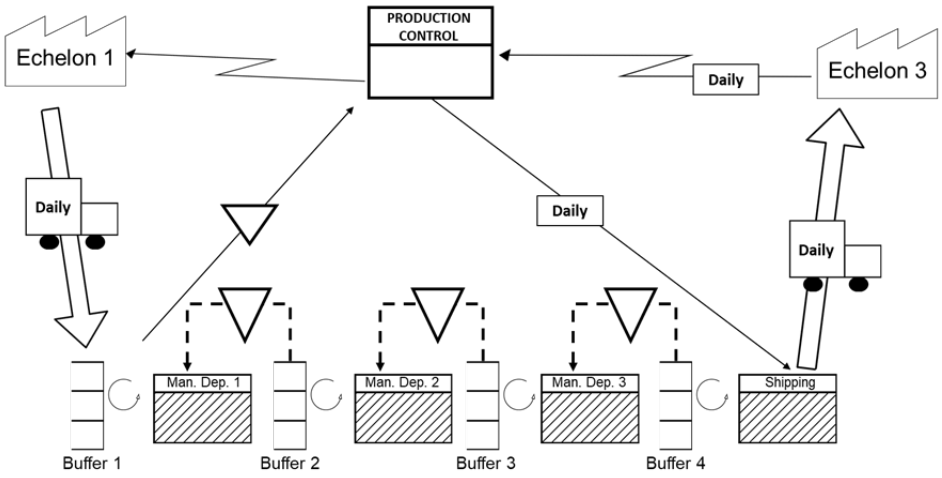

Fig. 1. Supply Chain structure

Production activities is activated by a pull mechanism and is triggered by the demand downstream. Every day, when the day starts, orders from final customers are collected. Each order demands a certain quantity of items of a product family. If the available stock is enough to fulfil the demand, the order is immediately processed and the quantity of items demanded are picked by the shipping department and delivered. Therefore, the inventory level in buffer is controlled starting from the first product family (Product 1): if the consume of stocks reached a batch size threshold, the production of a batch is then triggered. The algorithm that manages the production of batches is graphically represented in the figure 2.

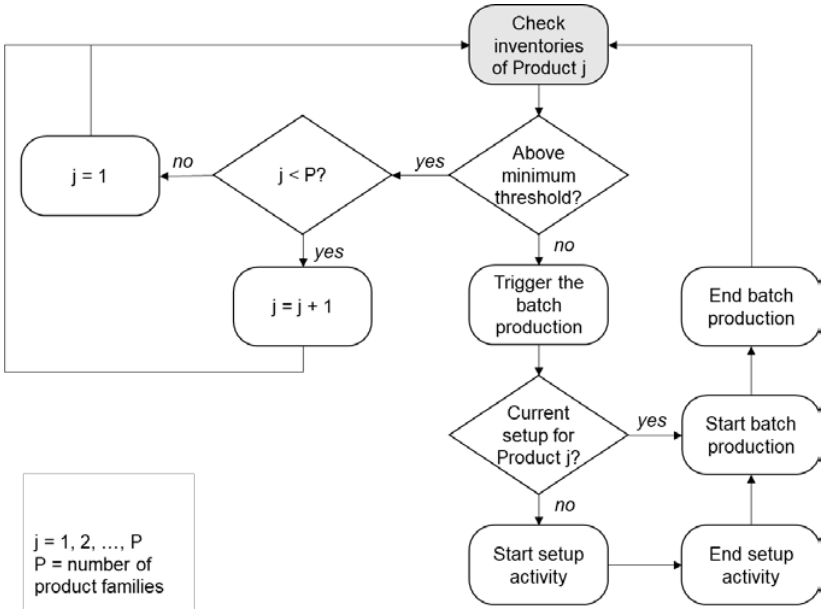

Fig. 2. Production batch trigger algorithm

3.2 Experimental parameters

A resume of parameters setting is presented in table 1.

Table 1 – Recap of experimental parameters

Parameter	Value	Measure
demand per product	10	Units per day
Number of products families	10	
Working time	8	hours per day
Machine saturation	95	Percentage
Batch size	20	Pieces
Tproduction / Tsetup	0,1	
Tproduction	0,0506667	Hours
Tsetup	0,5066667	Hours
Demand Coefficient of Variation	0,5	
Minimum Stock Threshold	20	Pieces
Raw materials supply quantity	20	Pieces

3.3 Experimental variables

In this research, Lean SC is simulated through the implementation of batch size and setup time reductions. To verify that the effects of the Lean improvements do not show up just in particular cases, the batch and setup reductions have been applied at different reduction levels: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%. Since now, the term “lean implementation” is used to indicate the batch size and setup time reduction. Moreover, one aim of the study is to test how the lean implementation of different SC players impacts on final results. Then, different levels of “participation” have been set: stage2, stage3, stage2 and stage3.

Preliminary Results

The performance is measured in terms of stock variance. This decision was driven by computational power limitations. Firstly, impact of single practice implementation has been evaluated, focusing on understanding how advantages of a practice are distributed

among SC players. Figure 3 presents stock variance reduction while Lean is implemented in the second stage. Simulation results highlights that impacts of LSC practices are not concentrated in system where they are implemented: practices as setup time reduction and order batch size reduction do not lead for sure to positive impact on stock variance in the stage where they are implemented and presented a negative effect on upstream stage. Secondly, combined implementation of Lean have been simulated in order to understand potential synergies between LSCP practices in the results of SC performances. Figure 4 presents the sum of impacts of Lean implemented singularly in stage2 and Lean implemented singularly in stage3. Figure 5 presents the actual impacts of combined implementation of Lean in stage2 and stage3. Simulation results show the impact of implementing Lean in more stage is better than the sum of single implementations impacts.

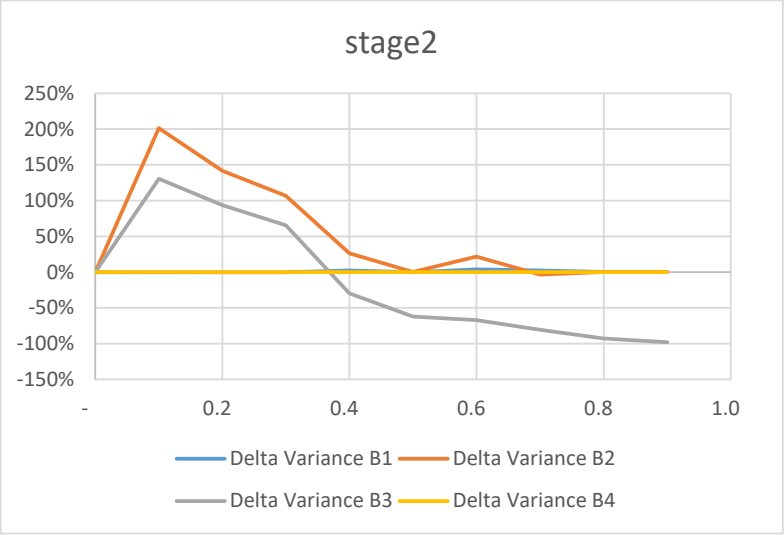

Fig. 3. Impact of Lean implementation in stage2

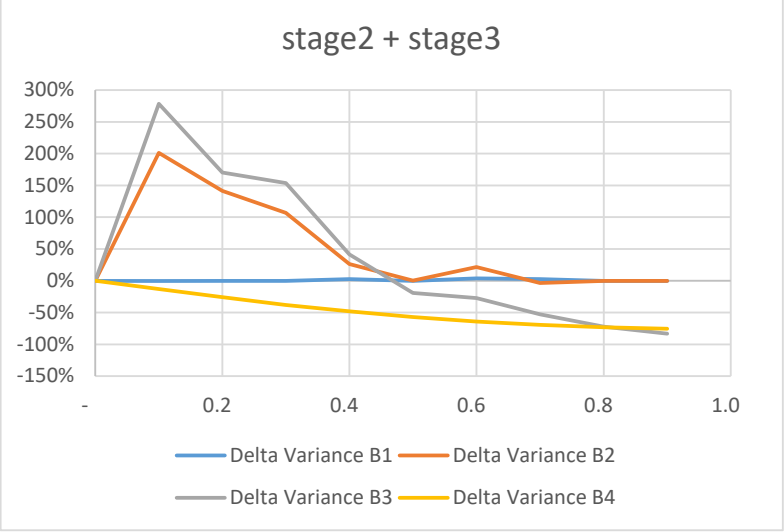

Fig. 4. Summed impact of single Lean implementation in stage2 and stage3

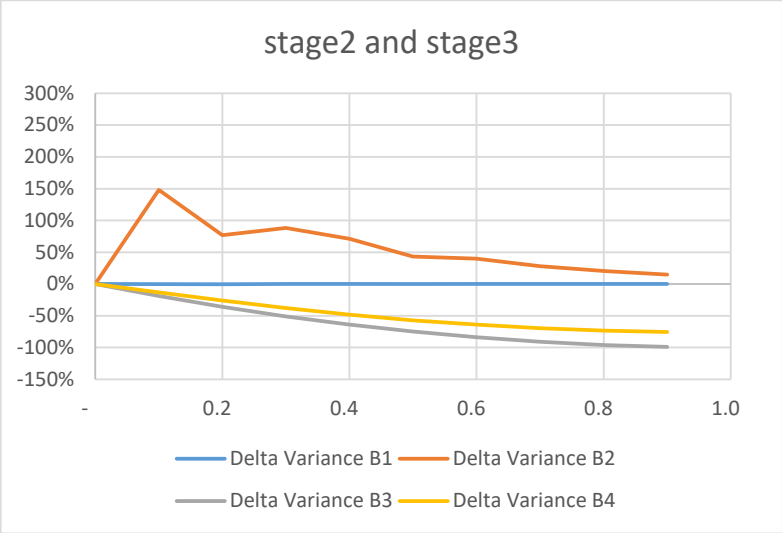

Fig. 5. Actual impact of Lean implementation in stage2 and stage3

Conclusions

The integration of the activities and the involvement of all players along the chain through long lasting relationships are required in order to reduce the wastes and increase the value for the customers. The research aims at investigating reasons and dynamics which could explain why Lean Supply Chain is not spread in industry as Lean inside single organizations.

It has been found that when a player implements Lean, it impacts also on other players, specifically the next one upstream. The batch reduction may lead to some misalignment in the production that could lead to negative effects on the variance of stock levels, counterbalancing the positive effects of batch reduction. This result should raise manager awareness on the potential impacts that could derive from lean implementation in a single stage of the Supply Chain. Indeed, it is necessary to take into account some trade-offs between the positive effects, resulting from the batch reduction, and the negative ones, arising from the batch misalignment. From the simulations it resulted that, for certain ranges of batch reductions (small reductions), the performances get worse compared to the initial situation. This means that if the company is not prepared or is not willing to make a significant effort, the lean implementation may conclude in a backlash.

In addition, combined Lean implementation of close players of the Supply Chain leads to synergies, compared to the single implementations, obtaining higher benefits in terms of stock variance reduction. In fact, in this case, there will not be misalignments in the production that lead to negative effects that worsen the variance. In addition, this result suggests that it is preferred to perform very small improvements along the whole chain instead of big improvements in a single point. However, if one or more players arrest the improvement process, the further efforts of the other players will be dampened, discouraging them and making them stop improving as well. Managers can learn that the involvement and the commitment of all the players in the Lean journey are necessary in order to reach positive results. Reaching necessary commitment is difficult, especially along a Supply Chain, where different organizations have different objectives and priorities. This could provide an insight on the reason why today, the Lean implementation at Supply Chain level is not implemented as inside single organizations.

These outcomes reflect the findings of the literature review, from which we learned that restricted applications, low understanding and low commitment (of managers or

personnel) are some of the causes that make the Lean implementation fail. Therefore, the research lends itself to represent a quantitative explanation to support the current theoretical literature.

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Power plant preventive maintenance scheduling problem: a 0/1 mixed integer linear programming approach based on cost and reliability to establish and effective policy

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Abstract

This paper gives an approach to preventive maintenance scheduling of power plants in an electric system. This optimization problem has been formulated using a cost-based criterion. The main aim is to know which power plants must stop their production of electricity for periodic inspection over a time horizon. This activity has a considerable impact on power systems because an unforeseen failure in a power plant may cause a general breakdown and the demand of customers for electricity could be unsatisfied. A realistic applied example is included.

Keywords: Preventive maintenance scheduling, Power plant, Cost optimization

Introduction

The problem of power plant preventive maintenance scheduling is an important issue of the power industry. It is usually treated in the long-term exploitation of electric production systems and requires determining the period for which generating units of an electric power utility should be taken offline for planned preventive maintenance over a time horizon. The objective is to minimize the total operating cost while a set of constraints is satisfied (Besnard et al., 2011).

Preventive maintenance is an expensive activity for power generation companies. It requires shop facilities, skilled work force, replacement parts, keeping records, etc. However, the cost of avoidable outages may imply ten or more times the actual cost of repair. Thus, this high cost makes it imperative to economic operation that maintenance be scheduled into the operating schedule (Mohammadi et al., 2008).

A review of the recent literature shows that diverse methods have been proposed. These include: multiobjective optimization (Jafarian et al., 2012); mixed integer programming (Alam et al., 2017); decomposition methods (Canto, 2008); genetic algorithms (Giftson and Asir, 2012); heuristic techniques (Lee and El-Sharkawi, 2008); particle swarm optimization (Ekpenyong et al., 2012); meta heuristic-based hybrid approaches (Dahal and Chakpitak, 2007); neural networks (Mohammadi et al., 2008); harmony search (Fetanat and Shafipour, 2009); hybrid evolutionary approach (Reihani et al., 2010); ant colony (Fetanat and Shafipour, 2011); simulated annealing (Schlünz and Van Vuuren, 2013); and intelligent optimization techniques (El-Sharkh, 2014).

The main contribution of this work is to present a global approach to the problem under study, designing a model based on a cost perspective, and achieving an optimal solution. The research performed here encompasses a wide range of power plants: thermal, nuclear, hydroelectric, and wind power plants. In addition, a complete set of constraints is included to model the real world for power systems. The model analysed is representative of current energy production systems in many countries and regions.

Problem definition

The power plant preventive maintenance scheduling problem consists in disconnecting a power plant periodically to review its functioning and to detect potential failures. The planned maintenance is designed to lengthen the life of power plants and to maintain their safety. Since power plants are integrated into a global electric system, an unpredicted failure might hit the system by causing an undesirable interruption in the power supply and subsequent customer dissatisfaction. A double perspective can be distinguished: cost (Saraiva et al., 2011; Umamaheswari et al., 2017) and reliability (Giftson and Asir, 2012; Mollahassani-pour et al., 2015). Electric energy demand must be supplied at a convenient reliability level and the associated cost of shutdown of a power plants grid should be as low as possible.

This problem is categorized as a 0/1 mixed integer linear programming problem. Its complexity must be addressed and arises from the enormous size of the system to be modelled. A large number of variables are present in the formulation, especially considering the binary variables, which are the most difficult to handle.

The time planning horizon selected is 1 year (13 periods or 52 weeks). A time interval of 13 periods is the option for this study. The average maintenance lasts 4 weeks. The notation for periods of time will be ‘k’, varying from 1 to 13. Two parts are distinguished in each period of time, weekdays and weekends, according to the electric demand, with the larger demand occurring during weekdays. Each part is divided into three different subparts depending on the electric demand. The aforementioned subparts, from higher to lower demand are peak, shoulder, and valley. Thus, there are 6 subperiods with different durations. Its notation will be ‘n’, varying from 1 to 6. The previous distribution is repeated three times according to three possible electric demand scenarios, ‘s’: high (s_h), medium (s_m), and low (s_l). This is a way to model the stochastic nature of the power demand. A probability of occurrence has been assigned to each scenario.

Mathematical formulation of the problem

In the following, the power plant preventive maintenance scheduling problem is formulated according to a mathematical model and an optimization perspective. Objectives such as cost minimization and consecution of a certain reliability level are proposed by imposing an objective function and satisfying a set of constraints (Jafarian et al., 2012; Lusby et al. 2013; Zhong et al., 2018).

The most relevant variable in this problem is the maintenance variable, whose notation is $x_{i,k}$. It is a binary variable (0/1) that indicates the following: $x_{i,k} = 0$: power plant i is not in maintenance during period k; $x_{i,k} = 1$: power plant i is in maintenance during period k.

Another 0/1 variable involved is $c_{i,k}$, which denotes the maintenance start-up and is indicated as follows: $c_{i,k} = 0$: maintenance of power plant i does not start at the beginning of period k; $c_{i,k} = 1$: maintenance of power plant i starts at the beginning of period k.

Costs are the *objective function* of the problem. They are divided into five types: fixed cost (it does not depend on the power production), start-up (cost of putting a power plant into operation), shutdown (cost of disconnecting a power plant), production (cost of producing a megawatt-hour), and maintenance (cost of putting a power plant into preventive maintenance). Fixed, shutdown and maintenance costs are negligible in comparison to start-up and production costs. The expression for the total cost is:

$$\sum_{i\in I}\sum_{s\in S}\sum_{k\in K}\sum_{n\in N} q_s \cdot \left(f_i \cdot y_{i,s,k,n} + g_i \cdot p_{i,s,k,n} \cdot \tau_n\right) \qquad (1)$$

The first term refers to start-up cost and the second to production cost of power plant i, subperiod n, period k, scenario s ($); I = index set for power plants; S = index set for demand scenarios; K = index set for periods in demand scenario; N = index set for subperiods in a period; q_s = probability of demand scenario s;. f_i = start-up cost of power plant i ($); $y_{i,s,k,n}$ = start-up variable of power plant i, subperiod n, period k, scenario s; g_i = electric energy cost produced by power plant i ($/MWh); $p_{i,s,k,n}$ = output of power plant i, subperiod n, period k, scenario s (MW); and τ_n = duration of subperiod n (h). $y_{i,s,k,n}$ is a 0/1 variable whose value is given by the next criterion: $y_{i,s,k,n}$=0: power plant i does not start at the beginning of subperiod n, period k, scenario s; $y_{i,s,k,n}$=1: power plant i starts at the beginning of subperiod n, period k, scenario s.

The cost of the electric energy produced by a power plant is applicable only to thermal and nuclear power plants. Hydroelectric and wind power plants do not have production costs because the resources used are free. The start-up costs are also equal to zero.

The *constraints* of the problem are classified in five sets: maintenance, production operation, maintenance and connection, generating volume, and wind power constraints.

MAINTENANCE CONSTRAINTS

a) Maintenance window: the maintenance of the power plant i has a duration of β_i periods.

$$\sum_{k\in K} x_{i,k} = \beta_i \qquad \forall i \in I \qquad (2)$$

b) Period: a maximum number of maintenance ψ_k is imposed in period k.

$$\sum_{i\in I} x_{i,k} \le \psi_k \qquad \forall k \in K \qquad (3)$$

c) Maintenance continuity: when a power plant is removed from the electric production system for maintenance, it completes the maintenance with no interruption.

$$x_{i,k} - x_{i,k-1} \le c_{i,k} \qquad \forall i \in I \quad \forall k \in K \qquad (4)$$

For k=1, select $x_{i,0}$=0.

d) Precedence: this constraint ensures the order to follow in maintenance. If the maintenance for power plant i precedes the maintenance for power plant j, then

$$\sum_{k_n=1}^{k} c_{i,k_n} - c_{j,k} \geq 0 \qquad \forall k \in K$$
$$c_{i,k} + c_{j,k} \leq 1 \qquad \forall k \in K \qquad (5)$$

e) Exclusion: power plants i and j cannot be in maintenance at the same time.

$$x_{i,k} + x_{j,k} \leq 1 \qquad \forall k \in K \qquad (6)$$

f) Interval: a number of 'e' periods are introduced between maintenances of power plants i and j. A sequence is provided. If δ is the time horizon, then the formula is

$$c_{i,k} = c_{j,k+\beta_i+e} \qquad 1 \leq k \leq \delta - \beta_i - e$$
$$\sum_{k=1}^{\delta-\beta_i-e} \left(c_{i,k} + c_{j,k+\beta_i+e}\right) = 2 \qquad (7)$$

g) Overlap: there is an overlap of 'u' periods between the maintenance of power plants i and j. Power plant i is the first plant out of service.

$$c_{i,k} = c_{j,k+\beta_i-u} \qquad 1 \leq k < \delta - \beta_i + u \qquad (8)$$

h) One-time maintenance: each power plant has only one outage for maintenance over the time horizon considered.

$$\sum_{k \in K} c_{i,k} = 1 \qquad \forall i \in I \qquad (9)$$

i) Deadline: the maintenance for power plant i must finish before the end of period T_i.

$$\sum_{k=1}^{T_i-\beta_i+1} c_{i,k} = 1 \qquad \forall i \in I_d \qquad (10)$$

I_d is the set of power plants affected by this constraint.

j) Crew availability: the number of people required for preventive maintenance cannot exceed the available crew within each period of time.

$$\sum_{i \in I} CN_i \cdot x_{i,k} \leq CR_k \qquad \forall k \in K \qquad (11)$$

CN_i is the number of people who are needed by unit i and CR_k is the total number of people who are available at period k.

k) Maintenance working hours: the number of maintenance working hours used is less than the number of working hours available within each period of time.

$$\sum_{i \in I} WHN_i \cdot x_{i,k} \leq WH_k \qquad \forall k \in K \qquad (12)$$

WHN_i is the number of working hours needed for the maintenance of unit i and WH_k is the total number of working hours available at period k.

l) Geographical location: it enforces a maximum number of maintained wind farms, NPM_R^{max}, in a region R from a set of regions G, to avoid the reduction of electric capacity during the time horizon.

$$\sum_{i\in R}\sum_{k\in K} c_{i,k} \le NPM_R^{max} \quad \forall i\in R \quad \forall R\in G \qquad (13)$$

PRODUCTION OPERATION CONSTRAINTS
a) Production level bounds: each power plant is designed to work between minimum and maximum power capacity (MW).

$$v_{i,s,k,n}\cdot \underline{p}_i \le p_{i,s,k,n} \le v_{i,s,k,n}\cdot \bar{p}_i \quad \forall i\in I \quad \forall s\in S \quad \forall k\in K \quad \forall n\in N \qquad (14)$$

$\underline{p}_i$ = nominal minimum power for power plant i (MW); $\bar{p}_i$ = nominal maximum power for power plant i (MW); and $v_{i,s,k,n}$ = connecting variable for power plant i, subperiod n, period k, scenario s. $v_{i,s,k,n}$ is a 0/1 variable whose value is given according to the criterion: $v_{i,s,k,n} = 0$: power plant i is not connected in subperiod n, period k, scenario s; $v_{i,s,k,n} = 1$: power plant i is connected in subperiod n, period k, scenario s.

b) Demand supply: power production in each subperiod must meet the electric demand, with a constant value in the considered subperiod of time.

$$\sum_{i\in I} p_{i,s,k,n} = d_{s,k,n} \qquad \forall s\in S \quad \forall k\in K \quad \forall n\in N \qquad (15)$$

$d_{s,k,n}$ is the power demand in subperiod n, of period k, in scenario s (MW).

c) Reserve: the reserve is a margin of action if some eventuality occurs. If $rr_{s,k,n}$ (MW) is the reserve in subperiod n, of period k, in scenario s, usually calculated as a percentage of the electric demand, then the results is as follows:

$$\sum_{i\in I} v_{i,s,k,n}\cdot \bar{p}_i \ge d_{s,k,n} + rr_{s,k,n} \quad \forall s\in S \quad \forall k\in K \quad \forall n\in N \qquad (16)$$

d) Start-up: it establishes the start-up logic for thermal and nuclear power plants. The variable $y_{i,s,k,n}$ must satisfy the following constraint to model the start-up costs:

$$y_{i,s,k,n} \ge v_{i,s,k,n} - v_{i,s,k,n-1} \quad \forall i\in\{I - I_2 - I_4\} \quad \forall s\in S \quad \forall k\in K \quad \forall n\in N \qquad (17)$$

I_2 is the index set for hydroelectric power plants and I_4 for wind power plants. When n is equal to 1, the applied contour condition is the condition that corresponds to the last subperiod of the previous period (when k = 1, 0 is selected for the connecting variable).

MAINTENANCE AND CONNECTION CONSTRAINT
It models the correlation between $x_{i,k}$ and $v_{i,s,k,n}$.

$$\begin{aligned} &x_{i_1,k} + v_{i_1,s,k,n} \le 1 \quad \forall i_1 \in I_1 \quad \forall s \in S \quad \forall k \in K \quad \forall n \in N \\ &x_{i_2,k} + v_{i_2,s,k,n} \le 1 \quad \forall i_2 \in I_2 \quad \forall s \in S \quad \forall k \in K \quad \forall n \in N \\ &x_{i_3,k} + v_{i_3,s,k,n} = 1 \quad \forall i_3 \in I_3 \quad \forall s \in S \quad \forall k \in K \quad \forall n \in N \\ &x_{i_4,k} + v_{i_4,s,k,n} \le 1 \quad \forall i_4 \in I_4 \quad \forall s \in S \quad \forall k \in K \quad \forall n \in N \end{aligned} \qquad (18)$$

For nuclear power plants, only equality exists because they are always connected, except when in maintenance. I_1 = index set for thermal units and I_3 = index set for nuclear units.

GENERATING VOLUME CONSTRAINTS

a) Minimum volume: it is related to a particular country and to coal thermal power plants. A minimum production using national coal is required to maintain jobs.

$$\sum_{n \in N} p_{i_1,s,k,n} \cdot \tau_n \ge \underline{E}_{i_1} \cdot \left(1 - x_{i_1,k}\right) \quad \forall i_1 \in I_1 \quad \forall s \in S \quad \forall k \in K \qquad (19)$$

$\underline{E}_{i_1}$ is the minimum energy (MWh) to be produced by power plant i_1. The parameter τ_n is the duration of subperiod n (h).

b) Maximum volume: this is applied to thermal power plants. Legislation enforces a maximum limit of energy production to reduce the environmental impact.

$$\sum_{n \in N} p_{i_1,s,k,n} \cdot \tau_n \le \overline{E}_{i_1} \cdot \left(1 - x_{i_1,k}\right) \quad \forall i_1 \in I_1 \quad \forall s \in S \quad \forall k \in K \qquad (20)$$

$\overline{E}_{i_1}$ is the maximum energy (MWh) to be produced by thermal power plant i_1.

c) Water volume: it is related to hydroelectric power plants. A basin water reserve cannot be used only to produce electricity because of human consumption and irrigation.

$$\sum_{n \in N} p_{i_2,s,k,n} \cdot \tau_n = E_{i_2,s,k} \cdot \left(1 - x_{i_2,k}\right) \quad \forall i_2 \in I_2 \quad \forall s \in S \quad \forall k \in K \qquad (21)$$

$E_{i_2,s,k}$ is the energy (MWh) to be produced by hydroelectric power plant i_2 in period k of scenario s:

$$E_{i_2,s,k} = 0.12 \cdot \frac{\overline{p}_{i_2}}{\sum_{i_2 \in I_2} \overline{p}_{i_2}} \cdot \sum_{n \in N} d_{s,k,n} \cdot \tau_n \quad \forall i_2 \in I_2 \quad \forall s \in S \quad \forall k \in K \qquad (22)$$

WIND POWER GENERATION CONSTRAINTS

a) Maximum energy allowance: when the electricity produced by a wind power plant reaches a certain level, it must be stopped because of the impossibility of disconnecting other power plants, such as nuclear power plants.

$$\sum_{n \in N} p_{i_4,s,k,n} \cdot \tau_n \le \overline{E}_{i_4,s,k} \cdot \left(1 - x_{i_4,k}\right) \quad \forall i_4 \in I_4 \quad \forall s \in S \quad \forall k \in K \qquad (23)$$

$\overline{E}_{i_4,s,k}$ is the maximum energy (MWh) to be produced by wind power plant i_4 in period k of scenario s.

b) Functioning hours: the number of hours that a wind power plant works is dependent on the wind regime of the geographical area considered. An average percent of the total number of hours in the time horizon is imposed.

$$\sum_{k \in K} FH_{i_4,k} \cdot x_{i_4,k} \leq r_{i_4} \cdot TNH \qquad \forall i_4 \in I_4 \qquad (24)$$

$FH_{i_4,k}$ represents the working hours associated with wind power plant i_4 during period k. THN is the global number of hours of the time horizon, and r_{i_4} expresses the percentage applied according to the wind regime in the geographical area where i_4 operates.

Model and methodology for the problem

The problem analysed is modelled as a 0/1 mixed integer linear programming problem because of its linearity and the inclusion of real and integer variables. The integer variables considered are binary. The model in this paper also includes real variables.

In compliance with the objective function and the constraints described in the previous section, the problem is modelled in the following form:

Minimize (1), subject to (2-24).

Application example

An application example based on a high-dimensioned realistic power system, similar to the Spanish one, was undertaken to validate the proposed analysis. The power system characterised has the following features: 100 power plants (50 thermal, 20 hydroelectric, 8 nuclear and 22 wind), 3 power demand scenarios, 13 periods, and 6 subperiods.

The entry data are: set of constraints, probabilities for power demand scenarios, power demand order for periods; peak, middle, and low duration in a period; fuel cost for thermal and nuclear power plants; power reserve; power demand, power plant capacity, nominal maximum power, etc. Owing to space limitations, the information is not detailed here.

After running the model for the application example using the industrial software GAMS, the findings are described below.

a) Objective function: The total cost of the system is $1,387.904 million.

b) Maintenance schedule: The time-plan is displayed on Table 1. The power plants labelled 1-50 are thermal, 51-70 hydroelectric, 71-78 nuclear, and 79-100 wind.

Table 1 - Maintenance schedule

PP/Per	1	2	3	4	5	6	7	8	9	10	11	12	13	*PP/Per*	1	2	3	4	5	6	7	8	9	10	11	12	13
1					●									51						●							
2													●	52	●												
3						●								53										●			
4					●									54		●											
5							●							55		●											
6									●					56													●
7		●												57			●										
8				●										58									●				
9						●								59													●
10													●	60				●									
11											●			61										●			
12										●				62							●						
13											●			63										●			

14				•									64			•									
15	•												65								•				
16						•							66											•	
17					•								67	•											
18								•					68					•							
19											•		69								•				
20		•											70					•							
21									•				71											•	
22												•	72						•						
23	•												73					•							
24								•					74							•					
25						•							75						•						
26										•			76			•									
27											•		77					•							
28						•							78							•					
29											•		79		•										
30				•									80									•			
31			•										81								•				
32					•								82					•							
33				•									83		•										
34								•					84		•										
35			•										85												•
36										•			86		•										
37										•			87									•			
38	•												88					•							
39												•	89						•						
40							•						90											•	
41									•				91		•										
42									•				92	•											
43			•										93		•										
44							•						94											•	
45		•											95	•											
46										•			96			•									
47				•									97				•								
48						•							98	•											
49								•					99					•							
50	•												100								•				

c) Power produced by four representative power plants for the medium demand scenario
Four graphics are provided that represent the average amount of power produced (MW) by an example of a thermal, a hydroelectric, a nuclear and a wind power plant in the three demand scenarios with respect to the total number of subperiods (78).

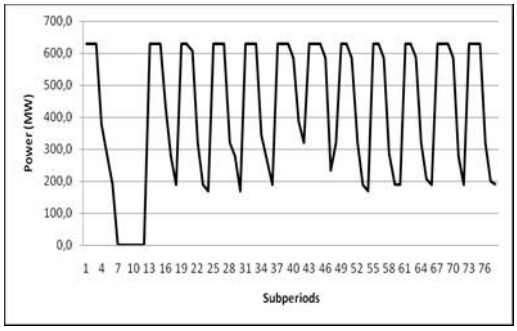

Figure 1 - Power by thermal power plant 20

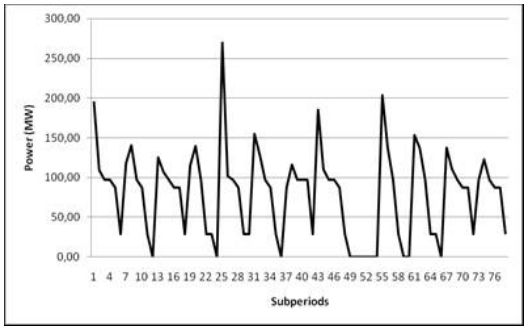

Figure 2 - Power by hydro power plant 65

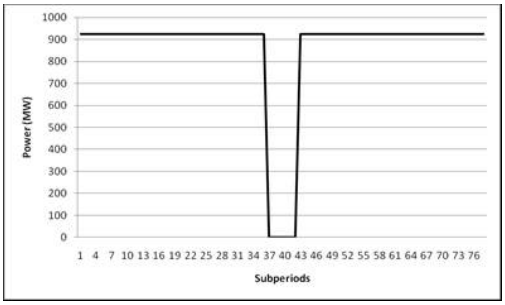

Figure 3 - Power by nuclear power plant 72

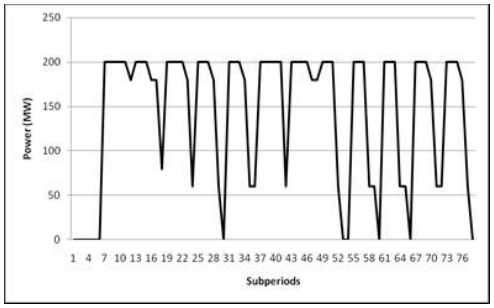

Figure 4 -Power by wind power plant 9

d) Cost associated with two representative power plants for the medium demand scenario
The following two graphics represent the average variation of cost (million $) for a thermal power plant and a nuclear power plant in the three demand scenarios with respect to the total number of subperiods (78). In line with the situation of no power produced, the total cost associated with the power plant under maintenance is zero. The global cost for hydroelectric power plants and wind power plants is also zero.

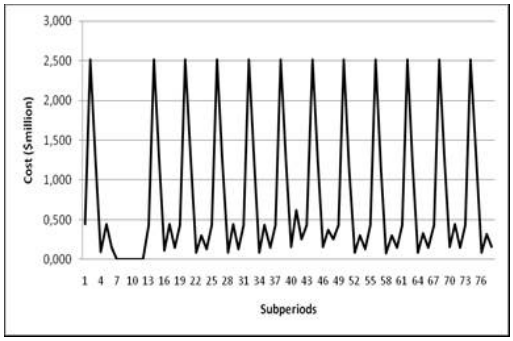

Figure 5 - Cost for thermal power plant 20

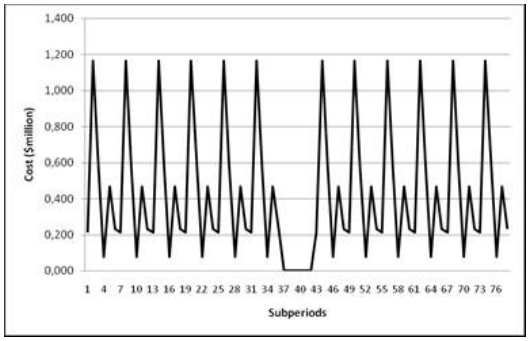

Figure 6 - Cost for nuclear power plant 72

The graphics for power and cost show a conventional way of functioning by the power plants considered.

Conclusions
This paper has explored the power plant preventive maintenance scheduling problem. In order to achieve a high quality service, its analysis stems from an essential need to maintain the electric supply of an electric grid. There are two main targets that address this problem: determining the periods of time to take down power plants for planned preventive maintenance over a certain time horizon and obtaining the specific power to be generated by every power plant and its cost according to a set of constraints imposed.

The problem under study is highly complex. The inclusion of topics related to maintenance, production operation, generating volume, and wind power, make this study quite detailed. The proposed solution provides insight into the problem using a cost perspective and after modelling a high number of constraints, providing a realistic frame.

The proposed model and methodology was applied to a large-sized and realistic electric production system to verify its efficiency. The results obtained are consistent and reflect the expected behaviour and effective performance of the electric system analysed. In addition to the specific maintenance schedule, findings obtained include the electric power produced by the power plants, as well as the associated costs, and demonstrate that the analysed methodology works correctly, in line with empirical situations.

The main contributions are: i) an integrated model for generator maintenance scheduling has been formulated for an adequate maintenance strategy; ii) several costs have been combined into a complex and general model for a power system to increase its efficiency; iii) different types of power plants were considered, including renewable energy in terms of hydroelectric and wind energy to obtain more sustainable power systems and to reduce the impact on the environment; iv) the model designed to analyse this complex problem uses a wide variety of variable and constraints; v) the results may well be an effective policy if they are applied to other realistic electric grid cases.

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Measuring and visualizing delivery schedule variations in automotive supply chains

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Abstract
The purpose of this paper is to describe and categorize inaccuracies in delivery schedules shared in European automotive supply chains, to relate types of inaccuracies to performance, and to propose how to measure and visualize inaccuracy types for value adding information access in suppliers' planning processes. We first develop new measures of delivery schedule accuracy measurement and suggest how to process delivery schedule data for accuracy measurements. We then conclude the following from analyzing two years of delivery schedule data from five suppliers in European automotive supply chains: The value of information sharing is determined by the accuracy and visibility of the data. In automotive industry supply chains, measurement of late daily variations during, and schedule nervousness should complement traditional random and systematic accuracy measures. Weekly delivery schedules have very low accuracy on longer than 8 to 10 weeks horizon. A large proportion of schedule inaccuracies are due to schedule nervousness, and inaccuracies follows Pareto pattern based on customer and item groups, and escalate upstream supply chains.

Keywords: Big data, delivery schedule, Information sharing, performance measurement, supply chain management

Introduction
Numerous academic literature has studied variations, uncertainties and quality in demand information shared in supply chains. This study focuses on the measurement and visualization of delivery schedules, i.e. planned order information generated from MRP calculations and transferred to suppliers in supply chains – normally using daily EDI transactions. This is a common form of demand information sharing in, for example, the automotive industry. For several suppliers, this is the major, and sometimes only, demand information used as gross requirement in their production planning (Jonsson and Myrelid, 2016; Wang et al., 2016). Due to inaccuracies (i.e. schedule inaccuracy and bias) the information is not always used as intended (Jonsson and Myrelid, 2017) and/or results in unnecessary rescheduling, reworking, safety mechanisms, and/or backlogs (Myrelid, 2017). Schedule inaccuracies may escalate upstream supply chain tiers (Forslund and Jonsson, 2007), and the extent depends on item commonality, planning frequency, planning period, frozen periods, etc. (e.g. Myrelid, 2017).

Consequently, studies identify that delivery schedules are widely adopted in practice but that they are associated with inaccuracies. Still, no identified study has detailed and empirically analyzed the commonality or severance of different types of inaccuracies, or how to measure and visualize schedule variations to be managed in the suppliers' planning processes. Such studies would, for example, be important in order to motivate and initiate studies on delivery schedule measurement, delivery schedule quality causes, and delivery schedule inaccuracy mitigation, and efficient and effective delivery schedule usage in supply chains.

The purpose of this paper is to describe and categorize inaccuracies in delivery schedules shared in European automotive supply chains. More specifically, problems and analysis relate to the following RQs:

RQ1: How could delivery schedule inaccuracies be measured and visualized for suppliers?

RQ2: What is the amount and type of delivery schedule inaccuracies in automotive supply chain delivery schedules?

RQ3: What is the performance effects of different types of delivery schedule inaccuracies?

Literature review

We leverage three streams of research in our work. *The first area* pertains to demand information visibility and utilization in supply chains. This literature moves beyond the importance of information sharing and focuses on the quality, and the extent to which the shared information is useful, easy to use and really used to generate value (Barratt and Oke, 2007; Jonsson and Myrelid, 2016; Viet et al., 2018). Information quality dimensions, such as, accuracy, timeliness and readily usable format determines the quality and visibility of shared information. EDI is a formal mode of information communication where data is communicated in standardized format and following a routinized time schedule (e.g. daily). The communication between sending and receiving actors can normally be fully integrated. The usefulness of the delivery schedule data can therefore to quite a large extent be expected to be a function of the accuracy.

The second area is plan/schedule stability and schedule accuracy measurement. The two major streams of schedule stability of relevance for this study are time fence management and MRP nervousness. Time fence management concerns the generation of stability in plans using time fences and specified planning policies or guidelines of restrictions for different time zones (e.g. Ho et al., 1995). The period corresponding to the throughput time of an order in the workshop normally constitutes a frozen time zone. Since orders within this time interval are already released, changed plans may result in increased production costs and decreased production efficiency and delivery service. Consequently, all types of delivery schedule variations within a frozen time zone can be expected to have negative performance impacts. Frequently changing planned order schedules is called MRP nervousness (e.g. Ho et al., 1995). Studies have presented measures of MRP nervousness and suggested solutions to reduce nervousness (e.g. Ho et al., 1995; Pujawan, 2004; Li and Disney, 2017). Schedule accuracy measurement is covered in detail in the forecast literature, but the literature calls for more empirical studies on its effects (Syntetos et al., 2015). Forecast accuracy is traditionally measured in terms of random and systematic deviations between actual and forecast values. Mean absolute percentage error (MAPE) and BIAS are commonly used forecast measures. Similar measures should be possible to use to measure delivery schedule accuracy. It is hard to say what is a good or a bad forecast accuracy performance – as it depends on planning bucket sizes and item aggregations, planning horizon and specificity of the item. A recommendation of the German automotive association VDA (2008) suggests that 90-95% schedule accuracy on item level corresponds to medium performance for weekly planning buckets on 3 to 8 weeks horizon (time lags). Less than 90% accuracy is a bad performance in

this recommendation. In a delivery schedule environment, schedule nervousness contributes to the schedule inaccuracies and it would therefore be relevant to distinguish between nervousness-generated inaccuracy and non-nervousness-generated inaccuracy.

The *third area* is literature about our empirical phenomenon, i.e. delivery schedules, schedule inaccuracy performances, and the automotive industry. This literature is more limited compared to the two first areas. It has been reported that measuring the impact of forecast errors is difficult (Kerkkänen et al., 2009), and various buffering and dampening approaches and performance effects of schedule inaccuracies is defined and used (e.g. Koh et al., 2000; Myrelid, 2017). Supply chain information sharing in the automotive industry has been studies with some different focuses, but common for the studies is that they indicate that EDI based delivery schedule data sharing is associated with problems related schedule variations (Wang et al., 2016; Myrelid, 2017), lack of trust (Jonsson and Myrelid, 2016), lack of risk assessment (Simchi-Levi et al. 2015), and that there is a potential of applying advanced data analytics to improve the quality of data sharing in automotive supply chains (Hennelly et al., 2017). However, literature is almost absent from detailed empirical analyses.

Methodology

A multiple case research approach is used to analyse two years' delivery schedule records received by five global suppliers in the automotive industry. The schedules are used as gross requirements in the suppliers' demand management processes. The suppliers act as first-, second- and third-tier suppliers, so this set up allows us to conduct comparative analysis between schedules received from OEMs and suppliers. We apply a mixed-method approach combining quantitative analysis of a large set of delivery schedule data and qualitative data analysis of schedule usage at the respective supplier. To validate our findings, we have discussed the findings with representatives from three OEMs and the studied suppliers in interviews and two common workshops. Suppliers are chosen to be different in terms of types of items, manufacturing strategies and delivery patterns.

Quantitative data collection and preparation

Delivery schedule data from five suppliers were collected for years 2017 and 2018, and stored in a database. The following 11 variables were extracted from the delivery schedule database: (1) Customer number, (2) Item number, (3) Ship to gate address, (4) Order number, (5) Forecast indicator, (6) Demand date (The date on which the item should arrive at the shipping address), (7) Plan received date (The date when the plan is received), (8) Delivery schedule ID, (9) Quantity, (10) Demand bucket (This field indicates the time period covered by the demand in the delivery schedule. 1=daily demand, 2=weekly demand, 3=monthly demand, 4=yearly demand, 5=Biweekly demand). For each supplier a number of data preparation steps were performed to generate an analysis-ready data format:

(1) First a schedule grouping logic was defined. We choose to group schedules in groups of schedules with identical combinations of Customer number-Item number-Ship to gate address-Demand date or Customer number-Item number-Ship to gate address-Demand week, respectively, depending on whether daily or weekly aggregated data was being generated.
(2) The delivery schedule data contained multiple demand buckets (daily, weekly, bi-weekly and monthly) which had to be aggregated. First all schedules were converted into daily buckets, i.e. weekly, bi-weekly and monthly buckets where evenly split into daily demands. In cases where multiple schedules were received on a certain planning day, only the last schedule received was used. This generated daily data that was further processed.

(3) Weekly aggregated data was generated by taking the last daily demand for each week, i.e. only the last daily data for each planning week was used.
(4) As the data received only contained explicit updates to schedules we had to fill with implicit data: (a) For days when no update for a certain schedule group was received but any other schedule group for the Customer-Item-Address was updated the updated volume for the schedule group was set to zero. (b) If no updates for the Customer-Item-Address were received all schedule groups for that Customer-Item-Address were updated by copying the volume from the previous day. The same procedure was also followed on weekly data, however, data was copied from the previous week.
(5) For each schedule group we defined a reference volume, i.e. the volume that was most likely delivered to the customer. For weekly data we used the volume the week before the demand week as reference volume. For daily data, the analyses performed did not require any reference volume being defined.

Customer metadata, comprising of customer group (3 to 102 categories per supplier) and OEM/Tier1 mappings, was appended to the dataset. Similarly, item metadata, comprising of item group mappings (7 to 300 categories per supplier), was appended to the dataset. Table 1 summarizes some supplier characteristics.

Table 1 - Case characteristics

	Case A	**Case B**	**Case C**	**Case D**	**Case E**
Item	Standard/ medium value	Variants/ Systems/ Medium value	Standard/ low value	Variants/ medium value	Variants/ Systems/ Medium value
Manufacturing strategy	MTS	MTS/ATO	MTS	MTS/ATO	ATO
Delivery pattern	Batch	Batch and sequence	Batch	Batch and sequence	Batch and sequence
Supply chain position	2nd/3rd tier	1st-2nd tier	1st-2nd tier	1st to 3rd tier	1st-3rd tier
Proportion OEM demand	0	0.98	0.89	0.74	0.88
No. of item groups	9	7	67	300	61
No. of customer groups	3	72	102	35	11
No. customer group-item groups	16	59	827	370	130
No. of delivery schedule records	913,004	837,857	11,648,190	278,634	2,291,395
No. of delivery schedule groups	24,931	28,451	514,796	9,622	69,744

Note: Weekly data

Quantitative data collection and analysis

Based on the literature review we define the following types of variations and measures to be measured and described in delivery schedule data:

(1) Late variations: We used daily planning buckets to measure the extent of late quantity changes (within two weeks from delivery). Any quantity change (no matter amount of change) was measured. Two weeks lag time was decided as this was the average frozen period at the suppliers.

(2) Random variation: We used the mean absolute percentage error (MAPE) to measure the random forecast error, on weekly planning buckets and planning horizons between 0 and 20 weeks. For each schedule the absolute percentage difference between the scheduled volume and the reference volume was calculated. As reference volumes could be zero and thus the percentage error is undefined, we set those errors as being 100 % if the scheduled volume was greater than zero. Following this we calculated the mean of the absolute errors

for the schedules, possibly partitioned by a relevant categorical variable (customer groups, Tier/OEM, item group), was reported. We also calculated the fraction of plans that has an absolute percentage error less than 10, 20 or 40%, respectively.

(3) Systematic variation (BIAS): Systematic schedule variation was measured as systematic over- or under dimensioned weekly volumes on 1 to 20 weeks planning horizon.

(4) Schedule nervousness: –We calculated the fraction of plans that changed from the current schedule until the week before the demand week. A modified version of this metric was used for determining the time-dependent variance, which we here use as a definition of schedule nervousness. We measure nervousness as being the fraction of schedule groups that are changed from the current schedule until the week before the demand week, and that change either to or from zero volume. We then report the fraction of variance accounted for by nervousness. Figure 1 shows an example of how changes to planned volumes of a Customer-Address-Item group shift over time. Black denotes planned volumes greater than zero. The x-axis represents demand weeks, and the y-axis represents schedule weeks.

(5) Backorder: We use backorder to measure performances/consequences of inaccurate schedule information. A backorder was defined based on the schedule data as schedule groups where demand date or demand week are prior to last non-zero volume update to the schedule group. We also filter backorders by only considering one- or two-week backorders. By this we avoided to include the limited set of schedules that are long-term backorders, most likely faulty added schedules or system errors.

Figure 1 - Visualisation of delivery schedule nervousness

Findings

Measuring and visualizing delivery schedule inaccuracy

MAPE – the ’traditional’ forecast accuracy measure of random variations – is also a relevant measure to measure random delivery schedule variations. Measuring MAPE of delivery schedule data requires that a delivery schedule group database is created, and that bucket sizes (daily/weekly/monthly) are determined. In this study we have worked with daily and weekly buckets.

In our analysis (Figure 2 and Table 1) we identify that the average weekly item-level MAPE with 4 weeks of time lag for the five suppliers varies between 20 and 60%, and for 8-10 weeks lag it varies between 20 and 100%. MAPE measures continuously improve for shorter time lags. For longer than about 10 weeks time lag the average MAPE values are in general high in absolute values: 40 to 60% for three suppliers and lower for one and higher for one supplier. This indicates that the accuracy for weekly schedules on longer than 8 to 10 weeks time lags are associated with very high random variations (MAPE). The ‘Fraction of number of plans’ graph in Figure 2 indicates that Case C receives a larger fraction of the total number of schedules far in advance, which may explain why its MAPE-values are higher. The ‘Fraction of total volume’ graph further shows that the total volumes are lower the longer the

time lag is, especially for time lags longer than 8-10 weeks. These findings, consequently, question the value of sending schedules far in advance, with time lags longer than about 10 weeks – at least if using weekly time buckets.

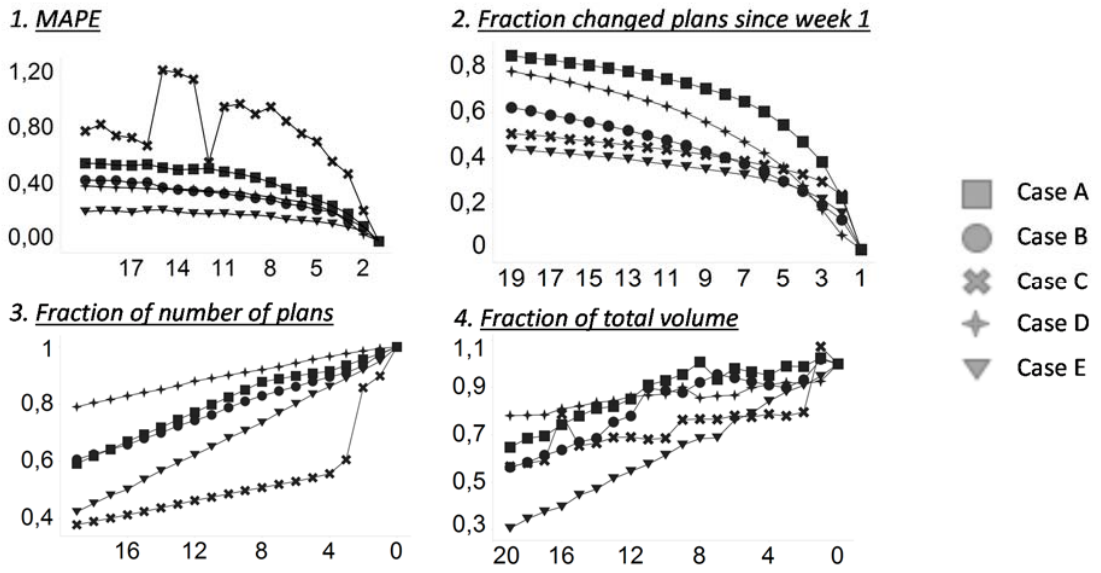

Figure 2 – MAPE and fractions changed, number and volume of plans across cases on 1-20 weeks time lags

Figure 3 shows the fraction of schedules being 10%, 20% and 40%, respectively, inaccurate in terms of MAPE. 21-36% of the suppliers' schedule groups have larger MAPE than 10% on 4 weeks lag, and 28-53% have larger MAPE than 10% on 8 weeks lag. Consequently, for all suppliers, we see a dramatic increase in the fraction of inaccurate plans during the last 4 weeks before delivery date, and for most suppliers this fraction decreases dramatically also when extending the time lag from 4 to 8 weeks. For some suppliers (B and D) it is about the same fraction of schedules that are 10%, 20% and 40% inaccurate, i.e. this indicates that those being inaccurate are very inaccurate. These suppliers use ATO manufacturing strategies and sequence deliveries, which may indicate that a limited amount of variant items may be more inaccurate. For suppliers A, C and E, however, there is quite smaller fractions of schedules being 20% or 40% inaccurate compared to those being 10% inaccurate. These suppliers make standard items to stock. Still, for all suppliers there is a large fraction of schedules (17-37%) being 40% inaccurate on 8 weeks time lag. Another observation is that Supplier A, but also Supplier E, which apply MTS strategies, have generally higher MAPE values than the other three suppliers. Table 2 shows that the fractions of items with late variations are 57%, 43%, 31%, 25% and 12%, respectively. Consequently, relatively large fractions of all items are associated with late schedule changes within frozen time zones. It is not clear to the suppliers if and how customers apply time fence management and frozen time zones. This, however, indicates that customers are not consistently using frozen plans.

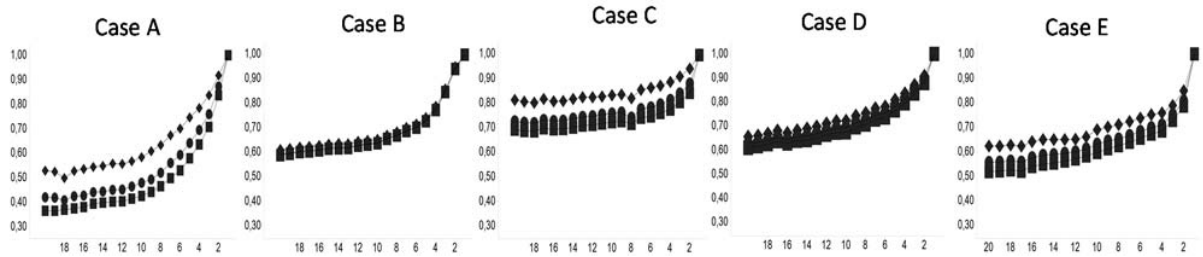

Figure 3 - Fraction of plans being 10, 20, 40% inaccurate on 1-20 weeks time lags (highest graph represents 10% and lowest graph 40%)

Analyzing the distribution of MAPE across item groups and customer groups (Table 2) shows that for some suppliers (especially supplier D), a small proportion of customer/item groups stands for a large proportion of inaccurate schedules. This pattern is especially clear for late variations. We also compared MAPE and the fraction of late variations between schedules received from an OEM and from another supplier. For all suppliers having both OEMs and suppliers as customers, the fractions of late variations are (41 to 132%) higher for schedules from customers acting as a supplier in the supply chain. This pattern also exist but is not as significant for MAPE. For one of our suppliers the MAPE is much higher, and for one it is much lower, when schedules are received from OEMs and for two there are quite small differences. All in all, we confirm a bullwhip-type of effect where variations increase upstream the supply chain – mainly because of increasing late variations within suppliers' frozen time zones. We have studies random and late variations separately, but we also see that there is a strong correlation between the size of random (MAPE) variation and fraction of late variations, which indicates that items with large random variation (MAPE) tend to end up in larger fractions of late variations, compared to items with low random variation.

Table 2 - Late vs random variation exploration

	Case A	**Case B**	**Case C**	**Case D**	**Case E**
Fraction Late/MAPE (8 weeks) for all	0.25/0.31	0.43/0.17	0.31/0.95	0.57/0.42	0.12/0.29
Fraction late variation for OEM/Tier	NA (all T1)	0.40/0.93	0.31/0.57	0.41/0.44 0.58(T2)	0.11/0.17
MAPE (8 weeks) for OEM/Tier	NA (all Tier1)	0.16/0.39	1.03/0.30	0.59/0.53 0.74(Tier2)	0.28/0.39
% of item/customer groups 80% late	25%	5%	NA	26%	21%
% of item/customer groups 80% MAPE	38%	7%	NA	44%	23%¤
Spearman correlation MAPE (8w) vs Late variation	0.59**	0.91**	0.84**	.85**	0.89**

Note: **p<.01

Figure 4 shows the ratio of schedule variations (and, thus, indirectly MAPE) that is caused by schedule shifts to and from zero quantities. These schedule variations are defined as nervousness. The nervousness ratio is relatively high for four of the five suppliers. On weekly basis, the nervousness stands for more than 70% of the variations on 10-20 weeks horizon, and for more than 50% of the variation on 2-9 weeks horizon. Only one of the five suppliers show very low nervousness ratio on weekly basis. On daily basis (days 1-14), no supplier shows very low nervousness ratio, with four suppliers having ratios about or above 40%. Consequently, these findings show that schedule nervousness is a key cause for schedule variations – both for weekly schedules and for daily schedules within the frozen zone. The

high daily nervousness ratios further indicate that several customer companies don't have frozen plans.

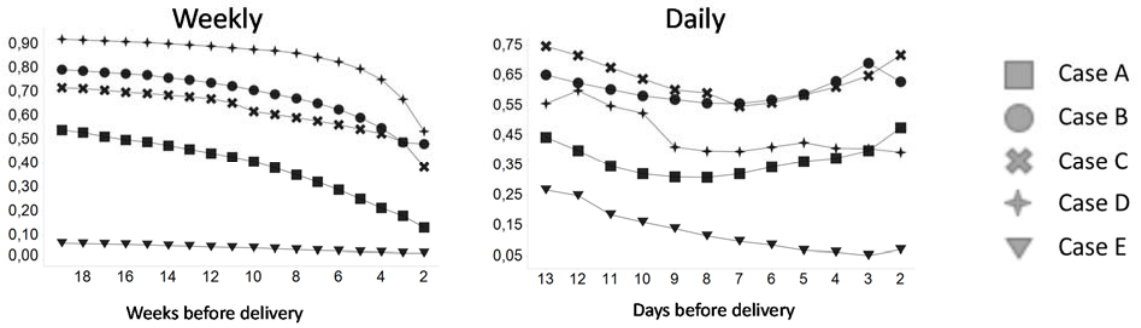

Figure 4 - Schedule nervousness ratio

Performance effects of schedule inaccuracies

Performance effects were in this study measured as backorders, i.e. if a schedule group results in a delivery after the registered delivery date. Table 3 shows that 0.1 to 0.8% of all schedule groups result in backorders. This corresponds to 26 to 3904 backorders per supplier. Figure 5 compares the MAPE and BIAS between schedule groups resulting in backorders and schedule groups where the delivery is shipped on time. For four of five suppliers, the MAPE values with 1 to 8 weeks of time lags are much higher for schedule groups resulting in backorders. For three of five suppliers, the MAPE is higher during the entire measurement horizon (20 weeks). Regarding BIAS, we see that schedule volumes resulting in backorders are on average under-estimated, while they are on the average delivery quantity or slightly over-estimated for schedules delivered on time.

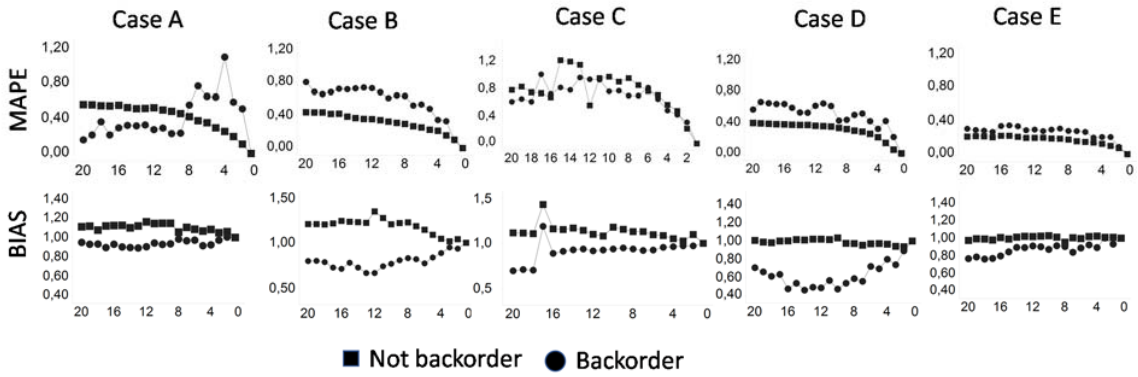

Figure 5 - MAPE/BIAS for backorder and non-backorder schedules

Table 3 shows that for Supplier A there are significantly more late changes in schedules resulting in backorders compared to those not resulting in back orders. Supplier A was the one where MAPE did not differ between backorder and non-backorder schedule groups. Consequently, all suppliers show higher random or late variations in schedules resulting in backorders compared to schedules not resulting in backorders. All suppliers show negative BIAS for schedule groups resulting in backorders.

Table 3 - Fraction of late changes for backorder and non-backorder schedules

	Case A	**Case B**	**Case C**	**Case D**	**Case E**
	Bulten	Autoliv	Floby	Plastal	Heléns
Fraction (%) backorders of all schedule groups	0.8%	0.5%	0.3%	0.4%	0.1%
Fraction (%) backorders of late groups	55%	27%	60%	51%	36%
Fraction (%) backorders of not late groups	19%	12%	58%	42%	24%

Note: All fractions are significantly different (Chi-square, p<.01) except for Case C.

Discussion and conclusions

How to measure and visualize inaccuracies

We proposed how to process and group delivery schedule data for accuracy measurement on different levels of aggregation. We also developed new measures of late schedule variations and schedule nervousness, and explored and measured five types of delivery schedule variation measures at five suppliers. These analyses suggest measuring and visualizing random, systematic and late delivery schedule variations with different time lags. Random and systematic variations correspond to common forecast accuracy measures, while measuring late variations is not as emphasized in the literature. Our findings suggest that daily planning buckets are used for measures within frozen time zones (here we have used two weeks as a standard length for a frozen zone), and weekly buckets are used for a planning horizon up to about 8-10 weeks. On longer horizons than 8-10 weeks the weekly schedule data shows high inaccuracies, so our study questions the value of weekly measurement for time lags larger than 8-10 weeks. We have not analyzed inaccuracies on monthly data, but perhaps the schedule data shows 'good enough' accuracy for longer time lags if using monthly buckets. Random and late variations are highly correlated, but their respective performance effects differ between suppliers so both types of measures need to be monitored. This requires that both daily and weekly delivery schedule databases are needed to be developed.

We identified clear Pareto patterns in the data, which indicate that different groups of customers may have different planning parameter settings/logics. Deeper comparative analysis of customers would be interesting. Findings also showed relatively larger schedule inaccuracies for customers acting as suppliers in a supply chain, compared to customers acting as OEMs. This verifies that schedule inaccuracies increase upstream supply chains (Forslund and Jonsson, 2017) and a bullwhip type of variation exists in the schedules (Syntetos et al., 2016). This is consequently one of the explanations for why schedule inaccuracies vary between customers. As large nervousness ratios were identified in the data, it is also motivated to track nervousness – both on daily and weekly schedule group data. These measures could identify customers with relatively high nervousness (e.g. because of lacking frozen time plans).

Amount and type of inaccuracies

In relation to target MAPE values suggested by VDA (2008), our analysis shows that the average random schedule inaccuracies are quite much larger than targets. About 40% of all schedule groups are more inaccurate than the 10% with 4 to 8 weeks of time lags, which is defined as 'bad' accuracy by VDA. We have not identified any target values for BIAS and late variations to compare with. We did not identify any large BIAS in any of the suppliers' data, but the fraction of schedules with late variations is in absolute terms very high: 12-57% of all schedule groups at the analyzed suppliers. Conceptually, late daily variations should not exist if appropriate time fence management policies are applied, but this indicates that it is not the case in the industry, and the performance consequences are severe. The nervousness ratios

are also high for four of five suppliers (around or above 50% of all schedule changes are of nervousness type). This indicates that quite a large amount of the schedule inaccuracies perceived by suppliers in automotive supply chains (both weekly MAPE with 2-10 weeks of time lags and late daily variations) may be caused by parameter settings and planning logics in customer companies' planning systems, rather than from end consumer demand uncertainties. I.e. variations are to large extent internally generated, rather than being caused by external demand.

Performance effects of inaccuracies

Many studies have analysed the relationship between information sharing and performance (e.g. Barratt and Oke, 2007). Our findings show that the performance of information sharing is not only a function of sharing information. Rather, and in accordance with Barratt and Oke (2007), Jonsson and Myrelid (2016), Viet al. (2018), our findings show that the accuracy, variation and corresponding visibility of shared information have direct performance effects, and consequently, need to be measured and visualized in value added information sharing. We empirically analyse the relationship between forecast errors and performances and extend previous research on supply chain information quality (Forslund and Jonsson, 2007) by measuring types of forecast inaccuracies with performance effects.

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Operations Risk Management and Resilience

Risk and resilience in export sustainable supply chain management: a value chain approach

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Abstract

The study seeks to explore key drivers and barriers for building a system of risk and resilience for export Sustainable Supply Chain Management (SSCM). Scholars have proposed a number of risk and resilience models aimed at enhancing the sustainable performance for a single value chain actor. These models, however, lack the interrelationships of direct and indirect dyads. This is an abductive study and adopts a multi-case study strategy in the agri-food industry. 32 semi-structured interviews are conducted with mangers in supply networks. The research identifies several types of drivers forming a sustainable management system of risk and resilience.

Keywords: Risk Management, Resilience, Export Supply Chain.

Introduction

Focal actors are often in control to sustainability-related misbehaviour in their supply chain by various stakeholders (Leat et al., 2013; Stone and Rahimifard, 2018). This chain charge effect places focal actors in responsibilities for building reputable systems of risk and resilience in order to manage misbehaviour that can happen beyond their direct control (Stone and Rahimifard, 2018). Yet, the present importance of export Sustainable Supply Chain Management (SSCM) is positioned on direct suppliers, which lead the focal firms to reconsider those direct and indirect relationships with other chain actors (Yan et al., 2015), that can be a positive source of sustainable value along the supply chain.

Previous scholars (e.g. Christopher and Helen, 2004; Pettit, 2011; Stone and Rahimifard, 2018) have called for analyzing export SSCM with the focus on the phenomenon of risk and resilience. Producers, exporters and importers as key chain actors collaborate to supply a wide range of products to the end-customers in export markets (Esfahbodi et al., 2016). Hence, there is a need to examine key drivers and barriers that have high effects on those actors for establishing their SSCM, especially their systems of risk and resilience in relation to their food chain losses and waste (Leat et al., 2013). These are related to the chain structure, resources and total value as economic of costs and return and non-economic of social and environmental issues. This will create a great sustainable business for actors and their dyadic relationships where innovation can also occur in SSCM (Fearne et al., 2012). Thus, the study seeks to explore key drivers for building a system of risk and resilience for export SSCM. Scholars have proposed a number of risk and resilience models aimed at enhancing the lead sustainable performance for a single

value chain actor. These models, however, lack the interrelationships of the existing direct and indirect dyads.

The present study applies abductive multiple case-studies to answer research questions below, following calls for theory development approaches in sustainable supply chains (e.g. Thiele, et al., 2011; Song et al., 2017). Accordingly, the use of Value Chain Analysis (VCA) perspective has been applied to response to several calls (e.g. Thiele, et al., 2011; Jraisat, et al., 2013) in order to surround the study's findings by reflecting the perspective through its foundation when used for dyadic buyer-seller relationships in supply chains. This paper provides relevant views from managers in dyadic actors in the Jordanian agri-food network exporting products from Jordan to UK. The study poses the following research questions:

RQ1. How do focal actors in their network build a system of risk and resilience for their export SSCM?

RQ2. What contextual factors have an impact on these focal actors' identifying of each driver for establishing their SSCM, especially their risk and resilience in relation to losses and waste in practice?

The structure of this paper is as follows. The theoretical background on export SSCM and risk and resilience is presented. Next, the research methodology is described. Then, key findings of case analyses are illustrated. Discussions on theoretical contributions and managerial implications is provided. Lastly, conclusions are provided with highlighted future research and limitations.

Theoretical Background

In food supply chains, there is a need to develop a new conceptual framework for export Sustainable Supply Chain Management (SSCM) with the focus on the phenomenon of risk and resilience. This framework can provide a protocol to analyze food chain losses, including waste for fresh fruit and vegetables (FFV) along the export supply chain. This is, in turn, to examine sustainability performance for the export SSCM with a focus on its drivers.

Producers, exporters, and importers as key chain actors collaborate to supply a wide range of FFV products in order to fill the demand in export markets. A large percentage of the FFV is produced in Jordan, due to the unique climate in the off-season, where Jordan Valley is the lowest point on Earth that enables production of FFV during winter for export markets. The UK market is one of the main importers for a number of FFV from Jordan, especially during the winter season. Hence, there is a need to examine key drivers that have high effects on those actors for establishing their SSCM (e.g. Esfahbodi, et al., 2016), especially their risks and resiliencies in relation to their food chain losses and waste (e.g. Leat, et al., 2013; Stone, et al., 2018). One of these key drivers should be examined is the structure of the food supply chain. A second factor is related to various resources, which are used by various actors for their activities along the export supply/value chain. These resources such as human, financial, information and physical components are key factors to make SSCM for food chain loss programmes. A third factor should be the total value as economic of costs and return and non-economic of social and environmental issues along the food supply chain. In fact, there are high potential for resilient sustainable approaches (Pettit, et al., 2011; Stone, et al., 2018) to minimize food chain losses and waste and at the same time perform efficiently in export markets. This will create a great sustainable business for all actors and their dyadic relationships where innovation can also occur in SSCM (Fearne, et al., 2012; Lewis, et al., 2014).

The failure of new food products such as FFV often comes due to not matching or designing to consumers' needs or not producing efficiently (Jraisat, et al., 2013). On the other hand, several new technologies and innovations have been provided for food production over the past decades. As a result, food companies have struggled to select and apply the most efficient and effective procedures and technologies in order to develop new products. Thus, product development process has to be an effective and efficient by sending the information required to the suitable actor in the chain in order to meet or exceed expectations of consumer and then enhance its success rate. The kind of this information has to be markets and consumers' demands, food losses and waste, and managerial and technological information exchange throughout the complete chain (Benner et al., 2003).

Food chain loss is defined as measurable qualitative and quantitative loss along export supply chains (Corradoa, et al., 2017). This loss can occur either due to food waste such as human action or inaction such as expiry dates, extra size of needs, throwing away wilted produce or food loss such as inadvertent loss in food quantity because of infrastructure, logistics, markets, and management limitations of a given value chain (Donovan, et al., 2015) . In a nutshell, food chain losses can either be the result of a direct quantitative loss or arise indirectly due to qualitative loss (Hodges et al., 2011). In many countries, the value chain faces losses and this current problem has not been analysed in detail by government nor private sectors (Satya, et al., 2017). According to reports of World Bank, Food Agricultural Organisation (FAO) and local organizations, an estimation of around 30% is identified as losses in many countries (Corradoa, et al., 2017). However, the exact data of losses are unknown because of no exact know-how on doing analysis for export-food chain losses, lack of full analysis for this subsector, lack of understanding for the types of losses (i.e. quantitative and qualitative), and lack of required resources and available systems of food security.

The agri-food supply chain has experienced major risk caused by the increase levels of losses, wastes and innovation in the past years (Kamalahmadi et al., 2016). This has led to interconnectedness among various actors in the FFV supply chains (Jraisat, et al., 2013), which have dependency among entities in the supply chain thereby making the supply chain complex (Christopher et al., 2011). The dependency results in the effective running of the FFV chain in a stable business environment, but with great potential to risk and disruption in an unstable business environment. An risk in supply chains is defined as an uncertainty in the chain which leads to disruption (Ho et al., 2015). A further definition is given by Heckmann et al., (2015) as the potential loss for a supply chain in terms of its target values of efficiency and effectiveness evoked by uncertain developments of supply chain characteristics whose changes were caused by the occurrence of triggering-events (e.g. disturbance, disruption, disaster, hazard or crisis.). The interdependency between an organisation and its supply chain concludes that a risk indirectly affects the chain actors, especially the focal actors. Zhao et al,. (2017) analysed specified risk source as antibiotic resistance, weather related risk and natural disasters, policy and institutional risk and unethical issues in agri-food supply chain. Figure 1 illustrates the risk sources for the agri-food supply chain and its actors.

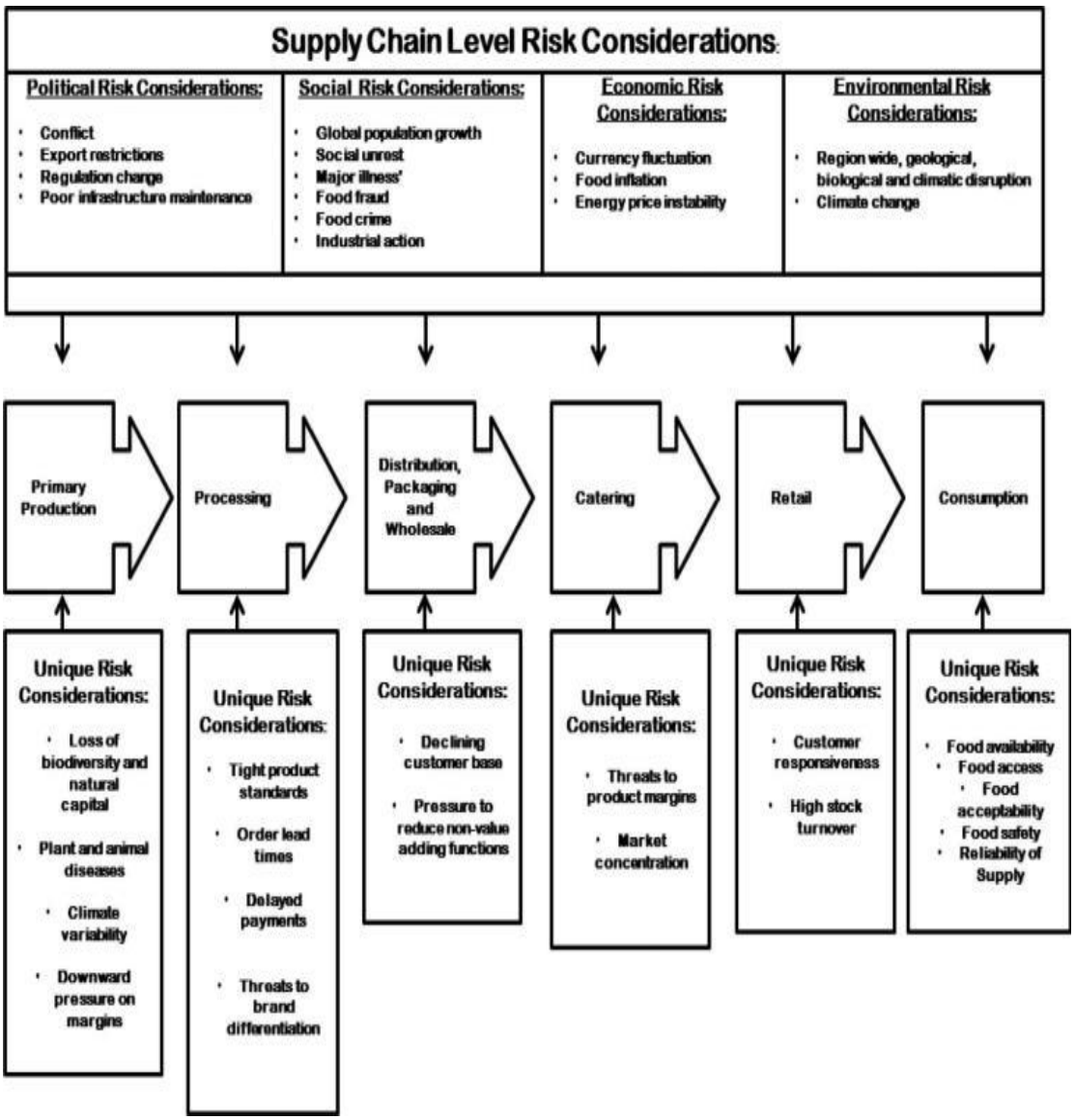

Figure 1- Risks in agri-food chains
Source. Adopted from Stone and Rahimifard (2018)

In export SSCM, actors work to create resilient FFV supply chain which can be relied on adding value to their dyads for better sustainability. Christopher and Peck (2004) defines resilience as the ability of a supply chain to return to normal operating performance, within an acceptable period, after being disturbed. Ran et al., (2011) indicate resilience as the respond to risk which causes disruption in the business. Kamalahmadi and Parast (2016) provide phases of supply chain resilience to include anticipation, resistance and recovery and responses. The extent in which an organisation is said to be resilience depends on the capabilities and resources available. For a supply chain to be effective, it must have a resilience plan against disruption and unforeseen event (Brandon-jone et al., 2014). Organisation with a structured resilience framework can manage reputation and operational risk, operating cost reduced through resource management. Figure 2 illustrates resiliencies for the agri-food supply chain and its actors

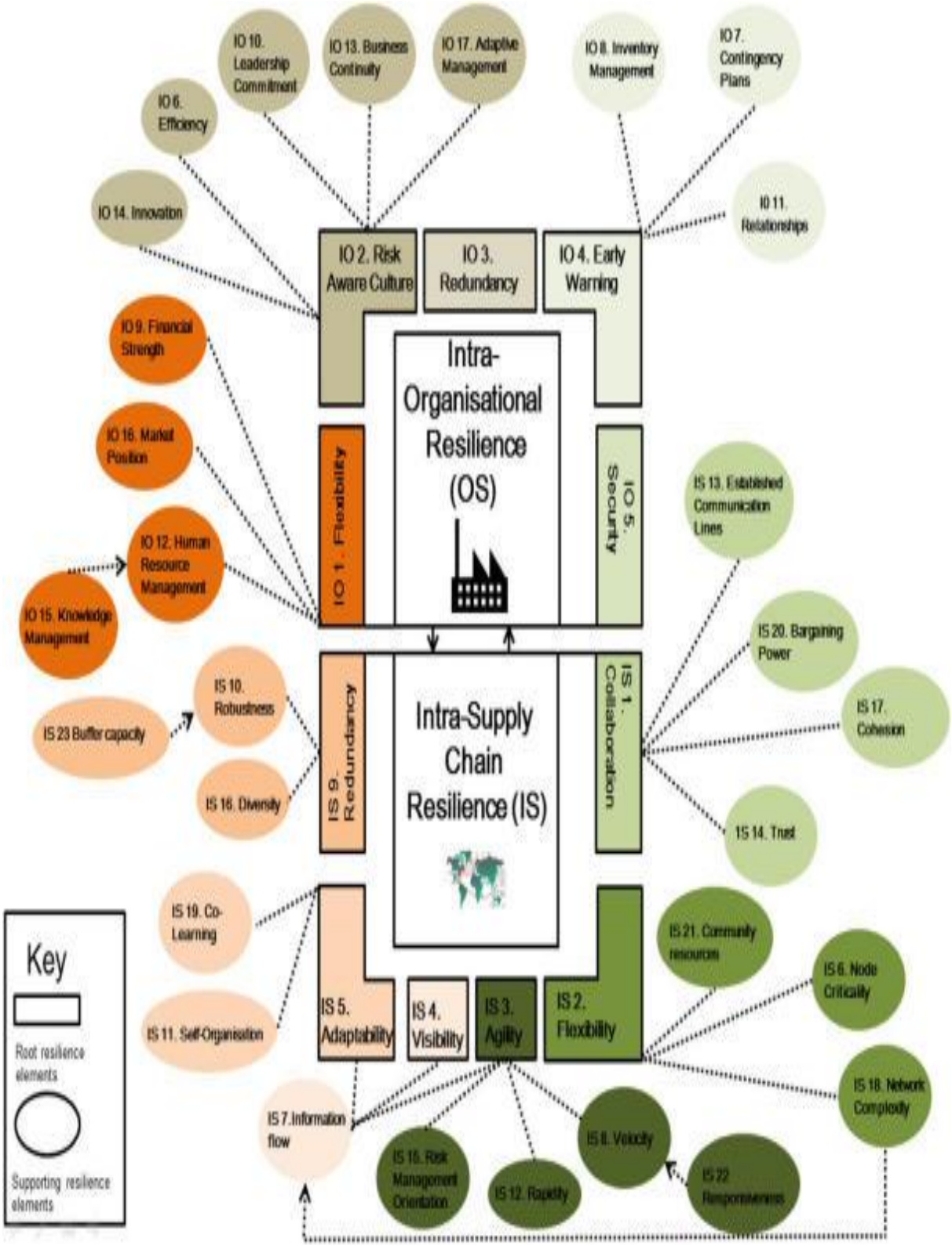

Figure 2. Resiliencies in agri-food chains
Source. Adopted from Stone and Rahimifard (2018)

Methodology

This is a qualitative case study with an abductive approach. It seeks to provide a conceptual framework that can be developed from both existing literature and contextual field data (Eisenhardt, 1989). The cases are two from the context of FFV supply chains exporting products from Jordan to the UK. 32 Semi-structured interviews are conducted with different actors around the focal actors in both direct and indirect dyads. This research applies within case and cross-case analyses (Miles and Huberman, 1994). By exploring and explaining the several types of drivers forming a sustainable management system of risk and resilience, it became possible to develop the framework.

There are two case studies, including ten dyads of five direct and five indirect dyads, which have been selected on the basis of theoretical sampling in order to provide new insights into an emergent theory (Eisenhardt, 1989). These cases are identified as sustainable direct and indirect relationships by certified bodies and each actor should have systems of risk and resilience for FFV looses and wastes and drivers' functions in FFV supply chains. This sampling selection is based on advanced research of the online directory of sustainable firms in Jordan and it included firms that have been working for at least five years with various dyadic firms in FFV supply chains. This led to a list of 80 firms, which were then shortlisted to 10 firms based on three steps: satisfactory achievement records, positive email responses and an initial interview. Then, each firm was asked to identify a dyadic collaborative firm to form the unit of analysis as a dyadic relationship. This is where two different FFV supply chains (Case: SC 1 and SC2) of different 10 dyads (unit of analysis) of two different focal actors (sub-unit of analysis) are examined. Each FFV supply chain is formed of a type1-retailer-importer (for dyads A1, A2), type 2-importer-exporter (for dyads B1, B2), type 3-retailer-distrubutor (for dyads C1, C2), type 4-distributor-wholesaler (for dyads D1, D2), type 5- wholesaler-importer (for dyads E1, E2) (Table 1). The basis for these studies was semi-structured interviews with six managers at each dyad. Managers as key informants were selected because they provide an overview of the topic. Jordan is one of the developing countries which has agreements and contracts across FFV chain actors, including collaborative dyads for the UK markets (Jraisat et al., 2013).

The interviews were conducted and recorded by the author in person, who were asked the same questions. The interviews were also transcribed and then sent to the managers for revisions. The approved interviews were used to develop the case studies, which were analysed through cross-case analyses (Miles and Huberman, 1994).

Findings and Discussions

Academic researchers have proposed definitions, frameworks and key findings to carry out development in export SSCM (e.g. Fearne, 1998; Burgress, 2006; Pang et al., 2012; Esfahbodi, et al., 2016). Their research studies are formed based on key underpinning concepts that can be termed the building blocks of assumptions and frameworks. However, a wider body of knowledge about dyads is needed to overcome overlapping concepts in order to generate consistent findings (Esfahbodi, et al., 2016). Thus, the intention of the present research is to contribute to the body of knowledge by providing new propositions for management of risk and resilience for direct and indirect dyads attached to better sustainability performance for the dyadic actors in FFV supply chains.

Both the literature review and cross-case findings support the suggestion that drivers of risk and resiliencies are the main key for adding value between dyadic actors that affect their sustainability performance, and this is also based on good control of losses and wastes for both actors and their export SSCM (Taylor and Fearne, 2006). Findings from cross cases highlighted how dyadic actors at both levels, chain and dyad, share

drivers for a long term dyads, and this reflects a positive risk and resilience approach. The key findings have highlighted the fact that both dyadic actors in all relationships for direct and indirect dyads (A1, A2), (B1, B2), (C1, C2), (D1, D2), (E1, E2) generally identify high effects of the antecedents in drivers for better management of losses and wastes in FFV supply chains. See table 1 for the types of drivers of building risks and resiliencies for FFV supply chains.

Table 1: Drivers of risks and resiliencies : cross-case comparison based on chain level /dyad level-focused themes

Case Study		External-focused Key theme (Chain level-focused)						Internal-focused Key theme (Dyad level-focused)					
		Risk drivers			Resilience drivers			Risk drivers			Resilience drivers		
		Social Risks	Environmental risks	Economical risks	Collaboration	Flexibility	Agility	Social Risks	Environmental risks	Economical risks	Flexibility	Culture	Warning
Case 1 (SC1)	Relationship A1	H	H	H	H	M	H	H	M	H	H	M	H
	Relationship B1	H	H	H	H	H	H	H	H	H	H	H	H
	Relationship C1	H	H	H	H	H	M	H	M	H	H	H	H
	Relationship D1	H	H	H	H	H	H	H	H	H	H	M	H
	Relationship E1	M	M	L	L	L	L	L	L	M	L	L	L
Case 2 (SC2)	Relationship A2	H	H	H	H	H	H	H	M	H	H	H	H
	Relationship B2	H	H	H	H	M	H	M	L	H	M	M	M
	Relationship C2	H	H	H	M	H	M	H	L	H	M	M	H
	Relationship D2	M	H	H	L	L	H	M	L	M	M	M	M
	Relationship E2	M	L	L	L	L	L	L	M	M	L	L	M
Overall Score		H	H	H	M	M	M	H	M	H	H	M	H

Level of scoring from the perspective of dyadic actors: High (H), Medium (M), Low (L).

The value chain model (Porter, 1985) dominates as a tool for the strategic analysis of firm value creation and as a conceptual map for the description of activities actors perform in inter firm relations for risk and resilience. The working actor and the customer/consumer had distinct roles of production and consumption, respectively. In this perspective, the market, viewed either as a locus of exchange or as an aggregation of consumers, was separate from the value creation (Walters and Lancaster, 2000). However, the interactions between working actors and customers are not seen as a source of value creation (Normann and Ramirez, 1994; Wikstrom, 1996). In fact, the value chain for direct and indirect dyads amongst actors in an industry should be embedded in a larger stream of activities that we term the "value wheel" in the present research (Harland, 1996; Lambert and Cooper, 2000; Croom et al., 2000; Walters and Lancaster, 2000). The value

wheel includes the value chains of several working actors and focal actors under the explored topic (Berger et al., 2004; Pang et al., 2012; Barroso-Méndezet al., 2014). Motivated by this issue, we have proposed the conceptual framework for partnership in SAVC above.

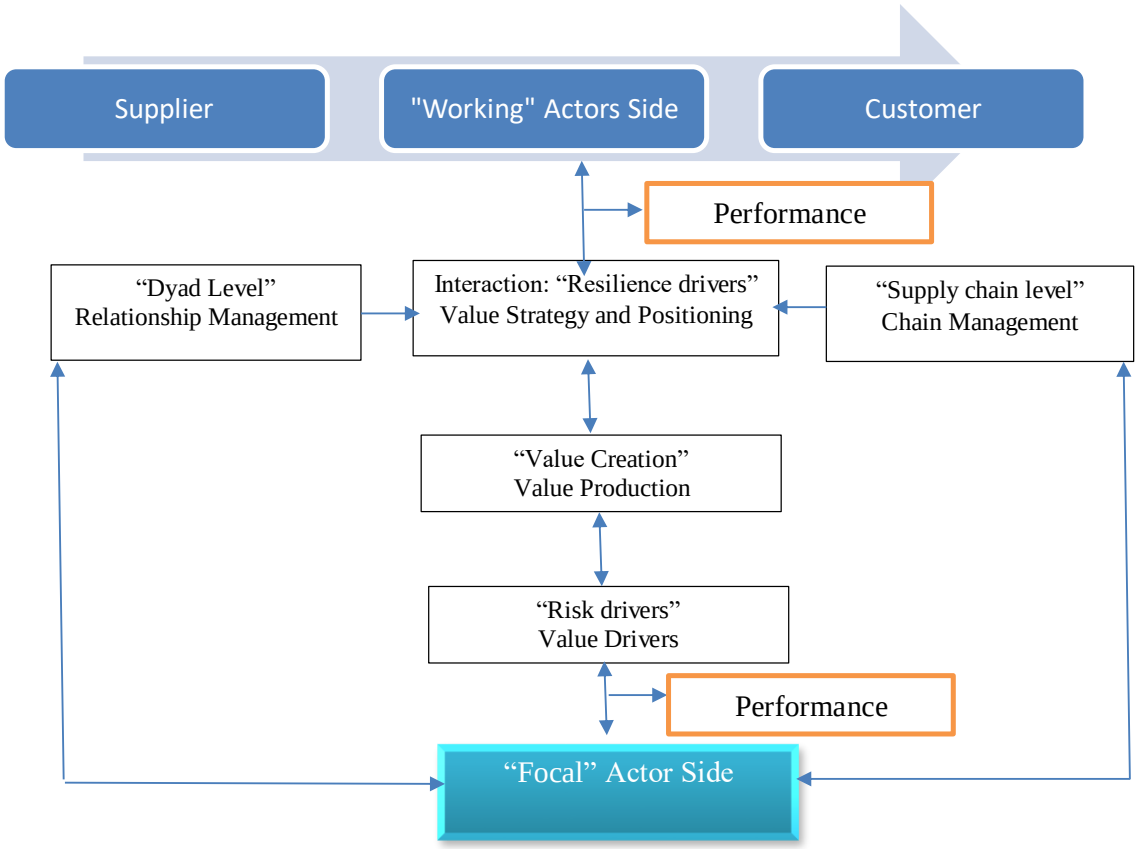

Figure 1-Conceptual framework for drivers of risk and resilience in agri-food supply chain "Value Wheel"

Conclusion and Contributions

This research raises interesting areas of study. First, the conceptual framework indicates significant opportunities for future studies. A key opportunity exists at the direct and indirect levels which are developed within the FFV supply chain context. Prior research has highlighted that dyads (e.g. Porter and Millar, 1985; Bailey and Francis, 2008; Jraisat et al., 2013) and value creation (e.g. Prahalad and Ramaswamy, 2004; Francis, 2004; Xue et al., 2011) are needed at various levels of risks and resiliencies' development and then improvement, raising questions about criteria for each level of development and improvement to support working actors (e.g. focal actor and other actors) form sustainable activities at each level. This study is qualitative in nature and the conceptual framework needs to be tested through further qualitative studies or quantitative studies involving large-scale surveys. The study considers only perspectives of local value chains and, therefore, future research should consider perspectives of export value chains.

Another potential area of study is the role of dyadic relationships (e.g. lack of ties among partners) in dyads from the perspective of both partners. When ties among value

chain members are direct about better relationship results between two actors, value creation will have a limited impact on sustainability performance. Alternatively, when such ties correspond to direct and indirect links with respect to other actors along the value chain activities, value creation will have a perfect, long-term impact on sustainability performance (e.g. Hsu et al., 2008; Amara et al, 2016). Therefore, it remains to be verified how drivers of risks and resiliencies and value creation influence sustainability development and chain actors' performance especially in the field of agri-food (e.g. Martinez and Poole, 2004; Van-Der-Vorst et al., 2007; Mikkola, 2008; Pang et al., 2012). It also remains to be examined to what extent different country contexts influence these drivers in FFV supply chains.

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How Does the Contingent Sustainability-Risk-Cost Relationship Affect the Viability of CSR? An Emerging Economy Perspective

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Abstract

Companies pursue sustainable operations for a variety of reasons, including to protect firm from reputational risk. However, sustainability may increase operational risks, disrupting supply chain performance. This contingent sustainability-risk-cost is poorly understood. To redress this gap, we conduct a multi-method study and document industry-specific risk profiles in an emerging economy setting. We interview 46 key informants in food, automotive, textile, white goods industries, and prioritize industry-specific risks by applying fuzzy analytical hierarchy process (Fuzzy AHP). Theoretically, we find that sustainability behaves as a limits-to-growth system. Sustainability initiatives engender different risk profiles across four industries for both social and environmental dimensions.

Keywords: Supply Chain Risk Management, Sustainability, Emerging Economies, Industrial Comparison, Fuzzy AHP

Introduction

Sustainability is increasingly a strategic imperative (Fawcett et al, 2015). Companies pursue sustainable operations for a variety of motivations. A small number of self-selecting companies, for instance, are true believers (Brockhaus et al, 2017). They pursue sustainability because it is the right thing to do. Investments are made regardless of cost. Most companies, by contrast, are motivated by a desire to improve corporate image or enhance operational efficiencies. That is, sustainability supports the companies' competitive strategy by immunizing a firm from reputational risk and reducing operating costs (O'Callaghan, 2007; Ganesan et al., 2009; Siegel, 2016). Although these companies desire to protect or burnish their reputations, they are much more cost conscious. They must make the business case for sustainability, demonstrating a positive return on investment.

The sustainability-risk relationship may, however, be more nuanced. Anecdotal evidence, for instance, suggests that sustainability strategies may actually increase operational risks, disrupting both supply chain and organizational performance (Hofmann et al., 2013). Consider how glitches associated with sustainability-driven branding negatively affected operations at Chipotle and Volkswagen. Chipotle Mexican Grill built its identity on the popular notion of "Food with Integrity." However, repeated supply shortages of eco-friendly inputs such as beef and pork required Chipotle to pull fast-selling products from its menu. Worse, food contamination caused E. coli and norovirus outbreaks, damaging Chipotle's reputation and leading to a 29.7% drop in same store sales. For years, Volkswagen built its identity on high-performing, highly efficient clean diesel technology. The carbon-footprint reducing technology, however, didn't actually exist. To perpetuate the clean-diesel narrative, software-driven "defeat devices" had been installed to cheat on emissions tests (Newman, 2015). Volkswagen was assessed an $18.2 billion fine. Worse, Volkswagen incurred billions more in lost sales.

These sustainability-induced behavioral and operational risks—and the subsequent operational disruptions—increase a variety of costs even as they expose the firm to a different kind of reputational risk. However, this contingent sustainability-risk-cost relationship is largely overlooked and remains poorly understood (Seuring and Müller, 2008).

This contingent sustainability-risk-cost sequence, however, is likely to have a more-pronounced adverse impact on sustainability efforts in emerging economies. zTo improve the long-term viability of sustainability initiatives in emerging markets, we elaborate theory on the sustainability-risk interaction across diverse industries. The goal: define the contingent sustainability-risk-cost relationship to help decision makers develop effective risk-management strategies, a process that begins by recognizing and prioritizing risks (Jüttner, 2005; Carter and Rogers, 2008; Zanoni and Zavanella, 2012). To do this, we pursued a multi-method research program. To gain insight into industry-specific risk profiles, we employed a Fuzzy AHP methodology with managers from the food, automotive, apparel, and white goods industries operating in Turkey, a leading emerging market. To contextualize the findings and better grasp why certain tradeoffs exist and how they are managed, we used semi-structured interviews.

Theoretical Background: The Sustainability-Risk Relationship

The extant research has long noted that sustainability and risk are related. In fact, Carter and Rogers (2008, p. 366) explicitly called sustainability "the ability of a firm to understand and manage its economic, environmental and social risks in the supply chain." Even so, scholars acknowledge that our understanding of the sustainability-risk relationship is fragmented, meager and unsatisfactory (e.g., Seuring and Muller, 2008; Gouda and Saranga 2018). Despite the paucity of empirical research on the sustainability-risk relationship, research has, alluded to three pertinent points related to our research; sustainability is a response to stakeholder priorities (Hofmann et al., 2014); sustainability may engender risks (Anderson and Anderson, 2009); risk mitigation strategies may require customization (Giannakis and Papadopoulos, 2016).

These ideas, which are embedded in the sustainability literature, are neither explored in depth nor empirically tested by the extant research. This reality calls for 1) a brief review of risks identified by the supply chain literature as well as 2) an empirical exploration that considers the nuanced bi-directional sustainability-risk relationship.

Understanding Risk Profiles and Risk Mitigation

A firm's sustainability efforts and supply chain risk are subject to influence from a combination of industry level dynamics and its institutional environment (e.g., Zsidisin and Ellram, 2003; Canzaniello et al., 2017). At the industry level, firm performance is generally determined by unique structural issues that influence the level and nature of competition (Porter, 1980; Dyer and Singh, 1998; Chen et al., 2007; Haleblian et al., 2012; Brockhaus et al., 2017). How a firm responds to these forces shapes its overall risk profile (Pratt, 1964; Thompson and Dean, 1996; Short et al., 2012; Goerlandt and Reniers, 2017). That is, firms may place different priorities on risk dimensions in reaction to characteristics unique to their industry.

On the other hand, institutional theory emphasizes homogeneity, isomorphism, and adaptive change as the three forms of pressure on firms to conform to their institutional environment. It suggests that commonly accepted policies and norms translate organizational members, their structures, and their processes into an isomorphic format (Eisenhardt, 1988). Following institutional theory, firms and their industries are assumed to converge on a shared approach, which could effectively reduce the costs of risk mitigation. Thus, when possible firms will attempt standardize their approach to risk prioritization and mitigation.

Methodology

This study employs a multi-method research design, which includes quantitative analysis and qualitative interviews. To begin to understand the sustainability-risk-cost sequence in emerging economies, we recruited 41 participants from five different Turkish food supply chains for interviews and on-site observations at 32 companies. This initial study identified five major risk categories and established the baseline for comparison as interviews were conducted in the automotive, apparel, and white goods industries. For sustainability to become mainstream practice, we must become more concerned with making sustainability practices viable in emerging economies (Evrendilek and Doygun, 2000). These industries attract significant investment, but manifest distinct industry structures (Seuring and Müller, 2008). Thus, we can expect diverse strategic priorities and unique supply chain practices. We purposefully recruited partnering-firms positioned at different points along the supply chain within each industry.

We first apply Fuzzy AHP analysis to inductively derive priorities for five dimensions of risk salient to environmental and social sustainability initiatives. We asked respondents to make qualitative evaluations of the risk dimensions and make pairwise comparisons with respect to environmental and social sustainability distinctively. Decision-making in multi-criteria problems becomes very challenging when some parameters are not in quantitative form. Analytical hierarchy process (AHP) overcomes this challenge, and offers an approach to incorporate qualitative assessment parameters, specifically for the cases where expressing preferences through exact numbers is very difficult (Chan and Kumar, 2007; Wang et al., 2012). Fuzzy AHP further extends this method by taking the fuzziness of decision-makers into account for valid cross-case comparison and consider potential uncertainty of responses (Zadeh, 1965; Deng, 1999). For each pair (e.g. behavioral versus opportunism), respondents rated their relative importance through a 9-point Likert scale ranging from equally preferred (1) to extremely preferred for the more important dimension (9). Each respondent rated all possible permutations of pair-wise comparisons, which are then used to determine a triangular fuzzy number (Saaty, 1980). Finally, each dimension's triangular fuzzy

numbers are defuzzified using CFCS (Opricovic and Tzeng, 2003). We further conducted a series of in-depth interviews (Creswell, 2007) to understand the dynamics behind how environmental and social sustainability affects each dimension of risk in the Turkish economy.

Findings

We posited that the nature and prioritization of risks for each industry is influenced by both industry and institutional forces for environmental and social dimensions of sustainability. We used weights obtained through fuzzy AHP analysis to develop industry-specific risk profiles. Table 1 displays these risk weights and rankings for both environmental and social dimensions of sustainability.

Table 1 – Weights and Rankings of Risk Dimensions Within and Across Industries

Environmental Sustainability				
	Weights			
Risk Dimension	Automotive	Food	Apparel	White Goods
Safety and Traceability Routines	0.2854	0.1981	0.1878	0.1261
Organizational Routines	0.2723	0.2263	0.3322	0.2334
Behavioural	0.2206	0.2744	0.1261	0.2391
Opportunism	0.1139	0.1992	0.1775	0.2498
Systems Design	0.1078	0.1020	0.1764	0.1517

Social Sustainability				
	Weights			
Risk Dimension	Automotive	Food	Apparel	White Goods
Safety and Traceability Routines	0,0412	0,1070	0,1435	0,1101
Organizational Routines	0,2678	0,2489	0,3260	0,1762
Behavioural	0,3271	0,2959	0,1908	0,2855
Opportunism	0,2720	0,2714	0,1638	0,2704
Systems Design	0,0919	0,0768	0,1759	0,1579

Whereas differences in weights and rankings illustrate the trade-offs idiosyncratic to each industry's competitive dynamic (Pratt, 1964; Porter, 1980; Chen et al., 2007), their commonalities support the idea that there are forces driving the four industries toward limited isomorphism (Scott and Meyer, 1982; DiMaggio and Powell, 1983; Scott, 1995). Next, we analyse each industry, highlighting distinctive characteristics of each industry's risk profile.

For the automotive industry, high-priority sustainability-driven risk dimensions are different for environmental and social dimensions. Safety and traceability, organizational routines and behavioral risk dimensions are ranked with high impact on environmental sustainability, whereas behavioral and opportunism risk dimensions are found to be very critical for social dimension. Systems design is ranked very low in both environmental and social dimensions. Managers reported that rapidly advancing

production technologies require them "to implement new technologies to survive" in an industry that "has been turned into a computer model." Organizational routines direct capital investments in advanced production technology to emphasize effective responses to "environmental pressures [that] are shrinking the market." Despite the emphasis on technology adoption, key informants stressed that "[they] do all of [their] work with people," who are tasked with ensuring environmental and quality standards. A lapse here threatens dire consequences. Hence, they use technology to control the behavior of people. Even though the company targets perfect performance, problems are generated at the time people execute the process, and thus occupational accidents are often human-induced. One reason is "save the day approach of employees", having no motivation for environmental or social priorities. The industry lacks educated employees; employees are mostly self-educated. They mentioned that technology is critical to automotive industry to prepare the companies to their evolving future, but it doesn't work without qualified employees.

In Turkish food industry, ranking of environmental and social dimensions are very similar; sustainability induces the greatest risks in the behavioral area. Specifically, a pervasive lack of awareness, knowledge, and care pertaining to sustainability permeates the food industry. Most firms have yet to widely recognize its importance. Managers pointed out that behavioral risks exacerbate organizational and opportunism risks. The low level of "awareness and knowledge" makes driving change difficult. Further, intense competition in the food industry makes profits razor-thin. As a result, investments in automation to reduce waste are often eschewed in favor of low capital investment and revenue-maximizing strategies. As one manager expressed, "I usually face [sustainability] problems with manual processes." Profit pressures also motivate opportunism as decision makers cut corners to protect profits. For example, in the cold chain, managers explained that fish that "should be disposed of" is actually "frozen again to resell." Managers in the food industry also place minimal priority on system design risks when considering environmental and social sustainability, but for the opposite reason. In contrast to the automotive industry's adoption of systems established by long-term global partners, food industry members have no incentive invest in standardized systems to improve sustainability. Characteristic of a hypercompetitive industry (Jin et al., 2017), frequent entries and exits by partners in the food supply chain created a perception among managers that "subcontracting is risky in Turkey" and requires firms to pursue flexibility over a standardized system so as to maximize their ability to work with diverse suppliers and customers.

Organization routines risk dimension is ranked with greater impact on environmental and social dimensions of sustainability in apparel industry. Turkey's apparel industry has low barriers to entry, is heavily reliant on labor and often generates hazardous waste (e.g., chemical dyes) that are loosely regulated and expensive to properly dispose. Managers thus isolate organizational routines as the most pervasive and potentially costly. Specifically, managers highlight the need for procedure-based rules to ensure that process standards are achieved. These rules must extend to worker conduct and waste disposal. Intense competition complicates the sustainability challenge because "anyone who buys a textile machine calls himself a textile manufacturer." Cost is a primary differentiator. Business survival is possible with lower costs, and global customers require low margins and fast deadlines from the emerging countries like Turkey. However, implementing social and environmental needs investment. This raises the important dilemma in apparel industry; baring environmental and social cost to be eligible as the supplier, but not allowed to reflect that revised price to customers. As a

result, emphasis on near-term survival significantly hinders Turkish apparel makers from accumulating the necessary level of experience and sophistication to steadily improve organizational routines needed to promote greater sustainability.

The Turkish white goods industry is dominated by local brands rather than global producers. Hence, competition is fierce among local brands, all of which utilize a modular and labor-reliant production process of common components, resulting in goods that offer nearly identical performance and are thus mostly differentiated by cost or branding. To compete, decision makers at Turkish white goods firms are tempted to "cut corners" when it comes to promoting sustainability. In this case, behavioral and opportunism risks comingle, exacerbating each other. For instance, employees at the retail level turn to greenwashing or they mischaracterize sustainability performance to secure sales, relying on consumers' ignorance and apathy regarding product sustainability. The tendency toward corner cutting is pervasive across the entire supply chain network. Managers thus described a need for stronger organizational routines to curb corner cutting and promote more legitimate efforts to enhance sustainability.

To summarize, whereas competitive intensity, capital intensity, and labor intensity induce tradeoffs among safety and traceability routines, opportunism, and behavioral risks, institutional forces guide the organizational routines and system design risks.

Conclusion

Our research empirically validated the nuanced view of the sustainability-risk interaction. Specifically, our research documented a contingent sustainability-risk-cost relationship, suggesting that the sustainability-risk relationship possesses the characteristics and behavior of a limits-to-growth systems archetype (Senge, 2006). Indeed, managers confirmed that sustainability initiatives cause or exacerbate a diverse set of risks, increasing the cost of operating sustainably. This reality makes it more difficult to cost-justify sustainability initiatives. The identification of distinct risk profiles provides a starting point for decision makers to understand the nature of risks their companies are likely to encounter.

By demonstrating the need for industry-specific risk mitigation strategies, we respond to Giannakis and Papadopoulos' (2016) call for research on the nature of risk mitigation at the industry level. Ultimately, companies should seek to transfer best practices within an industry rather than across industries. However, institutional factors clearly apply isomorphic influence to all industries in our study. For instance, an overall lack of emphasis on system design illustrates the combination of inadequate regulatory framework and generally export-dependent industries. Although both industry-level idiosyncrasies and economy-level institutional forces guide an industry's sustainability-risk interaction, the result is often that firms across all industries lack a holistic view on sustainability.

This study has some limitations, which offer further research opportunities in the area. First and foremost, the area of research, which integrates sustainability and risk specifically across different industrial settings, still needs to be explored deeply. A further examination of industries in different country settings would provide a rich discussion to compare the characteristics across industries as well as across different country settings.

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Dangling between sustainability and resilience supply chain practices: employing paradox theory to explore tensions

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Abstract

Drawing upon paradox theory, this paper conceptually proposes a dualism paradox framework for exploring the relationship between supply chain sustainability and resilience. Building basis from the literature which have collectively explored sustainability and resilience, we use and repurpose a dualism approach to paradox theory as a research lens for the SC context. We demonstrate the applicability of the framework to exploring the SC sustainability and resilience relationship. Our future research will test the proposed framework empirically.

Keywords: Sustainability, Resilience, Supply Chain

Introduction

Today's supply chains (SCs) are increasingly complex, dynamic and interdependent (Gunasekaran et al., 2014; Levalle & Nof, 2015). In this context, SCs must ensure that organisational effectiveness is improved (Gunasekaran et al., 2001) and function is maintained whilst also to meeting the needs of changing and ever-increasing market and stakeholders demand (Sheffi & Rice, 2005). Uncertainty and volatility increase as SCs are more dispersed geographically and diverse, covering a wide variety of products, services and communities (Xiao & Wang 2014). SC collapse has devastating impacts (Burnard et al. 2018), potentially costing lives (Tukamuhabwa et al., 2017).

SC resilience concerns the SC ability to effectively respond to, and recover from, a disruption, preferably to a better state than before (Tukamuhabwa et al., 2015). Unpredictable human and natural events, of any scale, can occur at any point and at any time, disrupting the SC (Zineb et al., 2017); causing problems for dependant business and

stakeholders. Therefore, it is ever more important that SCs develop capabilities to handle unknown threats and function in disruption scenarios. SC sustainability is central to tackling global issues such as climate change, pollution, resource consumption, and social justice, associated with production, consumption and trade. Today, stakeholders and firms concerned about environmental and social issues within the SC are driving action on SC sustainability (Mani et al., 2018). Economic sustainability, underpinning SCs actions, are increasingly dependent on social and environmental SC performance (Carter & Rogers, 2008; Ortiz-de-Mandojana et al., 2016; DesJardine et al., 2017), so sustainable SCs are now increasingly framed as an investment, rather than a business cost; important for competitive advantage, and their survival (Katiyar et al., 2018).

There are three ways of exploring sustainability and resilience as disciplines: resilience as a component of sustainability, sustainability as a component of resilience, or resilience and sustainability as separate objectives (Marchese et al. 2018). These three distinctions in the literature highlight the complexity of joining resilience and sustainability approaches. Joining has so far been unclear (Pizzol, 2015), and in the context of SCs, relatively unexplored (Fahimnia & Jabbarzadeh, 2016; Zahiri et al., 2017). Sustainability and resilience approaches are different: "sustainability prioritizes outcomes, and resilience prioritizes process" (Redman, 2014). Sustainability and resilience share complementary characteristics, however adoption can also lead to conflict, such as sustainability reducing protective redundancies for resource use efficiency gains (Levalle & Nof, 2015). Both sustainability and resilience are important for SC survival and growth, and as a result, neither approach can be ignored in favour of the other.

There is a lack of literature incorporating the relationship between SC sustainability and resilience, which highlights a significant knowledge gap in our understanding of these two issues when taken together. SC managers deal with both sustainability and resilience, and an informed understanding of how those decisions are made and what is the impact on SC performance measures are important for them to know, so that both can be effectively optimised for SC performance. However, prior to this, the relationship between sustainability and resilience requires contextualising in a means that can explore how the relationships can be described. For this purpose, paradox theory has been explored and used for its suitability for application in sustainability research, its novelty for exploring complex relationships and because it has been posited as useful in SC research (Xiao et al., 2019).

Literature Review

There are only a few research papers which have considered sustainable or environmentally sustainable (green) and resilient SC collectively, with a few others also exploring these in the context of agile and lean SC. This review will explore those highlighted connections between sustainability (including green focused) and resilience in context of SC, demonstrating the research gap.

Some of the papers exploring elements of sustainability and resilience, also explore lean and sometimes agile aspects of supply chain management, and their relationship, whilst for the sustainability component, the environmental aspect is the emphasis. Govindan et al. (2014) proposed a conceptual model for implementation of lean, green and resilient practices, in focal, upstream and downstream contexts. In looking at the relationship resilience practices had on SC sustainability, 'flexible transportation' and 'flexible sourcing' did not have a significant impact. Green practices 'ISO 14001 certification' or 'reverse logistics' also did not have a significant impact. However, resilience practices 'SC risk management', 'waste elimination' and 'cleaner production'

did have a significant impact. This research considered only a small number of practices, and were categorised into upstream, focal and downstream components. This research, although recognising the existence of conflicting practices, did not consider them as part of the research. Govindan et al. (2015) explored the simultaneous implementation of lean, resilience and green paradigms for SC competitiveness, however, integration of these techniques and identifying issues related to these techniques remains problematic. When measuring for customer satisfaction, the practices deployed for improving performance do not interfere for this performance measure. Using this approach, it was possible to validate the practices which contribute most to competitive advantage. These are just-in-time (lean), flexible transportation (resilient) and environmentally friendly packaging (green). Azevedo et al. (2013) explored how green and resilience in combination can form an "eco-silience" measure for SC. Upstream green and resilience were united, with validity confirmed through a case study, however, this index weighs the two approaches without considering implications for their trade-offs, with no detractions for conflicting practices.

Carvalho et al. (2011) explored synergies and divergences between lean, agile, resilient and green paradigms and the effect of those paradigm practices on SC attributes. Between green and resilience aspects, there were divergences in context of capacity surplus, inventory level and replenishment frequency, but synergies in the level of integration and lead time. Cabral et al., (2012) builds on this work by developing an integrated analytical process to support decision making when making appropriate lean, agile, resilient and green practices, and KPIs to be implemented in a SC with a focus on SC competitiveness. The importance of the paradigms for their impact on SC competitiveness were ranked, with the most appropriate agile, followed by lean and resilient equally, and finally green. Green is the least important, as it is seen as an inconvenience by SC decision makers, and efforts usually go to minimum necessary requirements, however, many green initiatives are done so with the intention of reducing costs. The relationship between these different approaches were otherwise not discussed, with no conclusions drawn concerning green and resilience practices.

Ruiz-Benítez et al. (2017) explores the relationship between resilience, lean and green practices, in an aerospace context for SC environmental performance, concluding that lean practices are drivers of green and resilient SC practices. Whilst Ruiz- Benítez et al., (2018) explores resilience and lean practice implication on SC sustainability performance, concluding that lean practice drive resilience practices, which overall drive sustainability performance. Most papers look at a one-dimensional view of practice to performance with sustainability and resilience, whereas exploring their practice and performance relationship collectively could provide new insight.

In recognising that research in SC sustainability and resilience is limited, Fahimnia & Jabbarzadeh (2016) conducted a trade-off analysis on how sustainability practices impacted the capacity for SCs to tolerate uncertain disruptions. With a multi-objective optimisation model, sustainability performance was assessed, and the model tested in a case study. The case study demonstrated that a SC designed to a business-as-usual sustainability scenario was unable to cope with disruptions and satisfy demand, whereas a resiliently-sustainable SC designed for disruption and business-as-usual scenario was able to meet demand at a slight increase in SC cost (Fahimnia & Jabbarzadeh, 2016). Whilst this paper explores the relationship between sustainability practice, as defined by the type of SC design adopted, and resilience performance, the findings cannot be generalised as their model needs further validation, further the model does not consider resilience practice.

Ivanov, (2017) through a simulation study, explored the interconnections between sustainability and resilience in SC. Disruption propagation and sustainability factors were analysed for creating a resilient SC which mitigated ripple effect and improved sustainability. If a disruption cannot be localised, a ripple effect occurs impacting SC performance. Sustainability factors such as sustainable sourcing enhances the ripple effect, whereas facility fortification mitigates it and improves sustainability. Storage facility reduction in downstream SC also improves sustainability but can cause the ripple effect. This paper highlights the relationship between event and outcome for both a measure of resilience and sustainability. However, this is just limited to three practices, and further practices need to be explored for broader managerial insight, particularly with resilience practices on sustainability.

Eltantawy (2016) argues that in supply management, for sustainability to be achieved, trade-offs between economic, environmental and social outcomes must be effective and ensure longevity for the firm. However, trade-offs are challenging because of tensions between divergent demands. In approaching resilience as a core component of sustainability, supply management ambidexterity, pursued through a paradox lens, is considered to describe two approaches for resilience, resisting damage from an event (exploitation) and quick recovery from that event (exploration). As the author considered resilience as a nested attribute of sustainability, the philosophical approach excludes considerations between sustainability and resilience. Supply management resilience framework for sustainable performance incorporates engineering resilience (through cultural and operational competency) and ecological resilience (through situational awareness, and access to keystone vulnerabilities). Popadopoulos et al. (2017) also considers resilience as a component of sustainability in exploring a framework which considers SC and infrastructure resilience as an important component of community and resource resilience. Using big data, it is argued that swift trust, public private partnership, and quality information sharing enable shaping SC resilience and critical infrastructure resilience.

A multi-objective decision-making model for designing a pharmaceutical SC was tested in a case study. The pharmaceutical industry is vulnerable to both internal and external disasters, and with stakeholder interest in environmental and social issues, objectives of minimising harm of disruption and to the society and environment were sought. The paper provides a series of optimisation and SC design recommendations (Zahiri et al. 2017). The approach to sustainability and resilience in SC for this paper focuses specifically on the characteristics of the SC design and the decision-making process in how to make optimisations and does not contribute in terms of practice or relationship to the research approach set out in this report, however the performance measures could be utilised.

Karutz et al. (2018), attempts to conceptually connect SSCM and RSCM through case study research in automotive SC. SSCM is prioritised over RSCM by SC managers. In their framework, connections are highlighted between SSCM and RSCM, with diversity and transparency enabling strategies of both approaches. This paper made some initial steps toward connecting SSCM and RSCM, proposing possible interconnections between objectives. However, the role of practices or strategies to performance is not yet considered and this paper requires expansion and further empirical analysis to validate and build upon their initial findings.

As highlighted in the literature review, there are several previous studies exploring interconnection between aspects of sustainability (or environmental sustainability) and resilience in SC context, but this research area is underdeveloped and the relationships

unexplored in context of how sustainability and resilience relate considering tensions and trade-offs among practices and particularly their collective impact on SC performance. Building upon the literature and to address this research gap, a framework for a sustainable-resilient SC is required.

Theory and framework development

In developing a sustainability and resilience relationship framework for SC context, their relationship was initially explored. Other literature has explored the relationship outside of SC context as a form of tension (Redman, 2014; Lizarralde et al., 2015). Conflicting interests generate tensions, and as the different goals of sustainability (outcome-oriented) and resilience (process-oriented) have conflicting interests, the tension literature is a suitable means for exploring this relationship. Lizarralde et al. (2015) highlights the nature of the tensions between sustainability and resilience (Table 1), informed from an urbanism perspective.

Table 1. Tension between sustainability and resilience (adapted from Lizarralde et al. (2015).

Area of tension	**Sustainability**	**Resilience**
Goal	Transition	Adaptation
Process	Incremental changes	Capabilities developed from learning mistakes and past events
Performance outcome	Efficiency	Redundancy
Threat rate of change	Constant degradation (environmental/social/economic)	Shock change, unknown extent and time
Agenda	Achievement	Capacity

Tensions are described as conflicts between two factors and often explored in sustainability challenges. There are four approaches to sustainability tensions, these are: win-win, trade-off, integrative and paradox (Van der Byl & Slawinksi, 2015; Brix-Asala et al., 2018). The win-win approach attempts to reconcile either the social and/or environmental performance with economic performance; trade-off accepts the goals as being in conflict, requiring that a choice is made; integrative approach attempts to ensure that all three approaches to sustainability are equally balanced; whilst paradox seeks to understand the nature of tensions along with how actors work with them, enabling the ability to view and evaluate complex sustainability issues and embrace them (Van der Byl & Slawinksi, 2015; Brix-Asala et al., 2018). A paradox tension can be derived as having three main core components (Brix-Asala et al., 2018: 426):

1. Actors embrace the tensions between goals rather than resisting or avoiding tensions;
2. Actors attend to competing and interrelated demands simultaneously;
3. Paradoxes are dynamic demands which can be managed only by continuous cyclical responses in the form of practices.

Currently, research utilising paradox has been rarely applied in SSCM, despite its relevance (Matthews et al., 2016). Whilst most researchers utilise an instrumental perspective to explore conflict, Xiao et al. (2019) utilises a paradox perspective. Due to both complementing and contradicting components of the sustainability and resilience relationship, paradox theory is appropriate. A tension can be viewed in multiple ways, however, seeking to treat the issue as a paradox will enable solutions to these tensions beyond instrumental confines (Xiao et al., 2019). There are three kinds of paradox which

are highlighted in the literature, these are paradox (including duality), dilemma and dialectic (Smith & Lewis, 2011):

- Paradox consists of "contradictory yet interrelated elements that exist simultaneously and persist over time; such elements seem logical when considered in isolation, but irrational, inconsistent and absurd when juxtaposed".
    - Dualities, two opposites which exist within a unified whole, have an internal boundary which highlights opposing elements, the external boundary demonstrates a synergy between them.
- Dilemmas are competing choices with advantages and disadvantages. This can become paradoxical when those choices contradict and interrelate in a way that choices between them are short lived and their tension resultantly resurfaces.
- Dialectic contradictions (of two propositions) are resolved through integration, which overtime will gain new opposition. This can become a paradox when elements are contradictory and interrelated. Combining elements promotes similarities, neglecting differences, resulting in temporary integration. The new formulation and opposition therefore maintain the core characteristics of the original contradictory elements.

The dilemma and dualism approaches to paradox are potentially particularly appropriate means of viewing the issues, with literature sought to explore those types of paradoxical relationships. Papers discussing practice-performance relationships in paradox context were explored. A paper exploring dualistic paradox in management science (Fajoun, 2010) offered a relevant framework in which sustainable and resilience SC management relationship with performance can be applied.

Farjoun (2010) explored stability and change as a duality paradox. Stability and change are interrelated, complementry practice and performance process and outcomes, whilst simultaneously capable of practice-performance contradictions. This relationship is highlighted in their duality framework which classifies stability and change relationships. This relationship highlights that stability, existing in opposition with change, matches the organisational paradox of exploitation vs. exploration, whereby firms utilise both to enable success, despite strategies also existing in tension (Andriopoulous & Lewis, 2009). Stability and change in these circumstances of exploitation/exploration exhibit different practices and outcomes, which do not complement. However, there are circumstances when stability and change are dependent on each other. Change can enable stability through managing variables which ensure that the performance goal is static around changing circumstances, whilst stability can enable change through provision of systems that are designed to manage elements of unpredictability or to encourage innovation (Farjoun, 2010).

Through the exploration of existing application of paradox theory on practice and performance relationships, a framework has been borrowed and applied to SC management in the context of sustainability and resilience approaches and their relationship to SC performance. As highlighted in other research exploring sustainability and resilience (Redman, 2014; Lizarralde et al., 2015; Wilson, 2018), the relationship between sustainability and resilience exhibits synergistic and conflicting components, demonstrating tension across disciplines. Previous research utilises an instrumental perspective to explore tensions (Xiao et al., 2019), however, paradox is increasingly seen as a means, suitable to sustainability related issues, which can be used to manage tensions. Existing literature has informed how to frame the paradox relationship between sustainability and resilience. Smith & Lewis (2011) identified three kinds of paradox in their literature: dualism, dilemma and dialectic. A dualism framework from operations

management was located (Farjoun, 2010) and borrowed for SC context, replacing stability and change dualism with sustainability and resilience. Stability and change organisational practices are a dualistic paradox (Farjoun, 2010). Dualism explains a paradox as two components, which separately are conflicting, yet must exist together as they are co-dependent (Smith & Lewis, 2011). Sustainability and resilience align with the dualism of stability and change as sustainability and resilience share similar complementing and conflicting components. Whilst Farjoun (2010) explores stability and change as practices of exploitation (stability enabling stability) and exploration (change enabling change) respectively, and exploitation and exploration approaches can be applied to resilience through resistance (exploitation) or adaption (exploration) (Eltantawy, 2016), this approach does not accurately describe the relationship between sustainability and resilience. Sustainability and resilience are best categorised in terms of success requirements: sustainability as structured (standards, quotas, KPIs) and resilience as adaptive (redundancy, flexibility, agility) (Redman, 2014; Lizarralde et al., 2015). Like exploitation and exploration, structured improvement and adaptive improvement reflect working with known (exploitation, structured improvement) and unknown (exploration, adaptive improvement) outcomes.

Whilst structured and adaptive processes are placed in opposition, the dualism aspect of this paradox emerges when considering how complementing approaches also apply. Resilience practices can enable sustainability (integration, communication), and sustainability practices can enable resilience (improving reputation, sustainability risk assessment). Using Farjoun's (2010) framework as a template, these relationships are structured into four quadrants (Figure 1), which show oppositional elements (Q1 and Q4) and complementary elements (Q2 and Q3). Quadrants are summarised below.

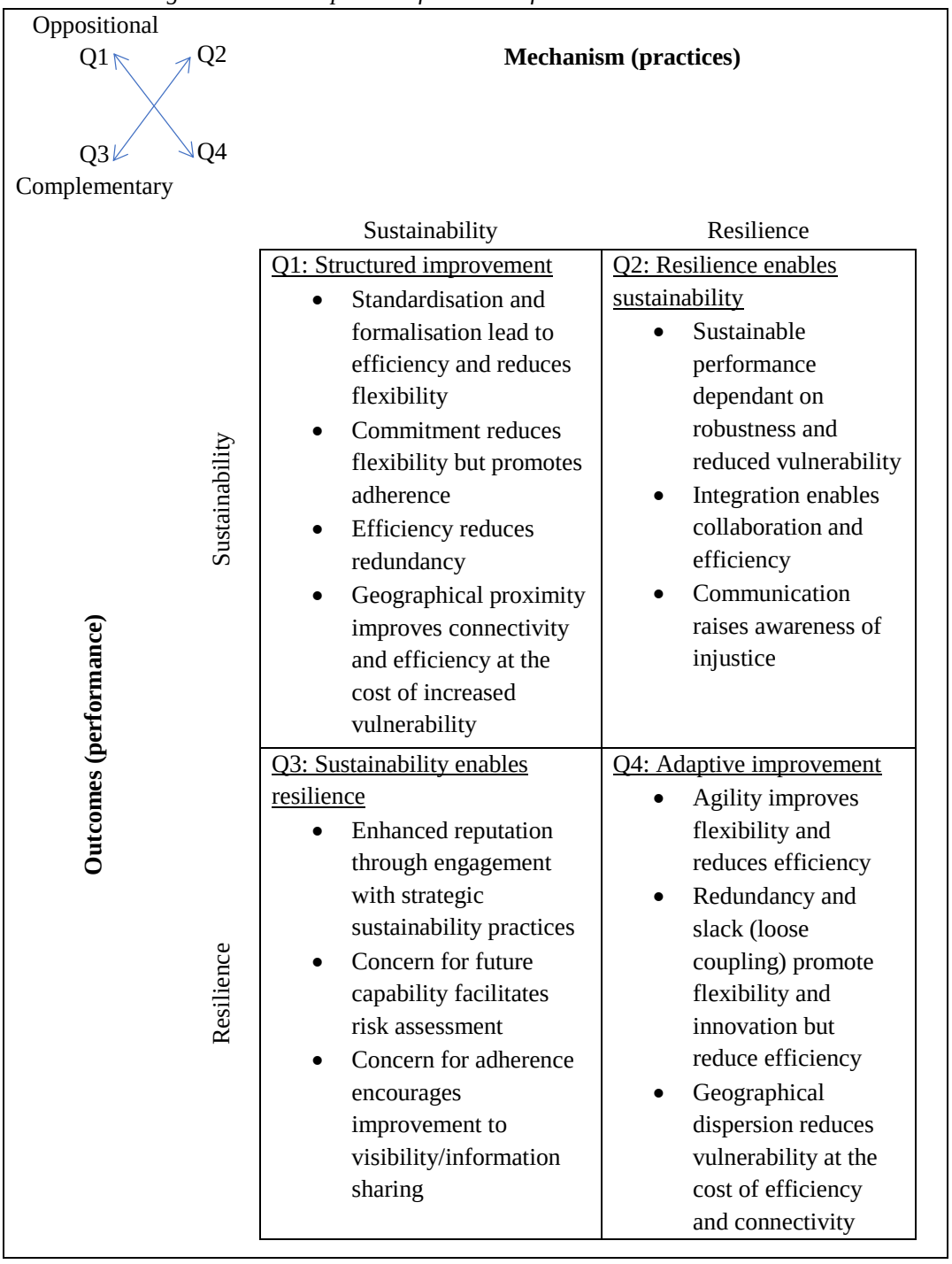
Quadrant one, structured improvement: This focuses on how sustainability approaches can lead to sustainability outcomes, with attention focused around efficiency measures, commitment and maintaining standards.

Quadrant two, resilience enables sustainability: This quadrant focuses on how resilience approaches contributes to sustainability outcomes in process-oriented considerations, with the role of longevity in sustainability, integrating systems and communication highlights a core component of this section.

Quadrant three, sustainability enables resilience: This quadrant focuses on how sustainability approaches contributes to resilience outcomes in outcome-oriented considerations that have consequences for reputation, risk assessment and visibility.

Quadrant four, adaptive improvement: This focuses on how resilience approaches lead to resilience outcomes, with attention on agility, flexibility and redundancy.

Figure 1. Dualism paradox framework for sustainable-resilient SC.



Next steps

To develop this framework further and explore its potential contribution empirically SC managers will be interviewed to thematically understanding their experiences and knowledge with regards to SC sustainability and resilience practice implementation. This will be followed by quantitative analysis exploring practice implementation consequences.

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The application of predictive analytics in supply chain risk management – a literature review

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Abstract

In recent years, various trends like outsourcing strategies have changed the way supply chains are managed and have increased the attention towards preventing supply chain disruptions. Therefore, supply chain risk management (SCRM) has gained growing awareness. In the literature, various authors call for further investigating the development of early warning risk management systems. To achieve this, predictive analytics can help organizations in deciding on adequate precautionary actions to minimize potential risks incurred. Therefore, the objective of this paper is to analyse the state of the art in supply chain and operations management regarding the application of predictive analytics in SCRM.

Keywords: Supply chain risk management, predictive analytics, literature review

Introduction

In todays globalized economy, sustainable success of businesses not only depends on successfully managing within the company's boundaries—in fact, managing risks evolving from the supply chain seems crucial. Companies need to be aware of potential risks and be able to consider them in managerial decision-making. Thus, risk management in such complex environment requires continuous and dynamic approaches. Predictive analytics can help organizations in deciding on adequate precautionary actions to minimize potential risks incurred. Hence, this technology has the potential to refine SCRM as it supports organizations by informing them about possible future scenarios. Therefore, the objective of this paper is to analyse literature that aims to merge the two scientific domains predictive analytics and SCRM. The following research question can be derived for the present work: *What is the state of the art regarding the application of predictive analytics in supply chain risk management?* The rest of the paper is structured as follows. First, theoretical foundations of SCRM and predictive analytics are discussed shortly. The research methodology applied is then displayed and executed. Finally, the results are presented and discussed in order to derive prospective research directions.

Key concepts

Risk has been discussed extensively in the literature in a wide variety of domains such as insurance, engineering, and also finance and economics within the last 30-40 years (Romeike, 2018). The management of risk is an integral part of ensuring sustainable success of companies in a long-term perspective (Diederichs, 2013). Managing supply chain risks (SCR) has become more and more relevant in today´s complex and global supply networks (Wu, Blackhurst and Chidambaram, 2006). To date, no consensus has been reached in the scientific community on the definition of SCR (Ho *et al.*, 2015). Heckmann, Comes and Nickel (2015) devote an article to filling the scientific gap by devising a suitable definition as well as describing essential features of SCR. This definition can be applied across all domains and covers both the consideration of potential sources of risk as well as their impact. Therefore, SCR in the context of this research can be defined as follows:

> *"Supply Chain Risk refers to uncertainty and severity of the events and consequences of any activity that adversely influence any part of a supply chain leading to potential loss in terms of its target values."* (Heckmann, Comes and Nickel, 2015)

Regarding a classification scheme of SCRs, there is also no consensus between various researchers. Ho et al. (2015) analyze existing classification schemes in their literature review and on this basis derive a comprehensive classification for SCRs as illustrated in Figure 1, generally distinguishing between macro and micro risks.

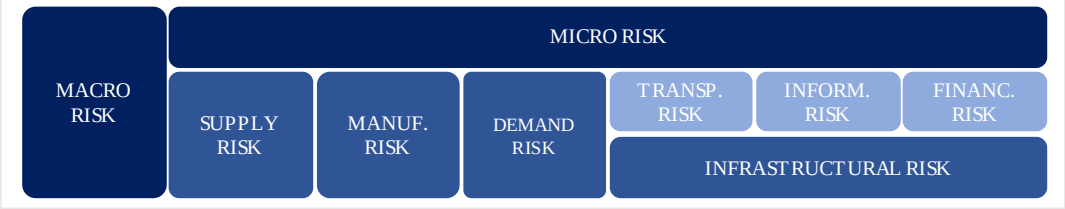

Figure 1: Supply chain risk classification [own illustration according to (Ho et al., 2015)]

Macro risks refer to those SCRs that reflect undesirable and relatively rare external events that could have a negative impact on the object under investigation. They can be further divided into natural risks (e.g., earthquakes) and man-made risks (e.g., wars). In contrast, micro-risks are those SCRs that are caused either by a company's internal activities or by relationships with upstream and/or downstream companies in the supply chain. Furthermore, micro risks can be subclassified into four categories which are supply risks, manufacturing risks, demand risks and infrastructural risks. While supply risks refer to adverse events in conjunction with downstream partners, demand risks relate to undesirable events associated with the upstream companies in the corresponding supply chain. In addition, manufacturing risks are those unintended events within the company's boundaries that relate directly to internal capabilities regarding the value creation process itself, its quality and its profitability. In order to ensure the sustainable functioning of a supply chain, it is also necessary to consider infrastructural risks. Managing these requires focusing on three subcategories: Information risks, transportation risks and financial risks. To each of these categories different risk factors can be assigned (Fan and Stevenson, 2018; Ho *et al.*, 2015; Rao and Goldsby, 2009; Zsidisin and Henke, 2019).

The discipline of SCRM is a relatively new research field and arose from the need to ensure business continuity in the presence of SCRs. The risk management framework, which has been adopted for managing SCR by many researchers, consists of four central phases: Risk identification, risk assessment, risk treatment and risk monitoring (Fiege,

2006; Gleißner, 2011). The identification of potential risks constitutes the basis of the risk management process (Romeike, 2018). Thereupon, the identified risks are quantified and assessed in risk assessment (Fiege, 2006). This assessment is normally conducted according to two dimensions: The probability of occurrence and the potential impact of the considered risks (Diederichs, 2013; Fiege, 2006; Gleißner, 2011; Romeike, 2018). In addition, in the context of risk assessment it is also important to take into account the phenomenon of risk accumulation arising from existing dependencies between risks (Haimes, 2009). Once the risks have been assessed companies should, after careful consideration by management, identify the resources required to manage the it. Therefore, the objective of risk treatment is to keep the overall risk to which a company is exposed in an acceptable range (Pfohl, Gallus and Köhler, 2008). The fourth and final phase of the risk management process is risk monitoring. Risk monitoring verifies the effectiveness of the measures adopted as part of risk treatment. Target-actual comparisons are conducted to determine whether the company is operating within its individually defined risk limit (Reichling, 2003).

Over the last decades, digital technologies enabled a plethora of data and information being captured, analysed, shared and stored within different application areas (Choi, Wallace and Wang, 2018; Tiwari, Wee and Daryanto, 2018). Both researchers and practitioners agree that, by collecting and analysing this huge amount of data, also referred to as "big data", essential improvements can be obtained, especially in the context of supply chain and operations management (Addo-Tenkorang and Helo, 2016). According to Tsai et al. (2015) , business analytics illustrates the utilization of analytical techniques applied to a vast amount of data in order to create and extract valuable knowledge for data-driven decision making. Business analytics can generally be subdivided into the following three categories: Diagnostic Analytics, Predictive Analytics and Prescriptive Analytics (Ereth and Kemper, 2016). In the present work, the focus is on predictive analytics. Predictive analytics can be defined as the systematic analytical process of revealing meaningful patterns and underlying relationships of variables to turn data into strategic information and thereby improve decision-making (Abbott, 2014; Bose, 2009; Dinov, 2018). Though, it is important to mention that no statistical algorithm can predict future developments with hundred percent certainty. Over the past years, various methods for predictive analytics have been developed in order to, as the name already suggests, predict future outcomes built upon historical data (Gandomi and Haider, 2015). Lu (2017) distinguishes between offering numerical and categorical predictions. While the most common predictive analytics method for making numerical predictions are regression analyses, categorical predictions are mostly based on classification approaches (Abbott, 2014; Kuhn and Johnson, 2016). Regression analysis is a statistical technique used to model the relationship between dependent and independent variables. Build upon this relationship, predictions of unknown target variables are generated based on known predictors (independent variable). Regression analyses are the most widely used method for predictive modelling (Montgomery, Peck and Vining, 2012). Classification identifies which category a new observation belongs to grounded on given information from a training data set. Classification is counted as a supervised learning technique. Supervised learning means creating predictive models based on existing datasets. These so-called training datasets already contain the results that are to be predicted. Common classification algorithms are decision trees, Bayesian classification, support vector machines (SVM) or artificial neural networks (ANN) (Abbott, 2014; Eckerson, 2007; Lu, 2017; Rehman *et al.*, 2016).

Research methodology

In order to answer the defined research question, a structured literature review is carried out. Structured literature reviews usually differ from a more narrative review in their methodical concept, establishing an in-depth description of the stages taken to select, examine and analyse relevant sources with the objective of minimizing biases and increasing transparency. The scientific approach of a structured literature review is adopted from Denyer and Tranfield and distinguishes four stages (Denyer and Tranfield, 2009). Each stage contains, according to the authors, more detailed specifications, which should be carried out in order to meet the requirements of the review (Denyer and Tranfield, 2009). Figure 2 summarizes the proposed methodology. This literature review provides an informative overview and focuses on the evaluation of the thoroughly selected literature.

Figure 2: Stages of a systematic literature review (Denyer and Tranfield, 2009)

Stage I has been completed already by phrasing the research question. The present sections include both stage II and stage III by subdividing them into five steps. First, the search terms are defined and relevant databases as well as further criteria of the search queries are determined. Thereupon, evaluation criteria for the selection of relevant studies are defined. The next step describes the process of searching the databases. Furthermore, an additional search based on citation reviews and within additional search engines is conducted. The section concludes by providing an overview of relevant literature. The last section of the paper summarises the results (Stage IV).

Definition of search terms and databases

Today, applying search queries in online databases is the prevailing method of identifying relevant literature aiming at collecting, structuring and synthesizing existing knowledge. Table 1 shows the keywords applied in the database search queries. The following major online databases were considered: Business Source Premier, EmeraldInsight, ScienceDirect, Taylor & Francis and Wiley. We used a combination of terms related to both research fields connected through an "AND"-operator (e.g., "predictive analytics" AND "supply chain risk management").

Table 1: Considered search terms of the structured literature review

PREDICTIVE ANALYTICS	SUPPLY CHAIN RISK MANAGEMENT
PREDICTIVE ANALYTICS	*SUPPLY CHAIN RISK*
ADVANCED ANALYTICS	*SUPPLY RISK*
PREDICTIVE MODELING	*SUPPLY NETWORK RISK*
PREDICTIVE DATA MINING	

Definition of evaluation criteria for study selection
The evaluation of relevant literature in the declared databases took place in February 2019. Studies, which were published in another language than English, were not included. No explicit starting point of the structured literature review has been chosen. Furthermore, based on the research question defined, the abstracts needed to show that the investigations apply methods from predictive analytics in SCRM as objective of the research. In some cases, the abstract did not clarify if the paper fulfilled these criteria. Those publications were kept for further analysis.

Search in databases
During the search process in distinct databases, publications must correspond to the defined evaluation criteria above while reading the abstract (1st check). Thereafter, the chosen publications have been examined within a deeper analysis to check if they match the mentioned criteria defined above (2nd check).

Additional searches based on citation review / additional search engines
To also consider articles published in non-scientific magazines or lower-ranked journals, search queries using the Google search engine have been performed. Furthermore, keyword searches in databases can be misleading because keywords are not used consistently across publications (Lecy and Beatty, 2012). Therefore, snowballing is applied to effectively expand the relevant literature for this review. Snowballing refers to using the reference list of a paper or the citations to identify additional papers. The evaluation criteria mentioned were also applied to the results of this additional search.

Screening and overview of relevant publications
In summary, by scanning the documents in line with the defined evaluation criteria, the search queries resulted in 24 articles (1st check). In the next step, an in-depth examination of the remaining papers was carried out. As a result, eight articles proved to have limited relevance in relation to the objective of the study. Thus, the final sample, after removing duplicates, consists of 16 articles. By the application of snowball sampling four more articles could be added, increasing the total number of publications to 20. The annual distribution of publications in the period from 2003 until 2018 is shown in Figure 3. In 2003, Bruzzone and Orsoni (2003) published the first article implementing predictive analytics in SCRM. With one exception in 2008, the remaining publications are limited to the period from 2010 to 2018. In the following section, the results of the literature review will be discussed in more detail.

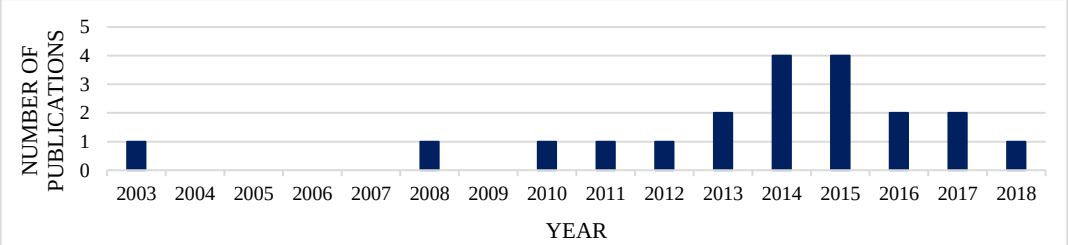

Figure 3: Distribution of publications per year across the period studied

Reporting
The studies examined can be classified according to the framework by Ho et al. (2015) . Seven of the twenty studies did not provide any information about which risk categories are examined. The remaining 13 publications include the investigation of micro risks,

four also examine macro risks. Regarding the further subdivision of micro-risks, it can be stated that ten studies include the consideration of infrastructural risk, seven studies consider supply risk, four studies manufacturing risk, and another four studies demand risk. A closer look at the ten publications that consider infrastructural risk reveals that seven publications examine transport risk, five studies information risk, and one study financial risk. Figure 4 illustrates this evaluation.

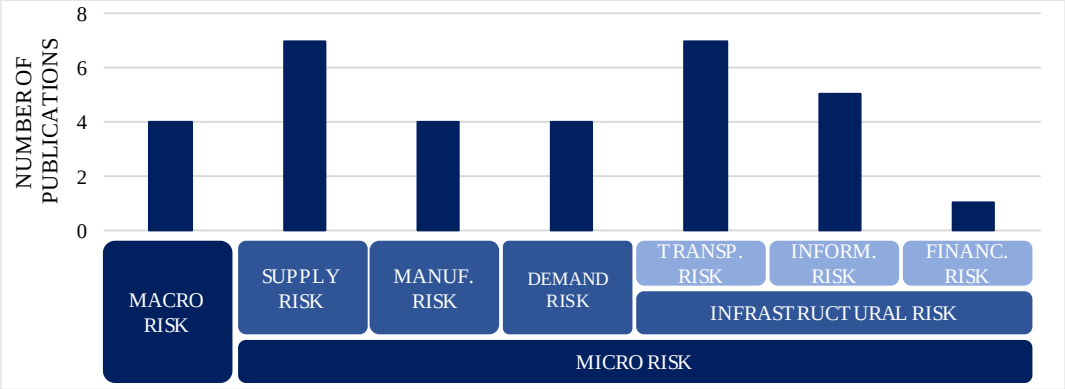

Figure 4: Distribution of publications according to supply chain risk categories considered

By analyzing the screened literature, it can be concluded that the application of predictive analytics is almost exclusively limited to risk assessment. Only one article focusses on the preceding phase of risk identification (Zage, Glass and Colbaugh, 2013). Within risk assessment either the probability of occurrence, the potential impact or the interdependencies between different risk factors is predicted (dependent variable). Ten studies focus exclusively on the prediction of the probability of occurrence of specific risk factors, four further studies focus on the potential impact. Two studies combine these parameters and try to predict both the probability of occurrence and the potential impact. One study is confined to the investigation of the potential impact in combination with existing interdependencies between individual risk factors. Moreover, two investigations consider all three parameters mentioned. To enable these predictions, independent variables are analyzed ("predictors"). Generally, the definition and discussion of these variables is often very limited or completely missing. This may be related to the fact that the quantification of risk using corresponding indicators has been named a major challenge within SCRM in the literature within the last years (Atwater *et al.*, 2014; Heckmann, 2015; Rao and Goldsby, 2009; Tang and Nurmaya Musa, 2011). Table 2 provides an overview of the various dependent variables predicted as well as the number of independent variables on which the prediction is based.

Table 2: Results of the structure literature review regarding the predicted variable(s)

Publications	**Number of independent variables**	**Dependent variables**		
		Probability of occurrence	Potential impact	Interde-pendencies
(Atwater *et al.*, 2014)	46	✓		
(Baroud, Francis and Barker, 2013)	42	✓		
(Bruzzone and Orsoni, 2003)	5		✓	
(Cao and Zhang, 2016)	16	✓		
(Chen, Xia and Wang, 2010)	-		✓	

(Emmenegger, Laurenzi and Thönssen, 2012)	-	✓		
(Garvey, Carnovale and Yeniyurt, 2015)	12		✓	
(He *et al.*, 2014)	-	✓	✓	
(Jamshidi *et al.*, 2018)	14	✓	✓	✓
(Jiang and Chen, 2014)	14	✓	✓	
(Kumar Sharma and Sharma, 2015)	23	✓		
(Kumar, Narahari and Wright, 2014)	-	✓		
(Shang, Dunson and Song, 2015)	8	✓		
(Sharma and Routroy, 2016)	14		✓	✓
(Silva *et al.*, 2017)	-	✓		
(Teuteberg, 2008)	-	✓	✓	✓
(Wu, Chen and Tsau, 2017)	19	✓		
(Ye, Xiao and Zhu, 2015)	-	✓		
(Zhao and Yu, 2011)	-		✓	

In addition to the risk assessment phase, other process steps of SCRM are considered in some articles, in order to provide a comprehensive process model for the application of predictive analytics in SCRM. While Chen, Xia and Wang (2010), Wu, Chen and Tsau (2017) and Zhao and Yu (2011) additionally proposed strategies within risk treatment, Ye, Xiao and Zhu (2015) also considered the preceding risk identification phase. Emmenegger et al. (2012) and He et al. (2014) even broaden these considerations and include the complete SCRM process as described in the previous section. Nevertheless, based on the analyzed studies, it can be said that there is no harmonized approach in the literature of how to implement predictive analytics into SCRM. Only six of the articles provide further details by depicting a process model on which their investigations are based (Atwater *et al.*, 2014; Emmenegger, Laurenzi and Thönssen, 2012; He *et al.*, 2014; Jamshidi *et al*. 2018; Ye, Xiao and Zhu, 2015, Zhao and Yu, 2011). However, out of these six publications only Emmenegger, Laurenzi and Thönssen (2012) and He et al. (2014) present a holistic process model that considers all phases of the risk management process presented.

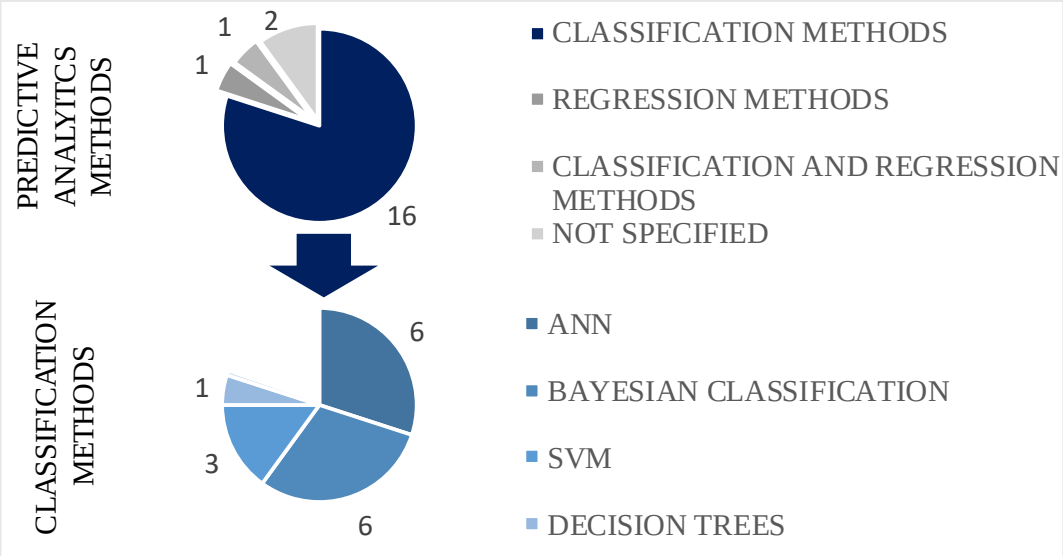

Figure 5: Distribution of publications according the predictive analytics / classification methods applied

Furthermore, a distinction can be made regarding the predictive analytics method applied. As already mentioned, in predictive analytics regression- and classification-methods can be distinguished. 16 of the publications examined adopt classification methods. Only one publication implements exclusively regression analysis (Atwater *et al.*, 2014). Furthermore, one paper combines both methods (Kumar, Narahari and Wright, 2014). As already stated, classification-methods identify which category a new observation belongs to, based on given information from a training dataset. Based on our literature analysis it can be stated that for predictive analyses of SCR often Bayesian classification (six publications) as well as ANN (six publications) are applied. SVM is used in three publications. One publication bases its prediction on the application of decision trees. Figure 5 shows both the general breakdown of the screened literature with regard to the predictive analytics method applied and the further proportional subdivision of classification methods.

Conclusion

This paper presents a structured literature review on the application of predictive analytics in SCRM. In general, it can be noted that there is not an extensive body of literature in this scientific field yet. This may be related to the fact that the quantification of risk factors using corresponding risk indicators has often been referred to as a major challenge of SCRM in literature within the last years (Atwater *et al.*, 2014; Heckmann, 2015; Rao and Goldsby, 2009; Tang and Nurmaya Musa, 2011). Nevertheless, our work has provided several insights into the topic of predictive analytics in SCRM. It was found that there has been a focus on both transportation risk and supply risk even if these were usually not considered exclusively in the different investigations. Furthermore, predictive analytics was almost solely applied in the risk assessment phase to either predict the probability of occurrence (74%), the potential impact (47%) or the interdependencies (16%) between different risk factors. For potential applications of predictive analytics in risk identification, risk treatment and risk monitoring additional research may be required. Regarding the independent variables on which the predictions are based it can be noted that there are major variations both in terms of the number and in terms of the object of quantification even within the same risk category. Therefore, further research is also required in this scientific area. Regarding the predictive analytics methods applied, 80 percent of the papers examined adopt classification approaches. The application of ANN and Bayesian classification is in the focus. Finally, it should be noted that within the screened literature a framework for the adoption of predictive analytics in SCRM is only provided in two cases. However, these do not cover the entire risk management process. For this reason, the need for further research can also be referred to here.

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A network analysis of stakeholders at seaports: a case study of Hamburg

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Abstract

A seaport is an essential central place of economic and cultural interchange with complex stakeholder structure. The stakeholders at seaports interact with each other using different communication means and devices. This research is using an interview study to analyse the stakeholders' network at the Port of Hamburg along with the cooperation aspects related to risk management. The results indicate that there is no central stakeholder who coordinates the risk management activities. This work shows the potential cooperation has on the risk management process. Furthermore, this research will support the development of a conceptual framework for cooperative risk management in seaports.

Keywords: Network analysis, Risk management, Seaport

Introduction

More than 80% of global trading volume is transported by sea, making seaborne transport the most important transportation mode (UNCTAD, 2015). Seaports are essential logistics hubs, where different operations take place: the seaside, for loading and unloading vessels; the storage area, for storing and handling the different loads; and the landside, for distributing and collecting the freight by using several complementary transportation modes (Nagi et al. 2017). Seaports stakeholders interact with each other in different scenarios, with each seaport having a different network structure. These network structures reflect the complex operations that are carried out at seaports.

Seaports have been evolved in immediate proximity to residential areas exposing the population to various risk categories. For this reason, cooperative risk management can play an important role to efficiently mitigate different risk sources such as natural disasters, oil spills and explosion of dangerous goods at seaports. This paper focuses on analysing the network of stakeholders at the Port of Hamburg (Germany) with a particular

view on the field of risk management. The paper aims to analyse the network in order to understand the communication intensity, means and cooperation aspects related to risk management in the seaport. For this purpose, this work addresses two research questions:

(i) Which stakeholders exist in a seaport system ?

(ii) How do seaport stakeholders interact with each with respect to their risk management activities?

The rest of this paper is structured as follows. In a background section, an overview of seaports and main aspects of risk management and network structure are presented. Thereafter, the methodology selected to address the research questions is described. The results and analysis follow subsequently. The paper closes with a short conclusion and outlook for future research.

Background

This section delivers an overview of seaports in general and the relevant research areas combined in this paper: risk management and network structure. Relevant aspects, functions, and processes are briefly elaborated which serve as a theoretical foundation for the network analysis of stakeholders in seaports.

Seaports

Seaports have a complicated structure with different categories of stakeholders inside and outside the port. As an interface linking overland transportation and sea, seaports provide an integrated platform serving as a backbone for different operations and international trade, and as a key enabler for the economic growth of the hinterland (UNCTAD, 2015). Seaports need to carefully handle and process ships along with the different transhipment operations effectively and efficiently (Da Cruz et al., 2013).

Seaports play an essential role in the sector of exports, imports, transportations and travel; and therefore an important element of economic growth (Yoo, 2005). Transport integration is the core function of seaports, but at the same time, a seaport is an important source of employment as well as a powerful factor in national and regional development. Different cargo categories are processed by seaports, such as bulk, break bulk and liquids.

The different processes that occur at seaports including handling, transportation and storing require the involvement of numerous actors (Nagi et al., 2017). The stakeholders at seaports can be categorized into internal stakeholders such as port authorities, shipping companies and port operators as well as external stakeholders such as federal, state and local government (Notteboom and Winkelmans, 2002). The high number of actors increases the network complexity with the associated communication means. These communication means, such as radio devices and online platforms are essential to handle various sources of risks.

Risk management

A standard definition of the term risk in the discipline of management studies does not exist (Henschel, 2008). Damodaran (2007) defines risk as a “higher probability event where there is enough information to assess both the probability and the consequences” whereas Aven and Renn (2009) define risk as a consequence in a certain setting where the consequences are uncertain and might have considerable impacts on humans.

Olsson (2007) distinguish between risk and uncertainty based on the level of event probability. Uncertainty considers only an event and its probability is completely unknown. With risk, a sense of the relative level of event probability can be achieved.

The definition of risk management in this research is adapted from Norrman and Lindroth (2004) definition of supply chain risk management (SCRM). Risk management in seaports is defined as the cooperation with partners within the network of seaport by applying risk management process tools to deal with risks and uncertainties that might have considerable impacts on the economy, the environment and/or the health and safety of people.

ISO (31000:2018) presents the risk management process that should take place within the risk management context of an organization. According to this standard, the risk management process should be integrated with management strategies, be embedded in the corporate culture, and be suitable for the business processes of the organization. The consultation and communication with external and internal stakeholders should take place at every phase of the risk management process in order to create the context for the identification, analysis, evaluation, management and monitoring of risks. These stakeholders, especially at seaports, form a network with complex relationships and activities..

Network structure

The network structure presents the number of actors, the relationships between them, and the heterogeneity and relative characteristics of their relationships (Afuah, 2013). Network analysis aims at examining relational systems in which actors exist and can determine how the structure of relationships affect behaviours (Rowley, 1997).

The core set of actors are located based on their prominent position in the studied system. Each actor is requested to indicate other actors who are also significant in the system (Burt 1980). One of the serious challenges that many network researchers face is the foundation of appropriate measures of the network structure such as network cohesiveness and centrality (Seidman, 1983; Rowley, 1997).

Network cohesiveness expresses how “tightly-knitted” and “loosely-knitted” networks are (Seidman, 1983). Centrality refers to the position of an actor in the network relative to the others. There are three types of centrality discussed in the social network literature. These are “degree”, “closeness” and “betweenness” centrality. The degree centrality defines the centrality of an actor by the number of connections an actor has with other actors in the network. Closeness centrality represents the actor ability to access all other actors in the network independently. Betweenness centrality considers as well access to other actors based on the existence of an intermediary actor that is located between other actors in the network. This can be represented as the level of control an intermediary actor has over the access of other actors to different regions of the network (Rowley, 1997).

Concerning the development of knowledge networks, two categories can be distinguished. First, intentional knowledge networks, which are built up from scratch. Second, emergent knowledge networks exist already but should be refined in order to be highly productive (Seufert et al., 2004). The structure of knowledge network should be considered dynamically since knowledge is continuously updated and transferred.

In the case of seaports, the network of stakeholders comprises different clusters with each representing a unit of analysis. Examples include authorities, shipping companies and terminal operators. A problem, which represents the event of risk, can be decomposed

into sub-problems with each sub-problem being resolved by a specific actor. The cooperation among the actors is necessary to implement the required strategy to prevent the occurrence of certain risk sources or mitigate the risk's consequences.

Methodology

This section presents the methodology of the paper that is based on the seaport of Hamburg as the main case study.

This research is using an explorative interview study within a single case study approach with multiple units of analysis in order to analyse the stakeholder network of at the Port of Hamburg along with the cooperation aspects related to the risk management activities.

Exploration studies might not have any propositions, but the research question can be explored using experiments, survey, interviews, or other research methods. Such studies should have a clear purpose and the person who is carrying out this explorative study should state this purpose along with criteria that will judge the success of the study (Yin, 2003).

A Single case study can represent a major contribution to theory and knowledge building. A rationale for a single case study is the representative or typical case (Yin, 2003). The case study of the Port of Hamburg can capture the different conditions and circumstances of the daily operations of a seaport. An embedded design of the case study involving multiple units of analysis is chosen in the Port of Hamburg since each stakeholder category represents a unit of analysis. A semi-structured interview study is used to explore the structure and interactions of stakeholders at the seaport.

Coding is an important approach to analyse and organise textual data. Data analysis is a challenging and crucial aspect of qualitative research. The coding process allows the researcher to connect and communicate with the data in order to generate explanations, develop clusters or generate a theory that is grounded in the data (Basit, 2003).

The 15 interviews were carried out with different stakeholder's categories such as authorities, terminal operators and shipping companies, with an average duration of one hour per interview. These interviews were coded using the software MaxQDA (https://www.maxqda.com/). MaxQDA is a Computer Assisted Qualitative Data AnalysiS (CAQDAS) package that is specially developed for the qualitative analysis of qualitative data. Afterwards, a frequency analysis is carried out to determine the core cooperation aspects among stakeholders at the Port of Hamburg with a focus on activities related to risk management.

Three distinct approaches for qualitative content analysis can be used: conventional, directed, or summative. The conventional approach is very suitable for describing a certain phenomenon, especially when the existing literature and theories on the examined phenomenon are limited. For the analysis of interviews in this paper, coding categories are extracted directly from the text data using the conventional approach. These categories are then used to organize the set of codes and interpret the findings from the interviews (Hsieh and Shannon, 2005).

A thorough definition of the unit analysed is essential to enable proper decisions about what to be counted and analysed (Saeed and Kersten 2017). In this study, the interviewed stakeholder, as a subject, is selected as a unit of analysis for the frequency analysis of cooperation aspects.

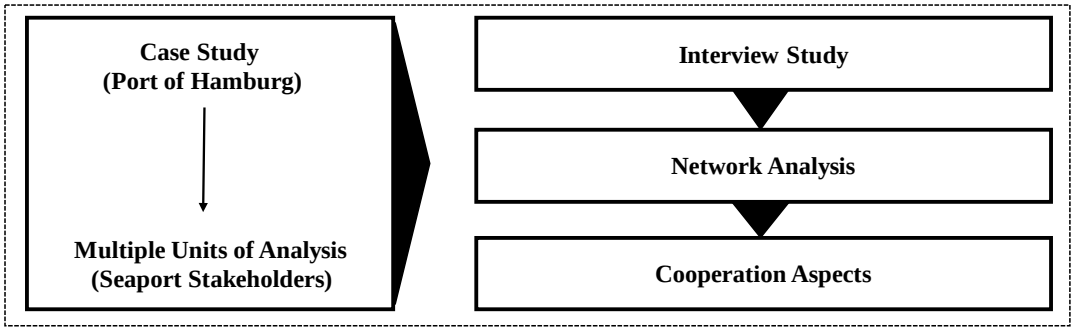

Figure 1 – Approach of the research work

Gephi software is used in this research to generate and analyse the network structure of stakeholder at seaports. It is a visualization and exploration software that is based on open-source code. The communication intensity values among stakeholders gathered during the interviews study serve as the main input for the software to generate the network graph. Figure 1 summarizes the overall approach of this research work.

Results and discussion

This section presents the results of the research based on the steps elaborated in the methodology. The first subsection presents the results of the network analysis using Gephi. Afterwards the cooperation aspects are elaborated with examples mentioned by the interviewed partners.

Network structure

The network of stakeholders in seaports is complicated since many information flows occur among different set of stakeholders in specific scenarios. The interview study contained a main part to analyse the intensity of communication among the stakeholders in the Port of Hamburg with regards to risk management. Each interviewee was requested to verify and fill out a communication intensity value (based on the frequency of warnings, disclosures and two-way communication) using a developed stakeholder map.

The used ordinal scale has 5 values (0: no communication – 4: very high communication). These values were used as input to create a network and communication intensity map using Gephi to analyse the network structure. The position of each stakeholder in the network is based on the value generated by the software using Yifan Hu layout algorithm that is suitable for large networks. The thickness of each arrow represents the intensity of communication based on the defined ordinal scale. Each arrow is bidirectional, meaning that both partners in the network initiate the communication.

As it can be observed from Figure 2, terminal operators, shipping companies, fire brigades, waterway police as well as the authority for environment and energy play an important role in the communication with different stakeholders in the activities associated with risk management. The focus is specially concentrated on the reactive process and the emergency as well as evacuation plans. For instance, environmental risks, once identified, have a direct influence on initiating a communication channel between the authority for environment and energy with other relevant stakeholders, especially the waterway police and the fire brigade.

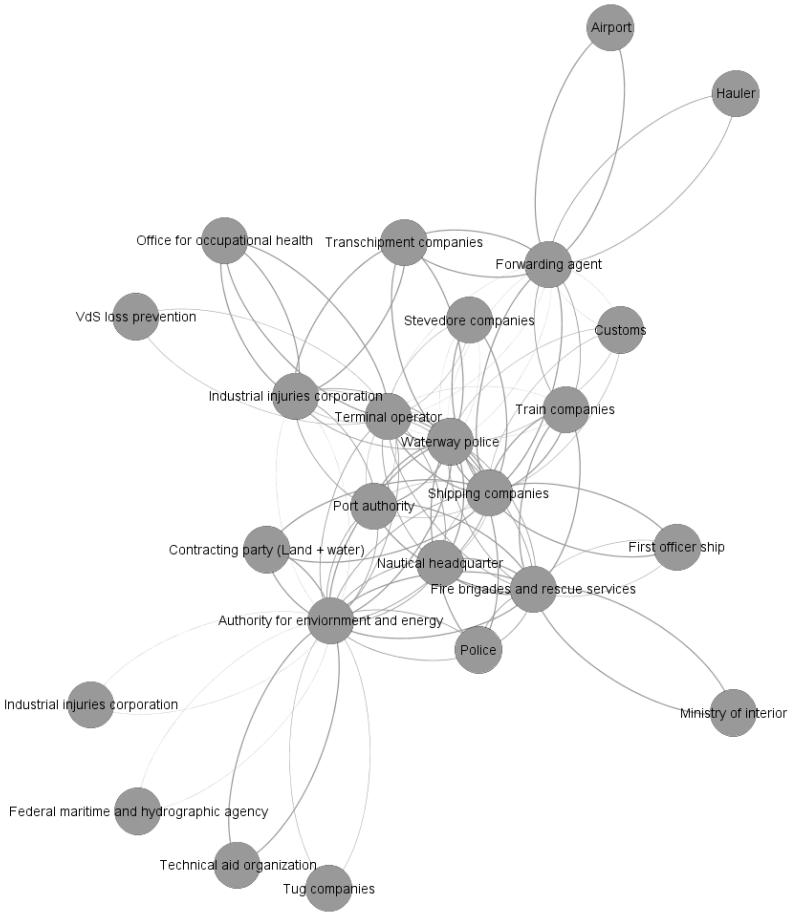

Figure 2 – Network graph of the stakeholders at the Port of Hamburg

The maximum centralization theoretically is the centralization that can be obtained in a perfectly centralized star-shaped network based on a central individual talking to everyone. The network centralization can be calculated as the sum of differences between the maximum and the other individual's centrality values, with a normalization in the range from 0 to 1 using the division by the theoretical maximum centralization (Crowston und Howison, 2003). The ideal theoretical centralization of a network comprising 25 nodes (stakeholders) is 11.74 calculated using Gephi. The calculated centrality depends on the values of closeness centrality for each stakeholder (example is shown in Table 1).

Equation (1):

$$\text{Network centralization} = \frac{\text{Calculated centrality of the overall network}}{\text{Ideal theoretical centrality}} = \frac{4.59}{11.74} = 39\%$$

Equation (2):

calculated centrality of the overall network = $\Sigma\,(1 - \text{Max}\,(CC))$

where CC: closeness's centrality

Equation (3):

Ideal theoretical centrality = $\Sigma\,(1 - \text{Max}\,(CC))$ for star-shaped network

Table 1 – The top 10 closeness centrality values

Label	Closeness centrality	Label	Closeness centrality
Waterway police	67%	Port authority	55%
Terminal operator	65%	Forwarding agent	53%
Authority for environment and energy	65%	Industrial injuries corporation	52%
Shipping companies	63%	Nautical headquarter	51%
Fire brigades and rescue services	59%	Train companies	50%

The calculated centrality of the overall network as well as the ideal theoretical centrality can be extracted using equations 2 and 3, where N (number of stakeholders) = 25. The network centralization value indicates that there is no stakeholder who possesses a high number of connections with the other nodes in the network. This also validates one extracted aspect from the interview study, being the lack of a central actor who coordinates the activities related to risk management. Furthermore, it can be observed from the extracted values of closeness centrality (see Table 1) that the relative difference among the stakeholders, specially the top 4, is not significant, indicating the existence of a core set of actors that contribute to the management of different risk sources.

Cooperation aspects

This subsection complements the network analysis of stakeholders at the port of Hamburg. The stakeholders were asked to mention the cooperation aspects with the focus on activities related to risk management. Examples include handling of dangerous goods, proactive measures and risk specific response plans.

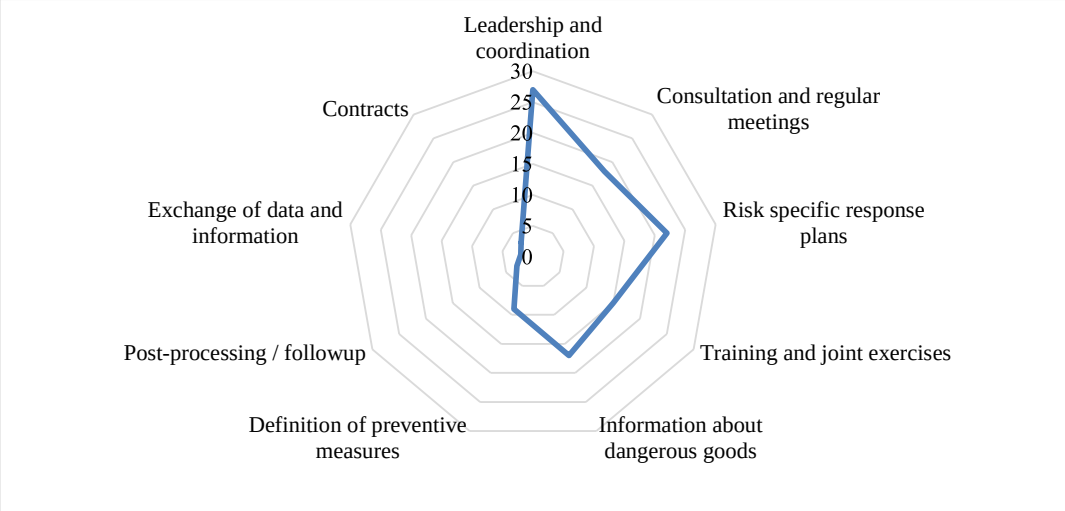

Figure 3 – Radar chart of the cooperation aspects for risk management at the port of Hamburg

Figure 3 presents the radar chart of the cooperation aspects mentioned by the interview partners with regards to risk management. The counting mechanism is based on a frequency count if the interview partner mentioned an activity related to that aspect. As can be observed, leadership and coordination as well as risk specific response plans are

the top cooperation aspects at the port of Hamburg based on the conducted interviews. In the following, several cooperation aspects are briefly explained.

Leadership and coordination
Leading a hazardous situation during the reactive risk management process is important in order to efficiently implement the required measures. As an example, the authority for environment and energy takes the lead with regards to environmental risks by assessing the situation and accordingly implementing the required measures. “Then the environmental authority comes as the competent authority and checks if the situation is cleanable or not cleanable and then orders the appropriate measures. If the authority is unavailable, we would be acting on a subsidiary basis and would work for the environmental authority” (#waterway police).

Risk specific response plan
An important cooperation aspect is the engagement in the reactive process. Examples include the emergency levels determined according to an initial assessment. Emergency management plays an important role to handle natural disasters such as flood or extreme winds. Responsible actors are carefully trained in each scenario in order to react efficiently using predefined measures. “If something happens, then we are no longer in risk management but in emergency management. For that case we completed a special training where we worked out everything that is reasonably imaginable with regards to the different scenarios” (#terminal operator).

Consultation and regular meetings
Stakeholders at the port of Hamburg stressed on the importance of regular meetings with authorities, terminal operators and shipping companies in order to get the latest updates on regulations, accidents, and other specific requirements. These regular meetings can also be organized for specific topics or sources of risks such as the handling of dangerous goods. “We have a dangerous goods circle, where we meet regularly and just talk without a tight agenda about the current hot topics. The circle comprises shipping companies, customs, police and also bulk career” (#shipping company).

Info / approval of dangerous goods
The aspect of dangerous goods was one of the most frequent aspects mentioned in the interview study. Many stakeholders cooperate to mitigate the negative effects of the risks associated with dangerous goods such as the wrong declaration of goods or the wrong handling leading to fires and explosions. “Normally we receive information on dangerous goods from the shipping companies or freight forwarders” (#terminal operator).

Definition of preventive measures
Defining the countermeasures in advance is important especially in emergency management to avoid the severe consequences of unexpected events such natural disasters. Examples include the cooperation between port authority and the terminal operators in the case of flood to protect the surrounding area and the citizens. “Waterway police help us to carry out a smooth process in order make sure that everything is planned correctly to avoid accidents such as the falling of containers” (#shipping company).

Exchange of data and information
Different stakeholders also cooperate in terms of data and information exchange to increase the efficiency of the knowledge management process. For instance, the exchange of data related to cargo accidents to carry out a root cause analysis. This in order to discover the root cause and prevent the occurrence of risk by defining suitable measures. “We exchange the data of cargo accidents to learn from each other in order not to have

the same accidents again. Based on that we carry out a root cause analysis" (#shipping company).

Post processing and follow up
Another important cooperation aspect is the post processing and follow up of the implemented measures during the risk treatment phase. The development of a damage report after mitigating the accident situation is an example of a follow-up process to document and improve the implemented measures and the communication process. "Every caller of us is obliged to write a damage report when he has completed a claim. It says in there: Who did I talk to, when did I talk, how long was I there, and what did I do" (#authority).

Each interviewed stakeholder cooperates only with his partners within a specific network cluster. This cooperation is not explicitly defined using specific knowledge and risk management process. Additionally, the aspects related to exchange of data and information, post-processing and definition of preventive measures were rarely mentioned, although they are essential for risk management, knowledge transfer and the continuous improvement process.

An efficient knowledge transfer process can be facilitated by the proper utilization of cooperation aspects among stakeholders in seaports. The definition of clear roles and responsibilities is required to coordinate the activities related to risk management. Additionally, the communication within stakeholders in a seaport is essential to coordinate and implement the treatment measures, especially in the case of emergencies (Nagi et al., 2018).

Conclusion

This paper aimed at analysing the network structure of stakeholders in the Port of Hamburg. The results of the network analyses are based on 15 semi-structured interviews with different categories of stakeholders. The analysis was carried out using Gephi software and its functions to generate the network structure of stakeholders at seaports. The cooperation aspects were extracted based on the coding analysis using MaxQDA. This work shows as well the potential a cooperation has on the risk management process. The definition of tasks and responsibilities as well as the mutual knowledge transfer among stakeholders can facilitate an efficient identification, assessment and handling of risks.

As it can be observed, there is no central stakeholder who manages or coordinates the activities related to risk management in seaports. The overall centrality of the network (39%) validates these results. The results also indicate that authorities represented by waterway police, fire brigades and rescue service as well as the authority for environment and energy together with shipping companies and terminal operator are primary actors when it comes to coordination, leadership roles and consultations related to the risk management activities, especially during the reactive risk management process.

Leadership and coordination and risk specific response plans are the most frequent cooperation aspects extracted from the interview study. These cooperation aspects are linked with natural disasters, environmental as well as operational risks associated with the handling of dangerous goods.

This work was limited to the interviews conducted at the port of Hamburg. 15 interviews were carried out to investigate and analyse the degree of cooperation for the activities related to risk management at the port of Hamburg. It is possible that certain

cooperation aspects were not mentioned during the interviews due to the nature and time frame assigned by each interviewee. Additionally, the coding mechanism might have omitted certain aspects that were mentioned by the interview partners. A survey study can validate and expand the results of the interview study. A larger set of stakeholders can be reached. Furthermore, the triangulation approach based on the interview and survey studies can increase the reliability of the results. Based on empirical study and the extracted requirements, a conceptual framework for cooperative risk management can be developed to utilize the cooperation aspects between the stakeholders and communications means based on the nature of covered risks. A conceptual model can be further extracted from the conceptual framework and validated using different scenarios with a set of stakeholders.

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Supply chain risk management and the role of firm size: a longitudinal study of Brexit

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Abstract: This paper examines how companies manage the contingent uncertainty associated with geopolitical events. We gather data from 10 semi-structured interviews with managers dealing with Brexit. We find that small companies follow a passive strategy due to limited resource availability. Medium sized companies initially follow a wait-and-see strategy and then change to a reactive strategy. Large companies follow a worst-case scenario approach that includes aspects of wait-and-see, reactive and pro-active strategies. We contribute to contingency theory by identifying that companies faced with the same external environmental condition take very different approaches to managing contingent uncertainty, due to resource availability.

Key Words: Supply Chain Risk Management, contingency theory, contingent uncertainty,

Introduction

Today's Operations Managers live in uncertain times. Trade disputes between the USA and China are prompting Operations Managers to reconsider their sourcing locations and target markets (Financial Times, 2019). Labour disputes such as the Gilets Jaunes strikes in Paris and political uprisings in Venezuela are impeding supply lines and disrupting distribution networks (The Economist, 2019). Operations Managers must decide how to manage the uncertainty that is created by these geopolitical events, otherwise, increased supply chain costs and delayed customer orders are inevitable.

Operations Management (OM) scholars have spent significant time exploring how firms manage supply chain risks using proactive, reactive, and passive risk mitigation strategies (Chopra and Sodhi, 2004; Grotsch et al., 2013; Ritchie and Brindley, 2007). Some scholars stress that firm size plays an important role in the type of risk mitigation strategy that a company will select (Ellegaard, 2008; Thun et al., 2011). For example, because large firms have greater amounts of resources in terms of time, money, and personnel, they can be proactive and make significant capital investments in flexible supply chain infrastructure to reduce the probability and severity of the risk event (Thun et al., 2011). Smaller firms do not have these slack resources and will tend to follow passive strategies reacting after the event has occurred (Ellegaard, 2008).

While the discourse surrounding how firms manage supply chain risk is detailed and extensive, little attention is paid to how firms manage the uncertainty created by geopolitical events. Risk describes decision situations in which probabilities are available to guide choice, while uncertainty describes decision situations in which information is too imprecise to be summarised by probabilities (Knight, 1921). Thus, risk applies to situations where we do not know the outcome of a given situation but can accurately measure the odds of the event occurring, while uncertainty applies to situations where we cannot know all of the information we need to set accurate odds in the first place (Knight, 1921). Risk is therefore a consequence of uncertainty and not a substitute (Figueira-de-Lemos et al., 2011). This means that supply chain risks result from uncertain situations. And, while the probability and severity of supply chain risks can be quantified and effectively managed, uncertainty in the supply chain is more difficult, if not impossible, for operations management to measure and address.

International Business scholars make an important distinction between two types of uncertainty that a firm may encounter (Clarke and Liesch, 2017; Figueira-de-Lemos et al., 2011). The first type is called 'pure uncertainty', which relates to the unpredictability of future events. Because the future cannot be known with complete certainty, pure uncertainty is impossible to reduce or eliminate (Figueira-de-Limos et al. 2011). The second type is called contingent uncertainty, which is knowledge-dependent and can be reduced as individuals learn more about a particular situation and develop contingency plans to manage the disruptive event (Figueira-de-Limos et al., 2011). In this paper, we are interested in how firms manage contingent uncertainty in their supply chain. We adopt the definition of contingent uncertainty provided by Clark and Liesch (2017) and apply it to the supply chain context as follows: Supply chain contingent uncertainty is defined as: "the extent to which the firm lacks knowledge about whether potentially significant and/or disappointing outcomes of its supply chain decisions will be realised" (adapted from Clarke and Liesch, 2017 p. 926)

The purpose of this paper is to answer the following questions: 1) *what are the different strategies that firms deploy to manage the contingent uncertainty that arises from geopolitical events?* And; *2) what is the role of firm size in the type of strategy that is deployed?* Our research, using Contingency Theory, takes a theory building approach to explore these questions. Our context of study is Britain's transition out of the European Union, or Brexit. Working longitudinally, we examine this geopolitical event as it unfolds; permitting real-time insights on the strategies that companies enact to cope with contingent uncertainty in the supply chain. While the firm acts as the unit of analysis, the UK's pharmaceutical sector is selected as the unit of reference.

The UK's pharmaceutical industry represents an extreme example of how supply chains can be directly affected by the uncertainty created by geopolitical decisions. Following the pro-Brexit vote in June 2016, the body responsible for approving and regulating the sale of pharmaceuticals in Europe (the European Medicines Agency), moved its Headquarters from London to Amsterdam creating uncertainty in new drug approvals for UK firms. Moreover, the UK government mandated that UK pharmaceutical companies stockpile a minimum of six weeks of all products to ensure that patients would not be left without lifesaving medications in the event of a no-deal Brexit (Reuters.com, 2018). We collect data using 10 interviews with managers at small, medium, and large pharmaceutical firms. The interview findings are corroborated through an analysis of primary documentation including policy documents, trade association briefs, and company strategy documents relating to Brexit. The findings from the primary data are further validated using secondary data sources gathered from databases including Factiva, Bloomberg, Financial Times/FT.com and ProQuest Archiver.

The remainder of the paper is organised in four sections. The next section reviews the pertinent literature to advance a conceptual model. Section three provides a justification of the research design and section four discusses the findings in relation to the literature to arrive at a framework of different strategies for managing the contingent uncertainty associated with geopolitical events. The paper concludes by outlining its theoretical and managerial contributions and highlighting potential fruitful areas for future research.

Literature Review

Contingency Theory and contingent uncertainty

Contingency theory asserts there is no single best way to organise and any method of organising will not be equally effective under all conditions (Galbraith, 1973). Central to contingency theory is the proposition that the structure, process, culture, and technology of an organisation must fit its external environmental if the organisation is to survive and be effective (Schoonhoven, 1981). One external factor that significantly influences how an organisation configures its structure and processes is the amount of uncertainty present in the external environment (Galbraith, 1973). Environmental uncertainty is defined as an inability to assign probabilities to the likelihood of future events (Knight, 1921) and is reflected by such factors as complexity, rate of change, and the availability and clarity of information (Galbraith, 1973). By matching an organisation's structures and processes to the external setting, a firm achieves fit with its external environment and, in turn, reduces the degree of perceived uncertainty (Burns and Stalker, 1961; Drazin and Van de Ven, 1985; Thompson, 1967).

Since these early writings, International Business scholars have categorized uncertainty into pure and contingent uncertainty (Clarke and Liesch, 2017; Figueira-de-Lemos et al., 2011). While pure uncertainty refers to future events that are impossible to know and plan for, contingent uncertainty implies that the more one learns, the more that individual can do to develop different contingency plans or alternatives (Figueira-de-Lemos et al., 2011; Jones, 2013). The more alternatives that an individual can identify, the more knowledge that is acquired and the less ignorant he or she becomes about the situation (Figueira-de-Lemos et al., 2011). Knowledge about an uncertain future event can be gained through tangible and intangible resource commitments (Hadjikhani, 1997). Tangible resource commitments are measurable; they relate to investments where it is possible to calculate both the input cost and financial outcomes, such as investments in supply chain infrastructure (i.e. production facilities, subsidiaries' offices or transportation vehicles) (Hadjikhani, 1997). Intangible commitments are difficult to quantify; they are specific to relationships and are difficult to redeploy to another relationship (Figueira-de-Lemos et al., 2011; Hadjikhani, 1997). The purpose of intangible resource commitments is to learn about and predict environmental changes and include such things as forming new relationships to gather knowledge about a disruptive event. (Figueira-de-Lemos et al., 2011; Hadjikhani, 1997).

In stable environments, characterised by low levels of contingent uncertainty, managers are able to draw on their experience while acquiring context specific knowledge, giving them more confidence when deciding on future resource commitments (Figueira-de-Lemos and Hadjikhani, 2014; Petersen et al., 2010). However, in unstable environments, managers must compromise between knowledge and resource commitment decisions, as past knowledge cannot be entirely relied upon in volatile markets (Figueira-de-Lemos and Hadjikhani, 2014; Petersen and Pedersen, 1999). When contingent uncertainty is high, managers will be reluctant to make tangible resource commitments because there is too much at stake and tangible investments are difficult and costly to reverse (Figueira-de-Lemos and Hadjikhani, 2014). Instead, managers are more likely to make intangible resource commitments to gain more knowledge about the situation and to bring perceived uncertainty down to more tolerable levels – what is termed a 'wait-and-see' strategy (Hadjikhani, 1997; Sull, 2005). With a wait-and-see strategy the company aligns its strategic focus to the particular market context, and reacts according to the present situation as-is, be it an opportunity or threat (Clarke and Liesch, 2017; F Sull, 2005).We adapt the definition of a wait-and-see strategy provided by Clarke and Leisch (2017 p.924) and apply it in a supply chain context. Specifically, we define a wait-and-see strategy as: a measured decision to make intangible resource commitments in order to gather knowledge about a disruptive event and reduce contingent uncertainty. Interestingly, the SCRM literature reveals little acknowledgement of the wait-and-see approach and instead focuses on the tangible resource commitments that firms make to reduce the probability and/or the severity of supply chain risks.

Supply Chain Risk Management

SCRM strategies are generally categorised as passive, reactive, or proactive (Craighead et al., 2007; Grotsch et al., 2013; Kleindorfer and Saad, 2005). Passiveness is when firms do nothing and respond haphazardly to the risk event after it has occurred (Grotsch et al., 2013). Passive strategies imply that tangible resource commitments are only made after the event to minimise its impact on the supply chain. Reactive strategies focus on reducing the severity of the risk event, while proactive strategies focus on reducing the probability of the risk event (Grotsch et al., 2013). Reactive strategies may including making tangible resource commitments in the form of surplus capacity, excess inventory, and multiple sourcing contracts, to reduce the severity of the event's impact on the supply chain (Sheffi and Rice, 2005; Thun and Hoenig, 2011). Proactive strategies are when companies plan ahead to eliminate the probability of the event occurring (Grotsch et al., 2013; Knemeyer et al., 2009; Mitroff and Alpaslan, 2003; Tang and Tomlin, 2008). Proactive strategies rely on tangible resource commitments in the form of control systems that help identify and assess supply chains risks (Chopra and Sodhi, 2004; Grotsch et al., 2013; Jüttner et al., 2003). If the risk cannot be avoided, proactive firms will embed flexibility in a firm's supply chain by investing in multiple sourcing contracts and flexible manufacturing equipment to allow for an agile response to the risk event (Kleindorfer and Saad, 2005; Trkman and McCormack, 2009).

While SCRM scholars discuss passive, reactive and pro-active strategies they fail to examine the role of wait-and-see strategies when managing contingent uncertainty. A wait-and-see strategy is not proactive because tangible resource commitments are not made in advance to reduce the probability of the disruptive event occurring, nor is it reactive as tangible resources are not committed to reduce the severity of the event. Moreover, a wait and see strategy is not passive, as the firm does not stand idly by as the disruptive event occurs and reacts haphazardly after the fact. Instead, a wait-and-see strategy is the deliberate commitment of intangible resources to acquire knowledge about the disruptive event to reduce contingent uncertainty.

In the main, SCRM scholars study large multinational firms and their approach to managing supply chain risk. One exception is Thun et al. (2011) who surveyed 67 small, medium, and large enterprises to find that small and medium enterprises (SMEs) were more vulnerable to supply chain risks due to weaker cash flow and equity positions. They found that SMEs try to deal with supply chain risks by building up redundancies (safety stock, overcapacity) which

absorb the impact of the risk event, while large companies systematically attempt to eliminate or reduce the possibility that a risk comes into effect. Moreover, they find that large companies have greater resource availability to invest in capital-intensive instruments such as strategic supplier development or tracking and tracing (Thun et al., 2011). Another exception is Ellegaard (2008), who conducted eleven interviews with small company owners to find they use defensive risk management strategies based on local sourcing combined with seeking out responsive, dependable and like-minded suppliers. Unlike Thun et al. (2011), Ellegaard (2008) found that small company owners avoided multi-sourcing contracts and building redundancies because of resource and expertise restrictions. Small company owners were found to spend little time and resources actively acquiring knowledge about suppliers and supply markets (Ellegaard, 2008). To synthesize this discussion, we now advance a conceptual model of the different types of strategies used by small, medium, and large firms to manage the contingent uncertainty that arises from geopolitical events (See Figure 1).

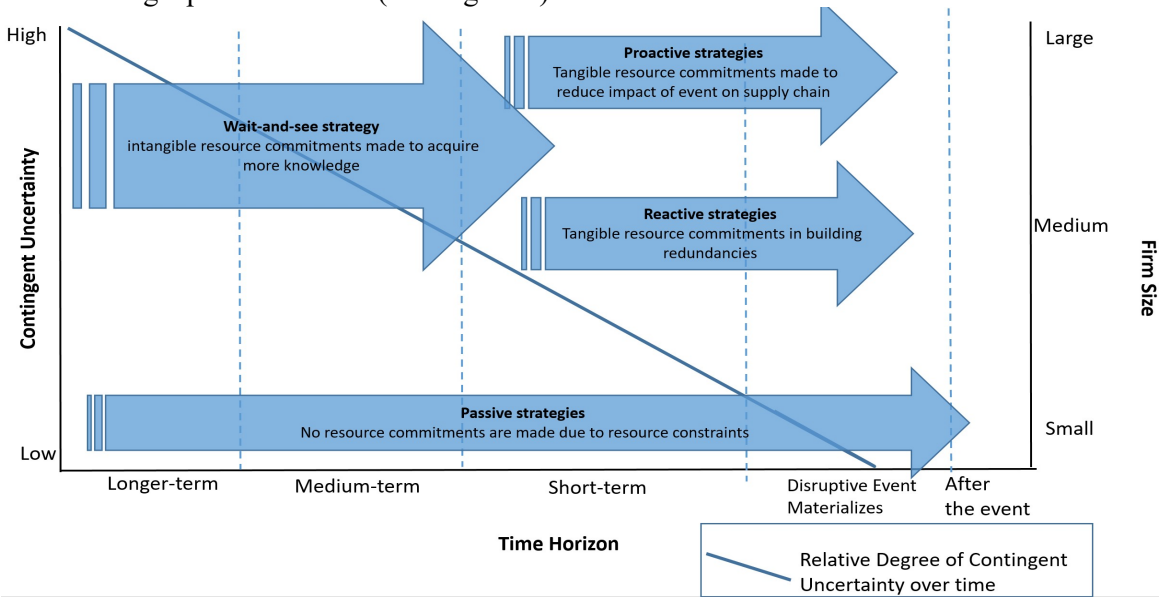


Figure 1: Conceptual Model: Strategies for managing contingent uncertainty in the supply chain

Research Design

Our research design is based on an theory elaboration approach (Ketokivi and Choi, 2014). To elaborate on theory, we worked in an abductive manner (Josephson and Josephson, 1996; Niiniluoto, 1999; Suddaby, 2006), continuously moving between the empirical data and contingency theory. While guided by a priori theoretical considerations, we remained open to unanticipated findings and the possibility that the general theory required reformulation (Merton, 1968). We situationally grounded the study within the context of firm's managing the contingent uncertainty resulting from the pro-Brexit vote. We conducted an in-depth investigation of the relationship amongst concepts including intangible and tangible resource commitments, contingent uncertainty and knowledge gathering. Throughout the study, we attempted to reconcile the idiosyncrasies of the data with existing theory and when unanticipated findings were identified we were able to elaborate on contingency theory (Ketokivi and Choi, 2014; Merton, 1968). Our context of study was Britain's departure from the European Union (or Brexit), while the unit of analysis was pharmaceutical firms.

Brexit and the Pharmaceutical Industry

On June 23rd, 2016, the people of the United Kingdom voted on whether to remain in, or to leave, the European Union (EU). The vote went 51.9% in favour of Britain departing the EU, with the outcome creating a profound sense of surprise and shock on both sides of the debate (Wincott et al. 2017a). In the aftermath of the vote, Britain's Prime Minister, David Cameron resigned and the Financial Times Stock Exchange (FTSE) 250 index fell by 13% (Rodionova,

2017). Another major casualty was the value of the British pound which fell by 13% in relation to the Euro. Ten months after the vote, the pound was still trading around 15% lower compared to the U.S. dollar and 12% lower compared to the Euro than before the referendum (Bowers, 2017). More than 2,600 pharmaceutical products have some stage of manufacture in Britain and 45 million patient packs are supplied from the UK to other European countries each month, while another 37 million flow in the opposite direction (Reuters.com, 2018). UK pharmaceutical firms were advised by the UK government to implement no-deal plans by the end of 2017 and were told "to ensure they have a minimum of six weeks additional supply in the UK, over and above their business as usual operation buffer, by March 29th, 2019" (Reuters.com, 2018). In our study, we consider the period between the pro-Brexit vote (June 26th 2016) to the half way point when Britain was due to leave the EU (March 29th, 2019) as the longer-term. The medium term is considered to be the one year period between Nov 18th, 2017 to Nov 29th, 2018, when Theresa May returned from Brussels with a withdrawal deal for ratification by U.K. parliament. The short-term period is considered to be from Nov 30th to March 29th 2019, when Britain was initially scheduled to leave the EU.

Data Collection

Qualitative data was gathered using the key informant technique (Marshall, 1996; Tremblay, 1957). A key informant is an expert source of information (Marshall, 1996), that provide the researcher with insights into a matter and can initiate access to corroboratory or contrary sources of evidence (Yin, 2013). Moreover, key informants possess knowledge or can make assessments that are not available in the public domain; knowledge that is often considered confidential, sensitive or privileged (Christopoulos, 2010). We followed guidance provided by Carter and Jennings (2002) in assessing who meets the criteria of a key informant. First, we interviewed individuals at the manager level of higher, as these individuals tend to have detailed experience of the organization to give an informed opinion (Carter and Jennings, 2002; John and Reve, 1982). Second, we interviewed individuals with at least 3 years of experience at the organisation so they could provide insights on how the organisation functioned and responded to disruptive events (Carter and Jennings, 2002). Third, we only interviewed individuals who had a detailed understanding of the phenomenon under investigation (Carter and Jennings, 2002), or more specifically, individual's whose day-to-day job role was directly affected by the Brexit process. Interview data was collected longitudinally, over a two year period from March 2017 to March 2019. Each interview lasted between 30 minutes and one hour and was transcribed verbatim for later coding and analysis. Firm size was determined by number of employees with >100 employees being categorized as small, 100-10,000 categorized as medium and 10,000+ categorized as large.

Organisation	Employees	Revenue per Annum	Size	Interviewees	Interview Date	Time horizon
Biological Solutions	30	£35 million	Small	CEO	4th October 2017	Long
				CEO	5th October 2018	Medium
UK Therapeutics	500	£68.3million	Medium	Operations Director	28th September 2017	Long
				Operations Director	9th October 2018	Medium
Large Pharma 1	+50,000	$22 billion	Large	Quality Assurance Director	4th October 2017	Long
				Supply Chain Director	2nd October 2018	Medium
Large Pharma 2	+100,000	£40 billion	Large	Supply Chain Director EMEA	16th June 2017	Long
				Supply Chain Director EMEA	4th October 2018	Medium
Large Pharma 3	+100,000	£30 billion	Large	Supply Chain Director	26th May 2017	Long
				Supply Chain Director	5th October 2018	Medium

Table 2 – Interviewee organisation and positions (anonymised)

Data Analysis

To analyse the data, we followed the approach of Craighead et al. (2007) who used key informant interviews to study disruptive supply chain events. Specifically, we used thematic analysis techniques (Braun and Clarke, 2006) and followed the three-step process outlined by Miles and Huberman (1994). In step one, we performed first-level coding to summarize and describe the data. In step two, we performed patter matching techniques (Miles and Huberman, 1994; Yin, 2014) to group together similar codes together and then attach these codes to higher order themes. In step three, we formalized and systematized the findings into propositions that explain the different strategies that companies deploy to reduce the contingent uncertainty associated with geopolitical events. To enhance inter-rater reliability, the coding process was carried out independently by three members of the research team and the codes were later compared to reach consensus on the key themes (Armstrong et al., 1997).

Findings and Discussion

Small Firms and strategies for managing contingent uncertainty

Biological solutions is a small company of 30 employees based in Germany that produces probiotics for food. When the CEO of Biological Solutions was first interviewed in October 2017 she explained her company's approach to Brexit as follows:

> "As far as I see it we don't have any strategy [for Brexit]…. we might have to have more import regulations if we want to sell into the UK …but we have this for many other countries, like when we sell something in to US, so we are quite used to doing this."
>
> -CEO Biological Solutions –Oct 2017

This quote demonstrates that Biological Solutions was adopting a passive, or do nothing, approach to Brexit in the long term. The biggest anticipated impact was not being able to access research funding from the UK Government, as well as restricted access to highly skilled scientists in the UK. When she was interviewed again a year later (October 2018), her company's strategy for managing Brexit had not changed and she explained that if there was a 'hard' Brexit, then her company would treat the UK like any other country outside of the EU in terms of customs declarations and duties and taxes. This finding is in-line with Ellegaard (2008), who argues that small firms will uphold the status quo, adopting a passive strategy of maintaining existing local sourcing contracts with dependable suppliers,. In addition, we found that this mall firm maintained its passive strategy over an extended period of time, even when the disruptive event drew closer. Our data suggests the primary reason for maintaining a passive strategy is resource constraints, in the form of insufficient human and financial resources. Biological Solutions did not have the resource slack to dedicate people to contingency planning, nor the financial slack to invest in buffer inventory. This leads us to posit that:

> *P1: Small firms will continue to follow a passive strategy over the long to medium term as they have insufficient resources to dedicate to reducing contingent uncertainty*

Medium sized firms and strategies for managing contingent uncertainty

UK Therapeutics is a medium-sized pharmaceutical company manufacturing sterile vaccines for allergy treatment at a single site in the UK. The interview conducted in September 2017 indicated the company was adopting a wait-and-see strategy in the long-term gathering information from trade associations to understand the implications of transportation delays, possible skill shortages and quality release planning, as explained by the Operations Director:

> "As a company it's a wait-and-see… we're looking at what would be the implications of being a third country." – Operations Director-UK Therapeutics-Sept. 2017

When the second interview was conducted during October 2018 (medium term), UK therapeutics had moved to a reactive strategy as it made tangible resource commitments to cover what they called 'no-regret actions'. This involved building a stock of licensed products at their

Spanish facility prior to the end of March 2019 and investing in resource for a UK Qualified Person responsible For Pharmacovigilance, or monitoring the effects of medical drugs after they have been licensed for use:

> "We are not shifting manufacturing [from the UK], but we're aiming to build stock of our licensed products and ship them to the facility in Spain before the end of March '19… This avoids double testing" – Operations Director-UK Therapeutics-Oct 2018

Our study of UK Therapeutics revealed that the company adopted a wait-and-see strategy initially, gathering information from their departmental managers as well as from suppliers. UK Therapeutics also faced resource constraints and put tangible resource commitments on hold so they could gather more information on the future EU-UK relationship. This finding differs from Thun et al (2011) who suggests that SMEs will adopt a reactive strategy from the outset. Instead, we found that UK therapeutics followed a wait-and-see strategy in the long-term and when they acquired more information then moved to a reactive strategy based on building inventory as opposed to shifting production capacity of excess suppliers Therefore, we propose:

> *P2: In the longer term, medium sized firms will manage the contingent uncertainty associated with geopolitical events by adopting a wait-and-see strategy, making intangible resource commitments to gather information about the disruptive event*
>
> *P3: In the medium term, medium sized firms will manage the contingent uncertainty associated with geopolitical events by adopting a reactive strategy, making tangible resource commitments in the form of buffer inventory*

Large firms and strategies for managing contingent uncertainty

Unlike the small and medium sized firms, we found that the large pharma firms adopted a mix of wait-and-see, reactive and proactive strategies over the long to medium term. The Supply Chain Director from Large Pharma 1 explained the mind-set at her company:

> "So all the way through we've taken a worst case assumption. So from day one we've assumed full WTO (World Trade Organization) conditions, we've assumed a full failure of the import-export simplifications that are currently available in the EU. We've assumed full customs and regulatory frictions on the way in, on the way through and on the way out of the EU. -Supply Chain Director – Large Pharma 1

The worst-case scenario approach to managing the contingent uncertainty around Brexit was also seen at Large Pharma 3:

> "We are planning for a worst case Brexit, what other people might call a 'hard Brexit', which is where we have no deal and we default to WTO terms and we default to having to retest all products coming in to the UK from the EU and vice-versa. We've responded very well in putting together all the right functions within the company to manage the workload and define and execute what we need to do, and we've made money available as well."
> -Supply Chain Director – Large Pharma 3

We found the worst-case scenario planning approach encompassed the information gathering aspects of a wait-and-see strategy, the redundancy building of a reactive strategy, and the shifting of supply chain infrastructure aspects of a proactive strategy. For example, the Supply Chain Director for Large Pharma 2 discussed how his company was providing supply chain information to policy makers to shape the outcome of Brexit:

> "There are a number of areas where we tried to influence what the final shape (of Brexit) would be. Government is really trying to collect true hard data around the impact of an absolute hard Brexit. So we've had to submit a lot of data around inventory levels, physical location of inventory and import plans post-March (2019) next year." - Supply Chain Director EMEA – Large Pharma 2

At the same time, the three large pharma firms followed aspects of a reactive strategy as they were building inventory and additional supplier capacity in their supply chains based on a worst-case outcome. While the UK Government had recommend that the large pharma companies hold a minimum of six weeks of stock, the three large pharma firms were building inventory over and above that requirement, as explained by the Supply Chain Director at Large Pharma 3:

> "We have been asked by the government to build an extra six weeks' worth of inventory. That's the way we mitigate risk of delays, by building more inventory in to the pipeline…..anything that is lifesaving, we already have high stock levels of and we will probably build more. Anything that is revenue critical, we're probably trying to optimise the stock of." -Supply Chain Director – Large Pharma 3

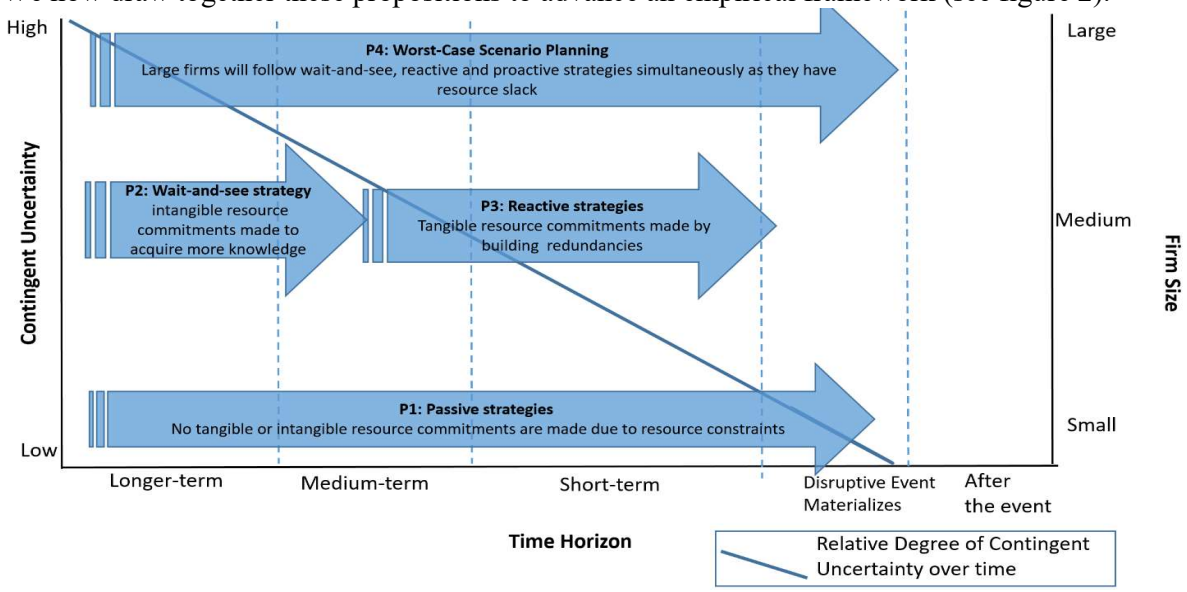
In addition to building redundancies in the supply chain, the large pharma company's strategy for managing contingent uncertainty also contained elements of pro-activeness. For example, from the long to medium term, the three Large Pharma firms were shifting production from their UK facilities to sites in Europe:

> "From the end of this year we will have a warehouse setup in the UK within which we are going to store the product for UK patients. The French warehouse is going to lose the UK inventory, but what we're going to do in France is we're going to have to do sampling of product that is made in the UK and is destined for the EU 27." -Supply Chain Director- Large Pharma 1

These quotes demonstrate that the large pharma firms adopted a worst-case scenario planning strategy which is comprised of a mix of wait-and-see, reactive and proactive approaches. This finding differs from the predominant view of SCRM scholars, who argue that firms will follow either a passive, reactive or pro-active strategy (Grotsch et al., 2013). Instead, we find that large firms will follow all three strategies simultaneously, as they have the resource slack that allows them to do so. The three large pharma firms immediately established Brexit task forces and started contingency planning based on a worst-case scenario. They provided information to trade associations and policy makers to influence the future shape of the EU-UK relationship, whilst building up inventory and shifting production capacity to European facilities We therefore propose that:

> *P4: Large firms will manage the contingent uncertainty associated with geopolitical events by following a strategy of worst case scenario planning, which includes wait-and-see, reactive and proactive approaches.*

We now draw together these propositions to advance an empirical framework (see figure 2).



Contribution and Future Research Directions

This paper contributes to contingency theory by identifying that firms will react to their external environment in different ways based on internal resource availability. Small firms will maintain a passive approach because they cannot afford to make investments in information gathering, building redundancies or shifting production between facilities. In the longer term, when contingent uncertainty is high, medium sized firms will follow a wait-and-see approach. As the nature of the event becomes clearer they will then switch to a reactive approach and build redundancies. Large firms will follow a worst-case scenario planning approach which includes using slack resources to gather information and using this information to influence policy. At the same time, large firms will be reactive and build redundancies whilst proactively moving production volumes to other facilities. These findings show that resource availability can make firms act in different ways when facing the same degree of contingent uncertainty in the external environment. We provide managers with an empirically informed framework for managing contingent uncertainty. Our findings show that organizational size and resource availability will dictate which strategy a firm will pursue. We suggest that managers should gather information in the first instance before making costly to reverse resource commitments. We also suggest that managers can use newly acquired knowledge to influence the course of geopolitical events.

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Supply chain resilience: investigating the Egyptian tourism industry situation after the Arab spring

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Abstract

This paper aims to add to the accumulative knowledge in the field through investigating the current situation of tourism industry in Egypt from a supply chain perspective, and how tourism businesses in Egypt understand the concept of resilience. Such investigation will help in achieving a deep and reflective understanding of current supply chain problems as issues affecting Egyptian tourism. Then identifying the main practices deployed by this sector to mitigate supply chain disruptions.

Keywords: Tourism Supply Chain, Tourism Resilience, Tourism Supply Chain Disruptions

Introduction

The tourism industry has become the world's preeminent industry, as it is one of the fastest growing economic sectors in the world. It plays an important role in the development of many countries. In 2017, it contributed USD 8,272.3bn to the global GDP (10.4%) and generated 313 million jobs in the world (World Travil and Tourism Coucil, 2018). The World Travel and Tourism Council estimates that by 2026, the value will increase to USD 10,986.5 billion, which would represent 10.8% of the world GDP (Szpilko, 2017). For tourism management, planning and assessing resilience is of growing concern since change processes and their interrelations have become more complex in an accelerated, globalized world, placing pressure on tourism to adopt and respond to various factors (Shinae, Hui, Beomcheol, & Chon, 2018).

In an era of growing political turmoil, socio-demographic, environmental changes, and volatility economy, the travel and tourism industry is facing a significant test. Political stability and safety are prerequisites for tourism, even the mere threat /risk of events such as civil war and terrorism can cause tourists to rethink their decision to visit a region (Dahles & Prabawa, 2015; Ghaderi, Hatamifar, & Khalilzadeh, 2018). In addition, to the previous challenges, the dynamic development of the tourism sector requires the enterprises, striving to maintain or achieve a competitive advantage, to take actions to meet the ever-increasing customer expectations.

Despite these challenges, less attention is given to what makes this sector succeed despite disaster. From the perspective of the tourism industry, this lack of research attention is somewhat surprising (Shinae et al., 2018). In addition, the industry needs to

be analyzed from an integrated perspective, that is, as a network of tourism supply chains (TSC) (Kim, Chen, & Linderman, 2015). As the processes involved in supply chain resilience (SCRES) such as adaptation and co-evolution are arguably difficult to understand by studying a single entity in the supply chain, they need to be examined across multiple related firms in a network (Kim et al., 2015; Rice & Caniato, 2003; Tukamuhabwa et al., 2017).

Egypt, as one of the developing countries, possesses one third of the world's known monuments. Egypt enjoys various fields of tourism attraction; the most important are archeological or cultural tourism that is one of the oldest types of tourism in Egypt. In addition to, beaches tourism, religious tourism, therapeutic tourism, eco-tourism, sports tourism, safari/desert tourism, maritime tourism, and finally conferences and festivals tourism (Rights, 2017). Tourism has long been a key contributor to Egypt's national economy along with the Suez Canal revenues and remittances from Egyptians living abroad. The total contribution of tourism industry to Egyptian GDP was EGP374.6bn (USD21.1bn), 11.0% of GDP in 2017. In 2017, the total contribution of tourism to employment, including jobs indirectly supported by the industry was 8.5% of total employment (2,425,500 jobs) (BMI, 2018). Tourism is a demand-driven activity largely influenced by visitors' perceptions of the safety of travel and destinations. Erratic events affecting such perceptions are numerous including acts of terrorism, wars, political uncertainty, social unrest, economic crises, natural disasters, and health and environmental hazards; all of which strongly deter travel (Sakr & Massoud, 2003).

The survival of business in tourism industry depends on identifying and managing threats and risks. The focus of this study is on identifying the main disruptions, the practices deployed by this sector to mitigate supply chain disruptions and the impact of tourism disruptions on different TSC members in Egypt context.

Tourism Supply Chain

The tourism industry comprises a network of organizations (Figure 1) involved in a series of diverse tourism activities, ranging from providing an entire variety of components of tourism services/products, (such as flights, accommodation), and ending with the sale of tourism products in the tourism region, and involves a wide spectrum of participants in both the public and private sectors (Szpilko, 2017). This industry also involve many components: accommodation, transport, excursions, but also bars and restaurants, handicrafts, food production, waste disposal, and the infrastructure that supports tourism in destinations (Tapper & Font, 2004).

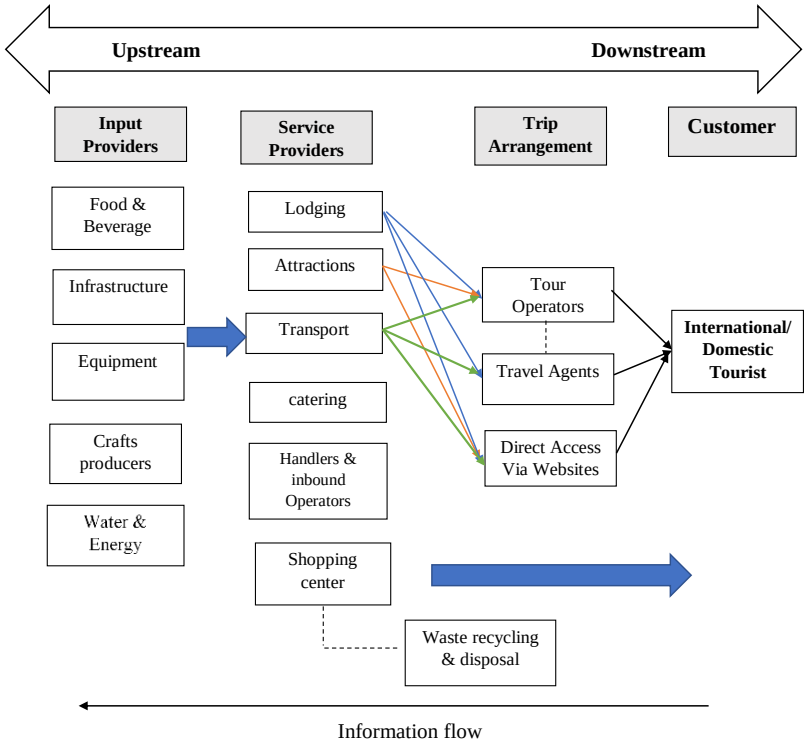

Figure 1: Tourism Supply Chain

Supply Chain Resilience

It is noticeable an evolution through time on research for SC and Resilience, as a result of the negative consequences of SC disruptions, the academic and practitioner community emphasized the need to address the design of SCs that are efficient while resilient to disruptions in regions where the industry is more susceptible to risks (Kamalahmadi & Parast, 2016; Pires Ribeiro & Barbosa-Povoa, 2018). Fiksel, Polyviou, Croxton, & Pettit, (2015) argued that resilience is an important capability that complements the traditional risk management processes in many companies.

Resilience in SC context has been described in simpler and broader terms by several authors (Pires Ribeiro & Barbosa-Povoa, 2018) However, The commonly cited definition of SCRES in the literature is that of Ponomarov & Holcomb, (2009,p.131) "*the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function*". It can be stated that SCRES can hardly be considered as an isolated term, as it is a product of business and industry needs and evolution. For many researchers, it is important to address resilience in combination with uncertainty, complexity, and risk (Kamalahmadi & Parast, 2016).

Resilience of Tourism

The unprecedented rise in the number of crises and disasters affecting the worldwide tourism industry has brought forth the importance of building resilience in the industry of tourism. Recently, resilience in tourism has been explored in the context of disaster and risk management (Sheppard & Williams, 2016). UNWTO (2011) identifies five types of disruptions affecting the tourism sector at local, regional or national level. These are: (1) environmental crises, including geological, extreme weather, and human-induced events; (2) political and societal events; (3) health-related crises; (4) technological incidents or failures; and (5) economic events.

Resilience in tourism context, refers to the industry capacity to deal effectively with self-inflicted crisis and disasters in maintaining the stability of the sector while ensuring the diversity and flexibility essential for further development and innovation (Orchiston, Prayag & Brown, 2016). Dahles & Prabawa (2015) described three different attributes of resilient TSC: survival, adaptation and innovation. The core features of a resilient system in the context of tourism as Cochrane (2010) named "*The sphere for tourism resilience*" are the ability to connect and understand market forces, collaboration between participants to create strong networks, sufficient flexibility to adapt to change ,and leadership normally provided by the public sector (COMCEC Coordination Office, 2017). A network structure supporting tourism resilience has to meet two fundamental criteria (Luthe & Wyss, 2014): preparing for disturbance by creating and maintaining diversity and responding to disturbance by creating and maintaining flexibility.

Tourism Disruptions in Egypt

Tourism in Egypt enjoyed a period of stable and continuous growth from the 1990s through the 2000s (Elshaer & Saad, 2017). However, this sector has been hammered since the uprising and what is known as Arab Spring in 2011 (Salman, Taw, Samy, & Artal-tur, 2017). Egypt suffered a series of political events and clashes during 2011. After January 25th, 2011 Egypt witnessed social, economic and political instability leading to drastic consequences in the hospitality and tourism industry (Salman et al., 2017). The following table 1 shows the main disruptions that faces the tourism sector in Egypt.

Table 1: Tourism Disruptions in Egypt

Disruption classification	**Disruption**
Political	• Violent incidents and terrorists' attacks (e.g., on January 25th, 2011 during the large demonstrations against the regime; in 2013 during the coverage of the coup against Islamist President Mohamed Mursi; in 2015 terrorists attacked the famous pharaonic temple (El Karnak), assassinated the Egyptian Attorney General and blew up the Italian consulate in downtown Cairo. Moreover, 12 Mexican tourists were mistakenly killed by military and security forces. The situation reached its peak in November 2015 after the crash of the Russian plane over Sinai causing the death of 224 passengers; in May 2016, EgyptAir MS804 crash into the Mediterranean Sea, killing all 56 passengers. Also, kidnapping and torture of Italian graduate student Giulio Regeni whose body was found in February 2016; in November 2017, the mosque attack in Northern Sinai which killed at least 235 people.
Economic (Saleh, 2010)	• Abrupt demand fluctuations due to: a. Global Financial Crisis (GFC) affected world tourism growth and hence the Egyptian tourism growth, the GFC leads to a sharp decline in the world growth rate of international tourists, average tourist expenditure, average length of stay, and a significant increase in the inter-travel period of international tourists. b. Income fluctuations, Accordingly, tourism demand notably responds to changing economic conditions in source countries. Risk exposure induces visitors to restructure their travel habits favoring a shorter duration of stay, closer and cheaper destinations, fewer tourist trips, and a tighter budget. (Sakr & Massoud, 2003). c. the gradual depreciation of the Egyptian Pound against the US dollar affected the consumer prices in Egypt, this has led to increase in the hotel operating expenditure by more than 25% in 2015 (Anter & Attia, 2017) Also, imposed restrictions on imports and increased tariffs on more than 300 products which affects food and beverage sourcing (Abdi, Counselor, El-habbal, Assistant, & Tate, 2017)

	• Unexpected rise of input costs (e.g., rise in fuel prices in 2015 affects the domestics tourism) • Unstable exchange rates - The cost of imports has soared in Egypt since the country abandoned its currency peg of 8.8 pounds to the U.S. dollar in November, • Lack of public investments – e.g., the new Grand Egyptian Museum project under construction and has been delayed due to a lack of funding.
Environmental	• Traditional tourism management practices - which results in undesirable social and environmental impact, thus threatening the tourism industry's prospects for continued prosperity (Gouda, 2012), For example, the coastal development project Construction was done in a traditional and primitive ways without an environmental impact assessment, either before or during construction implementation or after operation. • Frequent power outages - Egypt witnessed an energy crisis of unprecedented magnitude that caused endless lines at gas stations in various parts of the country, which leads to frequent power outages.
Globalization	• News (speed of circulation of bad news) - local and international mass media outlets have significantly contributed to the issues faced by Egypt's tourism industry by exaggerating the circumstances surrounding the revolution and the current state of affairs in the nation. The news about the region has primarily focused on the unstable political situation, mass demonstrations, acts of violence and lack of sufficient police protection. • Neighborhood political/security problems - Due to the proximity of Middle Eastern countries (i.e., Egypt, Syria, Jordan, Lebanon and the Gulf states), most foreign visitors consider them political and social complements rather than substitutes (Gouda, 2012).
Social	• Criminality - unemployment has fueled rising levels of crime, particularly theft. Foreign workers and tourist visitors are particularly vulnerable to petty crimes such as purse snatching and pick pocketing. (Anter & Attia, 2017)

Actions to Prepare/Recover from Disruptions.

Financial support actions taken by Egyptian Authorities:

- To deal with the tourism crisis, the Egyptian authorities agreed to allocate $5 million to support the sector (Anter & Attia, 2017).
- the Ministry of Tourism has been keen on supporting hotels and resorts through delaying loan payments, insurance and electricity bills in order to reduce operational costs (state information service, 2018).
- The government has delayed the collection of outstanding debt hotels (such as taxes and utilities bills) until 2018 in an attempt to prevent further hotel closures (BMI, 2017).

Political support actions taken by Egyptian Authorities:

- They agreed to launch a massive campaign to promote internal tourism (Ramzy, 2016), e.g., "Egypt in our Hearts" initiative that launched from 2015 and extended through 2016 encouraged domestic tourists in Egypt (Anter & Attia, 2017).
- Egypt fill the gap left by Americans and Europeans by relaxing visa restrictions on Chinese tourist groups (Rights, 2017).
- Minister of Egyptian tourism issued ‘Tourism Impact Plan’ which focuses on 6 main priorities to improve Egyptian tourism and is designed to deliver real and impactful results within 6 months: (Ali, 2019)
    - Working with international tourism partners to restore success;
    - Working in partnership with Egypt’s national carrier, EgyptAir, to develop new destinations, and to support charter and low-cost airline companies in bringing more tourists to Egypt;

- Enhance Egypt's tourism infrastructure by supporting investors and innovating with new ideas;
- Meet the highest international standards through upgraded product and service levels at tourist facilities;
- Working to bring foreign direct investment to Egyptian tourism;
- Develop the growing trend in Egyptian tourism of sustainable eco-friendly accommodation, transportation, and activities.

Actions taken by other organizations:

- Cutting costs was the main applied strategy in tourism and hospitality companies (Elshaer & Saad, 2017). Most tourism and hospitality organizations have engaged in downsizing strategies that included labor reduction and flexible programs of using employees (e.g. part-time or temporary jobs). Thus, managers have reduced the salaries of staff or laid off a considerable percentage of their staff (Nassar, 2012);
- Launch of low cost packages for group tours for domestic tourists in Egypt (Anter & Attia, 2017a);
- Traditional travel agencies and destination management organizations use the new technologies in order to provide greater benefit to their clients. Increasing innovation activities enable travel agencies to provide travel arrangements tailored to each customer's individual needs (Hadi, 2014).
- In terms of improving the image of its airports, Cairo hired the global security consultancy firm 'Control Risk' that specializes in assessing risk at airports, to obtain an internationally accredited by a neutral party safety certificate for its airports. The message they are trying to send is clear- Egyptian airports are safe.

Impact of Tourism Disruptions in Egypt

Egypt as a developing country affected by political unrest experience a decline in the number of international tourist arrivals and in tourism receipts from 15mn in 2010 to 5mn in 2016 (BMI, 2018) . This resulted in a clear continuous decline in the total contribution of the tourism industry to the Egyptian GDP from approximately 450bn in 2010 to 250bn in 2016 (BMI, 2018). Table 2 illustrates the impact of tourism disruptions in Egypt on different TSC members.

Table 2: Impact of Tourism Disruptions on Different TSC members

Disruption	SC member	Effect
Political	Accommodation	• Shortening of the duration of stay and tourist nights (BMI, 2018). • Reduction in hotel room occupancy rates, in 2015, overnight stays totaled 35.6 million, among which 19.6 million came from abroad, and 11.8 million from Europe. These three figures dropped respectively by 0.8%, 1.7%, and 9.3% over last years. The number of European overnight visitors reached its lowest level since 1958 (BMI, 2018). • The intensive decrease in the number of international tourist arrivals and hotel room occupancy rates has caused a sharp decline in cash flow and revenues of such organizations.(Mohammad, Jones, Abdelbary, & Sayed, 2012) • Due to the Russian plane crash travel to Sharm el-Sheikh has declined sharply and falls in occupancy rates led to over 50 hotels closing in 2016.(Rights, 2017)

		• Occupancy rates have fallen by 90% in Sharm el Sheik and by 80% in Hurghada (Rights, 2017).
	Tour operators	• A decrease in the number of international tourist arrivals (BMI, 2018). • Many countries including the US, UK, Japan and Germany among other European States issued travel warnings and evacuated their citizens (Rights, 2017).
	Travel agents	• Declining tourism revenues and increasing the percentage of unemployment (BMI, 2018). • Halting the flights of airlines such as easyJet, Monarch, Thomson and British Airways to Sharm el-Sheikh. Many airlines suspending flights to Sharm el-Sheikh, which was the most popular resort destination for many European visitors (Mohammad et al., 2012). • Cancelled business and the lack of new business have forced travel agencies in the nation to suffer extreme financial hardships and most have been forced to close (Nassar, 2012).
	Transportation	• Many flights reservations were cancelled, UK flights to and from the resort were grounded and cemented the perception that Egyptian airports and Egypt in general is not a safe tourist destination, also flights from Russia to Egypt were suspended (Harb, 2013). • travel insurance premiums increased or did not cover travel to the country (Rights, 2017).
	Attractions	• Popular attractions were left almost deserted. • The revenue of ancient Egyptian monuments and cultural attractions that were down to just £ 10.5 million from £ 250 million in 2010 (Rights, 2017) • Big price reductions lead to absence of revenues created by cultural tourism for example in Luxor complex, which normally attracts high spending visitors.
	Handlers and inbound operators	• Hotels and tour operators reduced their workforce by at least 20% and in many hotels this percentage was much large 40 or even 60% (Abdi et al., 2017). • Only 30% of workers on cruise ships remained on duty, however 50% were given unpaid vacations. As of the 400 cruise ships on the Nile only 40 were operating (Nasr, 2016).
	Tourism business (shopping centers, craft producers)	• Souvenir shop owners and vendors along the base of the Great Pyramid and near King Tut's tomb see only a few tourists patronizing their shops, so shop owners and vendors in business have been forced to close (Anter & Attia, 2017). • This has resulted in many layoffs adding to the total of job losses to the Egyptian tourism sector which has now reached 900,000 since the 2011 revolution (Nasr, 2016).
	Food and beverage suppliers	• High taxes, e.g., Importation of alcohol has an import tariff of up to 250 percent on beers, 1,800 percent on wines, and 3,000 percent on spirits excluding a 14 percent sales tax (Abdi et al., 2017).
	Tourist facilities providers (bars and restaurants)	• Restaurants that previously relied on the business of travelers have been forced to shut their doors as the rising food costs in the nation and steadily declining stream of customers has left restaurant owners with no other choice (Anter & Attia, 2017)
Economic (the depreciation of the Egyptian Pound)	Food and beverage suppliers	• With the devaluation, Egyptian consumers have seen high inflation rates, and Egyptian importers are facing increasing costs (El-Fiqi, 2014).

Environmental	Energy and water supplies	• In the summer, with tourism at its peak, power outages became a problem and the energy shortage a looming threat (Lakhal, 2013). • Water supplies to businesses were also disrupted, while the power outage also affected numerous state institutions including subway services, state television channels and radio stations, which could not air without electricity to run their facilities. (Lakhal, 2013) • As there was no electricity and not enough fuel for adequate transportation, the supply of bread and food was also scarce.(Ibrahim, 2014)
	Waste recycling and disposal	• Improper waste disposal from tourism facilities in the red sea • Increasing levels of waste from construction and operation of tourism facilities(Gad & Rab, n.d.) • the substantial garbage littering on the streets and desert threat the aesthetic beauty of the region, the sustainability of the tourism industry and the natural environment health (Ball & Taleb, 2011)

Challenges Facing TSC Management in Egypt

Driven by safety and security considerations, travelers shift to more secure destinations; above all, tourists value their personal safety and the ability to travel without threats to this safety. Therefore, if security is compromised in a particular region, it is not difficult for travelers to cancel bookings, postpone vacations or switch to other destinations.

Due to the proximity of Middle Eastern countries (i.e., Egypt, Syria, Jordan, Lebanon and the Gulf states), most foreign visitors consider them political and social complements rather than substitutes. As a result, all countries in the region suffer a decline in tourism due to an incident or instability in one country. For example, a wave of violence in the Palestinian territories is likely to have adverse impacts on tourism flows to Egypt (Gouda, 2012)

The vulnerability of the Egyptian tourism sector to external/internal shocks is further exacerbated by the high concentration of tourism traffic. The four largest tourism-generating countries, namely, Germany, Italy, France and the United Kingdom, account for nearly 50 percent of total arrivals to Egypt (BMI, 2018) Based on past records, these countries have proved to be highly sensitive to irregular events.

On the supply side, the tourism industry is highly competitive. It is well known that tourism is a perishable commodity as unsold hotel rooms or airline seats have no residual value. When events occur that expose visitors to personal risk, price competition becomes inevitable. To counter heightened safety risks, significant price discounts are often granted by business sectors (e.g., travel agencies, hotels). This practice stimulates low-price package tours at times of crisis, thereby curtailing the decline of tourist arrivals. The government administrative hierarchy and the lack of communication between stakeholders generate a significant slowdown of management (Ramzy, 2016). The major threats to the tourism industry in Egypt are political instability and socioeconomic problems, which in most cases lead to an increasing in the crime rates. The threat of terrorism remains as the current main disruption. It became clear that the tourism industry is highly susceptible to risk and that the list of risks and threats seem to be virtually without limit. There is also the impression that the Egypt's tourism industry in general tends to be reactive rather than proactive in addressing risks and threats, producing many impact evaluations but few risk forecasts which emphasis the need for more studies concerning TSCRES.

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Supply chain resilience: An analysis of Irish firm's priorities in the wake of Brexit

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Abstract

The modern trading environment exposes supply chains to a multitude and magnitude of risks and disruptions that affect the ability of firms to achieve the desired level of operational and financial performance. Supply chain resilience offers the opportunity to build a strong supply chain which will not only handle disruptions, but which can also learn and adapt in a more appropriate manner than competitors, thus attaining competitive advantage. This research will measure the key elements of supply chain resilience and their relative importance for Irish firms in light of the risks posed by Brexit.

Keywords: Supply chain resilience, Ireland, Brexit

Introduction

On the 23 June 2016, the UK public voted in favour of leaving the EU in a national referendum (Sampson, 2017). This decision has created a new Europe whereby the previous trading relationships, practices and protocols which have evolved since 1973 have become obsolete and redundant (Oliver, 2018). Whilst all member states across the EU are mindful of the potential negative impacts of a changed dynamic with the UK, Ireland is especially concerned as highlighted by the Irish government when they stated that, 'Due to the close economic, highly integrated and concentrated nature of the trading relationship with the UK, amongst all Member States Ireland could be the most adversely affected by the UKs withdrawal from the EU' (Government of Ireland, 2018, pp. 6).

Whilst Brexit brings an array of challenges for traders and in many respects is unparalleled, to many in supply chain management it is yet another example of a disruption that must be

managed (Saenz et al., 2018). Modern supply chains are exposed to an ever increasingly array of risks and obstacles that disrupt their ability to consistently operate at optimum performance expectations (Carvalho et al., 2012). Firms must manage external risks such as natural disasters and acts of terrorism as well as internal disruptions such as product life cycles, customer demand trends and supplier disruptions, and failure to adequately address these, in the event of their happening, can have catastrophic consequences for the firm (Ponomarov and Holcomb, 2009). Management teams must be mindful of the possible disruptions that could affect the planned performance levels of their supply chains and build an organisation with the appropriate culture and practices to proactively handle disruptions.

Supply Chain Resilience

Considering that supply chain management is now a key strategic management function, and one on which companies can utilise to leverage competitive advantage, any disruption to supply chain performance will negatively affect overall company performance (Christopher and Peck, 2004). Hitherto, risk management and risk mitigation were the management strategies and techniques commonly employed to minimise risks and disruptions that supply chain management teams deemed relevant to their firm from internal and external sources (Tang and Musa, 2011). The primary focus of risk management and mitigation is to create a robust supply chain which can forecast and withstand events outside of expected operational norms (Ho et. al., 2015). Firms utilising a risk management strategy successfully, can expect a level of continuance in operations regardless of internal or external risks which have been identified and quantified. The onus is at the firm level to ensure that there is a comprehensive system for identifying, quantifying and reducing risk but Rao and Goldsby, 2009 found in their research that the level of risk identification within firms is 'limited' and without a solid foundation it is difficult for a firm to address risk in the fitting manner (Rao and Goldsby, 2009). Consequently, risk management positions itself within the scope of those activities and events that it can identify (Bak, 2018). These aspects of risk management have resulted in the practice relying on historical data for predictable events (Das, 2018). The nature and scope of supply chain results in risk management often time lacking the required ability and latitude to handle the vast array and magnitude of risks that apply to supply chain activities and actors (Pettit et al., 2010, Vroegindewey and Hodbod, 2018 and Kamalahmadi et al., 2016).

In order to mitigate against some of the deficiencies identified with the use of risk management, an increasing number of firms are turning to supply chain resilience (SCRES), as it is deemed a more holistic approach for the management of disruptions, (internally and externally), (Kochan and Nowicki, 2018 and Melnyk, et al, 2010) and if embedded correctly in a firm, can be used as an enabler of competitive advantage (Ponis and Koronis, 2012 and Sheffi, 2005). The growing emphasis on SCRES is attributable to the principle that not all risk is controllable and firms must be agile in order to engage in proactive and reactive management techniques and protocols should a disruption event occur (Wieland and Wallenburg, 2013). It is those firms who can navigate their way through the disruption event from start to finish, stronger and faster than competitors who will gain competitive advantage (Ponis and Koronis, 2012 and Sheffi, 2005). Whilst SCRES as a concept is growing in stature and importance within supply chain management, as demonstrated in Table 1, the definition varies amongst literature and authors (Abubaker et al., 2017, Fiksel, 2006, Ponis and Koronis, 2012 and Sheffi, 2005).)

Table 1- SCRES definitions

Author	SCRES Definition
Christopher and Peck (2004, pp. 2)	The ability of a system to return to its original state or move to a new, more desirable state after been disturbed.
Sheffi (2005, p. 13)	Ability to, and speed at which they can, return to their normal performance level.
Fiksel (2006, p. 16)	The capacity for an enterprise to survive, adapt, and grow in the face of turbulent change.
Pereira (2009, p. 374)	The ability to change smoothly and rapidly, by either creating redundancy or increasing flexibility.
Ponomarov and Holcomb (2009, p. 131)	The adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions and recover from them.
Juttner and Maklan (2011, p. 247)	The supply chains ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new, more desirable state after being disturbed.
Zsidin and Wagner (2010, p. 3)	Consists of the ability to return to normal performance levels following a supply chain disruption.
Kumar et al. (2010, p. 3721)	The ability to maintain, resume and restore operations after any disruption.
Scholten et al. (2014, p. 212)	The adaptive capability of the supply chain to prepare for unexpected events, respond to disruption and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structures and function.

The primary differentiation between SCRES definition in literature relates to the end point of resilience with many authors determining recovery or the resumption of normal operations (pre-event) as being the culmination of SCRES. Numerous authors build upon this and include the ability to achieve a better performance level post disruption in comparison to pre-event levels and/or competition (Abubaker et al., 2017). Research by Abubaker et al. (2017) and Hohenstein et al. (2015), demonstrate the various viewpoints on SCRES with regard to the scope of SCRES through comprehensive systematic literature reviews. Following the review of previous research into SCRES, both research teams classified SCRES under 4 phases, namely; ready, respond, recover and growth. The two papers indicate that the primary focus of research thus far has been respond and recover, but there is an increasing level of attention on growth (Abubaker et al., 2017 and Hohenstein et al., 2015). Hohenstein et al. add that a common definition of SCRES "has to include all four phases" (Hohenstein et al., 2015, p. 101), and that the lack of clarity on the definition of SCRES has a major consequence for determining the key enablers or elements of a SCRES strategy.

Research into the enablers of SCRES at phase level has been limited without a standard and accepted definition of SCRES as much of the previous work has been focused on defining the concept (Mandal, 2014, Wieland and Wallenburg, 2013). Authors, such as Kamalahmadi and Parast, 2016, Hohenstein et al., 2015, Brusset and Teller, 2017, Christopher and Peck, 2004, Abubaker et al., 2017, Scholten et al., 2014, Pereira, 2009, to cite some examples, have all studied the antecedents of SCRES, but no one study has standardised the enablers which has led to further calls seeking to homogenise SCRES elements within each phase (Hohenstein et

al., 2015). This lack of consensus regarding SCRES enablers negatively impacts on the ability of a firm to identify priority elements and investment opportunities when embarking upon a resilience strategy (Mandal, 2014, Wieland and Wallenburg, 2013, Abubaker et al., 2017 and Manning and Soon, 2016).

In a recent study by Karl et al. the authors attempted to address this by reviewing previous research concerning SCRES elements, including those previously mentioned. In the study the authors reviewed 57 journal articles focused on enablers and elements of SCRES (Karl et al., 2018) in order to determine key elements for a SCRES strategy. Following the systematic literature review the paper concluded with a list of 13 key elements, as in table 2, pertinent to a resilience strategy (Karl et al., 2018).

Table 2 – Elements of SCRES

SCRES Elements		
Security	Risk Management	Robustness
Trust	Visibility	Agility
Flexibility	Information Sharing	Supply Chain Design
Redundancy	Collaboration	Knowledge Management
Financial Strength		

The authors conclude with the insight that any coherent and successful resilient supply chain will exhibit the characteristics in table 2, with relative importance shifting as the firm moves through the pre-disruption phase through to post-disruption phase.

Ireland and Brexit

The Irish economy at the macro and micro level is largely connected to trade with and through the UK and any trade impediments in terms cost and/or time could have a major consequence for Ireland (PWC, 2018). Ireland exported €33.6 billion worth of goods and services to the UK in 2015 and imported €29.4 billion (CSO, 2016). Whilst other member states exported more in terms of monetary value the intensity of trade is lower (Department of Finance, 2017). The monetary value of Irish exports to the UK equated to approximately 15% of global trade in 2015 ex Ireland whereas countries such as Germany and France experience lower exposure with 8-9% of their exports destined for the UK market. The figure for countries such as Finland and Denmark is lower again at 5-7% (Department of Business, Enterprise and Innovation, 2018) indicating the high level of dependence on UK trade for Ireland.

At a sector level the concerns of Irish traders are magnified. Sectors such as agriculture (including food and live animals), chemicals, manufactured goods and minerals all exhibit a strong reliance on UK trade. In the beef market for example, 50% of Irish beef is exported to the UK, which accounts for 70% of the total imports of beef into the UK. 53% of Irish cheese is exported to the UK. Furthermore, over €80m or 90% of Irish grown mushrooms were exported to the UK in 2016 (Irish Farmers Association, 2019). Figures are similar for the chemical sector, whereby 26% of the total exports from Ireland to the UK in 2015 were chemicals with the machinery and transport equipment sector following with a rate of 17% (Department of Finance, 2017). The same report by the Department of Finance calculated that of the top 30 global products most exposed by the UK exiting the EU, Ireland had 17 positions, primarily in the agriculture and chemical sectors (Department of Finance, 2017).

However, not only is the UK an important trade partner for Ireland, but as a peripheral island nation, the UK serves as a key transit network for European market access. Irish traders have historically utilised the UK road network to transport their goods from Ireland to mainland Europe, essentially using the UK as a bridge (Vega et al., 2018). Transit time from Ireland to Europe can be 60 hours for LOLO services and 40 hours for direct RORO service, whereas vehicles can travel the same distance in less than 20 hours by using the UK road network (Breen et al., 2018). Given the nature of the products that Ireland is primarily exporting, i.e. agricultural products and chemicals, time sensitivity and security are major transport characteristics that must be addressed and it is for these reasons that an estimated 53% of global non-UK destined exports transit through the UK (Lawless and Morgenroth, 2017). The decision to leave the EU will result in greater customs control checks at the point of entry and exit of the UK, all of which could negatively affect the transit time, cost and administration burden for Irish traders.

Problem Statement

Whilst research has not settled on a discipline wide definition of resilience (Mandal, 2014), this research defines resilience in the supply chain as the "ability to cope with the consequences of unavoidable risk events in order to return to its original operations or move to a new, more desirable state after being disturbed", (Juttner and Maklan, 2011, p.247). The research accepts Brexit as an unavoidable event that threatens major supply chain disruptions. The literature has shown that there is no consensus regarding the enablers of a resilient supply chain management strategy, and furthermore research is warranted in this area (Wieland and Wallenburg, 2013). This is all the more important in the light of Brexit and the potential disruption to Irish traders it brings, whether it be trading with or through the UK.

In order to address these concerns a research study was initiated in order to determine the key enabler(s) of SCRES within each of the four identified phases, as determined by Irish traders. Identifying the key enabler(s) in each phase will allow firms to proactively manage and invest in their resilience strategy and target key enablers for success.

Methodology

The study adopted a survey based research methodology whereby selected supply chain stakeholders were given the opportunity to rate the relative importance of the elements of resilience within each of the phases. The research followed studies such as those by Abubaker et al., 2017, Hohenstein et al., 2015, Adobor and McMullen, 2018 by deconstructing SCRES into four phases; ready, respond, recover and grow. The elements on which the respondents rated their relative importance were based upon the findings of Karl et al., 2018, specifically the 13 elements identified in their systematic literature review. Respondents were requested to rate the enablers as determined by Karl et al., on a five point Likert scale. Respondents were requested to complete this task for each of the four phases.

It was deemed prudent and reliable to request members of the supply chain workforce to complete the survey as it was in line with authors such as Brusset and Teller, 2017 who specify that it is the supply chain personnel who are key decision makers and informants regarding SCRES (Brusset and Teller, 2017). The online survey was distributed to 80 stakeholders in the supply chain sector in Ireland. The survey was emailed direct to the respondents along with a succinct explanation outlining the components of the survey in order to standardise respondent

understanding. The survey was open online for a period of 2 weeks and following email reminders, it was closed for public submission. The resultant response rate was 35%.

Results and Analysis

64% of respondents classified themselves as a senior manager or owner/director of the company they worked for. In addition, 61% of respondents had 16 years plus experience in the supply chain industry with a quarter of all respondents stating that they had over 20 years supply chain experience. No significant difference is seen when results are analysed within population groupings indicating a standard understanding of SCRES across industry experience, job level and industry sector.

In terms of phase averages, ready and grow were weighed 3.95 and 4.05 respectively, with respond and recover following with 3.85 and 3.91, signifying respondents placing a larger emphasis on the ready and grow phase of a resilient supply chain strategy, as opposed to respond and recover.

Table 3 – SCRES Phase Score

Ready	*3.95*
Respond	*3.85*
Recover	*3.91*
Grow	*4.05*

In the overall context of enablers across the four phases, visibility, supply chain design and agility received the greatest weightings from respondents, with security and redundancy deemed the least important elements. As can be seen in table 4, respondent placed a large emphasis on the inherent strength of the supply chain architecture.

Table 4 - Overall SCRES Element Score

Visibility	4.22
Supply Chain Design	4.21
Agility	4.15
Trust	4.11
Flexibility	4.09
Risk Management	4.08
Collaboration	4.05
Financial Strength	4.04
Knowledge Management	4.01
Information Sharing	3.95
Robustness	3.92
Security	3.54
Redundancy	2.83

When the respondent's data is disseminated into each phase of SCRES, commonality of importance is seen as opposed to standardisation, as shown in table 5. Aside from security and redundancy which are placed in 12th and 13th position respectively, no enabler has a consistent placing in the ranking across all four phases.

Table 5 – SCRES Phase Ranking

	Ready		Respond		Recover		Grow
1	Risk Management	1	Supply Chain Design	1	Visibility	1	Agility
2	Supply Chain Design	2	Risk Management	2	Financial Strength	2	Trust
3	Flexibility	3	Collaboration	3	Trust	3	Visibility
4	Visibility	4	Knowledge Management	4	Risk Management	4	Collaboration
5	Trust	5	Information Sharing	=	Supply Chain Design	=	Supply Chain Design
6	Agility	6	Agility	6	Agility	6	Knowledge Management
7	Robustness	=	Flexibility	7	Flexibility	7	Financial Strength
8	Knowledge Management	8	Financial Strength	8	Collaboration	=	Flexibility
9	Collaboration	9	Visibility	9	Robustness	9	Information Sharing
10	Financial Strength	10	Robustness	10	Knowledge Management	10	Robustness
11	Information Sharing	11	Trust	11	Information Sharing	11	Risk Management
12	Security	12	Security	12	Security	12	Security
13	Redundancy	13	Redundancy	13	Redundancy	13	Redundancy

The results show that all elements, aside from risk management, fluctuate in terms of weighing between the various phases. In the case of risk management, respondents found it was most important in the ready phase and its relative importance declined throughout the four phases of SCRES, whereby its lowest score was to be found in the growth phase. Elements such as supply chain design, risk management and flexibility are deemed important at the early phases of SCRES but as a firm moves to the recovery and growth phase of SCRES supply chain managers are more concerned with enablers such as visibility and trust. The importance of the financial strength of the firm peaks in the recovery phase.

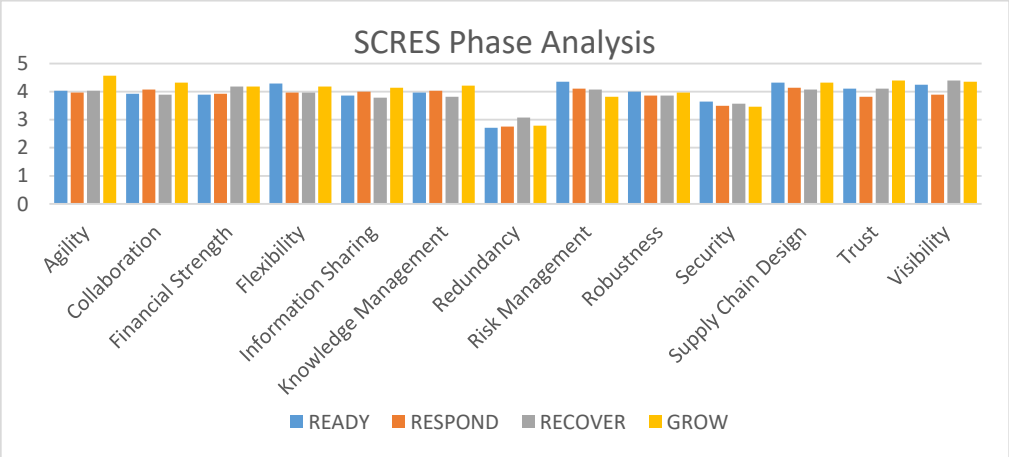

Figure 1 – SCRES Phase Analysis

The results show that the importance of the various enablers fluctuates in accordance to which phase they are embedded. Aside from risk management, all the enablers follow an oscillating path. In the case of risk management, it follows a constant trajectory in that it is deemed most important in the ready phase and loses prominence in the eye of the respondent to the point that its lowest rating is in the grow phase of SCRES. The fluctuating nature of the ratings indicate that the supply chain manager must ensure that SCRES enablers are aligned with phase placement.

Discussion and Conclusion

The research has shown that SCRES is a key enabler for a firm to gain or maintain competitive advantage when faced with adverse trading conditions, which can be exemplified by the possible difficulties faced by Irish traders as a result of Brexit. Additionally, the research and survey indicate that supply chain managers must be adaptive and agile when embarking on SCRES strategy as a myriad of SCRES elements are required, all with shifting levels of importance during the four phases of resilience. By utilising the four phases of SCRES, the research has been able to identify key stages of the resilience strategy and when coupled with the elements as acknowledged by Karl et al., 2018 in their systematic literature review, the research has been able to categorise the potential priorities of Irish supply chain managers at key points of their SCRES implementation and journey.

Whilst all elements received strong support from respondents, indicating validity in the research and the interconnectivity of SCRES elements, a strong supply chain design, is required at the outset of SCRES. A strong supply chain design creates a solid platform for the firm to be ready and respond to a disruption event and creates a solid footing on which to sit the elements that will bring the firm through recovery and onwards to growth. As the firm moves from ready through respond to recover and growth, supply chains should focus on their inherent visibility and agility to maximise the potential possibility derived from SCRES. Likewise, SCRES is predicated on a comprehensive risk management system that will create a strong foothold for recovery and growth.

It is incumbent on all supply chain managers to align phase position with element implementation in order to exploit SCRES to the fullest extent possible. Supply chain managers must ensure that the SCRES strategy evolves in line with the disruption event to ensure that the correct enablers and elements are employed and deployed at the opportune time.

On a cautionary note, Brexit at the time of research and writing, is a live event which thus far has been characterised by a lack of confirmation regarding the new trading environment, and the inherent protocols and systems, which will come as a result of the decision of the UK to leave the EU. At the time of writing traders are unaware of the exact expectations and consequences of this decision and as such respondents were asked to address an event devoid of all the details. With this in mind the author recommends that the results are taken as being preliminary in nature and recommends that further research is conducted when there are confirmed arrangements concerning the UK's withdrawal from the EU.

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Corporate Policy Antecedents of Supply Chain Disruptions – The case of Share Repurchases

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Abstract

Supply chain disruptions have detrimental effects on operating performance and shareholder value. To support corporates in their prevention, scholars developed sophisticated risk management and resilience concepts, all highly dependent on reliable funding. This paper argues that share repurchases, a popular use of cash reserves, consume essential resources required for operating stability. Matching SEC repurchase data with a novel set of disruption announcements for the S&P 500, we find evidence of the positive association of share repurchases with future disruptions, and the mitigating role of the COO. Results shed light on organizational dynamics and managerial short-term thinking preceding supply chain disruptions.

Keywords: Supply chain resilience, Supply chain disruptions, Resource allocation

Theory and purpose of study

Supply chain disruptions and their prevention

Supply chain disruptions impose significant negative consequences on a firm's short-term operations and long-term development (e.g., Hendricks and Singhal, 2005). Events such as delayed product introductions, delivery failures, or product recalls, diminish resources and eventually hurt the company's market position. Besides immediate costs from lost business or repairs, disruptions can cause significant long-term harm, for example if products do not get developed or entire factories have to be foreclosed. Hendricks & Singhal (2005, 2014) in several studies found reduced stock price performance and increased equity risk in the years following disruptions. According to Hendricks & Singhal (2014), supply chain disruptions indicate a malfunctioning of one or several subsystems along the corporate value chain. As there is a multitude of different subsystems and processes, there are also many different types of disruptions, differing both in their antecedents and consequences. Following academic literature, disruptions can however be broadly categorized as either due to internal or external risks (Peck and Christopher, 2004; Wu, Blackhurst and O'Grady, 2007; Pettit, Fiksel and Croxton, 2010). Internal disruptions derive from "operational contingencies" (Kleindorfer and Saad, 2005, p. 54) and usually are the result of insufficient quality assurance and risk management (Wagner and Bode, 2009). External disruptions include natural disasters, terrorism, and any other kind of macro development that is difficult to anticipate (e.g., Braunscheidel and Suresh, 2009; Pettit, Fiksel and Croxton, 2010).

In order to prevent supply chain disruptions, companies can proactively identify critical processes and install effective risk management systems, thereby reducing vulnerability (e.g., Kleindorfer and Saad, 2005; Peck, 2005). Risk management includes identification and assessment of risks throughout the supply chain and subsequent development of effective capabilities to absorb them (Kleindorfer and Saad, 2005; Sodhi, Son and Tang, 2012). Operations management literature provides a comprehensive view on such capabilities, including quality management processes (Lee and Whang, 2005), functional integration, and frequent information sharing (Braunscheidel and Suresh, 2009). However, not all disruptions can be avoided (Craighead *et al.*, 2007; Jüttner and Maklan, 2011), and especially macroeconomic events are difficult to predict. Firms therefore need to build up resilience to unavoidable disruptions to reduce their adverse impact (e.g., Pettit, Fiksel and Croxton, 2010; Ambulkar, Blackhurst and Grawe, 2015). As Craighead *et al.* (2007) show, the severity of a disruption is both related to supply chain characteristics and to a company's mitigation capabilities. Building up those capabilities requires effective internal integration and training (Riley *et al.*, 2016) and the agility to shift resources in case of need (Ambulkar, Blackhurst and Grawe, 2015).

Conceptual research on supply chain risk management and disruption mitigation has provided companies with effective tools and frameworks to protect their operations (e.g., Sodhi, Son and Tang, 2012; Ho *et al.*, 2015; Kamalahmadi and Parast, 2016). Companies willing to build a robust supply chain need to ensure a stable resource base dedicated to operations (Pettit, Fiksel and Croxton, 2010; Zhao and Huchzermeier, 2015) by investing in technology and equipment, human resources, and intangible assets such as supplier and distributor relationships (e.g., Kleindorfer and Saad, 2005; Bakshi and Kleindorfer, 2009). Consequently, corporate policies that divert financial resources from operations will hurt the supply chain in the long run. Intuitively, investment in operations should be a corporate priority and enable companies to increase the robustness of their operations. However, vulnerability rises with the complexity of supply chains (Craighead *et al.*, 2007) and disruptions remain prevalent (Germano, 2019; Sturcken, 2019). Existing literature demonstrated a failure of risk management systems in a variety of instances (e.g., Peck, 2005; Akkermans and Van Wassenhove, 2018; Scheibe and Blackhurst, 2018). While supply chain networks and partnerships have received wide attention (e.g., Bakshi and Kleindorfer, 2009; Cleeren, Dekimpe and van Heerde, 2017), there is a paucity of knowledge on internal decision mechanisms and trade-offs in budget allocation preceding disruptions (Wagner and Bode, 2009; Villena *et al.*, 2018; Zhang, Zhao and Pang, 2018). Peck (2005) and Scheibe and Blackhurst (2018) emphasize the role of managerial incentives, explaining that a misalignment of managers' goals and performance targets can create obstacles to risk management. Braunscheidel and Suresh (2009) point out that integrated supply chains are more agile, implying the need for effective "operations-finance" interfaces (Zhao and Huchzermeier, 2015), which ensure the deployment of sufficient financial resources for disruption prevention and resilience development. However, little is known empirically on the real-world effectiveness of this interface. Which corporate policies lead to a shortage of investment in operations? What roles do decision mechanisms and shareholder expectations play? Furthermore, what is the role of board power-balance? This study aims to fill this knowledge gap and focuses on share repurchases as an organizational antecedent of supply chain disruptions.

The role of share repurchases in corporate development

Share repurchases are a widespread instrument used in stock price management and corporate governance (e.g., Dittmar, 2000; Brav *et al.*, 2005; Vermaelen, 2005) as they

allow to both steer shareholder satisfaction and reduce funding costs through the following main mechanisms: 1) By buying back their own stock, companies reduce shares oustanding and thus increase earnings per share (EPS) (Hribar, Jenkins and Johnson, 2006). Higher EPS increase the value per share and thus the value of investors' holdings, facilitating investor-management agreement (Huang and Thakor, 2013). 2) repurchases signal positive operating prospects to the market, which leads to new investment being attracted (Comment and Jarrell, 1991). 3) Repurchases can reduce the cost of future capital raises as they correct pricing inefficiencies, reduce idiosyncratic risk (Busch and Obernberger, 2017), and increase liquidity (Hillert, Maug and Obernberger, 2016). Most traditional research on the operating effects of share repurchases focused on principal-agent problems (Akerlof, 1970) following the agency theory of free cash flow (Jensen, 1986): Through paying out funds in excess of those needed for operations, boards could avoid managerial overinvestment (Jensen and Meckling, 1976; Comment and Jarrell, 1991). However, recent evidence points to other motivators of share repurchases, which are effective regardless of productive uses of funds. First, managers may benefit from higher stock prices and EPS through stock options (Kahle, 2002; Bens *et al.*, 2003), and EPS-based bonuses (Kim and Ng, 2018) and are thus incentivized to repurchase shares to maximize their personal payoff. Second, activist shareholders focusing on short-term returns can use their voting power to pressure board members for large-scale buybacks (Huang and Thakor, 2013; Autore, Clarke and Liu, 2018). In these cases, share repurchases are deployed solely to extract value from the company and may diminish resources required for long-term corporate development.

Several studies have associated share repurchases with subsequent reductions in operating metrics like R&D expenses, capital expenditures, employment, and cash reserves (Fos, Almeida and Kronlund, 2016; Iyer, Feng and Rao, 2017). However, little is known on the long-term operating effects of repurchases. Bendig *et al.* (2018) show that share repurchases positively relate to future product recalls, thus demonstrating adverse effects to operating robustness. Swift (2018) found negative effects for corporate innovativeness, manifesting in patent quality. These findings indicate a trade-off between payout and necessary investment in the operating business, with potentially enormous consequences for firm and customer value. We thus derive a clear mandate to bring share repurchases to the attention of operations literature and analyze whether they relate to increases in the likelihood and frequency of supply chain disruptions.

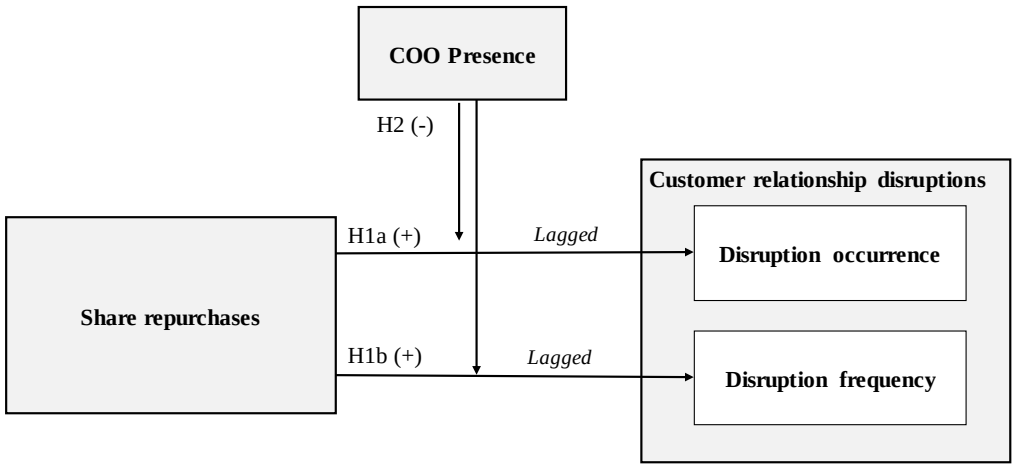

Figure 1: Research model

Hypotheses derivation

Figure 1 summarizes our research model. The risk of experiencing a supply chain disruption can be reduced through investment in physical, human, and intangible assets and robust processes (Pettit, Fiksel and Croxton, 2010; Zhao and Huchzermeier, 2015). While especially internal risks can be mitigated, companies further need to invest in proactive reduction of damage from externally caused disruptions (Craighead *et al.*, 2007; Bakshi and Kleindorfer, 2009). A lack of funding hence increases the likelihood of a disruptive supply chain event. Such a lack of investment occurs when firms prioritize other uses of funds. Conflicts in budget allocation may arise when corporate divisions are incentivized towards different goals (Wu, Blackhurst and O'Grady, 2007; Scheibe and Blackhurst, 2018). The theory of bounded rationality helps to understand why individuals take decisions that are not in the best interest of their organization (Simon, 1955). Managers often face individual incentives, in the form of contingent compensation or performance targets (March and Shapira, 1987; Brandenburger and Polak, 1996), to allocate budget to alternative uses with more immediate benefits. Share repurchases represent an opportunity for managers to maximize their own payoff and increase investor support (Sanders and Carpenter, 2003). Furthermore, following opportunist motives and information asymmetry on operating needs (Akerlof, 1970), shareholders might be more interested in cash payouts instead of new investment. Share repurchases have been shown to deprive operations of critical resources such as R&D and Capex (Fos, Almeida and Kronlund, 2016; Bendig *et al.*, 2018). If not aligned with operating investment needs, repurchases may thus impair firms in their supply chain risk management efforts.

Hypothesis 1a: A company's share repurchase volume has a positive association with the likelihood of a subsequent internal supply chain disruption

Hypothesis 1b: A company's share repurchase volume has a positive association with the frequency of subsequent internal supply chain disruptions

Resource allocation decisions take place within the top management team (TMT) (e.g., Hoskisson and Hitt, 1988), and, following upper echelons theory, are impacted by board structure and characteristics (Hambrick and Mason, 1984). Share repurchases are usually driven by the CFO and the CEO (Brav *et al.*, 2005; Banerjee, Humphery-Jenner and Nanda, 2018). Operating business needs, however, have to be brought to the attention of board members by middle managers (Villena *et al.*, 2018). Given the number of projects competing for funding, operating investment benefits from an advocate on board level. Literature showed that chief operating officers (COOs) are most prevalent in operations-intensive businesses (Hambrick and Cannella, 2004) and, following their responsibility for stable operations, improve financial performance, especially for functionally heterogenous boards (Marcel, 2009). We therefore expect the presence of a COO to ensure that supply chains receive sufficient resources even after share repurchases.

Hypothesis 2: The presence of a COO mitigates the likelihood to incur supply chain disruptions following share repurchases

Data and methodology

Sampling and measures

Our sample consists of all companies constantly listed in the S&P 500 index from 2004 to 2016, as US-listed companies became obliged to publish share repurchase information in 2004 (Banyi, Dyl and Kahle, 2008). Excluding Financial Services (SIC codes 60-67), we arrive at a final set of 252 companies.

The dependent variables in this study are the occurrence and frequency of supply chain disruptions. Following the classification by Ho *et al.* (2015), we included all "micro" disruption events, i.e., disruptions resulting from risks internal to the supply chain. Supply chain disruption events were extracted from PR Newswire press announcements in the Nexis data base using a supervised machine-learning algorithm. In a first step we trained the algorithm with 4,000 manually coded announcements. We then applied the optimized algorithm to a comprehensive set of ~475,000 announcements and received binary indications of fit for multiple disruption clusters. Subsequently, we manually reviewed all tagged announcements and accordingly validated or reclassified them

We use the annual dollar volume of share repurchases as our independent variable. Share repurchase data are drawn from firms' 10-K reports to the Security Exchange Commission (SEC), in which they reveal repurchase quantities, prices, and dollar volumes since 2004 (Banyi, Dyl and Kahle, 2008). According to Banyi, Dyl and Kahle (2008), SEC reports provide for highest measurement as they separate purchases of common stock, purchases of preferred stock and "non-cash" repurchases. As a result, SEC repurchase data have already widely replaced Compustat in finance literature (e.g., Busch and Obernberger, 2017). We manually extract repurchase data, cross-validate them and adjust for mergers and acquisitions during the observed period.

A binary indicator of COO presence is our moderator variable. We manually gathered COO data for all firms in our sample from 10K reports to ensure absolute measurement accuracy. Finally, we include several control variables driving supply chain disruptions. On firm-level, we include firm size, firm age, as well as several measures of operating performance and availability of funding: year-on-year sales growth and return on assets, financial slack, the leverage ratio, and Altman's Z. To reflect the complexity and riskiness of operations we control for capital intensity and R&D intensity. On industry-level, using the Fama-French Industry12 classification, we control for competitive intensity through the Herfindahl-Hirschman-index (HHI), technological dynamism and the industry's disruption intensity (average # of disruptions). Company and industry data are added from S&P's Compustat. Our final set consists of 2,772 firm-year observations.

Modeling

Prior to modelling we review all independent and control variables for multicollinearity. Correlations are all below 0.4 and variance inflation factors below 2.8, indicating that multicollinearity will not influence regression results. To analyze the likelihood of a disruption following repurchases we use a probit regression, while for the frequency of disruptions we employ negative binomial regression, a commonly used method for analyzing overdispersed count variables (e.g., Kashmiri, Nicol and Arora, 2017). Following a Hausman test, we specify the negative binomial regression model with fixed effects to address unobserved heterogeneity in firms' tendency to experience disruptions. The moderating effect of COO presence is tested for disruption frequency. Share repurchase volumes are log-transformed to correct for skewness. In addition to the above-mentioned controls, we account for time-fixed effects and winsorize repurchases and all continuous control variables to exclude outliers. As a lack of investment does not immediately manifest in operations, we forward-lag dependent variables by one and two periods, respectively. Finally, we include the lagged count of supply chain disruptions (in the previous year respective to our dependent variable), following Wowak et al. (2015), to reflect that disrupted operations increase the likelihood of further disruptions.

To ensure robustness or our findings we validate them with Compustat's repurchase measure as an alternative independent variable. Furthermore, as it is possible that using the repurchase-heavy S&P500 created a self-selection bias as the index naturally includes well-performing firms, we include a Heckman correction term following Hendricks, Hora and Singhal (2015). The inverse Mills ratio is insignificant in all regressions, indicating that self-selection concerns in our model are minimal. We also use robust Huber-White standard errors in all models (White, 1982) to correct potential heteroskedasticity.

Table 1: Regression output

	Disruption occurrence			***Disruption frequency***			***Moderation***	
VARIABLES	(1) T+1 - SEC Rep.	(2) T+2 - SEC Rep.	(3) T+1 – Compustat	(1) T+1 - SEC Rep.	(2) T+2 - SEC Rep.	(3) T+1 – Compustat	(1) T+1 - SEC Rep.	(2) T+2 - SEC Rep.
Log-Repurchases	**0.08****	0.01	**0.11****	**0.07***	0.03	0.01	**0.10****	**0.11****
	(0.04)	(0.04)	**(0.05)**	**(0.04)**	(0.04)	(0.05)	**(0.04)**	**(0.05)**
Interaction term COO- Rep.	-	-	-	-	-	-	-0.05	**-0.13*****
	-	-	-	-	-	-	(0.04)	**(0.04)**
Company has COO	-	-	-	-	-	-	-0.05	0.03
							(0.08)	(0.09)
Disruption sum in t0	**0.72*****	**0.70*****	**0.69*****	**0.11*****	**0.11*****	**0.09*****	**0.10*****	**0.10*****
	(0.05)	**(0.05)**	**(0.06)**	**(0.02)**	**(0.02)**	**(0.03)**	**(0.03)**	**(0.03)**
Industry disr. intensity	-1.74	-1.09	-0.71	0.27	0.18	0.30	0.23	0.17
	(1.83)	(1.35)	(1.99)	(0.16)	(0.16)	(0.22)	(0.18)	(0.19)
Firm size	**0.30*****	**0.31*****	**0.24*****	**0.44*****	**0.42*****	**0.43*****	**0.47*****	**0.39*****
	(0.04)	**(0.04)**	**(0.05)**	**(0.12)**	**(0.12)**	**(0.16)**	**(0.13)**	**(0.14)**
Firm age	-0.00	-0.01	0.01	-0.24	-0.30	-0.19	**-0.41***	**-0.41***
	(0.04)	(0.04)	(0.04)	(0.18)	(0.19)	(0.28)	**(0.24)**	**(0.23)**
Sales growth	0.05	-0.01	0.05	0.02	-0.02	0.01	0.03	-0.00
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)
Return on assets	0.00	0.02	0.02	-0.04	-0.05	0.07	-0.05	-0.09
	(0.05)	(0.05)	(0.05)	(0.06)	(0.08)	(0.10)	(0.06)	(0.09)
Capital intensity	0.00	0.01	0.04	**-0.17***	-0.14	-0.03	**-0.16***	-0.15
	(0.04)	(0.04)	(0.05)	**(0.09)**	(0.09)	(0.11)	**(0.09)**	(0.09)
R&D intensity	**0.08***	**0.08***	0.06	**0.14***	0.12	0.08	0.13	0.11
	(0.04)	**(0.04)**	(0.05)	**(0.08)**	(0.08)	(0.13)	(0.08)	(0.09)
Financial slack	**-0.08****	**-0.09****	**-0.09****	**-0.18*****	**-0.22*****	**-0.17****	**-0.20*****	**-0.27*****
	(0.04)	**(0.04)**	**(0.04)**	**(0.06)**	**(0.06)**	**(0.07)**	**(0.06)**	**(0.07)**
Leverage ratio	0.05	0.01	0.04	0.06	0.01	0.06	0.09	0.05
	(0.04)	(0.04)	(0.04)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)
Altman's Z	0.07	**0.10***	0.05	**0.29****	**0.35*****	**0.28***	**0.30****	**0.47*****
	(0.05)	**(0.06)**	(0.05)	**(0.12)**	**(0.12)**	**(0.16)**	**(0.13)**	**(0.14)**
Industry HHI	0.12	0.08	0.30	0.32	0.29	0.59*	0.29	0.10
	(0.29)	(0.31)	(0.33)	(0.21)	(0.21)	(0.31)	(0.21)	(0.19)
Ind. techn. dynamism	**-0.78***	-0.42	-0.70	-0.07	-0.10	0.13	0.08	-0.00
	(0.41)	(0.40)	(0.47)	(0.14)	(0.13)	(0.21)	(0.18)	(0.16)
Heckman correction	0.03	0.08	0.04	0.04	0.03	0.13	0.04	0.02
	(0.05)	(0.06)	(0.07)	(0.06)	(0.05)	(0.08)	(0.06)	(0.06)
Constant	-2.46	-1.51	-1.24	**0.83*****	**0.86*****	**1.16*****	**1.02*****	**1.18*****
	(2.02)	(1.44)	(2.20)	**(0.19)**	**(0.19)**	**(0.26)**	**(0.24)**	**(0.22)**

Discussion of findings

Table 1 presents regression results with standardized coefficients for our main regression and the moderation. Both the likelihood ($\beta = 0.08$, $p<0.05$) and frequency ($\beta = 0.07$, $p<0.05$) of supply chain disruptions are positively associated with share repurchases in the year after the repurchase. H1a and H1b are thus supported, implying that share repurchases reduce budget required for supply chain risk management and resilience development. Interestingly, the relationship disappears in the following years, indicating that the financial constraints resulting from repurchases manifest in operations already after a short time. Robustness tests using Compustat repurchases confirm results, but coefficients are less pronounced and significant. Our findings also confirm a significant

moderating role for COO presence on the relationship between share repurchases and disruption frequency. This moderating role is however only significant in the second year after repurchases ($\beta = -0.13$, $p<0.1$) and also renders the coefficient for share repurchases significant ($\beta = 0.11$, $p<0.05$). We infer that two years after repurchases, only companies without a COO face an increased number of disruptions, while in other companies the COO is able to mitigate an increase in supply chain risk. In the first year after repurchases, however, the COO does not exercise a significant influence in our model.

The regression results confirm our hypotheses and demonstrate that share repurchases indeed pose a threat to supply chain stability and thus corporate development. By distributing resources required for operating investments to shareholders, companies risk enormous consequences in terms of disruptions to their entire value chain. As investments are missed, companies fail to develop adequate risk management systems, and their vulnerability increases. However, having an operational expert on the board in the form of a COO can at least partially mitigate the consequences of repurchases, likely by ensuring that crucial supply chain investments are still made.

Implications and contribution

Theoretical implications

In this article we set out to unveil how corporate finance policies can impact operating stability and bring the topic of share repurchases to the attention of operations literature. Our results expose a trade-off between short-term shareholder appeasement (Brandenburger and Polak, 1996; Sanders and Carpenter, 2003) and long-term supply chain robustness. As literature showed, developing an effective supply chain risk management and resilient operating processes requires investment in the corporate resource pool (Bakshi and Kleindorfer, 2009; Pettit, Fiksel and Croxton, 2010; Zhao and Huchzermeier, 2015). Management decisions to distribute cash without alignment with operating needs can thus impair long-term corporate development. This article follows Zhang, Zhao and Pang (2018) in emphasizing corporate budget allocation mechanisms as a key tool to maintain the resource base required for supply chain robustness. Companies without effective operations-finance interfaces (Zhao and Huchzermeier, 2015) risk depriving the operating business of essential resources, and make their supply chains vulnerable to both internal and external risks. Operations literature thus needs to place a greater emphasis on functional interfaces and the role of corporate finance specifically.

In investigating corporate policies preceding supply chain disruptions, we focus on share repurchases and expose them as a driver of supply chain vulnerability. Share repurchases have long been largely positively view due to their financial market benefits (e.g., Dittmar and Field, 2015; Hillert, Maug and Obernberger, 2016), and thus received rather little attention in other literature streams (Sanders and Carpenter, 2003; Bendig *et al.*, 2018). This article builds up on recent contributions demonstrating negative operating effects of excessive buybacks (e.g., Fos, Almeida and Kronlund, 2016; Bendig *et al.*, 2018). In contrast to traditional theories of managerial overinvestment (Jensen, 1986), it appears that repurchases are frequently employed following motives that are not aligned with corporate long-term strategy (Sanders and Carpenter, 2003; Huang and Thakor, 2013). Motives like contingent manager compensation (Kahle, 2002; Kim and Ng, 2018) and investor activism (Brav *et al.*, 2008; Autore, Clarke and Liu, 2018) should be considered as potential antecedents of supply chain challenges. Companies conducting share repurchases at amounts beyond available excess cash risk severe disruptions of their

supply chain. Thus, this article introduces share repurchases to operations literature as a specific policy that may endanger supply chain robustness.

As budget allocation is determined within the TMT, we additionally ask whether a COO can mitigate adverse impacts from share repurchases. Literature demonstrated that the presence of a COO exerts a positive influence on financial performance (Hambrick and Cannella, 2004; Marcel, 2009) by ensuring that operations run smoothly and efficiently. Our results confirm that even when share repurchases curtail corporate investment budget, companies with a COO are partially able to attenuate the increased likelihood of supply chain disruptions. This study thus emphasizes the role of TMT structure in the context of resource allocation. As the moderating influence of the COO is only significant in the second year after repurchases, the question how far the COO's power as a guardian of stable supply chains reaches remains valid and deserves further academic attention. What is more, we demonstrate the utility of machine-learning applications to increase the variety of supply chain disruptions covered and thus the generalizability of regression results. Machine-learning techniques, if applied in a supervised and reviewed process, can be used to create powerful data bases of firm events.

Managerial implications

To ensure that share repurchases do not happen at the expense of long-term operations, companies can make several provisions. First of all, companies need to control the amount of share repurchases to ensure that only excess funds are distributed. Detaching bonuses and earnings per share, as well as tying stock options to longer vesting periods, would reduce managerial incentives to repurchase when the business is in need of funds. Furthermore, companies should be more wary of giving large stakes to institutional investors, and ensure transparency when facing pressure to repurchase shares. Second, given incentives to repurchase, firms need to establish strong functional interfaces and decision mechanisms, for example through dedicated investment committees.

Limitations

Our study is not free from limitations. First, given the multitude of variables that may drive supply chain disruptions, we cannot derive causality for the relationship between share repurchases and disruptions. Moreover, our study might be influenced by survivor bias, as companies that remained in the S&P 500 are likely to have experienced fewer disruptions over the observed period. There is a clear opportunity to apply the analysis to smaller corporations. Another limitation is due to the limited degree of public information: we classified disruptions according to press announcements, which sometimes reveal the degree of economic damage, but mostly do not. Research able to analyze the effect of corporate policies on the magnitude of disruptions could shed additional light on the relationship between budget allocation and supply chain vulnerability. Finally, our model treats all disruptions as comparable, though in reality each disruption has unique features. Future research could analyze the effects of share repurchases on different types of supply chain disruptions.

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Achieving Supply Chain Resilience through Organizational Capabilities

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Abstract

The purpose of this paper is to investigate Supply Chain Resilience (SCRES) with focus on supply, operations, and inbound and outbound logistics management capabilities. A model comprising of antecedents to the capabilities, their impact on SCRES, and the impact of SCRES on supply chain outcomes is developed and tested. Findings confirm the existence of the relationships between strategic focus, supply chain disruption orientation (SCDO), organizational capabilities and resilience outcomes, and confirm the established relationship between strategic focus and SCDO. This paper contributes to the literature by developing a theoretical model of SCRES and providing empirical support by testing it.

Keywords: Supply Chain Management, Supply Chain Resilience, Organizational Capabilities

Introduction

The complexity and global geographic spread of supply chains, their search for outsourcing and globalization options, and the increased volatility of demand have increased the types and frequency of disruptions experienced in supply chains. The damaging effects of disruptions such as natural disasters, government regulations, forecasting or supplier related issues can last for long if not addressed appropriately and instantly (Pettit et al., 2013). For example, a fire in a brake supplier facility that was supplying parts to Toyota caused a two-week closure of eighteen Toyota plants in Japan, and $195 million loss in revenues (Tomlin, 2006). Similarly, a key supplier failure to provide two critical parts caused Boeing Corporation to lose $2.6 billion (Blackhurst et al., 2005). Companies try to mitigate supply chain risk and disruptions by building resilient supply chains (Christopher and Peck, 2004; Ponomarov and Holcomb, 2009; Sheffi and Rice, 2005) that have the capability to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations.

Some supply chains demonstrate higher levels of resilience than others at the time of disruptions (Christopher and Peck, 2004). This research attempts to investigate some of the important antecedents of supply chain resilience. Specifically, the role of strategic focus (Sebastiao and Golicic, 2008), supply chain disruption orientation (Revilla and Saenz, 2017) and organizational capabilities (Ponomorov and Holcomb, 2009) are explored. Based on both traditional and emergent literature, we theorize and empirically test the hypothesis that organizations with higher capabilities are better at managing supply chain disruptions. Given the importance of organizational capabilities and supply chain resilience as competitive traits in dynamic and turbulent environments (Esper et al., 2010; Shore and Venkatachalam, 2003), it is somewhat surprising that the relationship between these constructs have not been empirically tested in the existing literature. This research attempts to bridge this gap.

The paper is structured as follows. First, the relevant theoretical background is described and the conceptual model is developed. Next, the methodology section described data collection, measurement, and validation. Next, the results of hypothesis testing are presented. Finally, we discuss our findings, and the theoretical and managerial implications.

Literature Review

Research in the area of supply chain resilience (SCRES) continues to grow (Melnyk et al., 2014), though much of it is theoretical. Specifically, the extant literature identifies a long list of capabilities necessary for improving SCRES (Pettit, Fiksel, and Croxton, 2010). However, given that all organizations are resource-constraint and can't invest in all capabilities, there is need for research that: (a) identifies capabilities most relevant for different functions, and (b) links these identified capabilities with supply chain outcomes (Hohenstein et al., 2015; Kamalahmadi and Parast, 2016).

The purpose of this research is to identify capabilities specific to supply, operations, and inbound and outbound logistics management that have a strong impact on SCRES and link those capabilities to supply chain outcomes.

Capability is defined as a combination of activities and processes that enable an entity (such as an employee, department, or organization) to handle turbulent change caused by disruptions (Craighead et al., 2007). Five capabilities are investigated for this research, namely, process, communication and coordination, collaboration, human resources, and information technology (Grant, 1991; Day, 1994). These capabilities and other constructs (i.e., antecedents to and outcomes of capabilities) were chosen, based on extant research, for their strong relevance to resilience in supply, operations, and inbound and outbound

logistics functions (Pettit, Fiksel, and Croxton, 2010). The model (see figure 1) depicts the major constructs and relationships between them.

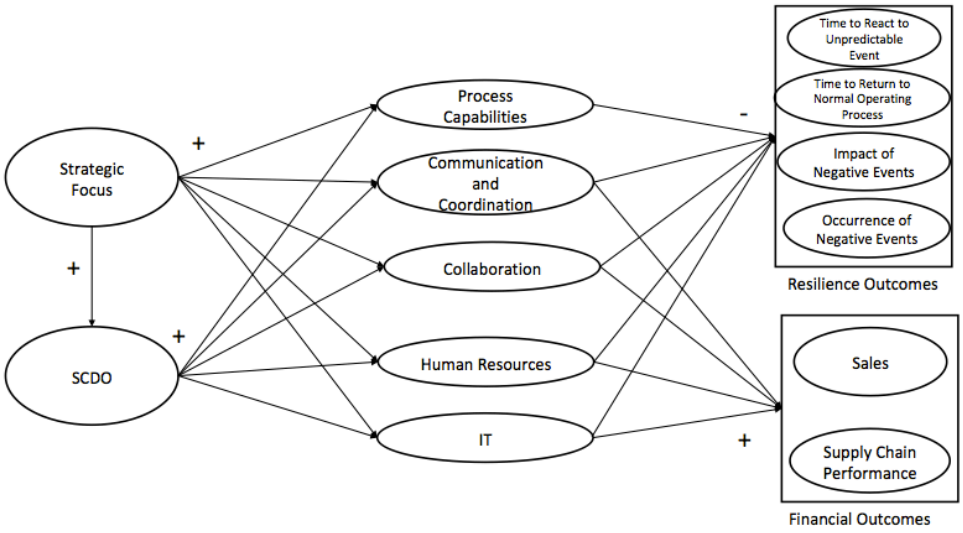

Figure 1 - Supply Chain Resilience Model

The supply chain strategy of an organization is the collection of objectives set for the supply chain and the policies and choices executed to support them. Supply chain strategy can be viewed as an umbrella for operations strategy (Perez-Franco et al., 2016). Accordingly, the strategic focus deals with the level of analysis, whether strategic, operational or tactical (Gunasekaran et al., 2001) and to allocate resources for either efficiency or responsiveness. We build upon Sebastiao and Golicic (2008) to define strategic focus as concentrating decision and directing efforts in a supply chain to balance cost and customer service outcomes. Focus on customer service and related outcomes is likely to lead to high resilience as compared to cost-focused outcomes.

In line with Bode et al. (2011), supply chain disruption orientation is defined as a firm's general awareness and consciousness of its environment and its openness to learn from supply chain disruptions. The stronger the firm's supply chain disruption orientation, the more importance is attached to the issue. This argument suggests that a strong supply chain disruption orientation leads to a stronger awareness, capability and motivation to act in case of a disruption.

Hypotheses Development

The conceptual model presented in Figure 1 illustrates the relationships between the constructs of interest. In this model, strategic focus and supply chain disruption orientation are linked with SCRES outcomes through organizational capabilities. All of the hypotheses presented below are developed out of the relevant literature. We hypothesize that as firms display greater strategic focus and supply chain disruption orientation; they will develop greater organizational capabilities and will be more readily equipped for establishing and maintaining supply chain resilience. As depicted in the model, the organizational capabilities will negatively influence the resilience outcomes but positively influence the financial outcomes. In addition, we argue that a higher strategic focus would result in a higher supply chain disruption orientation. We discuss

these relationships in detail in the following sections.

Table 1 - List of Hypothesis

H1	Strategic Focus is positively related to SC Disruption Orientation.
H2.a	Strategic Focus is positively related to Process Capabilities.
H2.b	SC Disruption Orientation is positively related to Process Capabilities.
H3.a	Strategic Focus is positively related to Communication and Coordination Capabilities.
H3.b	SC Disruption Orientation is positively related to Communication and Coordination Capabilities.
H4.a	Strategic Focus is positively related to Collaboration Capabilities.
H4.b	SC Disruption Orientation is positively related to Collaboration Capabilities.
H5.a	Strategic Focus is positively related to Human Resource Capabilities.
H5.b	SC Disruption Orientation is positively related to Human Resource Capabilities.
H6.a	Strategic Focus is positively related to Information Technology Capabilities.
H6.b	SC Disruption Orientation is positively related to IT capabilities.
H7.a	Process capabilities are negatively related to resilience outcomes.
H7.b	Process capabilities are positively related to financial outcomes.
H8.a	Communication and coordination capabilities are negatively related to resilience outcomes.
H8.b	Communication and coordination capabilities are positively related to financial outcomes.
H9.a	Collaboration capabilities are negatively related to resilience outcomes.
H9.b	Collaboration capabilities are positively related to financial outcomes.
H10.a	Human Resources capabilities are negatively related to resilience outcomes.
H10.b	Human Resources capabilities are positively related to financial outcomes.
H11.a	Information Technology capabilities are negatively related to resilience outcomes.
H11.b	Information Technology capabilities are positively related to financial outcomes.

Methodology

Since this research is aimed at theory testing of the proposed model, we used survey methodology. The survey was developed in stages as per accepted rigorous scale and survey development process (Dillman et al., 2014). This process included an extensive literature review, adoption of scales from extant literature (e.g. SCDO), iterative development of new measures, and review by knowledgeable managers and researchers.

A sampling of this study includes single informants whose primary job functions are logistics, supply chain, and operations management. In this research, the Amazon Mechanical Turk (Mturk) platform was used to find a suitable sample frame. Usage of Mturk to recruit respondents has been validated and found to yield results that are comparable to traditional surveys (Buhrmester et al., 2011). Also, Mturk is considered an adequate platform to reach participants with work experience in supply chain management, logistics, and operations management (Knemeyer and Naylor, 2011). Recruiting respondents from diverse backgrounds and locations, Mturk's sample ensures greater generalizability (Buhrmester et.al., 2011). To recruit respondents, we used the techniques of Schoenherr et al. (2015) to obtain valid responses. The results are provided in Table 1. Respondents were asked to indicate agreement with statements concerning

their firms' supply chain logistics integration activities and processes based on a five-point scale where 1 = strongly disagree and 5 = strongly agree.

Screening questions were asked at the beginning of the survey to limit participation to those who hold a title of manager, supervisor, senior manager, senior director, or member of a management/executive board at firms. Sample respondents were also screened with questions about whether their job function is supply chain management, operations management, or logistics management. If respondents did not satisfy the screening criteria, the online survey was terminated. Additionally, only one response per one IP address was accepted. Participants who completed the survey received monetary compensation for completing the assigned task. Based on these screening questions (job function), out of 1709 attempts to participate the survey, 406 respondents were able to complete the survey. The sample demographics are presented in Table 2.

Table 2 - sample demographics

		n	%
Primary Job Function	Logistics Management	73	18
	Supply Chain Management	170	42
	Operations Management	163	40
Job Title	Member of management Board	24	5
	Senior Management	21	4
	Middle Management	120	30
	Supervisor	241	61
Firm Size	Less than 250 employees	135	33
	Between 251 and 500 employees	108	27
	Between 501 and 1000 employees	65	16
	Greater than 1001 employees	98	24
Annual Revenue	Less than 10 million	191	47
	10 to 100 million	96	23
	101 to 200 million	74	18
	Greater than 200 million	45	11
Experience in SCM (in years)	1-5	182	45
	6-10	140	34
	11-15	45	11
	Greater than 16	39	10

Item purification of the original measurement items was conducted through a qualitative assessment of nomological validity, that is, that the scale expresses the relationships shown to exist based upon previous research (Hair et al. 1998). This was followed by quantitative analysis consisting of correlation analysis, reliability evaluation (using item-to-total correlations as well as Cronbach's alpha), and confirmatory factor analysis.

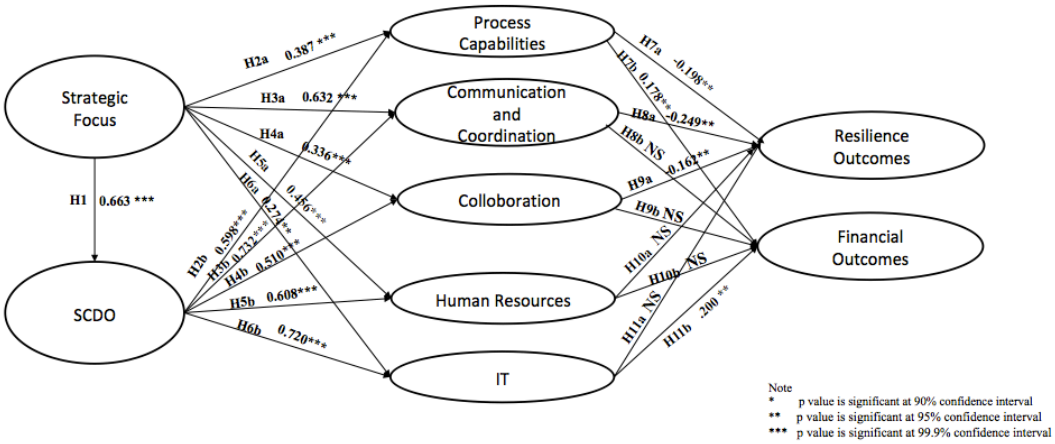

Figure 2 - Structural equation model results

Results

The scale items for measuring organizational capabilities and SCRES were first subjected to the exploratory factor analysis. The scale items were next subjected to confirmatory factor analysis and the nine-factor model was found to have good fit indices (CFI=0.95; IFI=0.95; RMSEA=0.04). All items included in the final research analysis are deemed reliable based upon Cronbach's Alpha scores meeting or exceeding 0.70. Hypotheses were tested using structural equations modeling. The results are provided in Figure 2. For each path, two values are presented: (1) the hypothesis number, (2) the standard estimate for the path if it is supported. We used the same fit indices for the structural model and overall; they similarly indicated a good fit to our model (*Chi Square= 561.21, CFI=0.92; IFI=0.92; RMSEA=0.04*).

Table 3 - Hypothesized Relationship Results

Hypothesized Relationships			**Std.Est**	**Supported Status**
H1: Strategic Focus	→	SCDO	0.663	Supported
H2a: Strategic Focus	→	Process Capability	0.387	Supported
H2b: SCDO	→	Process Capability	0.598	Supported
H3a: Strategic Focus	→	Comm. and Coord. Cap.	0.632	Supported
H3b: SCDO	→	Comm. and Coord. Cap.	0.732	Supported
H4a: Strategic Focus	→	Collaboration Cap.	0.336	Supported
H4b: SCDO	→	Collaboration Cap.	0.512	Supported
H5a: Strategic Focus	→	Human Resource Cap.	0.456	Supported
H5b: SCDO	→	Human Resource Cap.	0.608	Supported
H6a: Strategic Focus	→	IT Capability	0.274	Supported
H6b: SCDO	→	IT Capability	0.721	Supported
H7a: Process Cap.	→	Resilience Outcomes	0.198	Supported
H7b: Process Cap.	→	Financial Outcomes	0.178	Supported
H8a: Comm. and Coord. Cap.	→	Resilience Outcomes	0.249	Supported
H8b: Comm. and Coord. Cap.	→	Financial Outcomes	0.259	Supported
H9a: Collaboration Cap.	→	Resilience Outcomes	0.162	Supported

H9b: Collaboration Cap.	→	Financial Outcomes		Not supported
H10a: Human Resource Cap.	→	Resilience Outcomes		Not supported
H10b: Human Resource Cap.	→	Financial Outcomes		Not supported
H11a: IT Capability	→	Resilience Outcomes		Not supported
H11b: IT Capability	→	Financial Outcomes	0.201	Supported

General Discussion and Implications

The results confirm the existence of the relationships between strategic focus, supply chain disruption orientation, organizational capabilities and resilience outcomes. Firms that achieve higher organizational capabilities also appear to demonstrate high levels of resilience and better financial performance. The results also support the relationship between strategic focus and supply chain disruption orientation. However, interestingly, no relationship exists between human resources and resilience or financial outcomes. Similarly, no relationship exists between communication capabilities and financial outcomes but exists with resilience outcomes.

The lack of a relationship between human capabilities and outcomes can be explained by the illusion/perception that over relying on technology will overcome all problems we face. Another reason could be the lack of training and awareness of the human capital within the organizations. For communication capabilities, it makes sense that they will be critical during and after disruption recovery but we don't necessarily see that translating into financial outcomes. Our study responds to the need for more empirical studies in the topic of SCRES (Ali et. al., 2017) and confirm the results of Ponomorov and Holcomb (2009), Seville et.al (2015) and Brandon-Jones (2014), in establishing how organizational capabilities impact SCRES.

Relevance/Contribution

This research contributes to the body of knowledge for both academics and practitioners in several ways. First, a theoretical model of SCRES is developed comprising of antecedents, SCRES capabilities, and outcomes. Second, empirical testing of the relationships between the constructs expands the theory of SCRES. Empirical testing of the proposed model presented in this study advances our understanding of SCRES phenomenon and its antecedents in a comprehensive model. Also, valid and reliable scale items were developed for the constructs presented in the model through a literature review, interviews, and pilot studies. All scale items have been tested through confirmatory factor analysis for unidimensionality, convergent validity, construct reliability. All instruments are shown to meet the qualifications for validity and reliability. These items can therefore be used in future studies.

The results are also meaningful to supply chain managers. In general, the results demonstrate the importance of aligning strategy, orientation and capabilities to achieve higher resilience and better financial outcomes. More specifically, managers can invest in process, communication, coordination and IT capabilities to establish and maintain SCRES.

The first limitations of this research is data collection. Although the usage of Mturk has been validated (Buhrmester et al., 2011), the replication of this study employing non-panel participants would be a potential future research area to confirm and generalize the findings presented in this study. Secondly, the list of logistics capabilities is not all-inclusive. Future studies could incorporate additional capabilities and outcomes.

Acknowledgement

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Organizational and Individual Antecedents of Interfunctional Transactive Memory Systems for Operational Glitch Mitigation.

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Abstract
In this study we look into factors that underlie the development of inter-functional glitch mitigation transactive memory systems by drawing on the Motivation-Opportunity-Ability framework. On the one hand, we find that organizational policies (role formalization, cooperation incentives and the use of project managers) positively influence the development of inter-functional glitch mitigation transactive memory systems. On the other, we show the extent to which they have had experience working in other departments of the firm are important determinants of the level of development of inter-functional glitch mitigation transactive memory systems.

Keywords: operational glitches, transactive memory systems, industrial equipment manufacturing

Introduction
Glitches that interrupt the normal operations of an organization and command immediate attention are commonly labeled "operational glitches" (Koufteros et al., 2010; Tenhiala and Salvador, 2014; Tenhiala et al., 2018). Every manufacturer has to contend with the reality of operational glitches. Suppliers may deliver components with quality defects. Customers ask for modifications in product requirements midway through the development process. Incorrect engineering specifications generate manufacturability failures. Functionality problems only reveal themselves during final assembly. In order to restore normal operations with minimal performance loss, manufacturers need to be able to design and implement adequate remedial actions to the occurrence of operational glitches. In other words, manufacturers have to develop the ability to effectively mitigate the performance impact of operational glitches (Craighead et al., 2007).

There is agreement on the fact that effective glitch mitigation entails collaboration across multiple organizational functions (Craighead et al., 2007; Hoopes and Postrel, 1999; Scholten et al., 2014; Zsidisin et al., 2005). This collaboration is needed to identify the nature of the glitch, understand its potential repercussions and develop adequate remedies. In particular, inter-functional collaboration is needed to develop and implement amendments to original order-fulfillment plans that integrate knowledge and information from different departments. Integrating knowledge and information from different

departments ensures the adequate amendment of production schedules, production volumes and, if necessary, product specifications (Konijnendijk, 1994).

Unfortunately, we still lack a full understanding of how organizations can stimulate inter-functional collaboration for the purposes of operational glitch mitigation (Scholten and Schilder, 2015). In this study, we address this gap in our understanding by investigating factors that underlie the development of inter-functional transactive memory systems (henceforth TMSs) for glitch mitigation. Glitch mitigation TMSs are defined as informal information and knowledge processing systems between personnel in the manufacturing department and individuals in other business functions based on their transactive memories about each other's´ glitch mitigation expertise. We start from the assumption that the development of an inter-functional glitch mitigation TMS enables decision-makers in different functions to identify the particularities of each occurring glitch and to jointly develop remedial actions that simultaneously observe customer, design and manufacturing constraints.

In order to identify specific factors underlying the development of glitch mitigation TMSs, the chapter draws on the Motivation-Opportunity-Ability (MOA) framework (Blumberg and Pringle, 1982; Boudreau et al., 2003). This framework provides a conceptual basis for explaining knowledge sharing behaviors in work settings. We draw on this framework to identify specific organizational policies and managerial characteristics that are associated with more developed inter-functional glitch mitigation TMSs.

We employ the logic of the MOA framework to identify three organizational-level policies and three personal characteristics of managers heading the manufacturing department on the formation and development of inter-functional TMSs. We test our hypotheses using survey and archival data from 192 industrial equipment manufacturers in Europe.

Background

Inter-functional TMSs

Even though transactive memory research emerged through the study of romantic couples and small groups (e.g. Hollingshead, 1998; Lewis, 2004; Lewis et al., 2007), there have been multiple calls to extend it from the group into the organizational level of analysis. Differently from small groups though, organizations are partitioned into distinct formal structures, such as differentiated functional areas like R&D, sales, purchasing, product development or manufacturing. This aspect mandates a re-conceptualization of TMSs at this level of analysis (Klein and Kozlowski, 2000; Peltokorpi, 2012). We argue that the analysis of organizational level TMSs should be framed through the interactions among personnel located in different organizational functions. In this sense, we examine organizational-level TMSs by investigating the transactive memory processes that take place inter-functionally.

The MOA framework

The MOA framework has motivated several studies in the field of knowledge sharing in organizational settings (e.g. Argote et al., 2003; Siemsen et al., 2008). In line with its logic, we propose a conceptual model in which the formation and development of inter-functional glitch mitigation TMSs is a function of aspects that influence the motivation, opportunity and ability of multiple organizational actors to participate and encourage participation in one.

Motivation to engage in knowledge sharing refers to an individual's willingness to communicate her knowledge to co-workers or to elicit their knowledge to be

communicated to her (Borgatti and Cross, 2003; Boudreau et al., 2003). Opportunity to communicate or retrieve knowledge from co-workers is understood as the set of contextual factors beyond an individual's direct control that constrain or enable her behavior towards knowledge sharing. Finally, ability to communicate or retrieve knowledge from co-workers is about the capacity to transfer knowledge to or receive knowledge from co-workers. We use the logic of the MOA framework to identify organizational and individual antecedents to the development of inter-functional glitch mitigation TMSs.

Hypotheses Development

In order to influence the development of inter-functional glitch mitigation TMSs, organizational policies and Heads of Manufacturing must have an impact on encoding, storage or retrieval processes. We understand the development of an inter-functional glitch mitigation TMS to mean that personnel in the manufacturing department are aware of glitch mitigation knowledge and information possessed by members in other functions. It also implies that personnel in the manufacturing department lend credibility to glitch mitigation expertise located in other functions. It equally means that manufacturing personnel are able to coordinate the retrieval of inter-functional glitch-relevant knowledge exchanges effectively.

Motivation

Motivation is a critical component of the participation in knowledge exchange processes (Argote et al., 2003; Siemsen et al., 2008). Conveying information about one's expertise and making it available upon request involves costs that have to be outweighed by expected benefits (Argote et al., 2003; Borgati and Cross, 2003).The occurrence of glitches whose ownership spawns across distinct functions may generate resentment and engagement in blame games (Koufteros et al., 2010). In this sense, inter-functional relationships are liable to opportunistic behaviors that decrease the likelihood that manufacturing personnel will reach out to outside expertise during glitch mitigation efforts (Sitkin, 1992).

Cooperation incentives – defined as the extent to which individual rewards and compensation are tied to collective achievement – help to counteract these tendencies (Siemsen et al., 2007). In this sense, it is expected that the extent to which manufacturers implement compensation systems that reward overall goal attainment over departmental targets has a positive influence on inter-functional cooperative processes of encoding, storage and retrieval of glitch mitigation-relevant knowledge. Similarly, we expect the existence of inter-functional cooperation incentives to decrease the propensity of individuals and groups to restrict information searches in glitch mitigation situations.

Hence, we hypothesize that:

H1*: The greater the level of inter-functional cooperation incentives within the firm, the more developed its inter-functional glitch mitigation transactive memory system is.*

In order to understand the motivational antecedents of the engagement in inter-functional glitch mitigation TMSs processes, we also look at the Head of Manufacturing's propensity to cooperate with others. The extent to which an individual has propensity to engage in interpersonal relationships and collaborate with others is called her teamwork orientation (Eby and Dobbins, 1997). In the context of inter-functional glitch mitigation TMS development, we expect managers with high teamwork orientation to motivate and inspire subordinates to engage in interactions with others in spite of the pressures engendered by the occurrence of operational glitches (Nevo et al., 2012; Peltokorpi and

Manka, 2008). In particular, we expect them to prompt subordinates to seek information from outside functions during glitch mitigation activities. This reasoning leads us to hypothesize that:

H2*: The greater the level of teamwork orientation of the Head of Manufacturing, the greater the level of development of an inter-functional glitch mitigation transactive memory system.*

Opportunity

Opportunity is a second fundamental aspect underlying engagement with inter-functional knowledge exchange processes during glitch mitigation. It encompasses the contextual aspects that influence the possibilities of organizational actors to engage in the knowledge exchanges reflective of a TMS connecting multiple functions. These aspects provide organizational actors with opportunities to learn who knows what in terms of expertise relevant for glitch mitigation. Considering such aspects is important, because the extent to which individuals seek information from each other in search for solutions to glitches is contingent on their mutual knowledge of each other's domains of expertise (Borgatti and Cross, 2003).

In groups with few individual members, it is relatively easy to match expertise domains with specific individuals. In larger groups, such as organizations, there are many experts to keep in mind and much of their expertise is functionally differentiated. Thus, we expect an inter-functional glitch mitigation TMS in manufacturing firms to benefit from the existence of formal role definitions that assign responsibilities to specific individuals. Job descriptions and organizational charts help dispersed organizational actors to quickly identify what sort of expertise specific individuals are supposed to possess (Bechky, 2006). This enables the development of their knowledge of who knows what (Lewis et al., 2007). The formalization of roles within the organization also reduces ambiguity regarding the responsibility for particular tasks (Sine et al., 2006). This aspect facilitates transactive storage and retrieval processes by clarifying who can be expected to possess knowledge on what and what their usefulness might be in the context of particular glitches. Thus, role formalization should help individuals to construct a mental map that connects their own expertise to the expertise of others in the organization. In accordance with these conjectures, we hypothesize that:

H3*: The greater the level of role formalization within the firm, the more developed its inter-functional glitch mitigation transactive memory system will be.*

In order to understand the impact of contextual factors on the development of inter-functional glitch mitigation TMSs processes, we also examine the influence of the level of diversity in the functional background of Heads of Manufacturing. This level of diversity reflects the prior experience that individuals heading manufacturing departments have working in other functions (Bunderson and Sutcliffe, 2002). This level of diversity also reflects the opportunity these individuals have had in developing expertise pertinent to other functions than manufacturing and, thus, of granting subordinates with direct access to that expertise. While we expect traits such as teamwork orientation to positively influence the development of inter-functional glitch mitigation TMSs, we expect the level of diversity in the functional background to hinder it.

We expect this level of diversity of to be negatively associated with the inter-functional TMS development for two sets of reasons. Firstly, individuals with prior experience of working in other departments are more likely to possess broad expertise. Consequently, when approached by subordinates in search of information and knowledge from outside functional boundaries they are more likely to be in possession of such expertise. This

precludes them from directing subordinates to expertise holders from other departments. In addition, managers with experience in departments other than manufacturing may dismiss the need to engage in outside search and embolden the 'not-invented-here' syndrome (Alexiev et al., 2010; Odell and Grayson, 1998).

Secondly, subordinates who are supervised by individuals with high functional diversity in their background are less likely to engage in expertise search from outside functional boundaries. Research on advice seeking in organizations puts forward that there might be costs associated with admitting one's ignorance on certain issues (Borgatti and Cross, 2003). If subordinates perceive their departmental head to possess broad cross-functional expertise they are more likely to turn to him rather than to engage in more time-consuming searches outside the manufacturing function (Singh et al., 2010).

Hence, we expect that:

H4*: The higher the functional diversity in the Head of Manufacturing's background, the lower the level of development of an inter-functional glitch mitigation transactive memory system.*

Ability

Ability is another essential element underlying personnel engagement in inter-functional knowledge exchange processes. It refers to the general skills and information bases required to participate in the exchange of knowledge regarding glitch mitigation. One of the fundamental aptitudes to do so is to know who across distinct functions and hierarchical levels has relevant glitch mitigation knowledge and information. This entails being simultaneously aware of available glitch mitigation expertise and of who holds that expertise.

However, the ability to match information about multiple colleagues and their respective expertise domains is bounded by one's cognitive limitations. Thus, it has been proposed that in large groups – such as organizations – individuals in boundary spanning positions can serve as directories of information about distant others (Burke et al., 2004, Peltokorpi, 2012). More recently, these types of positions have crystalized in the role of the project manager (Gittel, 2002, Hodgson, 2002), especially in product development contexts. Typically, manufacturers assign project manager roles to individuals who become temporarily responsible for integrating the work of several departments for the purposes of a specific order. One of the ways in which project managers accomplish this goal is by centralizing information on the skills and expertise possessed by people in different functions (Anantatmula, 2010; Hargadon and Sutton, 1997; Hargadon, 2002). This enables them to serve as brokers in connecting knowledge seekers to knowledge holders.

The frequency with which manufacturers deploy individuals to these roles influences their ability to amass information about functionally dispersed colleagues and, consequently, to facilitate the retrieval of relevant expertise. In the context of glitch mitigation activities, this becomes critical for expertise-seeking behaviors given the large number of individuals involved and the unviability of everyone being informed about everyone else's mitigation-relevant expertise. Furthermore, in the context of glitch mitigation seeking and retrieving expertise has to occur swiftly and accurately. Project managers enable these processes by bringing forth their experience with past glitches and glitch mitigation solutions. In this sense, we hypothesize that:

H5*: The more frequently a firm uses project manager roles, the more developed its inter-functional glitch mitigation TMS will be.*

In our examination of the relationship between ability-related factors and the development of inter-functional glitch mitigation TMSs, we also study the role of managerial organizational connectedness. Organizational connectedness refers to the degree of direct contact a focal individual has with others in the organization, regardless of hierarchical position or departmental affiliation (Jaworski and Kohli, 1993). In other words, connectedness is about the network of contacts an individual has in the organization.

Connectedness provides individual organizational actors with the ability to access ideas from other actors with different backgrounds, disparate knowledge resources and diverse group memberships (Hansen 2002). Connected individuals also reduce the occurrence of inter-functional conflicts by engendering intimacy and trust among colleagues (Adler and Kwon 2002). Connected individuals also have more occasions to get to know multiple colleagues in-depth, including about the domain and extent of their expertise (Jansen et al., 2006; Jansen et al., 2009).

The more connected individuals are the more they are able to engage in effective cross-functional relations to access needed information resources (Tsai, 2002). In this sense, we argue that managers with high levels of organizational connectedness stimulate the development of inter-functional glitch mitigation TMSs.

Formally:

H6*: The greater the level of organizational connectedness of the Head of Manufacturing, the greater the level of development of an inter-functional glitch mitigation transactive memory system.*

Methods

Sample and Data Collection

The firms forming our sample come from the European industrial equipment manufacturing industry. We collected secondary data on financial performance, size, age, industrial domain and contact information. We collected primary data through four surveys per firm, customized to the Heads of the Sales, Design/Engineering, Manufacturing and Human Resources departments. We collected primary data on level of TMS development, cooperation incentives, role formalization, use of project managers and inter-functional interdependence. We also collected primary data on the Head of Manufacturing's teamwork orientation, level of organizational connectedness, functional diversity and tenure in the firm. We received complete responses (i.e. 4 delivered surveys) from 60 companies in Italy and 132 in Spain, totaling 768 individual respondents.

Measures

Our dependent variable is the level of development of inter-functional glitch mitigation TMS (TMS_{gm}). We measured it by adapting a scale developed in Lewis (2003) and used throughout most field research. The respondent for this scale is the Head of Manufacturing.

Our study employs six independent variables that correspond to the organizational and personal characteristics conjectured to influence the level of inter-functional glitch mitigation TMS development. We operationalized inter-functional cooperative incentives (CI) by adapting Campion's et al (1993) scale for goal and reward interference. This variable captures the extent to which the goals and compensation of individual employees depend on the performance of the firm as a whole. Role formalization (RF) refers to the degree to which the firm employs formal definitions for job descriptions and reporting relationships. We operationalize this variable by using Patel's (2011) three-item scale.

The extent of use of project managers (PM) is measured by a one-item question targeting the frequency of use of "liaison personnel with the job of coordinating the efforts of several departments for the purposes of a project" (Germain and Droege,1997). The respondent for these three constructs was the Head of Human Resources. In terms of the personal characteristics of Heads of Manufacturing, we measured teamwork orientation (TO_m) by adapting 4 items from Tangpong et al. (2010) and Zacharia et al. (2011). Organizational connectedness (OC_m) captures the extent to which Heads of Manufacturing have personal contact to other organizational actors across departments and hierarchical levels. We operationalize this variable using a four-item scale found in Jansen et al. (2006) and Mom et al. (2009). The respondent for both measures was the Head of Human Resources. The level of functional diversity in the background of the Head of Manufacturing (FD_m) is measured by directly asking these managers to designate all the departments in which they have worked in the firm. The variable is operationalized by counting the number of designated departments.

We also employ several control variables in order not to confound the relationship between the independent variables and the level of inter-functional glitch mitigation TMS development. We control for the level of inter-functional interdependence (IFI), firm age, and firm tenure of the Head of Manufacturing (Ten_m).

In order to isolate country and industry specific effects, we also included dummy variables that reflect different countries and SIC codes.

Results

The results of the linear regressions are in Table 1. Model 1 includes all of the control variables expected to have a direct effect on the level of glitch mitigation TMS development. Model 2 adds to the control variables the hypothesized effects of inter-functional cooperation incentives (H1), role formalization (H3) and frequency of use of project managers (H5). The impact of each of these organizational policies on the level of inter-functional glitch mitigation TMS development is significant ($p < 0.01$, $p < 0.01$ and $p < 0.05$, respectively) and in the predicted direction ($\beta_{ci} = 0.16$, $\beta_{rf} = 0.14$ and $\beta_{pm} = 0.10$, respectively). Model 3 introduces the personal characteristics of individuals heading the manufacturing department hypothesized to impact the development of an inter-functional glitch mitigation TMS (H2, H4 and H6). Results show mixed support for the hypothesized effects. On the one hand, H2 is not supported, since the effect of teamwork orientation is not statistically significant ($p>0.05$). On the other hand, we find support for H4 and H6. Regarding H4, the effect of the diversity in functional background is negative ($FD_m = -0.10$) and significant ($p<0.01$). Regarding H6, the level of organizational connectedness is positively ($OC_m = 0.11$) and significantly ($p<0.01$) associated with a higher level of inter-functional glitch mitigation TMS development.

Table 1: Regression Analysis

Independent Variables			
	Model 1	**Model 2**	**Model 3**
Intercept	2.92***	1.66***	1.59***
	(0.29)	(0.33)	(0.35)
Country	-0.32	-0.18**	-0.19
	(0.09)	(0.09)	(0.09)
SIC Code 34	-0.08	-0.05	-0.05
	(0.09)	(0.09)	(0.09)
SIC Code 36	0.06	0.16	0.16
	(0.13)	(0.12)	(0.11)
SIC Code 35 as secondary	0.01	-0.00	0.00

	(0.12)	(0.00)	(0.11)
IFI	0.26***	0.16***	0.12**
	(0.07)	(0.05)	(0.06)
Age	0.01***	0.01***	0.01***
	(0.00)	(0.00)	(0.00)
Size	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
TEN_m	0.00	0.00	0.01
	(0.03)	(0.00)	(0.00)
CI	-	0.16***	0.17***
		(0.05)	(0.05)
RF	-	0.14***	0.11**
		(0.05)	(0.05)
PM	-	0.10**	0.11**
		(0.04)	(0.04)
TO_m	-	-	-0.03
			(0.05)
OC_m	-	-	0.11**
			(0.05)
FD_m	-	-	-0.10***
			(0.04)
R^2	0.21	0.36	0.40
ΔR^2	-	0.15***	0.04**
F-Value	6.11	14.54	3.37

N= 192; ** $p < 0.05$. *** $p < 0.01$

Discussion and Conclusion

With this study, we have uncovered several aspects underlying the development of glitch mitigation capabilities in manufacturing firm. By studying the antecedents of inter-functional glitch mitigation TMSs, we have found that inter-functional cooperation incentives, the formalization of job descriptions and roles and the regular use of project managers enables the development of glitch mitigation capabilities. We have also found that certain characteristics of the Head of Manufacturing influence the development of glitch mitigation capabilities in manufacturing firms. More specifically, we found that the extent to which Heads of Manufacturing are networked with organizational actors independently of position or affiliation has a positive influence the development of a glitch mitigation TMS, whereas the degree of diversity in their functional background has a negative one. In what follows, we discuss the implications of these findings.

Previous research on glitch mitigation suggests that, in general, high levels of inter-departmental collaboration are required to address the operational challenges put forward by the occurrence of glitches (e.g. Hoopes and Postrel, 1999; Koufteros et al., 2010). Subsequent studies have evidenced that formal mechanisms such as periodic meetings (Tenhiala and Salvador, 2014) and the use of ERP systems (Tenhiala et al., 2018) are effective in achieving requisite levels of inter-functional coordination. Our study adds to this literature stream by examining organization and individual-level factors that are associated with the development of emergent and informal inter-functional coordination mechanisms in the form of glitch mitigation TMSs. These findings are important in that they provide firms with operative policies to develop an inter-functional glitch mitigation TMS and, in that way, enhance the resilience of their internal supply chains to operational glitches.

Our results regarding the characteristics of Heads of Manufacturing also address concerns about the conspicuous absence of human resource characteristics from the operations and supply chain management resilience literature (Ambulkar et al., 2016). By examining how personal characteristics of Heads of Manufacturing influence the development of inter-functional glitch mitigation TMSs, we offer insights on how managers in specific organizational positions relate to firm resilience to operational glitches.

Nevertheless, our results also confirm that some managerial characteristics can be detrimental to the development of inter-functional glitch mitigation TMSs. As conjectured, our results endorse that the variety in the Head of Manufacturing's functional background has a negative relationship with the level of development of an inter-functional glitch mitigation TMS. In spite of the frequent occurrence of operational glitches, glitch mitigation constitutes a situation of exception that mandates the quick reconfiguration of order-fulfilment plans. During glitch mitigation activities, manufacturing personnel have to engage in the search of the knowledge and information required for devising and implementing adequate new plans. Given the typical urgency presented by the occurrence of operational glitches, the tendency will be to prefer proximate over distantly located expertise in the organization. In this sense, our findings illustrate how the perception of a functional head with high breadth of expertise – a perception that may or may not be warranted – discourages manufacturing personnel from engaging in systematic inter-functional knowledge exchange processes. This finding also supports the observation that glitch mitigation efforts tend to favor timeliness over comprehensiveness (Oliva and Sterman, 2001).

Finally, we note that we did not find support for the hypothesis that the Head of Manufacturing's teamwork orientation has a positive influence on the development of inter-functional glitch mitigation TMSs. This result suggests that managers with high propensity towards cooperation are ineffective in motivating the behaviors conducive to inter-functional glitch mitigation TMS development. One possible explanation for this result is that managers´ intrinsic drive to cooperate is insufficient to influence the motivation of subordinate personnel to engage in knowledge exchanges across functional boundaries (Tierney et al., 1999). It could be that the Head of Manufacturing´s propensity towards teamwork stimulates cooperation within but not beyond the manufacturing function.

In summary, collectively these findings enhance our current understanding of glitch mitigation by exploring the neglected role of individual actors in the management of operational disruptions.

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Pharmaceutical Supply Chain Resilience: A Dynamic Capabilities Approach

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Abstract

Supply Chain Resilience (SCRES) is becoming increasingly important in the pharmaceutical industry, especially in the supply of drugs for cancer treatment, as cancer is one of the five most expensive diseases and new developments such as personalized medicine have led to changes in the pharmaceutical supply chain. The purpose of this paper is to elaborate the concept of dynamic capabilities for SCRES in the context of a pharmaceutical supply chain. For this purpose, a multiple embedded case study analysis of thirteen companies in the pharmaceutical industry spreading over Austria and Germany is undertaken.

Keywords: Supply Chain Resilience, Dynamic Capabilities, Pharmaceutical Industry

Introduction

While research in the area of SCRES has gained widespread attention (Jüttner and Maklan, 2011; Fiksel et al., 2015), and the body of knowledge continues to grow, further research is needed to validate existing and proposed SCRES constructs and relationships between them (Hohenstein et al., 2015; Kamalahmadi and Parast, 2016) and to investigate SCRES in the context of different industries (Hendry et al., 2018). In the pharmaceutical industry, SCRES is of increased importance as it has faced a number of disruptions in the past and issues specific to the industry. For example, damages to patient health and sickness due to counterfeit products, raw material shortages leading to scarcity of medicines and drugs, complexity of new drugs, dependence on off-shore manufacturers, waste elimination, product recalls, and diminishing protection provided by patents. These issues and their consequences translate into a need for higher resilience in the pharmaceutical supply chain as compared to the supply chains of other products, such as

consumer durables or office products. This need for higher resilience translates into requirements of near-perfect availability of supplies or ability to replace source if a disruption occurs, highly controlled storage conditions, and breach-proof transportation that assures the highest levels of integrity of the cargo (Bigdeli et al., 2013). Lack of resiliency in the pharmaceutical supply chain in dealing with disruptions can not only jeopardize the efficiency and effectiveness of the healthcare system, but also put patient health and life at risk (Moktadir et al., 2018).

Notably, over the past few years, researchers have addressed SCRES-related issues such as risk identification and assessment in the pharmaceutical industry (Breen, 2008; Enyinda et al., 2009; Ouabouch and Amri, 2013; Jaberidoost et al., 2015). However, a majority of these studies consider specific activities, such as outsourcing and off shoring, in isolation. Further, research in the specific context of the pharmaceutical industry is sparse. In sum, holistic research related to resilience in the pharmaceutical supply chain is limited (Aigbogun et al., 2014). Therefore, the purpose of this paper is to investigate how pharmaceutical companies build resilience into their supply chains. To do so, the theoretical context of dynamic capabilities, is adopted. Dynamic capabilities are the ability of a company to sense and adapt to changes in the external environment. For this research three categories of dynamic capabilities of sensing, seizing, and transforming (Teece, 2007) are used to guide this research.

The questions guiding this research are:

- How do pharmaceutical companies build resilience into their supply chains?
- How pharmaceutical companies prepare and respond to disruptions in their supply chains?
- What factors hinder and facilitate the process of building SCRES in pharmaceutical supply chains?
- How does SCRES help individual pharmaceutical companies improve supply chain performance?

The paper is structured as follows. First, the relevant theoretical background is described. Next, the methodology used in this research is presented followed by the preliminary findings. Finally, the main conclusions are presented and potential future research areas including the next steps are identified.

Theoretical background

This section provides a review of the literature relevant to understanding resilience in a pharmaceutical supply chain context. First, we define SCRES and identify the key findings from the extant literature. Next, we establish the uniqueness of the pharmaceutical supply chain to justify the context of this research. Finally, we review the literature on dynamic capabilities and explain why it is an appropriate theoretical lens for this research.

Supply chain resilience

SCRES in a broad sense refers to the ability of supply chains to prepare for, respond to and recover from disruption (Sheffi, 2005; Pettit et al., 2010), ideally leading to a phase of growth in order to emerge as stronger entities (Hohenstein et al., 2015). With growing volatility and uncertainty in supply chains, research in the area of SCRES has gained widespread attention (Jüttner and Maklan, 2011; Fiksel et al., 2015). Most studies investigate SCRES broadly (Hohenstein et al., 2015; Tukamuhabwa et al., 2015; Stone and Rahimifard, 2018). Consequently, the literature examining multiple tiers of a supply

chain or network is rather sparse (Tukamuhabwa et al., 2015). Further, while there has been an emphasis on supply chain disruptions caused by catastrophic events such as earthquakes and terrorism, there still is a lack of research using in-depth studies that considers SCRES in the context of different industries (Hendry et al., 2018). One such industry is the pharmaceutical industry; research in this industry is currently underdeveloped and needs further exploration, especially by undertaking research that goes beyond a dyadic perspective (Seuring, 2008).

In recent years, researchers have focused on applying, testing and exploring diverse strategies and capabilities broadly (Stone and Rahimifard, 2018; Aboah et al., 2019), in order to increase supply chain resilience (Wieland and Wallenburg, 2013), as well as factors that reduce and improve supply chain resilience (Blackhurst et al., 2011). The three disruption phases readiness, response, and recovery have been generally suggested in the SCRES literature (Sheffi and Rice, 2005; Ponomarov and Holcomb, 2009). More recently, a fourth phase has been identified (Pettit et al., 2010; Blackhurst et al., 2011; Hohenstein et al., 2015; Adobor and McMullen, 2018).

One common theme across the entire SCRES literature is that of learning from previous experiences may shift the organization to a further state (Ponomarov and Holcomb, 2009; Pettit et al., 2010). Scholten et al. (2019), for example have focused on how organizations can learn and adapt their routines in order to build SCRES for non-routine events. Six learning mechanisms have been identified that explain how organizational decisions and actions intentionally and unintentionally facilitate the adaptation of routines to prepare, respond to and recover from supply chain disruptions. Further research could be adopted on how learning mechanisms could help a supply chain to return to an improved functional state after a disruption (Scholten et al., 2019).

Pharmaceutical supply chain

The pharmaceutical supply chain (PSC) is somewhat different from the supply chains of other industries or physical goods, because of its criticality, speciality and complexity (Breen, 2008; Bhakoo and Chan, 2011; Bigdeli et al., 2013; Nsamzinshuti et al., 2017). Criticality refers to the availability or non-availability of drugs, as any disturbances that occur in the pharmaceutical supply chain can affect the efficiency of the healthcare system and jeopardize the supply of medicines (Breen, 2008).

Speciality refers to numerous regulations to which the pharmaceutical industry is subject (Mossialos and Oliver, 2005; Parmata et al., 2016). Researchers and practitioners agree that the PSC is a special supply chain and "cannot be treated like other commodities". The PSC underlies several regulatory requirements regarding the production, distribution, transportation and storage of pharmaceutical products (Bigdeli et al., 2013). Therefore, the management of both material and information flow in the pharmaceutical industry has become more important due to its complex and dynamic network structure (Jaberidoost et al., 2013). Complexity refers to the number of stakeholders in the supply chain (Nsamzinshuti et al., 2017). Numerous players in the pharmaceutical industry, such as pharmaceutical manufacturers, wholesalers, distributors, customers, information service providers and regulatory authorities, play a vital role in the provision and supply of medicines and save human lives (Bhakoo and Chan, 2011; Bigdeli et al., 2013).

Finally, the pharmaceutical industry is currently facing new challenges, as patents for medical products expires the economies of scale diminishes (PWC Report, 2007; Singh et al., 2016). The PWC Report (2007) points out, that the pharmaceutical manufacturers are already experiencing an underutilization of less than 50% at some sites. Lacking expertise of pharmaceutical companies causes the production of pharmaceuticals to be

handed over to contract manufacturers and an increase in cheap night courier services allows medicines to be delivered directly to pharmacies, reducing inventory levels and controlling product leaks more effectively (PWC Report, 2007).

To address these challenges related to criticality, speciality and complexity, SCRES is important, as pharmaceutical companies should understand how disruptions should be managed and how to become agile in order to deal with these situations (Mehralian et al., 2015). To meet these challenges a shift in this industry is imperative and therefore, pharmaceutical companies have to reduce costs and become agile (Singh et al., 2016).

More specifically, cancer is one of the five most costly conditions. New technologies such as personalized medicine are being used to treat cancer. This research is focused on the supply chain of medicines used for cancer treatments. Thus, it makes sense to initially focus on providing financial support for patients with this disease (PWC Report, 2007). Personalized medicine as a new technology will eliminate redundant treatments, reduce side effects of drugs, prevent and predict diseases and previous intervention as well as reduce health care costs (Bakhiet, 2018). The manufacture of tailor-made drugs requires a different manufacturing strategy, which is why pharmaceutical manufacturers should no longer follow the lean manufacturing strategy, but rather produce "assembly-to-order" in order to create agility (PWC Report, 2007; Bogle, 2017).

Dynamic Capabilities

The concept of dynamic capabilities was introduced by Teece et al. (1997), and is the ability of a company to sense and adapt to changes in the external environment as a key for sustainability and competitiveness. Teece (2007) defined three categories of dynamic capabilities: sensing, seizing, and transforming. Sensing is the activity including scanning, creation, learning and interpretation. Seizing follows and includes the response to sensed opportunities and threats. Transforming as a third category involves the reconfiguration of intangible and tangible assets with the goal to enhance, combine or protect companies' capabilities.

Dynamic capabilities are a competitive necessity in modern business as they help respond to environmental challenges (Ponomarov, 2012). This concept leads to evolutionary fitness by supporting the creation, extension and modification of a resource base and turning it into a long-term competitive advantage (Teece, 2007). This research focusses on the PSC and its evolutionary fitness, thereby making dynamic capabilities an appropriate theoretical lens. There are similarities between the concept of SCRES, including the phases of prepare, respond, recover and growth, and the dynamic capabilities categories. Sensing would ideally take place in the preparing phase, seizing in the respond, and transforming in the recover and growth phase. The categories of DC and the phases of SCRES informed our initial research model for this study (figure 1).

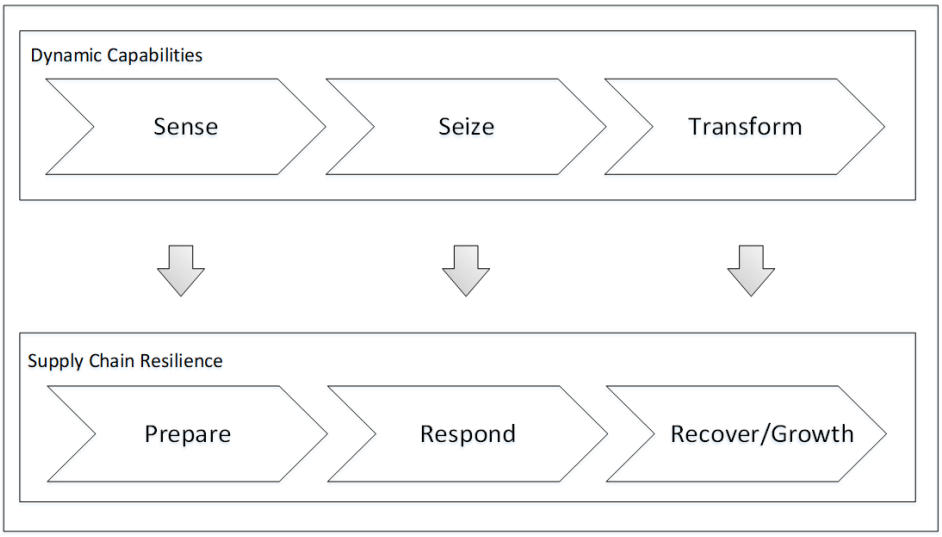

Figure 1 - Research model - link between dynamic capabilities and supply chain resilience (adapted from Hendry et al. 2018)

The dynamic capabilities theoretical lens helps to guide both the data collection process and the analysis of the findings. It helps to establish how the actors are "sensing" the current supply chain context, including developing an understanding of the disruption caused by supply chain risks, how they are "seizing" any associated opportunities, and finally, how they are "transforming" their businesses towards becoming more resilient.

Methodology

Not much is known about SCRES in the context of the pharmaceutical industry. Therefore, the case study approach was adopted to enable an in-depth investigation of the understanding of managers' perceptions of and responses to supply chain disruptions and their strategies to improve SCRES. The case study method is appropriate as it allows researcher to collect data from multiple sources to make sense of and begin to build a theoretical model of managers' perceptions and behaviours. The chosen approach facilitates extension of the existing dynamic capabilities theory, and the SCRES theory in the context of pharmaceutical industry, best described as a "theory elaboration" (Ketokivi and Choi, 2014).

In this research, a multiple embedded case study analysis of thirteen companies in the pharmaceutical industry spreading over Austria and Germany is undertaken. The pharmaceutical supply chain according to Carter et al. (2015), shown in figure 2, as the unit of analysis deals with a focal company, their suppliers, second tier suppliers, customers and carriers. The material flow goes from the supplier to the manufacturer via carriers to wholesalers and retailers or clinics/hospitals, which are also partly supplied directly by pharmaceutical manufacturers and wholesalers. In extant research, typically, the company type "retailer" includes hospitals, pharmacies and drug stores (Utami et al., 2009). In this work, a differentiation between retailer and clinics/hospitals has been made, as clinics and hospitals receive medical products directly from manufacturing companies. Drugs can be purchased from pharmaceutical retailer such as pharmacies and online-pharmacies (Gupta et al., 2012). In-person interviews and other data (e.g. archival data, documents, attending meetings, and secondary data) will be collected.

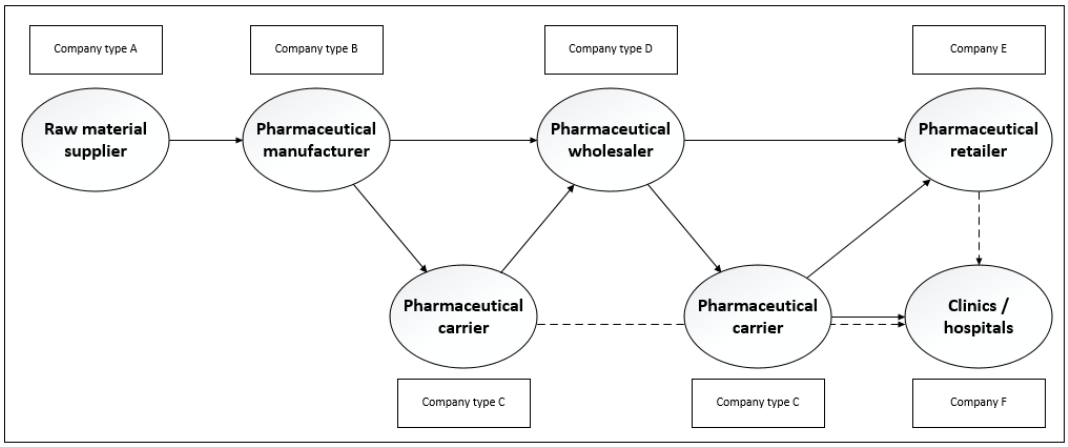

Figure 2 - Pharmaceutical supply chain as the unit of analysis

Data collection and analysis

Data will be analyzed, using NVivo 12, with a set of codes developed to identify themes around SCRES in the pharmaceutical industry. NVivo is a widely used tool in qualitative and mixed methods research with key strengths in the flexibility of reviewing and revising codes and search tools. This supports the iterative interaction between theory and data that is central to our approach. The applied iterative process in case research is based on what Dubois and Araujo (2007) drew from Ragin (1992) what is described as casing, a flexible, dynamic interaction between data and theory.

Preliminary Findings

The research team is in the process of finalizing the interview protocol. Interview protocol will include open ended questions around the concepts of dynamic capabilities and SCRES. So far, thirteen companies have agreed to participate, and eighteen interviews have been scheduled. We expect to have preliminary results of the study by mid of May 2019. We expect to report on the following: how pharmaceutical companies build resilience into their supply chains, respond to disruptions, factors that hinder and facilitate SCRES, and relationship SCRES to supply chain performance. Further, we will be able to identify similarities and differences related to building and maintaining SCRES between the pharmaceutical industry and other industries such as food industry (Hendry et al., 2018).

Sensing

We expect to find evidence for risks and challenges identified in the underlying supply chain from the cases. We will provide the evidence for each of these opportunities in a table including each category with quotes from the evidence and the related sources of the interviews.

Seizing

We expect to find in-depth insights of sensing opportunities and show the related categories in the pharmaceutical supply chain from the cases. We will show the evidence for each of these opportunities in a table including each category with quotes from the evidence and the related sources of the interviews.

Transforming
The third phase of transforming follows sensing the threats and seizing the opportunities in the underlying supply chain. Based on the cases we expect to find evidence of the transforming activities.

Relevance/contribution
This research contributes to the body of knowledge in several ways. First, this is one of the first empirical study seeking to investigate SCRES in pharmaceutical supply chains and includes both physical and support firms. It provides a comparison of the characteristics of the threats posed in the pharmaceutical industry with those in other industries. Further, it truly is a supply chain research as it includes multiple players across several levels in the supply chain. Second, depending upon the theoretical lens (for example, dynamic capabilities) that emerges as the most appropriate to study the phenomenon, the study is expected to contribute to that specific stream of research. Finally, SCRES implications for managers in the pharmaceutical industry will be discussed. The expected findings of this research are an elaboration of dynamic capabilities for SCRES in the context of a pharmaceutical supply chain.

Limitations and future research
This study has focused on the pharmaceutical industry. It could be interesting to conduct a study using dynamic capabilities as theoretical lens to study PSCs in other industries. Additionally, it would be beneficial to include companies from other countries than Austria and Germany that are part of the PSCs investigated in this research. An extension of this research into a longitudinal study would enable the companies to reflect on risks, opportunities and their impact, and provide greater insights into transformation part of SCRES.

Work-in-Progress Research
This research is still a work-in-progress project. We are currently finalizing the interview protocol and will start conducting the interviews in April of 2019. The next step in this research project is data collection. We expect to present initial findings from preliminary analysis during the conference.

Acknowledgement
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Supply disruptions' influence on internal operations and resilience: Balancing buffering and bridging

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Abstract

In this study, we explore the comparative effectiveness of two predominant strategies to deal with supply disruptions: buffering and bridging. Drawing from resource dependence theory, we propose that a buyer's dependence on a disrupted supplier determines the effectiveness of the two strategies in preventing the disruption from resulting in internal production failures and, subsequently, in decreased resilience. We suggest that in high dependence situations, bridging actions – as opposed to buffering actions – can more effectively mitigate the impact of supply disruptions. We test these predictions using an extensive, four-year database on disruptions to more than 300 buyer-supplier relationships.

Keywords: Resilience, Disruptions, Resource Dependence Theory

Purpose

In 2018, over fifty percent of the disruptions that firms experienced emerged from their first-tier suppliers (Riglietti and Aguada, 2018). Extant supply chain research offers a wide range of strategies through which firms may mitigate such disruptions' adverse consequences for their internal operations and performance (i.e., build resilience). Recent studies suggests that these strategies can be broadly distinguished into buffering and bridging actions (Bode et al., 2011; Mishra et al., 2016). Buffering actions, on the one hand, seek to minimize firms' exposure to disruptions by, for example, establishing redundant inventory or identifying backup suppliers. Bridging actions, on the other hand, strive to increase firms' influence over the exchange partner by acts such as intensifying information sharing or establishing personal relationships. Although these recent studies have provided valuable insights into intra- and inter-firm aspects that trigger buffering or bridging responses to disruptions, they offer no validation of the *actual* effectiveness of either strategy in preventing disruptions from causing internal production failures and performance issues for the buying firm. To address this

important omission, the purpose of the present research is to explore how and under which conditions buffering and bridging contribute to firms' resilience.

To study the effectiveness of buffering and bridging across different situations and in relation to each other, we draw from resource dependence theory (RDT) as an important conceptual perspective on exchange relationships. According to RDT, firms' susceptibility to adversity increases when they become more dependent on specific exchange partners for the provision of scarce resources (Pfeffer and Salancik, 1978). We therefore hypothesize that if the dependence of a buyer on a supplier increases, a disruption to that supplier is more likely to result in internal production failures and reduced resilience at the buyer. In doing so, we explore disruptions' direct *and* indirect effects on firms' performance (see Figure 1). RDT further suggests that the specificity of the scarce resources that characterize high dependence relationships makes the implementation of buffers extremely costly. In such situations, bridging is in the best interest of both the buyer and the supplier (Bode et al., 2011; Mishra et al., 2016). Consequently, we propose that the hypothesized adverse effects of dependence are more effectively mitigated when buyers engage in bridging as opposed to buffering.

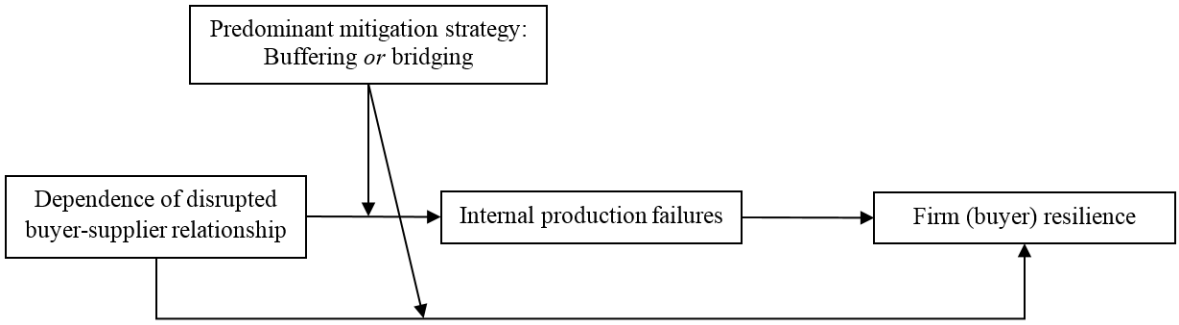

Figure 1 – Conceptual framework

Methodology

We will test our hypothesized relationships using an extensive database on disruptions to the more than 300 buyer-supplier relationships of an order-driven assembler of complex, highly technological products *(Company A).* This company is particularly appropriate for our research purposes because its suppliers deliver raw materials that range from standardized (low dependence) to highly customized (high dependence). Each year, *Company A*'s operations are disrupted more than 800 times due to, for example, production problems at these suppliers and subsequent delayed or cancelled deliveries of raw materials. In an ongoing collaboration with this firm, we have obtained access to *Company A*'s detailed records of the nature and impact of disruptions and ensuing actions toward suppliers for the past four years (2015-2018), complemented with internal reports and interviews.

From the obtained information, we will code our research variables. Records on supplier characteristics and production schedules enable us to respectively code levels of dependence and the occurrence of internal production failures. To operationalize buffering and bridging actions, we will build on the measures developed by Bode et al. (2011). Finally, we will gauge resilience for specific disruptions by determining the delivery reliability (in terms of on-time delivery and order accuracy) of *Company A* with respect to the customer orders affected by the disruption.

Because the disruptions are nested in both suppliers and time, we will conduct multilevel structural equation modelling (MSEM; Preacher et al., 2016) using Bayesian estimation to estimate model parameters. We will conduct these analyses in Mplus 8.1 (Muthén and Muthén, 1998-2017).

Findings

We have commenced coding the obtained information. In accord, the analysis of the data is at a preliminary stage, and we expect to finalize this at the end of April 2019.

Contribution

This study contributes to extant literature in several important ways. We relate the relative effectiveness of two important types of resilience strategies (buffering and bridging) to a buyer's dependence on the disrupted supplier. In doing so, we extend prior research that focused on aspects that provoke buffering or bridging actions without assessing these actions' subsequent effectiveness (cf. Bode et al., 2011; Mishra et al., 2016). Moreover, our approach to measuring disruptions' adverse consequences for firms may have important implications for broader resilience research. Specifically, besides determining disruptions' direct effect on firms' performance, we additionally estimate their indirect effect by means of subsequent internal production failures. This approach provides valuable insights into the mechanisms through which disruptions affect firms' resilience. Furthermore, we contribute to RDT by empirically illustrating how core notions of the theory manifest in a resilience context. More practically, our findings may guide firms in making better informed decisions about which mitigation strategy to pursue, thereby enabling them to more effectively mitigate disruptions' impact.

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Understanding the role of relational capital and buyer power in supply chain disruption recovery

– Buyer–supplier dyadic perspectives

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Abstract

The purpose of this study is to understand the link between relational capital and disruption recovery performance and how its efficacy changes with the use of mediated power. Using buyer–supplier matched pair data from the US manufacturing industry, we explore the role of the buyer's use of coercive and reward power in moderating the efficacy of relational capital in recovery performance. The results showed that while the buyer's use of coercive power is insignificant in moderating the relationship between relational capital and recovery performance, reward power complements the ability of relational capital, thereby contributing to increasing recovery performance.

Keywords: Relational capital, Mediated power, Supply chain risk management

Introduction

While supply chain risk management studies have brought significant understanding to ways to mitigate supply chain disruption, relatively little attention has been devoted to the disruption recovery stage; that is, what to do after a disruption event (Sodhi et al., 2012). As it is impossible to completely prevent supply chain disruptions, being able to figure out ways to respond to and recover quickly from them is crucial (e.g., Krause et al., 2007; Sodhi et al., 2012). Therefore, understanding a firm's successful disruption response/recovery approach is as important as understanding how to prevent disruption. However, the effectiveness of a collaborative buyer–supplier relationship in the disruption response and recovery stage is still unclear, and the impact of the dominant party's use of mediated power to motivate the other party involved in collective action for the recovery process is rarely examined.

This study addresses this gap in the literature by using the theoretical lens of relational capital and power in the buyer–supplier relationship. By using matched pair data to capture both the buyer and the supplier's perspectives, the results not only contribute to

understanding the dyadic nature of exchange relationships in the supply chain, but also contribute to understanding the buyer and the supplier's perception asymmetry of the presence of the power in the relationship. Adopting a buyer–supplier dyadic perspective can also lessen the possibility of single rater bias, such as an exception fallacy (Roh et al., 2013).

Social capital theory offers a framework for understanding how organisations acquire resources that exist outside of their boundaries and access the benefits of developing closer ties with other partners (Inkpen and Tsang, 2005). In particular, relational capital offers the benefit of achieving successful recovery from a disruption by lessening the worry about the other party's opportunism, thereby facilitating supply chain entities' interactions to promote collective sensemaking and resource reconfiguration (e.g., Olcott and Oliver, 2011). Along with relational capital, power has been considered to be another important relational aspect that influences buyers and suppliers in developing and managing their relationships (Yeung et al., 2009). Coercive power and relational capital are opposing components of social behaviour, as coercive power deteriorates the ability to trust, and the willingness to continue the relationship thereby weakens the relationship and relational benefit. Conversely, reward power and relational capital are complementary components, as reward power enhances the ability of reciprocity and trust in the relationship, and promotes collaborative supply chain relationships (e.g., Ireland and Webb, 2007).

In this paper, we seek to shed light on this phenomenon by investigating the role of power (mediated power: coercive and reward power) in moderating the efficacy of relational capital in supply disruption response and recovery performance.

Literature review and hypotheses development

In a disruption situation, there is a necessity for appropriate recovery actions, such as the rapid mobilisation and reconfiguration of supply chain resources (e.g., Craighead et al., 2007; Olcott and Oliver, 2011). As these actions cannot be successful through a single firm's effort, building collaborative relationships with partnering firms as a recovery enabler has been emphasised (Craighead et al., 2007).

Relational capital in the relationship permits privileged access to the key resources of others, promotes firms to engage in value creation (Lawson et al., 2008) and motivates the parties in the supply chain to take additional risks and cooperate even beyond contractual provision (Villena et al., 2011). One of the central roles of relational capital in the buyer–supplier relationship is reducing the expectation of opportunistic behaviour and transaction costs (Dyer and Singh, 1998). Therefore, the development of relational capital in the relationship has been suggested as not only a key mechanism that explains access to the other party's resources and information (Krause et al., 2007), but also one that fosters a sense of openness and reciprocity (Coleman, 1990; Zaheer et al., 1998; Kale et al., 2000), and encourages more favourable attitudes and a stronger alignment of interests (Nyaga et al., 2013); thereby parties are more likely to act according to common agreement (Ireland and Webb, 2007). Thus, relational capital in the relationship helps to foster successful recovery from a disruption situation (e.g., Olcott and Oliver, 2011). Therefore,

Hypothesis 1. The buyer and its supplier's accumulated relational capital that has been established prior to the disruption is positively related to their supply chain disruption recovery performance.

In addition to using relational capital, the buyer can use the influence mechanism based on their power–force compliance to motivate the supplier into going along with their wishes. Mediated power sources include coercive power and reward power (Zhao et al., 2008). In a disruption situation, by offering rewards when the supplier conforms to the buyer's influence attempt (reward power) or punishing the supplier when failing to conform (coercive power), the buyer can produce the intended changes in the supplier's behaviour to engage in collective action, thereby contributing to increasing recovery performance from the disruption.

When the buyer uses coercive power to motivate the supplier to be involved in collective action for the disruption recovery, the relational benefit from relational capital can be lessened. By forcing compliance on the supplier, the buyer may succeed in motivating it to rearrange and reconfigure its resources and engage in collective action. However, as many studies have indicated, there is a negative association of coercive power with a cooperative relationship (e.g., Maloni and Benton, 2000).

In particular, trust lies at the heart of relational capital (Johnson et al., 2013), and coercive power does not exist simultaneously in the relationships as they are opposing components of social behaviour (Ireland and Webb, 2007). When the dominant party uses coercive power, it decreases the efficacy of trust in the relationship (Yeung et al., 2009). This is because it signals that this party is not likely to maintain the relationship for the long term (Morgan and Hunt, 1994), and the target firm is also likely to take greater safeguards and seek mechanisms to reduce its vulnerability. This ultimately weakens the relationship, with an accompanying deterioration in relational benefit (Yeung et al., 2009; Nyaga et al., 2013).

The use of coercive power also lessens the ability of relational capital, which can reduce the fear of the other party's opportunism in the exchange relationship (Nyaga et al., 2013). Use of coercive power makes the target firm realise that the coercing party is succeeding by taking advantage of its dependence. This is viewed as opportunism, with the buyer being seen as expecting to gain at the expense of the supplier (Nyaga et al., 2013). Hence, it reflects the dominant firm's incompetence and thus reduces the ability of target firm's trust (Leonidou et al., 2008). Additionally, the buyer's reliance on coercive power implies that its supplier's performance is not satisfactory (Zhao et al., 2008). It damages the supplier's sense of competence and autonomy, which ultimately lowers motivation to continue the relationship with the buyer (Chae et al., 2017). Therefore,

Hypothesis 2. The buyer's use of coercive power towards its supplier during the disruption recovery/response stage negatively moderates the relationship between relational capital and disruption recovery performance.

To influence its supplier to engage in collaborative action for response and recovery, a buyer can also use reward-based power, which motivates the supplier to go along with its wishes by offering rewards and benefits. The use of reward power helps to increase social and financial benefits, and provides numerous relational advantages; thereby collaborative supply chain relationships can be expected (e.g., Maloni and Benton, 2000; Ireland and Webb, 2007; Nyaga et al., 2013). Consistent with these views, it is held here that a buyer's reward power complements the effect of relational capital in contributing to increasing recovery performance

The use of reward power can lead to two parties to be bound to each other and raises costs for negligence or opportunism, thus fostering a relational contract and trust between the two (Ireland and Webb, 2007). Its usage is based on a firm's ability to contribute resources to a relationship, which can also increase the ability of the target firm's trust by providing the perception that the powerful party has the capability to fulfil the necessary obligations of a transaction (Ireland and Webb, 2007). Additionally, reward power helps to promote common interests and collective goals within the relationship, as well as engendering a constructive and friendly atmosphere (Leonidou et al., 2008). These positive aspects will subsequently lead to high levels of trust in the relationship. While the power source's use of coercion and punitive action will most likely decrease relationship commitment, in contrast, when the customer uses reward power to meet the manufacturer's expectation of reciprocity, commitment could well be further enhanced (Nyaga et al., 2013).

Additionally, the use of reward power is based on the idea that parties cooperate in relationships with the expectation of giving and receiving rewards, which supports the norm of reciprocity (Pulles et al., 2014). The notion of reciprocity embodied in relational capital suggests that firms feel obligated to reciprocate certain actions by the other party (e.g., Adler and Kwon, 2002). When reward power is used to influence the other party, both parties adjust their behaviour and actions toward their partner (e.g., Ireland and Webb, 2007). When this reciprocal action in a supply chain exchange is rewarded or produces benefits, both parties engage in it. The reward giver gets better results and the receiving party gets the reward promised (Nyaga et al., 2013; Pulles et al., 2014). Hence, by positively associating with reciprocity and trust in the buyer–supplier relationship, use of reward power will complement relational capital and its ability to coordinate resources and capabilities between the parties. Therefore,

Hypothesis 3. The buyer's use of reward power towards a supplier during the disruption recovery/response stage positively moderates the relationship between relational capital and disruption recovery performance.

The proposed model investigates the moderating role of the buyer's power (coercive and reward power) in the relationship between relational capital and disruption response and recovery performance. Figure I illustrates these relationships.

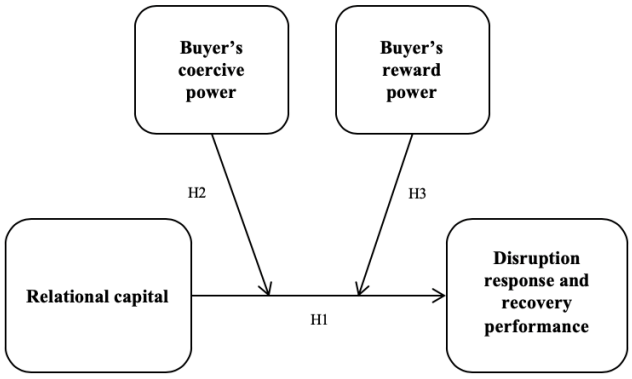

Figure 1 – Conceptual Model

Method

Survey administration and data collection

To test the proposed hypotheses, matched pair data (survey), from both the manufacturer (buyer) and its matched supplier, who had experienced the disruption, were utilised. Accordingly, matched pair questionnaires for the buyer and supplier were designed. For the buyer side, purchasing professionals who manage the procurement of direct materials across US manufacturing industries were targeted. Respondents were asked to recall a recently experienced (within two years) supply chain disruption that negatively impacted on their normal routine business or performance. To collect their matched supplier data, this first set of surveys for buyers included questions asking them to provide information about the disruption experienced and the contact details of the supplier involved. Subsequently, the named suppliers described in the main buyer survey were contacted. A total of 256 dyads were collected, with a response rate of 56.63% from the buyers, and 64.48% from the suppliers. 17 samples were excluded due to quality problems and missing data, leaving 239 valid dyads for statistical analysis.

Measurement instrument

The variables in the study were operationalised using previously tested and validated constructs. To collect matched pair data and capture the perspectives of both the buyer and their paired supplier, two different versions of the questionnaires are developed. For all the measurement items, a seven-point Likert scale was used. For the relational capital, 7 measurement items were adopted from Carey et al. (2011), Roh et al. (2013), Li et al., (2014) and Villena et al. (2011). To measure the disruption recovery performance, 7 items were adopted from Chowdhury and Quaddus (2016), Ambulkar et al. (2015), and Macdonald and Corsi, (2013), and modified to fit the context of the study. For the buyer's coercive and reward power, 4 items and 3 items respectively were adopted from Maloni and Benton (2000), Zhao et al. (2008), and Pulles et al. (2014). To operationalise the buyer and supplier's mutual perspective on the relational capital, the buyer's coercive and reward power, and the disruption response and recovery performance, we followed Straub et al. (2004) and Klein et al. (2007); we used the average of the buyers and the suppliers to produce the degree (magnitude) of the dyad.

Bias Control

Non-response bias was followed through a comparison of early and late waves of returned surveys. To minimise recall bias, the respondents were asked to report on a recent supply chain disruption that they had experienced and were asked for the exact month of the disruption (Bode et al., 2011). To reduce the possibility of single rater bias, such as an exception fallacy (Roh et al., 2013), this study used samples from both buyer and their matched supplier. To assess the existence of the common method bias, Harman's one-factor test and marker variable technique were conducted. Both the buyer and supplier model test results indicated that common method bias was not a problem in this study.

Control Variables

This study adopted several control variables: the size of the firm (measured by number of employees and firm sales); industry; the severity (impact size) of the disruption (measured

by financial loss); dependency on the exchange partner (measured by dependency on the other firm), and frequency of disruption (measured by the frequency of disruption occurred).

Analysis

Before examining the proposed hypotheses, we conducted confirmatory factor analysis (CFA) by use of Amos 14. Then, SPSS 21 was used for the moderated regression tests. Lastly, simple slope analysis was performed to assess the interaction effect. Table 1 presents the results of CFA. The average variance extracted (AVE) values are above the criterion of 0.50, and all of the composite reliabilities (CR) were well above the criterion of 0.70 Hence, it can be concluded that there is discriminant validity among the theoretical constructs. Additionally, none of the squared correlations were equal to or higher than the AVE for each individual construct in the model (see Table 2). The model fit indices results also showed good/acceptable fit. Taken together, these results indicate that the theoretical constructs exhibit good psychometric properties.

Table 1 – CFA results

Construct			Factor Loadings	AVE	CR	Cronbach alpha
MRC	Relational Capital in the relationship	MRC1	0.471	0.549	0.930	0.759
		MRC2	0.941			
		MRC3	0.909			
		MRC4	0.511			
MCP	Buyer's use of Coercive power	MCP1	0.992	0.569	0.874	0.657
		MCP2	0.772			
		MCP3	0.632			
		MCP4	0.546			
MRP	Buyer's use of Reward Power	MRP1	0.993	0.621	0.807	0.600
		MRP2	0.637			
		MRP3	0.686			
MRS	Disruption recovery performance	MRS1	0.535	0.567	0.867	0.786
		MRS2	0.818			
		MRS3	0.975			
		MRS5	0.739			
		MRS7	0.618			

* Chi-square: 129.5 (df= 78); CFI = 0.963; TLI = 0.943, GFI = 0.939; AGFI = 0.894; and RMSEA = 0.053.

Table 2 – Construct level correlation analysis

Constructs	(MRC)	(MCP)	(MRP)	(MRS)
(MRC)	1.000	-	-	-
(MCP)	0.343	1.000	-	-
(MRP)	0.296	0.464	1.000	-
(MRS)	0.400	0.277	0.253	1.000

Moderation test: interaction effect of coercive and reward power and relational capital

The data were examined using moderated hierarchical OLS regression techniques, with the results being presented in Table 3. Model 1, a base model, includes only the control variables, while Model 2 adds buyer–supplier mutual perception of relational capital (MRC) as an independent variable. In Models 3 and 5, the main effects of mutual perception of relational capital and buyer's use of coercive power (MCP) and of reward

power (MRP) are included, respectively. In Models 4 and 6, the variables for interactions between mutual perception of relational capital and buyer's use of coercive power (MRCxMCP) and between mutual perception of relational capital and buyer's use of reward power (MRCxMRP) are shown. From the results of moderated regression tests, support was found for H1 and H3, which indicates the positive impact of relational capital on disruption recovery performance ($\beta = 0.758$, $p < 0.001$), and the positive moderation effect of reward power on the relationship between relational capital and disruption recovery performance ($\beta = 0.150$, $p<0.05$) respectively. However, H2 was found to be not significant, thus providing evidence of no moderation effect of coercive power on the relationship between relational capital and disruption recovery performance ($\beta = -0.230$, n.s).

Table 3 – Moderated regression analysis

	Model 1 *B* *(std B)*	Model 2 *B* *(std B)*	Model 3 *B* *(std B)*	Model 4 *B* *(std B)*	Model 5 *B* *(std B)*	Model 6 *B* *(std B)*
Control						
Frequency	.035 (.087)	.018 (.045)	.018 (.046)	.015 (.037)	.017 (.041)	.012 (.029)
MFinancialloss	.000 (.078)	.000 (.074)	.000 (.073)	.000 (.068)	.000 (.060)	4.546E-005 (.043)
BuSize	.015 (.025)	.054** (.089)	.055* (.091)	.052 (.086)	.043 (.071)	.026 (.043)
SuSize	.000** (-.173)	.000* (-.087)	.000 (-.091)	.000 (-.086)	.000 (-.084)	-4.056E-005 (-.071)
BuRiskMgt	.028 (.037)	.064** (.085)	.062 (.082)	.067** (.089)	.055 (.073)	.061 (.081)
SuRiskMg	.036 (.039)	.003 (.003)	-.003 (-.004)	.013 (.015)	-.011 (-.012)	.010 (.011)
BuDep	.259*** (.250)	.089 (.086)	.071 (.068)	.125** (.120)	.071 (.069)	.127** (.123)
SuDep	.140** (.164)	-.005 (-.006)	-.025 (-.029)	.017 (.020)	-.029 (-.034)	.001 (.002)
BuAutomotive	-.086 (-.068)	.050 (.040)	.066 (.053)	.043 (.034)	.097 (.077)	.081 (.065)
BuElectronics	-.665 (-.399)	-.330 (-.198)	-.321 (-.192)	-.325 (-.195)	-.256 (-.153)	-.195 (-.117)
BuFood	.439 (.344)	.080 (.063)	.064 (.050)	.115 (.091)	-.022 (-.017)	-.016 (-.013)
SuAutomotive	-.209 (-.169)	-.196 (-.159)	-.211 (-.171)	-.200 (-.162)	-.218 (-.176)	-.205 (-.166)
SuElectronics	.573 (.330)	.199 (.114)	.192 (.111)	.201 (.116)	.149 (.086)	.096 (.055)
SuFood	-.507 (-.396)	-.116 (-.090)	-.100 (-.078)	-.131 (-.103)	.007 (.005)	.030 (.023)
Main Effect						
MRC		.758*** (.756)	.751*** (.750)	.758*** (.756)	.759*** (.758)	.785*** (.783)
MCP			.070 (.053)		.063 (.047)	
MRP				-.086 (-.072)		-.101 (-.084)
Moderating effect						
MRCxMCP					.152 (.073)	
MRCxMRP						**.229**** (.131)
S.E	.53334	.35263	.35273	.35260	.35146	.34682
Overall R^2	.216	.659	.660	.660	.664	.673

Adj R^2	.167	.636	.635	.636	.638	.648
R^2 Changes	.216	0.443	0.444	0.444	0.448	0.457
Overall model F	4.397***	28.681***	26.928***	26.958***	25.681***	26.723***

P <0.001***, P<0.05** ; Dependent variable: Disruption recovery performance

Control variables: BuSize (SuSize): Buyer (Supplier) firm size; BuRiskMgt (SuRiskMgt): Buyer (Supplier) firm's risk management level (basic - advanced); BuDep (SuDep): Dependence on the relationship with the supplier (Buyer); Frequency: frequency of disruption; MFinancialloss (severity of the disruption): Financial loss due to the disruption (mutual); BuAutomotive (SuAutomotive): Buyer (supplier) automotive industry; BuElectronics (SuElectronics): Buyer (supplier) electronics industry; BuFood (SuFood): Buyer (supplier) food & beverage industry

Main effect: MRC: Relational capital; MCP: Buyer's coercive power; MRP: Buyer's reward power

To probe these moderated effects further, interaction effects were plotted and found to be significant (H3) for high and low levels of reward power. High and low values have been defined as plus and minus one standard deviation from the mean (Cohen and Cohen, 1983), with Figure V illustrating these effects. First, high levels of mutual perceived reward power is shown to positively reinforce the relationship between mutual perception of relational capital and disruption recovery performance, as supported by a significant simple slope calculation ($\beta = 1.133$, $p < 0.001$). Low levels of reward power also have a significant effect ($\beta = 0.403$, $p < 0.05$). Hence, support is found for H3 relating to the positive moderating effect of a buyer's reward power on the relationship between relational capital and disruption recovery performance.

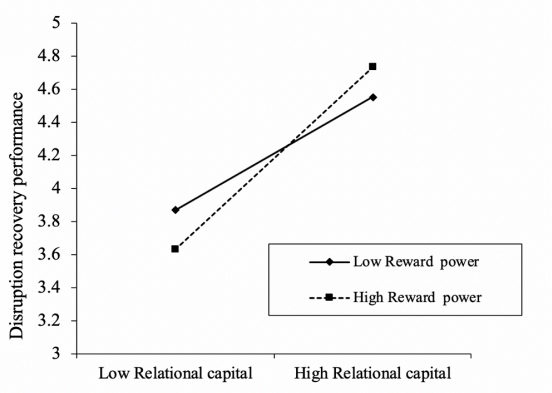

Figure 2 – Relational capital and disruption recovery performance by reward power

Conclusion

This study explores the role of buyers' use of coercive and reward power in moderating the efficacy of relational capital in disruption response and recovery performance. Our findings indicate that a buyer firm's use of reward power towards a supplier has a positive interaction effect with relational capital on disruption recovery performance. However, a buyer firm's use of coercive power was insignificant. That is, by mitigating the fear of opportunism in the relationship, reward-based power complements the ability of relational capital in a disruption situation, thereby motivating a supplier to engage more in resource reconfiguration and collective action in achieving timely disruption recovery. This finding is in line with the previous research on the complementary relationship promoting role of reward-based power (e.g., Ireland and Webb, 2007; Zhao et al., 2008). Conversely, a buyer's punitive approach to influence a supplier to go along with its wishes

is ineffective. This suggests that power should not be used exploitatively or coercively even in an urgent situation such as in a disruption situation, and indicates that reward-based power can complement the ability of relational capital in the disruption response and recovery context.

Our research can contribute to the body of supply chain management literature in three ways. First, this study captured both the buyer and the supplier's perspectives. The use of matched pair data allows for more comprehensive insights into how timely response and recovery can be achieved through the use of the parties' relationship and influence mechanism than is possible with a one-sided examination. Additionally, the results not only contribute to understanding the dyadic nature of exchange relationships in the supply chain, but this approach also reduces the possibility of single rater bias, such as an exception fallacy (Roh et al., 2013). Second, as it is impossible to completely prevent supply chain disruptions, paying attention to the disruption recovery phase is essential in supply chain risk management studies. However, relatively little attention has been devoted to this stage (Sodhi et al., 2012); not many studies have empirically examined how organisations can effectively recover from disruptions; and the speed of disruption response and recovery is rarely investigated. Hence, this empirical study can shed light on a relatively unexamined area. Lastly, our research is one of the first studies to examine the interaction effect of buyers' coercive and reward power and relational capital in the context of supply chain disruption. Although a number of studies have suggested relational capital's collective action and resource coordination promoting role in uncertain situations, such as a supply chain disruption situation, and it can be enhanced or lessened by the dominant party's use of power, very few studies to date have investigated the application of power in relational capital. From this, this study can suggest an appropriate theoretical framing to understand this barely investigated area.

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Social Supply Chain Risk Management: A Case Study in a Brazilian Company

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Abstract

This paper discusses the social risk supply chain management through a case study in a Brazilian company. We map the social risks and the main consequences of these risks tracked by the organization. By comparing the findings of the case study with the literature, the paper contributes to the academic studies with 2 new social risks, the main consequences of these risks, and the description of the company's strategy to manage its risks.

Keywords: Social Risk, Risk Management, Case Study.

Introduction

Academic researches in supply chain risk management (SCRM), in general, address the risks that occur due to interruption at some point in the chain, which later blocks the flow of materials, funds or information among the entities of the supply chain (Bode et al., 2011). Therefore, they approach the traditional view of SCRM, with the focus on avoiding interruptions along the chain to reduce financial losses that this disturbance can cause (Bode et al., 2011; Hofmann et al., 2014).

The risk management literature is diverse, but researches on financial risks have been studied for a longer time and have greater repercussion due to significant economic changes for organizations. However, this classical approach focused on financial performance does not consider the social view to be purely economic (Busse, 2016).

The social risks started to gain academic attention with the introduction of the concept of Triple Bottom Line (Elkington, 1994). Nevertheless, research on the social risks in which the supply chain of a company may be involved is still needed (Tang, 2018). Basta et al. (2018) also argue that when addressed, social risks are mostly

limited to labor rights and working conditions.

Therefore, the present paper aims to study the social risks in supply chains through a case study answering two research questions:

(i) The social risks and consequences found in academic literature are found / relevant also in a business enterprise?
(ii) What strategies does the company use to manage its social risks?

The case study considers a Brazilian company of Cosmetics, involved in the manufacture, industrialization, distribution and sale of cosmetics, fragrances and personal hygiene products. We compare and validate the results of the case with the list of 24 social risks and 13 consequences proposed by Cunha et al. (2019).

The remainder of the paper is organized as follows: Section 2 addresses the case study methodology. Section 3 presents the results and discussion of the case study, followed by a section presenting the concluding remarks and suggestions for future research.

Research Methodology

The present research adopted the case study methodology proposed by Yin (2013), composed of six steps: plan, project, preparation, collection, analysis, and sharing.

The plan aims to identify the relevant situation for the accomplishment of the case study in detriment to other research methods. Thus, the event to be studied within the context of real life is the management of social risks in supply chains.

We present a unique case as an exploratory study of a theme little covered by the literature. The present research considers common case study to capture the circumstances of a daily situation to provide processes related to some theoretical interest.

The project was carried out with a Brazilian company of Cosmetics recognized for its vision of sustainability, the principle of generating positive impacts on society and for being an organization that combines economic growth with the promotion of social and environmental well-being. The research question compares the social risks and the consequences that these risks can generate for a company covered by the academic literature with what is observed in a supply chains of a real company. The criteria for data interpretation to actual data that can reinforce, complement or contrast with the results derived from the academic literature to bring new insights to the strategies to mitigate these risks.

In the preparation stage, we developed the case study protocol, defining candidates, selecting the final case to be studied and synthesizing the initial definitions of the study.

Data was collected through documents made available by the company, interviews, and secondary documents from the internet. First, the professionals of the studied company answered an online questionnaire. This questionnaire was based on Cunha et al. (2019) and made available to respondents through the SurveyMonkey platform. Then, we conduced face-to-face interviews with open questions based on answers previously reported by company professionals. Finally, we compiled documents made available by the interviewees and secondary materials available on the website of the company studied.

The professionals considered in these interviews effectively deal with the risks of the company, and are: (i) the Supply Manager, responsible for Performance

Management and Relationship with Suppliers; (ii) the Audit Coordinator of Supply Management, and (iii) the Compliance Coordinator.

The data analysis considers the pattern matching technique, in which the theoretical reference is used as prognosis and compared with the results of the case study.

Finally, the sharing stage consists of the publication of the present paper.

Results and Discussion

The company's mission is to promote well-being through the mobilization of a network of people capable of integrating scientific knowledge and the sustainable use of the rich Brazilian botanical biodiversity, in order to deliver the cosmetics manufactured from natural elements of the Brazilian flora, processed, distributed and sold.

Through the online questionnaire, it was possible to understand that the company has three areas responsible for its risks, namely: (i) the Supply area, which deals with risks related to suppliers; (ii) the legal and Compliance area, an area concerned with issues related to labor laws, including the risks of corruption and bribery; (iii) the area of Corporate risks, encompassing other risks.

Through the interviews, it was possible to understand that the Brazilian cosmetic company has means of identifying social issues present in its supply chain through an audit carried out periodically by the company, through a complaint from one supplier over another (which has already occurred with a textile supplier), and through the media.

The interviewees stated that the company has a list of risks predefined by a multidisciplinary group (encompassing area of supplies, risk management, legal area and relationship with suppliers), which is reviewed every two years and serves as the basis for the supplier's audit checklist.

Among the 24 social risks found in Cunha et al. (2019) and listed for the interviewees, 11 of them are not on the list of pre-defined risks to be audited for the studied company, these being: unfair or low wages, although the same worries about workers' compensation however, it still cannot reach the level of detail of the amount paid by its suppliers to employees; access to drinking water; access to basic sanitation; unfair compensation; reallocation or rupture of indigenous peoples; exposure of communities near the end of activity; unavailability to public facilities; expropriation; exposure to unemployment; reallocations without explicit grounds and equality before the law.

Some of the social risks present in Cunha et al. (2019) do not fit directly with the area of cosmetics addressed. However, some risks such as low or unfair wages, exposure of communities close to the end activity and unavailability to public facilities are suggested as possible risks to be added to the list of social risks to be audited as they can cause significant damages to the company.

The respondents added two social risks to the list of Cunha et al. (2019): Corruption and Bribery and Compliance with Local Labor Legislation. Corruption and bribery should be added to the list presented in Cunha et al. (2019), as they may create critical social risks. For example, if the money destined to the aid of an Amazon community is diverted, the community will not receive the necessary assistance and may trigger various social risks. However, concerning local labor legislation, this risk applies to the cosmetics company studied because its suppliers

are within the Brazilian territory. If the company has suppliers located outside Brazil, the law to be followed should be the one proposed by the International Labor Organization (ILO, 2017).

Besides the company's identification of the social risks found in the academic literature, the developed questionnaire also addressed the consequences that these risks could bring to the company.

Regarding the consequences presented in Cunha et al. (2019), those that appear most frequently in the questionnaire are the damage of the company's reputation, the risk of operational stops, individual claims or collective action and payment of mandatory compensation by the court. The profit reduction consequence was mentioned only twice which demonstrates that the company has a social concern that goes beyond the financial consequence that these risks can cause.

In addition to the two respondent areas of the online questionnaire, the Audit Coordinator explained the process in more detail during the interviews. As strategy to manage the social risks that may be present in its supply chain, the company performs two types of audits, one related to the new suppliers and another related to the contracted suppliers of the company.

The main objectives of the Audit process for the company are to mitigate risk of shortages of products, to protect the company's image and the integrity of employees, contributing to the maintenance/ obtaining of certifications and awards which guarantee brand value, and to integrate company beliefs and values into the supplier relationship network, ensuring the development of the value chain.

The audit process takes place through a checklist questionnaire answered by direct suppliers. According to the criticality of the supplier, audits take place at one-year intervals (most critical suppliers) to five years (less critical suppliers). The company studied has a partnership with eight different companies that perform around 300 audits per year with their suppliers. The companies to be audited are defined by the company studied, and the process of auditing the suppliers happens with a marked date, that is, without surprise for the suppliers.

The checklist is based on six pillars: Quality, Environment, Health and Safety at Work, Legal Requirements, Code of Conduct, and Social Responsibility. In this way, the supplier can be classified into three groups: (i) approved; (ii) approved with restrictions, where the supplier is still able to sell, but must adapt within 3 months with the requirements demand in a corrective action plan; (iii) Disapproved, where the supplier will not be able to supply. The corrective action plans are individual and depend on the responses of each supplier. Some items make suppliers automatically disapproved, such as: forced or compulsory labor, child labor, environmental requirements, legal noncompliance, non-compliance with benefit payment rules, non-compliance with health and safety standards, and corruption.

Conclusion

The case study answered two research questions. The first one was answered as several social risks found in the literature coincide with the social risk monitored by the studied company. However, it became clear that social risks vary according to the area in which the company operates. Therefore, risks related to areas of construction, mining or oil and gas may or may not refer to the risks present in the area of cosmetics.

The second research question encompassed the strategy used by the company

to deal with its social risks. Cunha et al. (2019) presented the strategies in a general manner, whereas in the case study the process of supplier auditing was discussed as the strategy used by the company to manage social risk in its supply chain.

In this way, the main contribution of the paper to bring new insights to the academic literature through comparison between a real case and the results from Cunha et al. (2019). The social risks found by the academy may be included in the social supply chain management of the company. On the other hand, we demonstrate that the business environment brings updates back to the academy.

As future research, more case studies should investigate other supply chains, highlight disparities in relation to the private and public sector, and explore different types of organizations as well as different organizational areas, such as oil and gas, mining, construction, cosmetics, and textiles. Additional studies may also focus on the importance of stakeholders and their social risk management actions and other social risk management strategies.

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Supply chain resilience in relation to natural disasters: The case of category 1 and category 5 Queensland storms

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Abstract

Our study examines supply chain resilience (SCRES) building stages and the role of supply chain integration (SCI) in relation to natural disasters. As such, two specific storms in the State of Queensland (QLD), Australia and their impact on eight supply chains (SCs) were studied. The findings explain the nature of practices exercised by the affected case companies, associated with each stage of the SCRES building. Correspondingly, we also elaborate on the SCI behaviour of these case companies. We, therefore, contribute to the SCRES theory and practice by unpacking the role of SCI in face of natural disasters and inductively capture additional practices that altered within SCRES building stages.

Keywords: Supply Chain Resilience, Natural Disaster, Supply Chain Integration

Introduction

Natural disasters are becoming more frequent and more severe (Ronnenberg et al.,2017). In addition to this, area affected by natural disasters is growing and financial damage they cause to businesses increased from approximately $50 billion (USD) loss during the 1980's to $250 billion (USD) in losses in the last decade (UN, 2015). Moreover, 21st century natural disasters are recognised to be less predictive and more difficult to manage because of the cascading and prolonged effect (Corey & Deitch, 2011; Lawther, 2016; van der Vegt et al., 2015). For example, Tohoku earthquake and tsunami severely disrupted the automotive industry in 2011 (Matsuo, 2015) and superstorm Sandy caused breakdowns of infrastructure in multiple countries in 2012, with $75 billion of economic damage (Sales et al., 2012; WEF, 2015). In Australia, the most common natural disasters are tropical cyclones, floods and landslides, hailstorms, bushfires, heatwaves, and drought. These natural disasters have costed Australian economy $18.2 billion (AUD) annually in average, which represents 1.2% of average Australian Gross Domestic Product (GDP), and this cost is expected to increase and reach double value by 2040 (IAG, 2017; Handmer et al., 2018; Ronnenberg et al.,2017). With natural disasters

affecting organisations all over the world, resilience toward natural disasters is a subject of urgent research (van der Vegt et al., 2015).

Resilience has been defined as ability of company to bounce back after disruption to even improved state, and sustain operations during it (Tang, 2006). However, organisations do not operate independently, they function as part of SCs. Therefore, SCRES includes capability of SC to prepare for disruptive events, respond to it, and recover from it with continuity of operations maintained (Ponomarov & Holcomb, 2009). This definition recognises three SCRES building stages, namely Preparation, Initial Response, and Recovery, while later literature introduces a fourth stage i.e. Mitigation which relates to the identification and application of SCRES building processes and improvements (Scholten et al., 2014). However, there is limited research examining micro-foundations of SCRES building across the above-noted stages.

Consequently, we utilise structural contingency theory to examine SCRES building stages and SC practices that vary during these stages, drawing on findings from our investigation of two damaging storms in the State of QLD, Australia. In this regard, we focus on SCI practices of affected organisation and their SCs in sake of understanding their journey towards SCRES building. Our research design is based on multiple case studies drawing on semi-structured interviews and archival data. The paper is structured as follows: First, we review the literature on contingency theory, SCRES, and SCI; next, research methodology is presented, followed by research results and discussion; the paper finally summarises contributions and outlines future research.

Literature Review

Contingency theory

Contingency theory stands for custom made approach in management, depending on circumstances one SC faces (Lawrence & Lorsch, 1967). It also applies reductionist approach, where SC is built from different organisations, and each organisation is composed of different departments. Consequently, the environment in which SC operates will dictate structure of SC and organisations, and processes that take place between them.

Structural contingency approach explains that SC needs to align its goals to circumstances from the environment (Drazin & Van De Ven, 1985; Flynn et al., 2010; Sinha & Van de Ven, 2005). SC that faces natural disaster, will have to shift its goals and adjust its strategy. Goals will have to be changed from everyday profit increasing to reduction of financial losses, and from customer value creation to simple SCRES related goals, such as trying to keep operations ongoing, or try to re-establish operations. The alignment between changes in structure and processes and newly established goals in natural disaster environment are described as “fit” in work of Drazin and Van De Ven (1985). This indicates that SCs will seek for alterations in relationships and strategies in order to reach “fit” with newly occurred natural disaster as environment they operate in.

SCRES building

Nearly two decades of operations and supply chain management (OSCM) research resulted in multiple different frameworks of resilience building. Presence of different approaches in structuring SCRES building, different number of stages, and interchangeable utilization of terminology, indicates that additional research is needed in order to select or adapt one of existing setups (Pettit et al., 2010). Relying on structural contingency approach in this study, we recognised the common attribute of developed structures that consider natural disaster as contingency include stages before, during and after natural disaster, with additional stage of reflecting and improving, introduced by Scholten et al. (2014). Therefore, the present study applies SCRES building model, that includes four major stages, as follows: Preparation, Initial Response, Recovery and

Mitigation. Preparation stands for establishment of an emergency team, analytics of capabilities and potential hazards, and development and implementation of a safety, contingency and other plans (Henstra, 2010). Initial response is the first response after acknowledging immediate proximity of disaster, in the moment when disaster affects SC, or immediately before that moment. Safety is evaluated and security measures for life and property are applied (Henstra, 2010). The third step, Recovery, is applied after immediate danger of disaster has passed. Recovery plans are implemented, continuity of management ensured, and employee support is maintained. Mitigation is launched after recovery, and this stage includes identification of mitigation opportunities and continuous improvement plans. This step feeds Preparation step with necessary insights. However, practices conducted in these stages might differ depending on effect of natural disaster on specific company. While directly affected company will have to perform multiple safety related practices in Initial Response stage and invest additional effort in Recovery stage, just to be able to restart operations, indirectly affected company has no need to conduct emergency evacuation or safety plans, or rebuild.

SCI

SCI present strategical collaboration between organisations in SC and internally, in the organisation, with goal to provide maximum value to customers (Zhao et al. 2008). It consists processes that link SC organisations, including information exchange, integrated operations and strong relationships (Frohlich & Westbrook, 2001; Leuschner et al., 2013). However, one must wonder, what happens to SCI when the goal to maximise customer satisfaction or to facilitate connections between SC processes is changed? Does SCI differ when goal of profit-making is delayed on the priorities list and simple minimization of financial loses is prioritised, and goal of providing any product or service at all is prioritised over increasing customer satisfaction? This shift in final goal of SCI practices might alter practices completely.

In addition, structural nature of contingent approach is applied in terms of recognising different SCI orientation and SCI type. Contemporary OSCM literature distinguishes SCI into two broad clusters based on its orientation – internal SCI and external SCI (Das et al. 2006; Flynn et al. 2010; Schoenherr & Swink, 2012). While external SCI plays significant role in relations between companies and summarised effort invested in reducing spread of consequences of disruption on entire SC, internal SCI focuses on single company and questions how departments in that company functioned together while building SCRES. In addition, SCI with buyer and with supplier are distinguished as two separate orientations in external SCI and some other stakeholders SC's operations depends on, might become important for recovery of SC.

Literature identifies three types of SCI, namely, informational, operational, and relational (Leuschner et al., 2013). Informational SCI consist of information exchange, knowledge sharing, and communication. Operational SCI comprise of creation of joint practices and work processes, sharing resources, coordination of teams, collaboration on joined goals, and all supporting processes needed for that operations to be successful. Relational SCI refers to strategic partnerships and long-term orientation, it requires higher level of trust between parties and includes social bonding, and genuine understanding between parties. If two companies have close relationship they will make joined decisions faster and coordinate their activities, to build SCRES in more efficient manner. In accordance with discussion above, the study focuses on following Research Questions:

RQ1: "*How do practices of SCRES building stages differ across different companies, based on impact natural disaster has on specific company in the affected SC?"*

RQ2a: *"How SCI orientation and type vary during different SCRES building stages (with buyers, suppliers and internally)?"*

RQ2b: "*Which other stakeholders are important for SCs to build their SCRES?"*

RQ3: "*Are there any other practices that might simplify or proliferate SCRES, building, beside SCI?*"

RQ4: **"***How will meaning and measurement of SCRES differ in SCs depending on disaster's effect?*".

Research methodology

The qualitative research design is used due to the complexity of the issue under investigation and exploratory nature study. Publicly available documents include reports and statements that contribute to the knowledge considering natural disasters' effect on communities and government, and their experience and response. However, amount of data available on companies' experiences and response is scarce. Therefore, the research is designed as multiple case study including direct interviews with SC managers. In addition, publicly available governmental, scientific and media reports are examined.

Table 1– Natural disasters and supply chains captured

Natural Disaster	Category	Supply Chain and industry
Tropical cyclone Tasha (2010)	1	T1 - Agricultural
		T2 - Food
		T3 - T&L
		T4 - T&L
Tropical cyclone Marcia (2015)	5	M1 - Food
		M2 - Retail
		M3 - White goods
		M4 - T&L
Note: T&L=transportation and logistics		

As part of a larger study examining resilient SCs, this paper examines two specific storms and their impact on eight SCs. Semi-structured interviews with SC mangers of four different SCs per natural disaster are conducted. The industries varied form food production to transport and logistics (T&L)(*Table 1*). Secondary data examination is performed, including government documents, emergency services reports, satellite imaginary, previously published research, news articles and audio-visual material. These were analysed to better understand the overall impact of disasters utilizing thematic analysis (Eisenhardt et al., 2016; Yin, 2009).

Interviews

With purpose to grasp companies' experience with and response to natural disaster, this study used a purposive sampling method (Creswell, 2013). Only companies, members of SC that faced tropical cyclone (TC) Tasha and TC Marcia and their prolonged effects were selected. The unit of analysis is organization and its practices associated with SCRES, since this enables evaluation of SCRES as good practice on the one level of the SC replicated on the higher level (van der Vegt et al., 2015).

Total duration of all 8 interviews is 4 hours and 51 minutes. When saturation is reached, interviews were terminated (Hinkin, 1995; Lee, 1999). Interviews were conducted in person, using telephone, or skype conversation, from 21st August 2017 to 26th October 2017. All participants were male, currently holding middle or senior management position and performing a role of SC manager, in SCs during their response to effect of Tasha or Marcia. Transcripts were analysed using thematization process in excel and NVivo software. Table was generated for overview of all interviews with

themes listed and codebook was developed following Lee's (1999) and Van Manen's (1990) guidelines. Overarching themes were identified, followed by underlying codes.

Validity and reliability of data collection and analysis was evaluated relying on Yin (2009), Creswell (2013) and Bals and Tate (2018). For interviewing process specifically, Creswell (2013) was followed, all interviews were transcribed and enriched by notes, while increasing transferability. Guided by Kvale (1996, pp. 133-135) initial set of question included structured questions, as well as open-ended questions that were followed-up with additional questions when elaboration or confirmation of correct meaning capturing was needed. Additional sources, such as publicly available web sites of the companies, as well as interviewees' Linked In profiles, were used to compare information (Yin, 2009).

Secondary data

Two natural disasters, TC Tasha and TC Marcia with their prolonged effects, were reconstructed in order to understand their overall impact and impact on SCs. In addition, secondary data was enriched by interviewees' insights that referred to disaster description and impact. Collected secondary data was coded for overall description of natural disaster, and impact on QLD businesses and infrastructure. In total, 33 documents per each storm were included in analysis, documents referring to Tasha included interviews and statements from 25, and documents referring to Marcia included interviews and statements from 33 government officials, experts, and managers.

Discussion of findings

Natural disasters' reconstruction and impact

TC Tasha was category 1 cyclone that formed on 24th December 2010 and dissipated 2 days later. It made landfall on early morning on Christmas Day 2010 (local time), near Cairns, QLD, about 1,400 km north from Brisbane. TC Marcia formed on 15th February 2015 and dissipated 14 days later. It was a category 5 superstorm, and it made landfall on the morning of 20th February 2015 (local time) in Shoalwater Bay near Yeppoon, QLD, about 500 km from Brisbane.

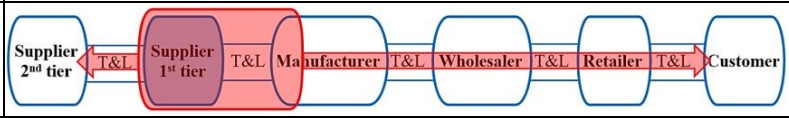
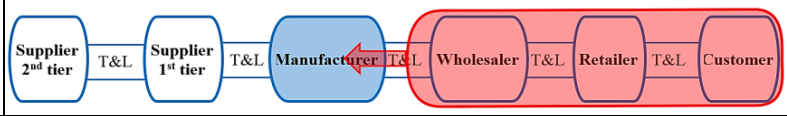
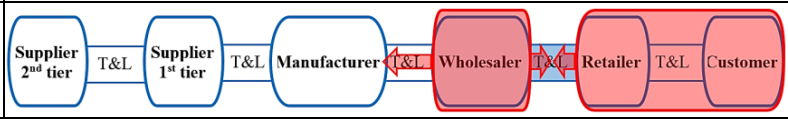
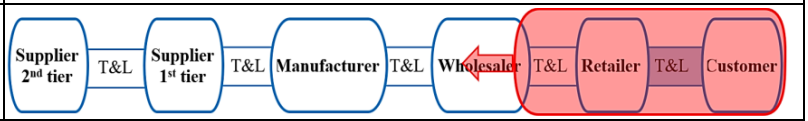
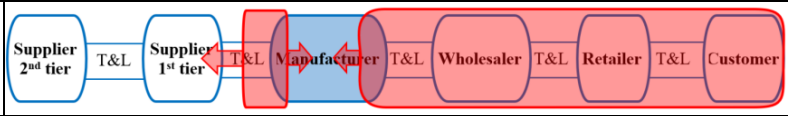
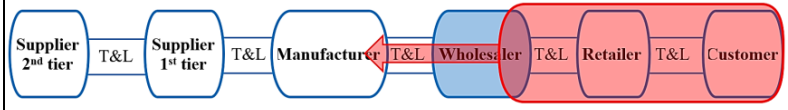
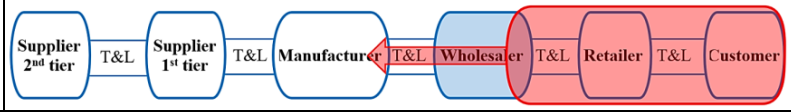
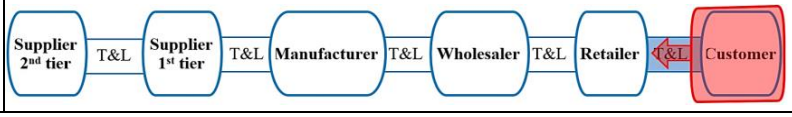
Although TC Tasha made landfall much further form QLD capital, affected the area with weaker winds and dissipated just 2 days later, the impact of this TC and its' prolonged effects was more severe than TC Marcia's impact. The reason for unexpectedly different effect of two storms lies in contingencies. Storms collided with additional events and had prolonged effects in terms of rain and floods. As a result of this TC Tasha directly affected QLD for 23 days and TC Marcia's direct effect lasted just 4 days, when floodwaters withdraw, and Marcia went offshore and weakened. TC Tasha caused 35 deaths while there is no death related to Marcia. In addition, scope of TC Tasha was significantly larger than Marcia. Tasha directly affected 42 out of 77 local government areas in QLD, while Marcia affected less than half of that, only 17 local government areas (as presented on the **Error! Reference source not found.**). Consequently, over 10% of business in entire Australia were affected by TC Tasha, while TC Marcia had much smaller effect. Insurance Council Australia (ICA) published that commercial losses during Tasha reached $4 billion (AUD), while during Marcia they were $139 million (AUD). Infrastructure damage occurred in both storms, however, damage and power outages during TC Tasha were more significant. Tasha caused road damage on length over 19,000 km, and some roads were closed for 3 weeks, while TC Marcia caused road closure for 3 days and length of damage roads was 1,000 km. The contingencies that shaped disasters' effect were not predictable, as well as duration or direction of storms. Since majority of natural disaster related attributes are not known before they occur, the

only approach to improve understanding of SCRES is through companies' experience and response.

SCs response

The first step of interviews' analysis was structural visualisation of SCs and effect of storms on them. Table 2 presents structure of SCs included in the analysis with directly affected part of SC marked with red circular shape, indirectly affected part marked with red arrow, and position of interviewed company in SC is marked with blue circular shape.

Table 2. Structural visualisation of SCs affected by TC Tasha and TC Marcia

SC name /type	Effect on interviewee's company	SC structural visualisation
T1 Agri	direct	
T2 food	indirect, able to provide insight about direct	
T3 T&L	indirect, able to provide insight about direct	
T4 T&L - courier	direct and indirect	
M1 food	direct and indirect	
M2 retail	indirect, able to provide insight about direct	
M3 white goods	direct and indirect	
M4 T&L - courier	direct	

RQ1: **"How do practices of SCRES building stages differ in different companies, based on impact natural disaster has on specific company in the SC affected?"**

All SC managers except scT4 were able to describe Preparation stage in building SCRES and confirmed preparation plan has been developed and emergency team pre-established. The difference in this SCRES stage were spotted in terms of different management level of participants of emergency team and complexity level of preparation plan. Emergency teams in companies varied from purely local engagement with notification of upper management to inclusion and physical presence of top management on the location, such as: "*We have a plan there for us that outlines the things that we need to do…"* when interviewee indicated plan is outlined for local members of the team, and "*That includes*

sales people, includes SC people… Directors and heads of different divisions and includes senior leaders…." Preparation plans varied from simple plan that instructed stock amounts "*It comes to planning, the buffering, understanding when those events occur and planning for them*" to complex risk evaluations and preparation plans, such as *"We have multiple emergency, safety and other plans developed. They are location and natural disaster specific…"*.

In Initial Response phase opportunistic operations were detected, just before natural disaster occurred *"We continued shipping … we tried to recognise as much revenue as we could. [Even] when we stopped shipping we continued processing orders"*. In addition, directly affected scT1 supplier invested time to evaluate safety and conduct emergency procures and evaluate strategies and damage later "*The first reaction always is the safety of the people involved. The second thing obviously is look at the crop [damage]"* while indirectly affected companies started evaluating strategies and potential damage immediately *"First reaction was" What is the level of cyclone?" …then "Where is it going to hit" … we do an assessment of potential business impact… we decided to continue to ship..."*.

ScT4 was not able to complete Recovery stage, and SC manager explained effect of natural disaster being direct – in terms of partially flooded facilities and indirect in terms of organisations in the same SC being unable to complete payments since they have bankrupted "*We were able to make deliveries but no one was ordering … because their stock was destroyed…. they just wouldn't physically be able to pay"*. All other companies described cleaning and repairing in case they were directly affected and later on, re-establishing operations and streaming towards full capacity of operations.

Mitigation stage was described in terms of learnings that bring upgrade to plans *"You get these events, execute them [plans], and then come back with the learning of those events so that you improve upon each time."*. However, companies interviewed from scT3 ands scT4 were not able to identify any Mitigation activities. This may occur since scT4 has never recovered completely and scT3 manager's position is in middle level management, so he might be unaware of top management decisions and plans upgrade.

RQ2a: "Will SCI orientation and type differ during different SCRES building stages (with buyers, suppliers and internally)?"

SCI was uniformly recognised as important enhancer of SCRES building. During Preparation stage SC managers focused on communication in building preparation plans, and communicating preparation plan among employees, indicating increased Internal Informational SCI, *"We already have mitigations in place, in terms of those risks. People are aware of those plans. They are communicated."*. Managers highly emphasized importance of Internal and buyer SCI, in terms of all three types, while describing Initial Response stage. This included Informational SCI *"Internal communication was critical. Being able to have full visibility of all of our orders. …"*, Operational SCI *"Each of different teams can integrate. They can come together, as a working group very quickly, formulate a plan and execute it…"*, and Relational SCI "*We communicated with understanding… we know each other for 20 years… people are working together …"*. When describing Recovery stage, SC managers were again highly focused on Internal and Buyer SCI in all three types of SCI, namely Informational *"It's about being seen and having that [informational] transparency...*", then Operational "*Bring extra capacity, extra people, extra trucks,*", and Relational "*Being able to work very closely with them, very closely…*". In Mitigation stage, only Internal Informational SCI was emphasized "*You keep capturing that knowledge…you can use [it] year after year…"*.

RQ2b: "Which other stakeholders are important for SCs to build their SCRES?"

SC managers described SCI practices with governmental organisations and community

as part of SCRES building. They emphasizes importance of SCI with government and community especially during Initial response stage, such as *"Basically, the approach was liaising with emergency services, liaising with bureau of meteorology to see which areas we need to focus on to put controls in place…*", or *"We communicated with local communities in order to put clear instructions where to go…*" and during Recovery stage *"Government coordinated movement of goods [in affected area] and we were in constant contact with them in relation to that*" and *"We made sure local communities get supported in terms of us delivering sufficient quantities to local stores. People needed our support…",* where interviewee implicates comprehension of joint recovery of SC and community. In addition to this, multiple secondary data documents announced call for industry to conduct integrative practices during Preparation and Mitigation stages, such as Authority of the Senate (2015). Parliamentary debates - Senate Official Hansard., MacKenzie, I. S. (2015). 2015 Callide Creek Flood Review (T. S. o. Queensland Ed. Vol. 1). Brisbane, QLD: Office of the Inspector-General Emergency Management, and DILGP. (2015). Severe Tropical Cyclone Marcia. Brisbane, QLD: The State of Queensland - The Department of Infrastructure, Local Government and Planning, as well as many other reports after 2015. However, the matter of additional SCI orientation was inductively captured, therefore collected data did not allow further analysis.

RQ3: "Are there any other practices that might simplify or proliferate SCRES, building, beside SCI?"

Trust was inductively captured during Initial Response and Recovery stages. SC mangers highly emphasized trust in relationships internally, within company "*It's the right thing to do, it comes back to values… Allow people to treat themselves as human, as part of a big mission, not just a number …"* and "*We also need them [truck drivers] to trust us and we [managers in T&L company] trust them on reporting back…",* and in relationship with buyer *"…put efforts and trust it will have the best outcome, to trust each other competencies and word*." Trust with T&L supplier was mentioned moderately in terms of its' importance for SCRES building *"… there's something to be said for developing long-term relationships with carriers who can obviously help you out during those events… You have to have that stronger bond*.", and in terms of luck of trust with T&L having negative outcomes for SCRES *"I would call it scavenging nature of freight…".*

RQ4: **"How will meaning and measurement of SCRES differ in SCs depending on disaster's effect?"**

When speaking about SCRES in terms of direct effect of natural disaster, SC mangers referred to re-establish operations as soon as possible as a primary goal. Only after operations restarted, SC managers explained their focus shifting to reach full capacity of operations, and after that, they paid attention on reduction of financial losses. In the times of natural disaster, financial concerns were not the first goal, however, when goals to operate and operate with full capacity were reached, financial issue was addressed. Eventually, when operations are established in full capacity and financial losses are minimised, companies return to everyday goals of profit and customer satisfaction. When describing indirect effect, managers described alterations in operations modes and capacity and primary goal to establish previous operations capacity, with minimisation of financial impact, together. In addition to this goal patter seems to be shifted just before the impact of natural disaster. During preparation phase and even initial response stage, some SC managers did opportunistic shipping and producing, in order to generate more profit and recover faster, later on. However, as soon as disaster has impacted SC, this goal was shifted to reestablishment of full capacity operations and minimisation of financial losses.

Summary

The study finds practices conducted during SCRES stages differ between different companies. In addition, practices of SCI and trust in relationships are different in different SCRES stages. This indicates that importance of SCI and trust varies, with SCI importance for SCRES building differing in terms of orientation and type. The literature did not offer much on this topic, with only few studies examining overall importance of collaboration for SCRES (Fayezi, et al., 2010; Scholten et al., 2015; Van del Adel et al., 2018). Moreover, results indicate that trust might be influencing SCRES which was not previously linked with SCRES in OSCM literature.

In addition, findings indicate SCI practices should include governmental organisations and community, in addition to internal, buyer and supplier SCI, which is consistent with disaster management literature (Zhang, Lindell, & Prater, 2008), but haven't yet been applied in OSCM literature.

In accordance with van der Vegt et al. (2015) implications, economic insights, and economical efficiency of building SCRES was important to SC managers, but only after operational gals. This indicates that immediate proximity of life-threatening situation for directly affected companies caused prioritisation of operational and delaying financial goals, while SC managers that haven't faced immediate life and property threatening situations, kept finances in their mind as a goal. However, financial goals under natural disaster as environmental contingency were not oriented toward profit gaining, they were completely oriented toward reduction of losses.

Conclusions

We make a significant contribution to our understanding of SCRES through in-depth examination of SCRES building stages. In addition, application of structural contingency theory is broadened in the area of SCRES in relation to natural disasters, and the nature of traditional SC practices under natural disaster contingency.

This study also integrates two research areas namely OSCM and disaster management that have not been combined in this context before, with purpose to answers existing ambiguity in the body of literature, indicating that risk analysis and preparation plans might be insufficient for SCRES building, but additional alterations of SC practices must be performed.

Study inductively identified SCI with government and community as important enhancers of SCRES, as well as trust within company and between organisations in SC. Practical implications in following these suggestions could be established.

Future research

Future studies might build on the present study trough building and testing model that presents relation between trust, SCI, and SCRES in the context of natural disasters. That model can be tested in a quantitative study. In addition, some of the findings were captured inductively, such as SCI with government and community, and trust between companies and within company being important for SCRES building. Therefore, the deeper understanding is needed in future research. In addition, the sample of 4 SCs per natural disaster are not generalizable and generalizability is suggested for the future studies.

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Environmental Risk Management in Supply Chains: A Multiple Case Study

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Abstract

The present paper explores the environmental risk supply chain management through multiple case studies conducted in three Brazilian companies. We compare the literature findings with the business reality, bringing insights on how environmental risks are managed by industries and their supply chains, what the potential losses perceived by companies are and the strategies adopted to hedge against them. The case studies' findings show that most of the risks found in the literature were considered by the companies and that two environmental risks highlighted by one of the companies can be added to the academic list.

Keywords: Environmental Risk Management, Supply Chain Management, Multiple Case Study

Introduction

Risk management is one of the most significant challenges faced by supply chains (Torres-Ruiz and Ravindran, 2018). Risks occur due to an interruption at some point in the chain, which successively clogs the flow of materials, funds or information among the entities of the supply chain (Bode et al., 2011). Global competition and outsourcing render supply chains more exposed to disruptions caused by several factors, such as uncertain economic cycles, consumer demands, natural and man-made disasters (Torres-Ruiz and Ravindran, 2018) and adverse environmental impacts (Levner and Ptuskin, 2018). Furthermore, supply chains are more vulnerable to stakeholder scrutiny, which might generate vulnerability to reputation damage (Christopher et al., 2011; Hofmann et al., 2014; Valinejad and Rahmani, 2018), access to capital and to regulatory compliance (Torres-Ruiz and Ravindran, 2018).

This paper focuses on environmental risks and presents a multiple case study on the topic, since the increase of diversity and the grow of the supply chains sizes, highlighted the importance of the environmental concerns in supply chain risk management research (Levner and Puskin, 2018), and the literature on supply chain risk management has largely overlooked ecological and social issues in their operations (Hofmann et al., 2014).

As suggested by Oliveira et al. (2019), case studies should be conducted across different companies in order to strengthen the practical field of environmental supply chain risk management and form a basis for comparability between academia and practice. Thus, in order to compare, validate and add new evidence to the findings of Oliveira et al. (2019), the present research aims to explore the environmental risks, the stakeholder effects and the consequences to the companies, as well as the environmental strategies adopted, by conducting multiple case studies across three large companies located in Brazil. The companies, here designated as companies A, B and C, are respectively a petrochemical company, an air compressor manufacturer and an agrochemical biotechnology company. More specifically, this paper aims to address the following Research Question (RQ): *Are the environmental risks, consequences and environmental strategies found in the academic literature also found/relevant in a business reality?*

The following section outlines the case study methodology adopted for this study. The results achieved through the conducted case studies are presented and discussed in Section 3. Section 4 presents the concluding remarks and suggestions for future research directions.

Research Methodology

The present research adopts the case study methodology proposed by Yin (2001), composed of six steps: planning, project, preparation, data collection, data analysis and sharing.

The planning intends to evaluate the relevant situation for the development of the case study in contrast to other research methods, justifying the choice of the case study method. Yin (2001) clarifies that the case study intends to investigate a contemporary phenomenon within its real-life context, particularly when the boundaries between phenomenon and context are not clearly defined. Thus, the case study method meets the need of this research which is to analyse environmental risk management in supply chains, since it uses several sources of evidence, and does not have a clear definition of the boundaries between the phenomenon to be studied and the context of the real life in which it is inserted.

Hence, the phenomenon to be investigated within a real-life context is the management of environmental risks in supply chains, addressing the consequences that these risks may generate for the organisations and the strategies adopted to hedge against these risks.

The project aims to elaborate on the research question, define the case study project (single or multiple) and define the criteria for interpreting the findings (Yin, 2001). Therefore, the main question of this study is centered around comparing and validating the environmental risks, consequences, and strategies proposed by Oliveira et al. (2019), with the real-life situations, observed and applied in the supply chains of three large companies located in Brazil.

Cauchick and Souza (2012) elucidate that, in the single case study, it is

expected that there will be greater depth in the investigation and less capacity of generalisation. On the other hand, in multiple case studies, there is a possibility of greater generalisation, with perhaps less deepening in the evaluation of each case. According to Herriott and Firestone (1983), the evidence resulting from multiple cases is considered more convincing, and consequently, the study is considered more robust. In order to provide greater robustness to the research, through the analysis of several organisational realities and the cross-referencing of these various cases, the present work undertakes a multiple case study.

The case studies were conducted in three large companies located in Brazil: a petrochemical company, an air compressor manufacturer, and an agrochemical and agricultural biotechnology company, chosen for being ones recognised for their sustainability visions and principles of generating positive impacts on communities and environment.

For the preparation, Yin (2001) proposes the development of a research protocol, which is extremely important to increase the reliability of the work, guiding the researcher in conducting data collection for cases. Thus, for this study, the research protocols were developed in order to guide the researchers in performing the collection of data from the multiple case studies.

Data collection considers multiple sources of evidence, such as: semi-structured interviews, documents, file queries, physical artifacts and direct observation (Yin, 2001). Yin (2001) recommends the use of several sources of evidence, since these multiple sources allow for greater detail in the collection of data. Considering the cases studies performed here, the data collection was conducted in the same way with the three companies under analysis. This collection took place in three different stages and used the following sources of data: documents provided by the company, semi-structured interviews and secondary documents sourced from corporate websites.

For data collection, a questionnaire was initially created based on a systematic literature review (SLR) performed by Oliveira et al. (2019) and was sent to the companies through the *SurveyMonkey* platform, in order to collect background information about their management of environmental supply chain risks. Then, three semi-structured interviews with different managers from the companies were performed in October and November 2018. Open questions based on feedback from the questionnaire were used in the interviews. Finally, the documents provided by the interviewees and secondary materials available on the companies' websites were compiled and analysed.

The professionals considered in these interviews are specialised in dealing with management of environmental risks, and are: (i) Environmental, Health and Safety Engineer of Company A; (ii) Environmental Analyst of Company B; and (iii) Environmental, Health and Safety Engineer of Company C.

The data analysis, according to Yin (2001), is concerned with the examination, categorisation, tabulation, testing or recombining of evidence, in order to produce discoveries based on empiricism. This step can be driven by four different techniques: to construct validity, internal validity, external validity and reliability (Yin, 2001). In this study, the technique adopted is the internal validity by means of the adaptation to the standard, where the theoretical references of systematic literature review are used as prognosis and compared with the results of this empirical study, in order to reinforce the validity of the study (Yin, 2001).

The final step of the methodology, sharing, aims to transmit the relevant information of the study through the presentation of the results (Yin, 2001). This

step is further presented in the following section.

Results and Discussion

This section presents the results and discussion of the case studies conducted in the three Brazilian companies. The online questionnaire and the interviews allowed for the evaluation of the environmental risks along the companies and their supply chains.

Firstly, through the online questionnaire and the interviews, it was possible to understand how the environmental risks and consequences were perceived and managed by the companies. Among the environmental risks listed for the interviewees, the ones considered for Company A were: greenhouse gas emissions (GHG) and ozone-depleting substances (ODS); industrial ash and soot emissions; chemicals and toxic effluents released into water or groundwater and oil; inefficient use of water; inefficient use of energy; and explosions, fires, chemical accidents. The most cited consequences that the risks may generate for the company were reputational consequences. Thus, the company realises that the losses go beyond the financial consequences that these risks can cause.

Company B considered the following environmental risks: greenhouse gas emissions (GHG) and ozone-depleting substances (ODS); chemicals and toxic effluents released into water or groundwater and oil; inefficient of raw materials; inefficient use of water; inefficient use of energy; non-compliance with sustainable laws and regulations; and explosions, fires, chemical accidents. For Company B, the most frequent consequence was the reputational consequence. The Company understands that damage to the companies' reputation can cause it irreversible losses.

Company C considered the environmental risks already mentioned, except the environmental risk related to industrial ash and soot emissions, especially as it is not closely related to its activities. With regards to consequences, those that were most frequent were financial and reputational consequences.

Respondents from Company C added two risks that were not previously included in the list of environmental risks related to the systematic literature review, with these being: inadequate disposal of hazardous solid waste and a risk of loss of biodiversity. These new risks should be added to the SLR list presented in Oliveira et al. (2019), as they may create critical environmental issues. However, the risk of loss of biodiversity is a specific risk related to the activity of Company C, which perhaps will not fit into the list of risks of all company.

Finally, regarding the strategies to deal with the risks, among the strategies identified in the literature, the most frequent strategies cited by the three companies were: wastewater and solid waste management; carbon and water footprint monitoring; efficient consumption of natural resources; substitution, precaution, and reduction in the consumption of chemicals and toxic waste; introduction of carbon emission reduction initiatives and practices (e.g., use of renewable energy, filters, freight consolidation, driver efficiency, etc.; auditing, monitoring suppliers and the use of sustainable criteria for supplier selection, encouraging suppliers and partners to promote a sound environmental policy.

It was observed that the companies have a robust environmental policy to deal with their environmental risks, once they consider most of the strategies identified in the SLR of Oliveira et al. (2019).

Regarding the consequences, the respondents of the companies reported that,

nowadays, organisations are becoming more aware of ecological issues, especially due to stakeholder pressures, legal requirements and environmental regulations. Thus, the companies perceived reputational losses in the same light as financial consequences. Furthermore, it was also concluded from the interviews that all the consequences are closely related since damage to a company's image directly affects the company's profits. The legal consequences are also associated with financial losses since fines and legal penalties minimise the company's profits.

Environmental risks caused by supplier irresponsibility and their failure to abide by environmental standards are still poorly addressed by the Companies. Only recently have the risks arising from the suppliers become a perceptible topic in the field of supply chain management, as mentioned by Torres-Ruiz and Ravindran (2018). For example, recently Company A has developed voluntary engagement actions of suppliers with a focus on sustainability, requesting them to report their greenhouse gas emissions and water consumption, as well as the risks, opportunities and strategies related to these specific issues.

Company C also pointed out that it seeks to engage with its suppliers, promoting workshops in order to influence and engage them into sustainable management practices. The workshops are also intended to encourage them to participate in the Reforestation Program which seeks to balance the emissions of greenhouse gases generated in their transport processes. Company B also emphasised that it is engaging with its suppliers regarding environmental issues, but did not mention specific actions or programmes adopted.

However, despite the engagement policies mentioned by the Companies, they did not have a well-structured matrix of the environmental risks from the suppliers. Companies A, B and C only audit the contracted service providers for the destination, treatment and transportation of their chemicals effluents and waste. Thus, it is found that the companies do not have well-structured management of environmental risks that exceed the borders of companies (environmental risks of the suppliers). Thus, due diligence, i.e. the co-responsibility and diligence of the counterparties, is a topic that needs to be addressed and further explored.

Conclusion

This paper explored the environmental risks in supply chains. This was accomplished through a multiple case study conducted in three Brazilian companies. From these cases studies, it was possible to identify the environmental risks, consequences, and strategies presented in the companies and its supply chains. The results achieved allow to provide an answer to the research question of this paper. The findings indicate that several environmental risks presented in the literature coincide with the environmental risk considered by the studied companies. However, it is relevant to highlight that although the types of adverse environmental impacts are universal, the risk types should be specified for every individual industrial enterprise (Levner and Ptuskin, 2018). For example, the risk of loss of biodiversity mentioned by Company C may not apply to another company.

The contribution of the present study for researchers was to perform a comparison and validation between the business reality and the academic findings from Oliveira et al. (2019), showing that the environmental risks found in the academic literature are in line with the environmental risks presented in a business environment. From the case studies, we realised that the environmental risks from

the suppliers are still poorly addressed by the companies, as opposed to the environmental internal risks of the companies.

Furthermore, our findings contribute to the supply chain risk management field as this paper introduces the environmental perspective and addresses the consequences that can be felt by the companies and environmental strategies from a practical business environment.

For future research, case studies should also consider different country perspectives to yield interesting insights from other cultures. Moreover, case studies conducted in different economic and climatic regions may result in different perceptions and effects of environmental risks. The region in which the company is located, the exposure to the risk, the intensity of stakeholder pressure and the legal requirements of the region will certainly influence the management of the environmental risks in the supply chain.

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Trust and formal control affecting perception of food safety risk in the supply chain: a study under the milk producers' perspective.

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Abstract

Although studies discussing risk assessment are abundant, attention over supply chain risk perception is considerably lower. Moreover, papers regarding food safety risk perception from supply chain members' perspective other than the consumer's point of view are also limited. Therefore, this research aims to investigate: how does formal control and trust affect food safety risk perception in the milk chain? Results show formal control as a potential factor to reduce risk perception in four out of five measured risk events. Trust was also found as an antecedent that reduces risk perception in all events and as a moderator in specific settings.

Keywords: Risk Perception, Trust, Formal Control

Introduction

Supply chain risk management has become a consolidated field of research over the last years. Nowadays, a solid background can be found on many of the traditional SCRM topics, such as risk assessment and identification tools, supply chain risk modelling, as well as mitigation strategies, processes and practices (Sodhi et al., 2012, Ho et al., 2015, Fahimnia et al., 2015, Vishnu et al., 2019). However, little attention is being given to risk perception.

Risk perception is the general assessment conducted by one individual regarding an specific context in order to make decisions (Mitchell, 1995, Ellis et al., 2010, Kull et al., 2014). Most of current publication links risk perception to other managerial approaches but discards its relevance to supply chain risk management. The few papers that contributes directly to SCRM focuses mainly on consumers' risk perceptions and its impact on supply (Van Kleef et al., 2007, De Krom et al., 2010, Bailey and Garforth, 2014) leaving a vast territory to explore (Vishnu et al., 2019).

Even if risk level as well as any other managerial information is properly assessed and provided, the final decision is a result of an individuals' perception of environment, that suffers impact of many subjective variables (Sitkin and Weingart, 1995, Kull et al., 2014). Therefore, even if reliable and detailed information is available, a decision-maker can

consider other aspects or even reinterpret the scenario leading to different outcomes than expected.

In the supply chain, the perception of risk may cause different behavior regarding control (Das and Teng, 2001, Kull et al., 2014). From this perspective, previous occurrences lead to a perception about the specific likelihood of a repetition or related situation and this apprehension may cause the individual to assume a different position regarding future scenarios (e.g. increase control).

Since perception can not be explained only by objective data as it is a complex cognitive response (Mitchell, 1995, Simon et al., 1999, Kull et al., 2014), this study proposes to focus on the relationship between risk perception and two other relevant supply chain relationship constructs: trust and formal control.

Additionally, this research intends to associate the perception of risk in a specific context. Although quantitative SCRM models are abundant in literature, there is still a significant gap between theory and applicability in industry and therefore empirical studies are valuable research material (Vishnu et al., 2019).

Therefore, based on previous modelling on risk level and risk perception, this paper proposes to test the association of trust, formal control and the perception of food safety risk in order to understand their reciprocal implications.

Sector-specific research, especially in the food industry are still necessary, due to differences between regulations, policies and even industry maturity that demand further investigation (Roth et al., 2008, Sodhi and Tang, 2012, Van Asselt et al., 2017, Vishnu et al., 2019).The dairy sector stands out for the amount of risk types and high level of occurrences worldwide (Roth et al., 2008, Bailey and Garforth, 2014, Van Asselt et al., 2017).

In this perspective, this paper aims to answer the following research question: how does formal control and trust affect food safety risk perception in the milk chain? In order to answer this question, this paper addresses the first step of the process by understanding the producers' point of view, since most of food safety risk still depends on proper production and handling protocols at the first stages of production (Fagnani et al., 2011, Van Asselt et al., 2017).

Brazil has recently faced a significant amount of investigations regarding multiple types of risk events in the dairy industry, involving mostly cases of fraud and chemical contamination (IGL, 2015, MPRS, 2019). Since it is also a country that lacks contextual and empirical research regarding SCRM (Ceryno et al., 2015) and the opportunity to study a current disturbance, this country was selected for delimitation.

Theoretical Background

As previously presented, risk perception is a personal assessment on a generic situation (Mitchell, 1995). On the SCRM perspective, previous occurrences – positive or negative – or situations that base risk perception are defined as risk events. Risk events are defined outcomes of risk (Manuj and Mentzer, 2008) or, in a simpler way, when something that was once risk becomes a concrete reality.

Risk events can provide foundation to assess risk probability, frequency, speed and impact (Sodhi and Tang, 2012). Also, they are critical to understand past situations and create mitigation strategies.

Formal control is the group of resource tools that are applied to verify if processes and outputs are complying with planned operations (Stouthuysen, 2012). As a part of risk mitigation and a continual improvement routine, formal control can affect agents' behavior and reduce risk (Das and Teng, 2001, Ju et al., 2011, Kull et al., 2014). As a construct, formal control can be divided into performance or output control – that focused

on the final outcome of a process – and behavioral or process control, that will approach both objective and subjective elements of the process itself (Das and Teng, 2001, Ju et al., 2011, Stouthuysen, 2012).

Trust is often mentioned as a potential factor to reduce risk, although it is highly discussed if it should be used as a substitute of formal control (Villena et al., 2011, Skinner et al., 2014). Although its relationship with risk and control has been discussed significantly, trust is found as both antecedent of risk and moderator of control – risk relationship (Das and Teng, 2001, Ryu et al., 2008). Considering the wide use of risk variable rather than risk perception on research papers, it is not clear how these constructs would interact in specific environments.

Many studies address risk perception in general. Even so, a few models included formal control, trust and risk perception under the supply chain's approach.

Das and Teng (2001) proposed a model that discussed the relationships between trust, control and risk perception that is one of the main references of this study. However, not only the original paper does not present empirical data, it does little to support further application, since the theoretical approach does not include scale or any data collection or analysis. Also, Das and Teng (2001) were focusing on strategic alliances when model was designed, which also reinforces the necessity to develop reviews, increment and data analysis of this constructs for the supply chain risk management perspective.

More applicable, Kull et al. (2014) presents a model about risk perception and perceived control as well as other cognitive and environmental aspects to understand supplier selection. The model presents relevant contributions of relationship proposals as well as scale testing. Yet, trust is only marginally discussed and does not participate as a construct on the model. Other models have as well partial connection to this proposal, but as observed in the main sources mentioned above, the construct relationship aims at a different direction than this article. To our knowledge, this papers' approach has not been addressed until this moment.

The scarcity of publications is even bigger when food safety risk is observed. Theoretical literature is easily found and vast due to contribution of many fields (Roth et al., 2008, Van Kleef et al., 2007, Bailey and Garforth, 2014), however, papers mainly focus on risk perception relation to demand, brand and other consumer-oriented constructs (De Krom et al., 2010, Bailey and Garforth, 2014, Van Asselt, 2017).

Food safety risks are also a wide range. In order to narrow perspective and provide a more accurate risk perception, as this construct is based on specific situations (Sitkin and Weingart, 1995), typical milk chain risk events were mapped in previous literature. As this data collection centers in the producer's perspective, five of the ten main risk events were included on final model, described as follows: (a) microbial contamination of milk, (b) contamination of cattle feed, (c) chemical contamination of milk, (d) contamination of cattle due to medication and (e) milk fraud (Baars et al., 1992, Van Kleef, 2007, Roth et al., 2008, Xu et al., 2010, Bailey and Garforth, 2014, Van Asselt, 2017).

Based on this scenario, three models were proposed considering, respectively, formal control as an antecedent of risk perception, trust as an antecedent of risk perception and trust as a moderator in 'formal control – risk perception' relationship, as presented in Figure 1.

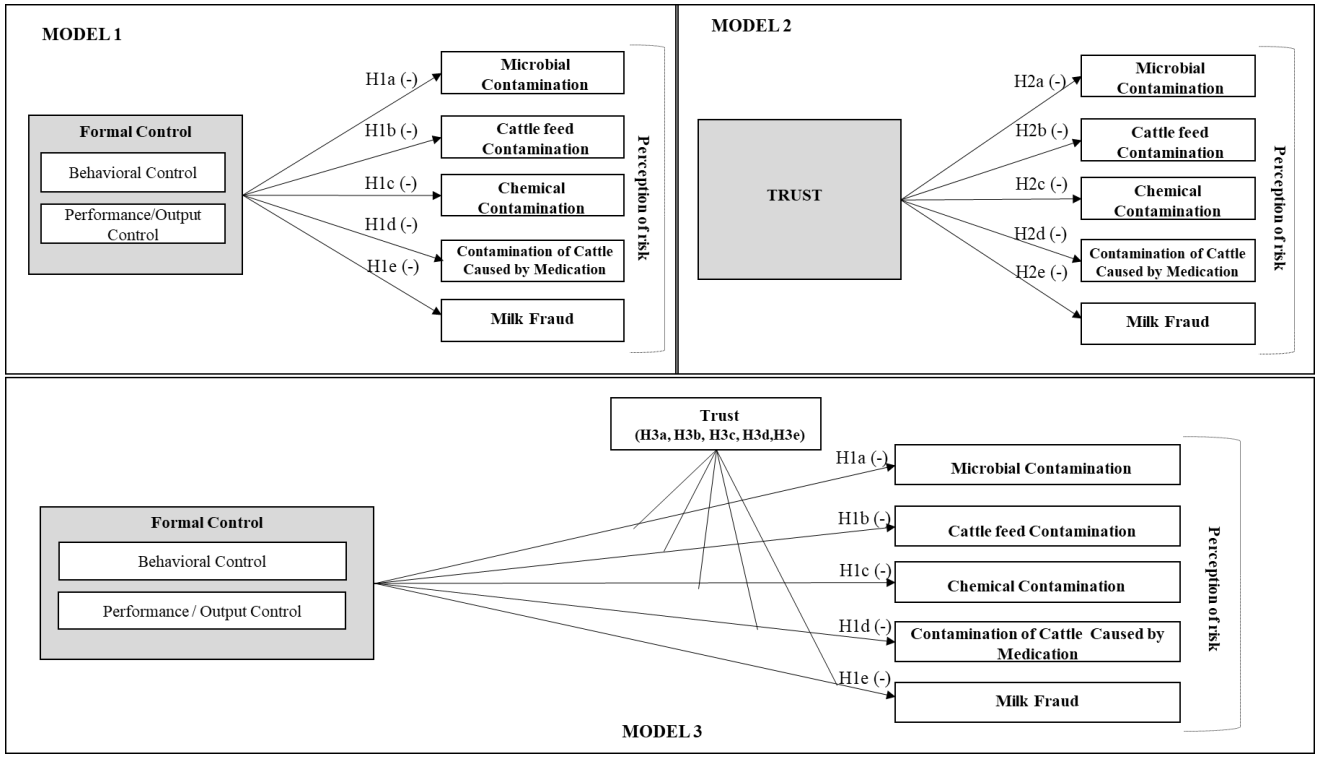

Figure 1 – Proposed models

Data collection and research design

As previously mentioned, Brazil was chosen for data collection due to recent risk events in the milk chain (IGL, 2015, MPRS, 2019). For this study, we considered the producers' perspective due to the concentration of food safety risk events on the initial stages of the milk supply chain (Roth et al., 2008, Bailey and Garforth, 2014, Van Asselt et al., 2017). Also, Brazilian milk supply chains are typically formed by a large group of producers (around eighty thousand only in south region) selling to a limited group of manufacturers, a group of approximately 300 companies (IGL, 2017). Therefore, a sample of producers was more suitable to obtain in the specific context.

The questionnaire consisted of a total of five blocks, structured as follows: 'demographic data', 'risk perception', 'trust', 'formal control', and 'contextual aspects'. The fist block included general information regarding milk production, producer experience and qualifications, farm location and technological level of production.

Kull et al. (2014) and Sitkin and Wiengart (1995) scales were used to measure risk perception. A 7-point scale was used for the seven items generated from this combination. This block intended to measure objectively the different aspects of risk perception (as a threat, as a possibility, as potential situation, etc.) in order to understand how likely to occur is the risk event according to respondent's assessment of the context. As risk perception is situation-based (Sitkin and Weingart, 1995, Kull et al., 2014) we replaced original scale risk events for via five specific conditions present in milk chains, according to literature: microbial contamination of milk (MICRO), cattle feed contamination (FEED), chemical contamination (CHE), cattle contamination by medication (MED) and fraud or adulteration of milk (FRA). The selection of risk events also considered the proximity of producers with the possible risk events, therefore final product occurrences

(e.g. package, retail storage, etc.) were not addressed. Also, since the risk perception is measured according to the specific scenario (Sitkin and Weingart, 1995), each risk event was measured as an independent construct.

The third block was built to measure how trustful the relationship between producer and manufacturer is according to the former's perspective. Respondents were required to consider their main client when exclusivity was not established. For trust measures, Ryu et al. (2008) scale was replicated as a main reference and was complemented by Ju et al. (2011) for norm-based information exchange items. Eight items were considered in this construct, using a 7-point scale.

For formal control, previously validated scale items were also merged (Stouthuysen et al., 2012; Crosno et al., 2015). This block was designed to understand the level of control producers understood to be subjected to by manufacturers. It is formed by two subsections: performance control (five items, 7-point scale) and process or behaviour control (six items, 7-point scale).

The last block intended to measure contextual aspects of government regulation and food law as a control variable. The scales proposed by Sebata et al., (2016) were adapted, as it was used only 3 constructs: 'food law and regulations' (7 items, 7-point scale), 'food control management and information flow' (8 items, 7-point scale) and 'analytical services' (10 items, 7-point scale). Since data collection was conducted by local government agents, the construct 'inspection services' from original paper was not included in order to avoid bias. Considering results from this final block were out of the ordinary (a significant amount of responses was marked as neutral by respondents), it was removed from this paper analysis, pending further tests.

Original scales were translated from English to Portuguese and minor adjustments were made to preserve meaning. Final adapted and integrated scales assessed by specialists (academic and practitioners) and further small adjustments were conducted based on their review. A pilot test was also conducted to reinforce scale's adequacy.

Data collection was conducted in loco by trained professionals from EMATER, a national government agency for agricultural development. Final count included 89 EMATER professionals involved in this data collection, occurring simultaneously in all 13 subregions of the Rio Grande do Sul state, south Brazil. A total of 265 valid cases was obtained and 23 cases were discarded for missing values or because they did not fit the sample description. Smart PLS version 3 and SPSS version 25 were used for data analysis and model testing.

Measurement and Construct Validation

In order to observe convergent validity, we conducted observations of the of the Average Variance Extracted - (AVEs). Initial results showed AVE > 0,50 for the variables representing risk perception in all five scenarios (MED, CHE, FRAUD, CATF and MICRO).

Therefore, variables with factorial loads of smaller values were removed according to threshold indicated in the literature (Hair et al., 2014). A total of 13 items was removed and although items were removed, observing that constructs integrity were maintained and still preserving more than three items each. As presented in Table 1, results after model adjustment presented satisfactory results (Hair et al., 2014; Ringle et al., 2014).

Table 1 – Final measurement validation after item removal

Variable	AVE	Composite Reliability	R Square	Cronbach's Alpha
Cattle Feed contamination	0.5634	0.9043	0.0172	0.882
Chemical contamination	0.6844	0.7576	0.3492	0.6745
Fraud	0.6788	0.8619	0.4758	0.7542
Cattle contamination by medicine	0.6569	0.8513	0.442	0.7306
Microbial contamination	0.5521	0.8508	0.5741	0.7833
Performance control	0.725	0.951	0	0.9355
Process Control	0.6551	0.847	0	0.7461
Formal control	0.7955	0.9285	0.9983	0.9085
Trust	0.587	0.9083	0	0.8814

Subsequently, discriminant validity was tested and one more item was removed in order to provide model fit (variable 'trust8'). Final correlations are presented on Table 2. Convergent validity and reliability values were also reviewed and remained in the appropriate value range.

Table 2 – Variable Correlations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cattle Feed contamination (1)	**0.759342**						
Chemical contamination (2)	-0.0285	**0.757892**					
Fraud (3)	0.0798	-0.3921	**0.823408**				
Contamination by cattle medicine	0.025	0.5506	0.0454	**0.812158**			
Microbial contamination (5)	0.05	0.277	0.1189	0.5493	**0.7424.96**		
Trust (6)	-0.1358	-0.4915	0.155	-0.6344	-0.7265	**0.76857**	
Formal control (7)	-0.0891	-0.4877	-0.0125	-0.5758	-0.5469	0.6457	**0.765572**

To assess significance of path coefficients, a bootstrapping analysis was processed on Smart PLS v. 2 (individual changes, 500 samples). For moderating effect, a multigroup analysis was conducted. Trust was recoded as dichotomous variable ('high level of trust' and 'low level of trust'). Cases were assigned to one of the two conditions (130 on high level trust and 135 on low) and Student's t-test was used to verify the significance of difference between groups. Both equal variances assumed and not assumed test were significant ($p<0,000$).

Findings

As presented on Table 3, regression analyses for the relationships between formal control and perception of risk events was found significant and negative in four occurrences: chemical and microbial contamination, fraud and contamination by cattle medicine. The 'formal control-cattle feed contamination' relationship, however, was not significant. Therefore, regarding Model 1, H1 is partially supported, since H1a, H1c, H1d and H1e were confirmed by data analyses but H1b did not hold significance to be considered validated.

The results indicate that producers perceive formal control as a factor to potentially reduce events that are directly related to their routine exchanges with manufacturers.

However, the lack of significance in the impact of formal control in cattle feed contamination may be linked to the fact that, in Brazilian context, manufacturers to not control this type of risk directly via laboratory and sample test analyses as conducted on the other four situations, but indirectly via producers reports, regulatory labels and licences and government monitoring of cattle feed production and storage (MAPA, 2006). In this scenario, results are coherent with context-specific formal control issues, as producers do not witness control processes for this risk type as part of the industry's regular monitoring protocol. In previous literature, cattle feed contamination, although highly critical to the entire supply chain, becomes the focus of attention usually after a significant event (Baars et al., 1992, Xu et al., 2010, Fagnani et al., 2011).

Since recent events in the specific region of study were mostly related to fraud and chemical contamination (IGL, 2015), it is possible that producers are not in contact with this concern on their regular routines. Further studies in different contexts are necessary to enhance understanding regarding this aspect.

As for Model 2 - that considers solely the relationship between trust and the five studied risk perception constructs - all proposed paths were significant, supporting H2 (H2a, H2b, H2c, H2d and H2e). However, it is also appropriate to highlight that the 'formal control-cattle feed contamination' relationship was found less significant ($p<0,05$).

Table 3 – Path coefficients

		Path Coefficients (Beta)	T	*Sig. (p-value)*
Model 1	FC-CATF	*-0.63*	*-1.023*	*.307*
	FC-MICRO	*-0.166*	*-5.77*	*.000*
	FC-CHE	*-0.433*	*-7.78*	*.000*
	FC-MED	*-0.027*	*-5.43*	*.000*
	FC-FRA	*-0.543*	*-10.485*	*.000*
Model 2	TRUST-CATF	*-0.132*	*-2.155*	*.032*
	TRUST-MICRO	*-0.516*	*-9.769*	*.000*
	TRUST-CHE	*-0.414*	*-7.383*	*.000*
	TRUST-MED	*-0.339*	*-5.847*	*.000*
	TRUST-FRA	*-0.429*	*-7.712*	*.000*

Finally, Model 3 considered trust as a moderator in the relationship between formal control and risk perceptions. As presented on Table 4, the moderating effect of trust was significant only in two of the five risk events: milk fraud and chemical contamination. Thus, H3 is only partially supported (due to significant values for H3c and H3e). Based on these results, it is possible to infer that when there is a high level of trust perceived by the producer, the negative relationship between formal control and risk perception of fraud and chemical contamination are more subtle. This output reinforces previous literature and can be interpreted as a positive use of trust in reducing potential risk and risk perception (Sitkin and Weingart, 1995, Simon et al., 1999, Das and Teng, 2002, Ryu et al., 2008) in milk supply chains but it also may present a liability due to the 'illusion of trust' effect and the possibility of opportunistic behavior (Ju et al., 2011, Villena et al., 2011, Skinner et al., 2014), especially regarding fraud occurrences.

Table 4 – Multigroup analysis

Model	Path Coefficients (Beta)	*Sig. (p-value)*
FC-CATF	*0.35*	*0.254*
FC-MICRO	*0.061*	*0.623*
FC-CHE	***0.343***	***0.000***
FC-MED	*0.046*	*0.32*
FC-FRA	***0.51***	***0.000***

Final considerations

Research findings contribute to current literature by: (a) bringing the discussion of risk perception perspective in the supply chain, a topic that still lack publication in the SCRM approach; (b) discussing food safety risk perception from the producers' point of view, which can also be used for discussion in related fields, (c) proposing a model to understand the relationship between trust, formal control and food safety risk perception and (d) providing a scale adaptation for food safety risk perception that can be both replicated or adapted to other food-related contexts.

From a managerial point of view, this paper highlights the relevance of formal control in reducing risk perception on potential risk events in the milk supply chain. Also, as trust is also a factor that potentially reduces risk perception, it indicates that practitioners should be oriented to establish long-term partnerships in the supply chain. On the other hand, managers may as well remain observant, since findings exhibited that trust can also lead to the reduction of risk perception which can lead to a reduction of formal control, followed by the increase of risk levels.

Further analysis will consider demographic data, such as producer level of experience and technological production level to test detailed typical behavior. Also, SEM analysis will be conducted on SPSS AMOS to consolidate consistency of results. Data collection will as well be expanded to include manufacturers and other supply chain members via properly adapted surveys.

As for research next steps, it is our intention to replicate the study in a different context, measure government interference on supply chain internal controls and companies' risk perceptions as well as the inclusion of comparative historical risk levels on the model.

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Perspectives on building a supply risk assessment in the White Goods industry

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Abstract

The well-established research on supply risk assessment has provided a strong theoretical basis allowing for a broad range of assessment methods to be proposed. However, the academic field lacks a similarly strong evidence base from the industry, mostly consisting of generic surveys offering a high-level feedback from practitioners. In collaboration with a multinational manufacturing company from the white goods industry, this paper proposes a novel survey methodology that deepens our understanding of supplier-buyer relationships and how each side perceives the process of risk assessment in different commodity families.

Keywords: Supply risk assessment, Survey, White goods

Introduction

Supply chain risk management (SCRM) became an extremely popular research subject ever since the advent of globalization and mass outsourcing (Gunasekaran & Ngai, 2012). Open markets and technological advances posed new challenges for companies to address, and the continuously growing complexity of supply chains has been calling for deeper analysis on identifying, assessing and managing potential risks.

The consistently increasing attention on SCRM has been motivating academics to frequently review the progression of the research field by conducting extensive literature reviews. The most notable literature review publications in recent years seem to be those by Colicchia & Strozzi (2012), Ho et al. (2015) and Fan & Stevenson (2018). These reviews offer a complete picture of the SCRM research field and provide a useful overview of the state of the art in terms of SCRM definitions, risk classifications and risk management methods.

In this paper, our focus lies on supply risk assessment (SRA) which involves analyzing and evaluating potential risks in the scope of supply management and sourcing. A summary of the most relevant background material can be found in the recent literature review by Tran et al. (2018).

Our research is mainly inspired by the theoretical work of Heckmann et al. (2015) which identifies three key characteristics of supply risk from the perspective of a company's organization: 1) the importance of clarifying the objectives that will drive the risk assessment, 2) the attitude of the company's management towards risk, and 3) the company's exposure to potential risks that stem from the characteristics of the organization, the supply chain and the supply base. In reference to the defined objectives and risk tolerances deemed acceptable, a risk assessment exposes a company's vulnerability to potential disturbances in its supply chain (Svensson, 2000; Peck, 2006).

Tran et al. (2018) classify previous publications on risk assessment in terms of their methodology and they make two notable observations. The first observation indicates an increasing attention towards quantitative methods, which can be explained by the extensive theoretical literature published in the past few decades, as well as our original note on the increasing complexity of the supply chain and the need for tools capable of analyzing it. The second observation connects the level of depth of the research analysis to the methodology, whereby qualitative methods tend to focus more on general supply chain risk concepts, while quantitative methods address specific risks.

Previous reviews (Ho et al., 2015) have commented on the limited availability of empirical SRA studies offering insight from the industry. This is understandable given the difficulty of academics to connect with practitioners, while companies also do not easily disclose information since exceptional knowledge or capabilities can give them a competitive advantage. Furthermore, empirical studies have not given enough attention to the supplier perspective (Fan & Stevenson, 2018), nor have they extended the scope to multiple tiers (Tran et al., 2018). Finally, case studies have been crowded on a few industries, such as the automotive sector, while context (e.g., industry, country, etc.) has been poorly addressed (Fan & Stevenson, 2018).

To address these research gaps, this paper proposes a deeper empirical study with the support of a case company in the industry. The research is carried out during a collaborative project with Electrolux, a multinational manufacturing company in the white goods industry. The proposed study consists of conducting interviews, using a structured questionnaire developed a priori, on a select group of suppliers and buyers. The intention is to collect insight from both supplier and buyer perspectives within the same relationship. We also seek to extend our reach beyond the first tier of supply by interviewing competing suppliers who share the same or similar sub-suppliers, or even by including sub-suppliers in the interview process.

While the interview process is ongoing, this paper seeks to make the case for this novel methodological approach in advance and to define the expected results. The remaining part of this paper is structured as follows: the next section briefly presents the profile of our partnering company, followed by a detailed explanation of the methodology proposed. Next, we describe the questionnaire structure and discuss the objectives and expectations from conducting this research. We close the paper with our conclusions and by outlining the next steps of this research.

Company profile

This research project is carried out in collaboration with Electrolux Appliances, and specifically, the central purchasing team responsible for the sourcing strategy of European production. This section briefly presents the company profile and the purchasing organization.

Electrolux is a leading global manufacturing company in the white goods market, with production facilities present in four continents and selling over 60 million products

annually. The company was founded in 1919 and is based in Stockholm, Sweden. It produces household ovens, refrigerators, washing machines and dishwashers (the four main product lines under Major Appliances), vacuum cleaners, air conditioners and other small domestic appliances (under Small Appliances), as well as commercial appliances (under Professional). More information on the general profile is available on the corporate webpage (http://www.electroluxgroup.com/en/electrolux-in-brief-492/).

The purchasing organization is separated according to direct material vs. indirect material vs. logistics. The direct material group (in scope here) is split between central and local purchasing. Central and local purchasing differ mainly in terms of responsibility. On one hand, central purchasing defines sourcing strategies, allocates business spend and manages the relational aspect with suppliers. On the other hand, local purchasing bears procurement responsibilities, such as ordering material from suppliers and managing material pricing records. Figure 1 shows the purchasing organization chart.

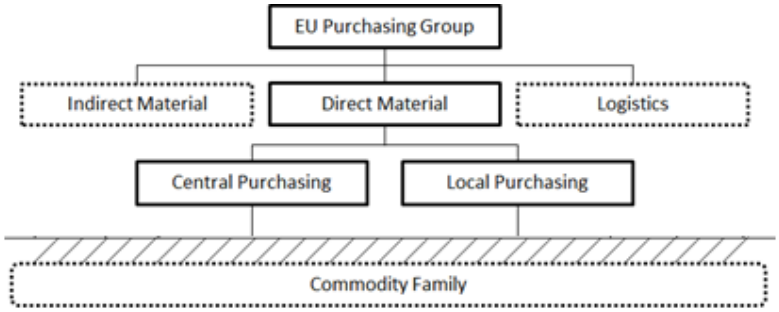

Figure 1 – Electrolux EU purchasing organization

At the lower level of the purchasing organization, responsibility is split by commodity family. There is a wide range of families with two levels; for example, plastic is one such family, with the specific plastic material types forming the sub-families. Some commodities are common across multiple product lines (e.g., electronics and plastics), while others may be specific to one product line (e.g., refrigerator vacuum insulation panels).

The group's objectives and key performance indicators (KPIs) are rather aligned with the industry and other manufacturing firms. The white goods market is generally considered a low-profitability and cost-oriented industry in comparison to markets such as automotive and telecom. In consequence, Electrolux has traditionally been strongly cost-oriented. In line with the historical evolution discussed in the literature review, the past 15 years have seen purchasing drilling down costs and maximizing LCC opportunities. However, in the last few years the mentality is changing, in line with the general trend in manufacturing industries and specifically the Electrolux company strategy, to balance cost reduction with quality performance, service level, innovation and sustainability. These aspects have always played an important role in the company's strategy; for example, Electrolux continues to be recognized as "Industry Leader in the Household Durables category" in the Dow Jones Sustainability World Index for eleven years now (Electrolux, 2019). What is now spreading instead across the organization is a 360° holistic mentality that is driven by purchasing in the back-end of the company towards a sustainable supply base formed by strategic partnerships. Since this new sourcing strategy allocates more business and responsibility in the hands of a few suppliers, attention is rising on the need to assess potential risks. It is in this context that

we choose to conduct interviews with select suppliers and buyers in order to study their perceptions on risk assessment.

Methodology

In the existing literature we can find examples of empirical research that consisted of case studies in the form of surveys or questionnaires. For example, Zsidisin et al. (2004) contacted purchasing professionals of manufacturing companies via telephone or email to collect general information about their involvement in supply risk assessment. The study covered seven companies from highly technical industries (computer, aerospace, semiconductor, cellular phone) that were known for having a proactive supply management approach.

Another example is the questionnaire that Lavastre et al. (2012) conducted by interviewing 142 professionals in 50 French companies. The content of the questionnaire covered general concerns on risk management such as risk attitude and use of different risk reduction methods.

A third and more recent example is found in the work of Kotula et al. (2018) who conducted semi-structured interviews with professionals from 20 case companies from the construction and electronics industries based in Germany or the UK. The interview protocol is included in the publication and consists of general questions on supply risk management.

Similar examples can be found in papers by Ganguly (2013) and Sarker (2019); the former conducted interviews in six organizations while the latter interviewed 18 representatives from a single case company.

While the above list is not exhaustive, we notice a similar approach among these empirical studies in that they offer an extraction of general insight from the industry with regards to risk management. Whether focusing on a single company or comparing multiple organizations, and irrespective of the number of respondents, the premise is typically one of discussing general concepts of risk management in order to test the extant theoretical literature. These surveys are undoubtedly useful in qualitatively or quantitatively analyzing the industrial approach and perception on risk management.

Given our collaboration with Electrolux, our study seeks to take advantage of the author's active participation in the company's purchasing organization for a deeper understanding of risk assessment perceptions in the industry. Our intention in this paper is to formulate and propose a novel semi-structured interview-based empirical methodology that will address limitations of previous studies.

Research objectives

Prior to designing the methodology we must define the objectives of the research that we intend to carry out. The main purpose of our research is to extend the public knowledge and understanding of how practitioners experience and perceive their companies' needs and challenges in assessing risks. As we progress in uncharted territory, we consider appropriate to use an explorative approach within our case company (Eisenhardt, 1989; Yin, 1994). Our work seeks to address four distinct aspects that have been identified as missing in previous studies:

1. the case of the white goods industry,
2. the perspective of suppliers,
3. the multiple-tiered nature of a supply base, and
4. putting suppliers in context according to their profile.

With respect to (1), in the previous section we already described the profile of our case company and how it relates to the topic of risk assessment. To the best of our

knowledge, there has been no previous publication on risk assessment (or risk management) using a case study from this industry (Fan & Stevenson, 2018). We believe the white goods industry is a valid addition to other manufacturing industries previously in scope and it is particularly interesting as its output is a product that combines components and technologies originating from a wide range of other industries and locations.

The above implies that by studying this company we gain access to a vast supply base with differing profiles that allows us to explore the perspective of suppliers (2) in contrast to what is mainly available in the literature (Fan & Stevenson, 2018). However, instead of choosing to approach a large number of suppliers that would force us to conduct a simpler, more general survey due to limited time availability, we prefer to focus on a few select groups of suppliers in order to study in depth the dynamics of some key commodities. In this way, we also have the possibility to approach both suppliers and buyers (i.e., commodity managers) in order to compare both sides of the relationship.

Furthermore, limiting the focus on a few competing suppliers within the same commodity offers the opportunity to investigate beyond the first tier of supply (3) (Tran et al., 2018). Suppliers can be questioned with regards to their own sub-suppliers which are likely to be similar in nature, in competition, or even common. If supplier-buyer relationships allow for it, we are likely to have the option of directly approaching sub-tier suppliers as well, which would offer a third perspective in a complex upstream supply chain.

The fourth and final aspect of our research focus is profiling suppliers in order to draw connections between their characteristics and their view or behaviour on risk assessment (Fan & Stevenson, 2018). Such differing characteristics, for example location, size or operational structure, are likely to affect their view as well as the buyer's view on potential risks.

Based on these four key aspects, we can proceed in formulating our four resulting research questions:

RQ1. How is risk perceived and assessed in the white goods industry?

RQ2. What are the differences between supplier and buyer perspectives on risk assessment?

RQ3. What additional insight can be gained by extending the assessment to multiple tiers?

RQ4. How are supplier profile characteristics affecting the assessment of risks?

In the following sub-section we design the structure of our proposed methodology in such a way to be able to address these research questions.

Research design

For the most effective empirical exploration of the aforementioned aspects, we have selected a semi-structured interview-based survey. The survey is applied in two ways: a) internally, completed by members of the purchasing organization, and b) externally, completed by the suppliers of Electrolux. Commodities and suppliers of different profile, market, process and location are involved. These characteristics can form the independent variables to the questionnaire, as summarized in Figure 2.

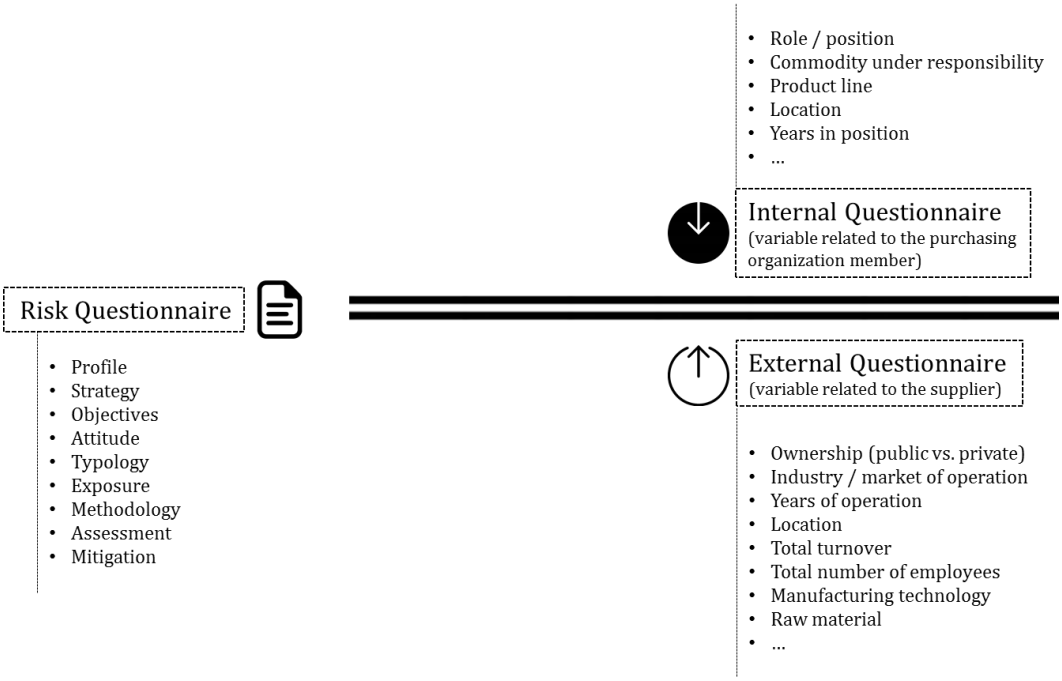

Figure 2 – Survey design

The supply base potentially at our disposal for the external questionnaire consists of approximately 500 direct suppliers spanning several commodity families, such as electronics, motors, wiring, plastics, metal parts, glass, rubber and tapes. This supply base is significantly diverse in terms of technology and materials, as well as share of Electrolux spend. However, as mentioned previously, we prefer to select a few key commodities and to focus on a smaller group of suppliers and their corresponding buyers within those commodities. To achieve a good balance of diversity and comparability, we have chosen to conduct the survey on the commodities outlined in Table 1. For each of the commodities listed, we shall involve in the survey 3-4 suppliers and 3-4 buyers. The behavior and perception on risk assessment can be compared among these commodities in relation to their characteristics, such as geography, type of raw materials, process automation, product customization and complexity, etc.

Table 1 – Commodities selected for the survey

Commodity	No. Suppliers	No. Buyers	Characteristics
Electronics	3	4	• Global sourcing (mainly China) • Long component lead times • High level of automation • Customized product • Low product mix
Cables	4	3	• Local sourcing (mainly Europe) • Long component lead times • Medium level of automation • Customized product • High product mix

Plastics	3	4	• Local sourcing (mainly Europe) • Chemical raw materials • Medium level of automation • Customized product (tooling)

We will conduct our survey with both suppliers and buyers in the form of face-to-face interviews that will be guided by the use of the appropriate questionnaire. This will allow for an easier explanation towards the interviewees and to ensure that questions are interpreted in the intended way. Moreover, interviews will facilitate a discussion in which to elaborate where deemed relevant and to ensure answers are appropriately matching the intention of the corresponding questions. Additional information or insight provided can be attached to the questionnaire.

Questionnaire structure

We have designed the survey in the form of an electronic questionnaire in excel, including a combination of open- and closed-form questions, many of which use the Likert scale. The survey is split in the following sections: i) profile, ii) market environment and company strategy, iii) risk of supply to Electrolux, iv) risk of (sub-tier) supply to Electrolux suppliers, and v) risk mitigation. Although the latter is not part of our focus, it is naturally linked to the assessment stage of SCRM and addresses the consequent business continuity aspect that is critical to the company's strategy.

We start with the profile of the supplier or buyer that serves to place respondents in context. In the case of buyers we are interested in their experience in purchasing and on the specific commodities under their responsibility, while in the case of suppliers we report basic company information such as industry, product portfolio, ownership, organization size and location(s). Suppliers are also asked about their certifications to investigate whether a formally recognized level of quality or sustainability can positively influence the behaviour or perception on risk assessment.

In the second section of the questionnaire, we ask both buyers and suppliers their perspective on the dynamics of the market and commodity in scope. We are interested for example in the perceived level of competition and balance of bargaining power, as well as the importance given to various corporate strategies of suppliers and their performance on a selection of KPIs ranging from cost and quality to service and corporate social responsibility (CSR).

Sections (iii) and (iv) consist of the main part of the questionnaire relative to risk assessment. Here we include several questions starting from how the respondents define risk and what are their attitudes, objectives and behaviours in evaluating risks. Then we enquire about types of risks, assessment methods and processes for the given company and commodity. On these questions we use a closed-form approach to test what originates from the literature. However, we couple those with open-form questions to extract insight on individual experiences that could shed light to additional forms of risk or assessment methods, and also to distinguish the inherent challenges among the different cases.

The final section on risk mitigation addresses questions regarding contingency plans, emergency response teams and risk-reduction methods. The questionnaire closes by requesting suggestions on how the given supplier-buyer relationship could better manage business risks.

Discussion

We previously justified our proposed methodology by distinguishing our approach from other surveys in four distinct aspects. In this section, we discuss how this approach can address the four research questions defined and what results we expect to attain after completing the survey.

This survey is intended for a company in the white goods industry, which we consider to be a valid case in the scope of multinational manufacturing companies. White goods consist of technical products resulting from a complex manufacturing process. They are constructed by assembling a large set of diverse components that result from different chemical and electromechanical processes. A significant part of these components is purchased from a vast selection of suppliers belonging to different markets and geographically dispersed around the globe. In comparison to other industries investigated in the literature as mentioned earlier in this paper, it is more complex than the electronics industry since it is located one tier upstream in the supply chain. Its complexity or component diversity is more comparable to the automotive or aerospace sector. Production volume of appliances runs on a similar scale as automobile production, however, they are part of a continuous, stable manufacturing schedule in contrast to automobiles that can vary based on new product launches. Aerospace also runs on spot project orders and with significantly lower volumes. The construction industry, also of interest in the extant literature, differs significantly as it is project-based and operates under a slower pace.

These characteristics render the white goods industry a particularly interesting environment in which to study risk management in general. The industry offers a vast supply base spanning across many different sub-industries, which expands the scope of potential risks. The stable nature of the manufacturing output boosts the need for business continuity and for disruption avoidance to be an integrated part of the operational process and the supply chain. Moreover, the complexity of the product portfolio translates to an equivalent complexity spread amongst suppliers, creating additional challenges that increase exposure to risks. As a final note, cost plays a key role in the white goods industry and can, in some cases, increase exposure to risks and compromise the resilience of the supply chain in the event of disruption.

One of the arguments we make in favour of the white goods industry is the diversity of its supply base. With a wide selection to our disposal, we have opted for three commodities that we believe can offer valuable insight. First, we share a similar interest with fellow researchers on electronics due to its highly technical nature, fast rate of technological change and continuous market growth. In our case, we have the possibility to view a perspective from the receiving end of the buyer as well as from the viewpoint of electronics manufacturers supplying the white goods market. We expect electronics manufacturers to have a lower bargaining power with respect to the buyers, mainly due to a high level of competition, but also with respect to their suppliers who produce the electronic components that benefit from a generally strong market demand.

The second commodity selected is that of cables, which in the case of appliances consists of power cords and wire harnesses. These products typically use standard components, such as wires and connectors, but they are customized to fit the application, for example in terms of length and combination of connections. This leads to a high level of complexity, which, coupled with the relatively low product cost, tends to call for a localized supply. An interesting comparison can be done with electronics since the two commodities share some materials (mainly terminals and connectors) but differ in geographical sourcing strategy and complexity. Also the level of production

automation can vary between types of cables, whilst electronics assembly lines tend to be highly automated.

The third and final commodity addressed in our survey consists of plastic parts. In this case, we move from electrical components to chemical raw materials and from a functional purpose to a more aesthetical one. Geography is strongly linked to the dimension of the parts; however, long-distance sourcing is unlikely, not only due to the impact of transport on cost but also due to plastic parts being by definition custom-made. In this commodity, the production process is rather simple (injection moulding) but performance is strongly dependent on the quality of the tooling.

In all three commodities, suppliers are likely to use similar or even common sub-suppliers. This provides an additional opportunity for our survey to extend beyond the first tier of supply. By interviewing competing suppliers, we expect to find matching statements in terms of risks in their market dynamics, but we also expect to find differences arising from differing strategies, operational structures, or even coincidental experiences. We also aim to directly interview tier-2 suppliers that can prove invaluable in providing a third perspective beyond the two-way supplier-buyer relationship. Essentially, a tier-2 supplier can offer a double perspective: on one side, in the role of supplier, thus placing the supplier of Electrolux in the role of buyer; on the other side, as a node closer to the source of the supply chain, where Electrolux buyers have limited visibility and control. As such, tier-2 suppliers can offer insight on potential risks that would not arise from interviewing Electrolux buyers or even Electrolux suppliers.

Our final research question addressed the correlation of supplier and commodity profiles with risk assessment. At this point, we highlight that throughout the discussion in this section we have considered supplier and commodity characteristics when arguing for their relevance to our study. These characteristics allow us to compare and contrast them from different perspectives, and, through this process, draw additional insight on behaviours and attitudes towards risk. Ultimately, we seek to increase the level of understanding and knowledge behind the risk assessment process, but we also suggest putting eventual theories and methods (as available in the literature) into perspective, considering that managing risks is subject to the given company's strategy and attitude towards risk.

Conclusion

In this paper we have argued that the empirical side of risk assessment research would benefit from a deeper investigation in the industry. We have identified four main areas of improvement on these qualitative studies. First, we argue for the validity of the white goods industry as a fertile environment for studying risk assessment methods in the scope of multinational manufacturing firms and we note that it has not been addressed so far in the extant literature. Second, the nature of the white goods industry and its products offers a vast and diverse supply base with the potential to explore different behaviours, strategies and attitudes towards risk. Third, given our involvement in the case company's purchasing organization and the dynamics of their supplier-buyer relationships, we have the opportunity to extend the survey beyond the first tier of supply in order to widen our perspective on the supply chain in scope and at the same time go deeper towards farther sources of risk. Fourth, we suggest exploiting the diversity of the supply base in scope in terms of profiling suppliers and commodities to explore the correlation between their characteristics and risk behaviours.

In the context of these four aspects, we propose a novel approach of conducting a qualitative survey. Our proposed methodology consists of conducting semi-structured interviews guided by a questionnaire provided a priori. Interviews are conducted on

both buyers and suppliers of the same commodities for a double perspective. We have designed two questionnaire versions to match the perspective of buyers and suppliers, referred to as "internal" and "external" questionnaire, respectively.

The next step of this research shall be to conduct the interviews, analyse the information collected from the respondents, and present findings that should contribute to our understanding of the industry's approach to risk assessment.

We recognize that to focus on the key aspects presented in this paper we have also limited the connection of our work to further studies in the extant literature. It will be useful to collect additional publications with empirical research and compare in detail the respondent profiles as well as the content of the surveys. Further research in the white goods industry will prove invaluable to compare with our findings, whether done with the same case company or with competitors in the same industry. A detailed comparison among the various industries studied so far would also provide knowledge about general behaviours in different industries, but also the possibility to spread learning from one industry to another.

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Unbundling the W's: the interface between organisational crises, social media narratives, and image repair strategies

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Abstract

Organisations are susceptible and vulnerable to crisis situations. These organisations have been able to exert resilience, and manage reputational damage, through crisis management protocols that include stakeholder engagement. However, given the rise of social media, a new cohort of stakeholders has emerged. Organisations are therefore faced with the task of managing new stakeholder relationships. This paper applies recent advancements in social media and crisis management discourse to investigate the prevalence of new, undiscovered stakeholders in crisis communications surrounding six prominent crisis situations. The results indicate that online stakeholders are becoming more powerful, urgent and legitimacy; thus shifting dynamics.

Keywords: Crisis Communication, Social Big Data, Stakeholder Salience

Introduction

Previous studies on crisis management have sought to identify effective methods and strategies for crisis communication. Crises can be unexpected and non-routine events or activities that interfere with an organisation's normal business operations, jeopardise its public image and damage the bottom line (Faulkner, 2001). Managing crises is an important process to prevent or lessen such interference, repair images and disseminate the responding information. Therefore, 'the communication following a crisis plays an integral role in this success' (Ulmer, 2001, p592). According to Coombs (2015), crisis communication is 'the collection, processing, and dissemination of information required to address a crisis situation'.

The recent prevalence of social media platforms has created a new and low-cost channel for

communication. These platforms have also changed the way that people search, publish and share information during crises (Oh et al., 2013). The use of new types of social interactions to report real-time crisis information somehow is more influential than the mainstream news. Given this, the main organisations are no longer the only influencer, rather, there are peripheral influencers that can gain legitimacy and become important stakeholders by creating and propagating crisis information. Hence, there is a new challenge for the main organisations to identify and engage with these emerging stakeholders to communicate crisis information.

In addition, the social media platform can encompass large amount of unverified information, including lies and false rumour (Oh et al., 2013), which can then easily spread anger, threats and aversion emotions to further worsen the crises (Jin et al., 2014). Assessing and scrutinising such information is therefore important for organisations to control crises, develop responses, and repair images. Previous studies in crisis management have identified an array of strategies for crisis communication and image repairing (e.g., Benoit, 2018). This study builds on the key lessons of from these studies, and builds on stakeholder theory and image repair theory to propose new solutions for crisis communication and stakeholder engagement via social media platforms.

Given the new role of social media platforms in crisis communication, scholars have put emphasis on the complex interconnectedness and centrality of emerging stakeholders in crises (e.g., Sedereviciute and Valentini, 2011). Using the stakeholder salience model (SSM) and social network analysis (SNA), this study aims to advance our understanding of the interface between image repair strategies and stakeholder salience. As such, this study aims to unbundle the critical W's. These include: *what* is the conversation, *who* is framing the conversation, *why* do crisis-stricken organisations respond, and *when* they do.

To unbundle the W's, this study is anchored in a research agenda to address:

RQ1: How do (emerging) stakeholders shape the conversation about crises using social media platforms?
RQ2: What topics of conversation, and which stakeholder groups, encourage crisis-stricken organisations to respond?
RQ3: Is stakeholder mapping an effective tool? And, can crisis-stricken organisations use stakeholder mapping to identify salient stakeholder groups?

Literature review

Grounded on traditional stakeholder theory, dominant logic in crisis communication discourse relates to the premise that: (i) a range of stakeholders will be involved in *ex-ante* and *ex-post* crisis communication (Wagner Mainardes et al., 2012), and (ii) organisations will attempt to communicate with certain stakeholder groups to manage the situation and reduce any reputational damage (Luoma-aho & Paloviita, 2010). To effectively manage crises, and reduce reputational risk (Benn et al., 2016), it is imperative for organisations to classify stakeholders and define dyadic stakeholder-organisation relationships. Parallel to the rise of social media platforms, however, interest and participation in crisis communication has become more accessible and fluid (Valentini & Kruckeberg, 2016), with organisations facing new challenges in stakeholder mapping procedures.

Traditionally, organisations could evaluate and categorise stakeholders with a scope to identify

the most salient stakeholder with prioritised stakeholder claims. Based on this evaluation process, an organisation could then respond directly to stakeholders with priori claims. Concomitant with the rise in social media, though, the evaluation of salience is becoming less static, with frequent changes in powerful, urgent, and legitimate stakeholders. What's more, social media has also introduced a new environment in which 'undiscovered', 'new', and 'unknown' stakeholders can emerge (Himelboim et al., 2014).

The fundamental challenges for crisis-stricken organisations, therefore, are:

i. Requirements to grasp – and difficulties associated with grasping – the complex relationship between crisis situations and social media platforms;
ii. The emergence of new stakeholder groups, with Wan et al (2015) identifying new stakeholder labels, such as social media creators, social media followers, and social media inactives.

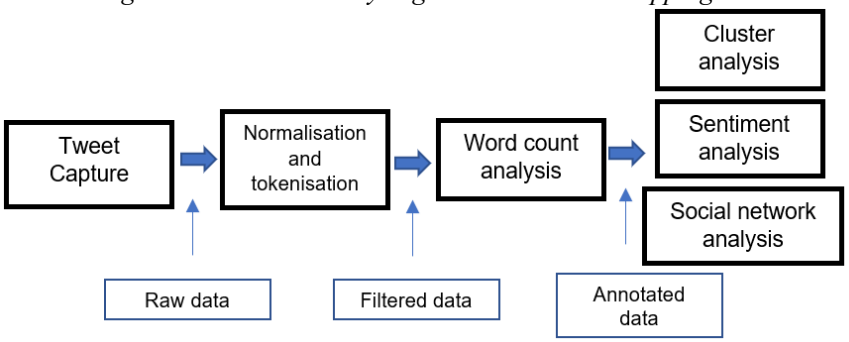
Addressing these challenges would make it possible for organisations to reconfigure their stakeholder maps, and thus recalculate salience calculations. Such possibilities could result in crisis-stricken organisations being better equipped to make optimal, rather than sub-optimal, crisis management decisions. An initial step toward providing a solution is provided by Sedereviciute and Valentini (2010). In their study, the author combined the Stakeholder Salience Model (SSM) and Social Network Analysis (SNA) to permit a mechanism to find and prioritise stakeholders on social media, with an emphasis on connectivity and content dimensions. The first dimension (i.e., connectivity), rooted in network theory, is based on connections between different online stakeholders on social media, as well as the dyadic connections between online stakeholders and the organisation. The core argument is that if an online stakeholder has a more prominent position in social media networks they will be viewed as more powerful. The second dimension (i.e., content), on the other hand, is preoccupied with the content and words propagated on social media platforms, such as Twitter, as well as the interest and relevance of this content for other online and offline stakeholders. Essentially, when an online stakeholder is seen as propagating interesting and relevant information on social media they will be deemed as urgent. When an online stakeholder is deemed both powerful (based on position) and urgent (based on content), they will be viewed as more legitimate by the crisis-stricken organisation, and thus will generally attract a response. As noted by Sedereviciute and Valentini (2010), these two dimensions will shift the traditional conceptualisation of powerful, urgent and legitimate stakeholders, and introduce new stakeholders into the mix, notably: unconcerned influencers (dormant stakeholders), concerned influencers (definitive stakeholders), unconcerned lurkers (non-stakeholder), and concerned lurkers (dependent stakeholders). This understanding will therefore be taken forward to assess *who* is important in crisis-related conversations on social media, and *how* they shape conversations on social platforms.

Methodology

Data Collection

This study develops a tweet analysing and stakeholder mapping tool to collect, extract and analyse the data from Twitter. The tool includes four analyses as illustrated in Figure 1: tweet word counts analysis (to classify trendy keywords); tweet cluster analysis (to identify dominant image repair strategies and prevalent crisis topics); tweet sentiment analysis (to identify the tweet sentiments and the pattern of information diffusion) and social network analysis (identify emerging stakeholders).

Figure 1. The tweet analysing and stakeholder mapping tool



The tweet datasets in this study are captured by a Twitter Application Programming Interface (i.e. QDA Miner and NodeXL), they contain seven recent crises and extreme events (Table 1). The software is selected based on their extensive features on exploring and analysing textual data.

Table 1. The Tweet dataset

Crises or extreme events	No. of tweets	Date
Cathay Pacific data breach	39,819	7 days (25/10/2018-31/10/2018)
Marriot International data breach	30,916	7 days (30/1132018-06/12/2018)
O2 UK day-long outage	25,243	7days (06/12/2018-12/12/2018)
United Airlines overbook incident	55,083	48 hours (09/04/2017-11/04/2017)
Mars/Snickers product recall	10,930	10 days (23/02/2016-03/03/2017)
Fiat-Chrysler dieselgate	4,303	7 days (10/01/2019-16/01/2019)

Prior to the analyses, the Twitter datasets are normalised and tokenised (Liau and Tan, 2014) in the QDA Miner software package to stem and remove stop words. Other high frequency but pointless words (e.g., HTTP, HTTPS, RT, etc.) are also removed and common misspellings are corrected.

Word Count Analysis

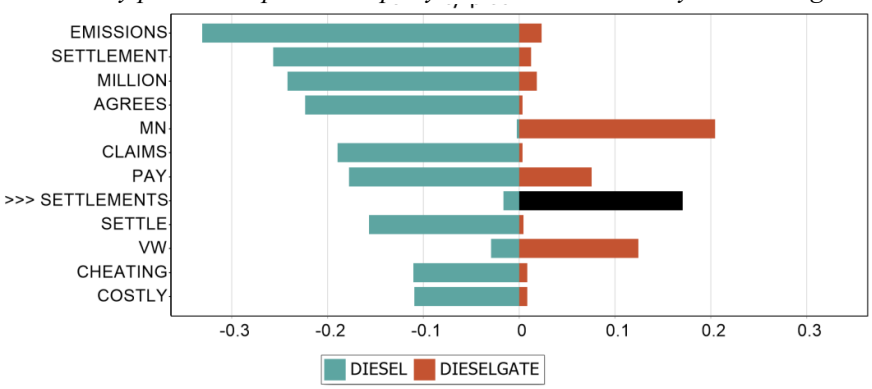
For word count analysis, the QDA Miner is used to generate word count frequency (Table 2) and predict the popular topics from the textual data. The major characteristics are also extracted in the proximity plot (Figure 2) (Mostafa, 2013).

Table 2. Word frequency table for the top 10 keywords

DATASET	KEYWORDS 1-5	FREQUENCY (CASE %)	KEYWORDS 6-10	FREQUENCY (CASE %)
Cathay Pacific Data Breach	MILLION	5383 (13.37)	INFOSEC	2833 (7.11)
	PASSENGERS	4589 (11.38)	USER	2728 (6.79)
	CYBERSECURITY	3817 (9.43)	SERVERS	2663 (3.39)
	REACH	3623 (7.43)	AIRLINE	2138 (5.18)
	RATAN	3369 (7.39)	PERSONAL	1990 (4.96)
Marriot International Data Breach	SECURITY	8634 (26.54)	GUESTS	4093 (12.98)
	MILLION	8418 (26.28)	AFTER	3604 (11.53)
	LEAK	6475 (20.69)	STARWOOD	3069 (9.56)
	GOOGLE	5368 (12.65)	CYBERSECURITY	2553 (8.07)
	HOTEL	5619 (17.76)	USERS	2363 (7.42)
O2 UK Day-long Outage	NETWORK	19828 (74.19)	OUTAGE	2378 (9.09)
	DATA	5283 (19.79)	EASILY	2294 (9.09)
	CUSTOMERS	3376 (11.88)	SIZE	2293 (9.08)
	MOBILE	3009 (10.54)	STRONGER	2293 (9.08)
	SERVICE	2431 (9.16)	JONNYGABRIEL	2288 (9.06)
United airlines Overbook Incident	PASSENGER	21111 (38.03)	PLANE	10965 (19.80)
	FLIGHT	20462 (36.42)	MAN	10269 (18.47)
	DRAGGED	16681 (30.19)	AFTER	7767 (14.04)

	CEO	12959 (22.93)	FORCIBLY	6645 (12.02)
	OVERBOOKED	11917 (21.52)	VIDEO	6511 (11.79)
Mars/Snickers Product Recall	CHOCOLATE	4264 (36.57)	ISSUES	1142 (10.39)
	BARS	3894 (33.91)	GERMAN	974 (8.90)
	COUNTRIES	3222 (28.59)	MASS	926 (8.48)
	PLASTIC	3275 (29.64)	PRODUCTS	868 (7.77)
	CANDY	1773 (15.89)	WIDENED	806 (6.58)
Fiat-Chrysler Dieselgate	EMISSIONS	2010 (44.95)	CHEATING	773 (17.78)
	MISSION	1478 (32.93)	VEHICLES	671 (15.22)
	PAY	1261 (27.31)	CASE	607 (13.06)
	DIESEL	1097 (23.36)	SETTLE	563 (12.74)
	SETTLEMENT	852 (19.36)	RECALLS	486 (10.13)

Figure 2. Proximity plot to compare the top keywords in the Fiat-Chrysler Dieselgate dataset



Cluster Analysis

The popular topics are developed based on the keywords and their co-occurrence by using Multi-Dimensional Scaling (MDS). A matrix of distances between the popular topics are calculated to generate key topic groups (Table 4).

Table 3. Key topics of the datasets

DATASET	Key Topics
Cathay Pacific Data Breach	*'**MILLIONS** of **PASSENGERSHIT** in **WORST** ever **AIRLINE** data hack link'*
	*'**AIRLINE** hack exposes 10 **MILLION** people's most personal information'*
	*'Cathay Pacific HIT by data leak affecting 9.4 **MILLIONPASSENGER** link'*
	*'Hong Kong carrier #CathayPacific is under pressure to explain why it took five **MONTHS** to admit it had been hacked and **COMPROMISED** the data of 9.4 million customers, including passport numbers and credit card details'*
	*'Just checked my email and yes, it turns out I am one of the 9.4 million Cathay Pacific passengers whose personal data has been **COMPROMISED**. Why wait 7 **MONTHS** to disclose this to the public? Link via @SCMPNews'*
	*'Post-breach, Cathay Pacific hit by **GROUPACTION** by UK **LAW** firm link via gcluley'*
Marriot International Data Breach	*'The world's biggest **HOTELCHAIN** Marriott **INTERNATIONAL** disclosed that unknown #hackers **COMPROMISEDGUESTRESERVATIONDATABASE** its subsidiary **STARWOOD** hotels and walked away with **PERSONALDETAILS** of about 500 **MILLIONGUESTS**. #CyberCrime link'*
	*'**FACEBOOK** exposed the **PRIVATEPHOTOS** of 6.8 million users back in September, but is only now admitting to the data breach'*
	*'Thanks to a second data leak, Google+ will shut down sooner than anticipated. Read more: https://t.co/9gyJ4GVmyt #technology #**GOOGLEPLUS** Link'*
	*'Google will **SHUT** down **GOOGLEPLUS** four MONTHS EARLY AFTER second data **LEAK** #gafe Link'*
	*'**DATABREACH**: Marriott, between 2014-2018?? #security #databreach Marriott HIT By Massive Data Breach, One Of **BIGGEST**?'*
	*'Marriott's breach **RESPONSE** is so **BAD**, security **EXPERTS** are **FILLING** in the **GAPS** ? at their own **EXPENSE**'*
O2 UK Day-long Outage	*'DATA **PROBLEMS** HIT O2 **MOBILE NETWORK** LINK'*
	*'**BREAKING** O2 down **ACROSSUK** as **CUSTOMERS** HIT by **NETWORK** and 4G **PROBLEMS** LINK'*
	*'@O2 I can't make voice calls. It says I have no **NETWORK**. Why are o2 saying this is Only a **DATA** issue? Myself and my partner cannot make calls'*

	*'O2, **BRITAIN**'s second **BIGGEST** network, reported network outages, leaving many customers unable to access internet services. h?'*
	*'Customers on one of **BRITAIN**'s **BIGGEST** mobile **NETWORKS** have found themselves with no service. O2 says it's **INVESTIGATINGISSUES** with its 4G network. Customers on Tesco Mobile and GiffGaff have also been hit by the outage.'*
	*'thank you for doing your best in restoring your network Appreciate the effort your teams put into it! Too many people rely on their mobile phones nowadays...it's not the **END** of the **WORLD**'*
	*'@O2 so I went a day without 4G, lost a days work, missed **IMPORTANT** emails and then I receive this today. Are you actually having me on? #o2outage'*
	*'Avengers 4: We're very sorry for Thursday's network issues. We **UNDERSTAND** how **IMPORTANT** it is to stay **CONNECTED**, especially this time of year. You'll receive a credit for two days of your monthly airtime subscription charges by the end of January.'*
	'*O2 blames network borkage on **SOFTWARE** glitch affecting third-**PARTY** supplier'*
	*'O2 network down: O2 blames **'GLOBALSOFTWARE** issue' for O2 data **OUTAGE** that prevents people from using 3G or 4G across the UK | City A.M.'*
	*'@O2 Whatcompensationcanweexpectfrom yesterday's outrageous network blackout? Have a **BUSEINSS** to **RUN** here!'*
	*'@O2I**RUN**my**BUSEINSS**onyournetwork, I assume you'll put out a link for compensation?'*
	*'We survived the war we can survive a no deal **BREXIT**!.... though admittedly we'll struggle if the O2 network goes down for a few hours...'*
	*'Fights when there's no chicken, People losing their **SHIT** without the O2 network. No **DEAL BREXIT** is going to be carnage.'*
United airlines Overbook Incident	'*United **DRAGGING** a **PASSENGER** from **OVERBOOKEDFLIGHT** was lesson in stupidity - LA Times'*
	'*That **PASSENGERDRAGGED** Off That **FLIGHT'***
	*'MAN gets **DRAGGED** off of United Airlines just bc FLIGHT was **OVERBOOKED**& no one voluntarily got off so they picked a guy and **DRAGGED** him out'*
	*'@united CEO OSCAR MUNOZ issued a **LETTER** defending his **EMPLOYEES**, saying the passenger was being ???DISRUPTIVE and **BELLIGERENT**. Seriously?'*
	*'@Mikel_Jollett @united **CEOMUNOZ** CALLS him **"DISRUPTIVE** AND **BELLIGERENT"** in EMAIL TO EMPLOYEES #LIAR RESIGN NOW! #united3411 #wtf #cnn'*
	*'MUNOZ is a moron United **CEODEFENDSACTIONS** of STAFF in VIRAL video, as lawmakers CALL for investigation'*
	*'**#NEWUNITEDAIRLINESMOTTOS** FLY **United** - Now with a free, priority **DRAG** off **SERVICE** randomly available to all **PAYINGPASSENGERS'***
	*'Non-PAYING #United Airlines employees more important than PAYING CUSTOMERS. FLY with #United and get ASSAULTED. The not so **FRIENDLYSKIES**.'*
	*'FLY the **FRIENDLYSKIES**...on Some Other **AIRLINE**. **#NEWUNITEDAIRLINESMOTTOS'***
	*'I'm absolutely disgusted, @united! I HOPE that POOR man will SUE the **HXXL** out of the **COMPANY**. #unitedAIRLINES #disgusting'*
	*'@united HOPE you get the **SXXT** sued out of your COMPANY, FXXKING disrespectful degenerates. **FXXK** you and your employees #neverflyunited'*
	*'I HOPE HE SUES THE HXXL OUT OF THIS **FXXK** AXS **AIRLINE'***
	*'Unbelievable. "Reaccommodate?" WATCH: **JIMMYKIMMEL** created a brutally honest COMMERCIAL for United Airline'*
	*'I had to share this. Too funny last night! United Airlines **COMMERCIAL** (**JIMMYKIMMEL** LIVE)'*
Mars/Snickers Product Recall	*This is the focal group which has the highest frequency words - "**CHOCOLATE**", "**BARS**", "**PLASTIC**", "**RECALL**", "**GERMAN**" – 'chocolate recall: Mars and Snickers bars in Germany contain plastic.'*
	*"**BIGGEST**", "**FOOD**", "**DRINK**", "**HISTORY**" – 'Mars recall spans 55 countries: is this the biggest food and drink recall in history?'*
	*"**CHOCCY**", "**HORROR**", "**CONFECTIONER**" – '**CHOCCYHORROR**, the recall of chocolates by confectioner Mars makes several front pages'*
	*"**ANNOUNCED**", "**MASSIVE**", "**BITS**" - 'Mars has issued a massive recall of chocolate bars after bits of plastic were found.' and 'Mars and Snickers just announced a massive recall in 55 countries.'*
	*"**NETHERLANDS**", "**PRODUCTS**" "**MANUFACTURED**" – 'AVA issues recall of Mars chocolate products manufactured in the Netherlands.'*
	*"**FUN**", "**SIZED**", "**WORSE**" – 'the mars candy bar recall is anything but fun-sized...and it just got worse.'*
	*"**MILKY**", "**SINGAPORE**" – 'AVAsg issues recall of Dutch-made Mars, Snickers and Milky Way chocolates in Singapore.'*
	*"**WIDENS**", "**SUPERMARKET**", "**MULTIPACKS**", "**UK**"– 'Mars chocolate recall widens to supermarket multipacks.' and 'Mars widens recall of chocolate to include UK after plastic found in bars.'*
	*"**CONTACT**", "**CARE**", "**HAPPY**", "**TEAM**", "**GOOD**" - 'Please check your product if it is labeled with Mars Netherlands, if it is, please contact your local consumer care team.' and 'Hi Ami, that's no good! Give our UK chocolate team a call at 800-862-6293. We'd be happy to help you out.'*

	*"**REMOVE**", "**SHELVES**", "**DFS**" – '**DFS** in Singapore removes Mars products from shelves following global recall.' and 'Mars, Snickers Milk Way and Celebrations pulled from shelves after plastic found in chocolate.'*
	*"**COST**", "**FIRM**", **MILLIONS**" - 'Mars, Snickers and Celebrations recall could cost firm millions.'*
	*"**CHILD**", "**FINDS**", "**FREE**" – 'Mars, don't recall your Mars Bars, simply offer any child who finds a plastic ticket a free Wonka-style tour of your chocolate factory.'*
	*This is the focal group which has the highest frequency words - "**CHOCOLATE**", "**BARS**", "**PLASTIC**", "**RECALL**", "**GERMAN**" – 'chocolate recall: Mars and Snickers bars in Germany contain plastic.'*
	*"**BIGGEST**", "**FOOD**", "**DRINK**", "**HISTORY**" – 'Mars recall spans 55 countries: is this the biggest food and drink recall in history?'*
	*"**CHOCCY**", "**HORROR**", "**CONFECTIONER**" – '**CHOCCYHORROR**, the recall of chocolates by confectioner Mars makes several front pages'*
	*"**ANNOUNCED**", "**MASSIVE**", "**BITS**" - 'Mars has issued a massive recall of chocolate bars after bits of plastic were found.' and 'Mars and Snickers just announced a massive recall in 55 countries.'*
	*"**NETHERLANDS**", "**PRODUCTS**" "**MANUFACTURED**" – 'AVA issues recall of Mars chocolate products manufactured in the Netherlands.'*
Fiat-Chrysler Dieselgate	*'FinancialReview .fiat Chrysler will PAY about $US800 **MILLION** in fines and costs to **SETTLE** US **LAWSUITS** that said the **COMPANY**'s cars violated clean-air rules.'*
	*'Fiat Chrysler **AGREES** to **EMISSIONSSETTLEMENT** WORTH $800M'*
	*'Fiat Chrysler to pay $515 MN in US '**DIESELGATE**' **SETTLEMENTS** Link'*
	*'Fiat Chrysler agreed to pay **HUNDREDS** of **MILLIONS** of **DOLLARS** to settle lawsuits accusing it of it rigging certain diesel-powered pickup trucks and Jeeps with illegal software to pass emissions tests. '*
	*'**EPS** for Fiat Chrysler AUTOMOBILES N.V. (**FCAU**) Expected At $1.01'*
	*'Fiat Chrysler AUTOMOBILES N.V. $**FCAU** Analysts See $1.01 **EPS'***
	*'It's hard to give credit to this administration for this settlement when @EPAAWheeler's EPA is still working to roll back emissions and fuel economy standards that will harm our **PUBLICHEALTH**, especially our children. #MomsDisapprove'*
	*'Fiat Chrysler to pay around $650M in emissions cheating case $FIATY #FIATY **#POLLUTION** #Environmentalconcerns **#ENVIRONMENT**https://t.co/BUvgfNID8c'*
	*'38,000 people a year die early because of diesel emissions testing failures | **ENVIRONMENT** | The Guardian #vw #dieselgate **#POLLUTION** #diesel #volkswagen #Germanauto #dasauto #citypollution'*
	*'FCA Will Pay Nearly $800 Million to Settle Diesel Emissions Claims **VOLKSWAGEN**'s emissions-cheating SCANDAL may have **GARNERED** the most **HEADLINES**, but it's not the only **AUTOMAKER** that's gotten into TROUBLE with its diesel ENGINES. In a STATEMENT, Fiat CHR?'*
	*'Dieselgate is back? **VOLKSWAGEN** again suspected manipulation of diesel'*
	*'Fiat Chrysler **RECALLS** 1.6M **VEHICLES** to **FIX** TAKATA AIR BAGS $TM #TM #Automobilerecalls #Automobilesafety #Productsafety'*

Sentiment Analysis

The sentiment analysis is applied to understand the motive behind the tweets. This study uses the lexicon-based method to the tweets to measure the semantic orientation, adopts the SentiStrength classifier (Thelwall et al., 2010) to analyse the sentiment expressed in the tweets.

Table 4. the overall sentiments of the datasets

Crises or extreme events	Overall sentiments
Cathay Pacific data breach	-0.570
Marriot International data breach	-0.704
O2 UK day-long outage	-0.502
United Airlines overbook incident	-0.413
Mars/Snickers product recall	-0.262
Fiat-Chrysler dieselgate	-0.581

Social Network Analysis

The social network analysis (SNA) (Coombs, 2002) is performed to identify the key stakeholders who are accounted for the information distribution. NodeXL is employed to calculate the in-degree (the total mentions of a twitter account), eigenvector centrality (the total connections to other influential accounts) and betweenness centrality (the numbers of shortest connections with other non-neighbouring accounts) of each account in the network.

Figure3. The O2 UK Day-long Outage dataset network based on Mention (@)

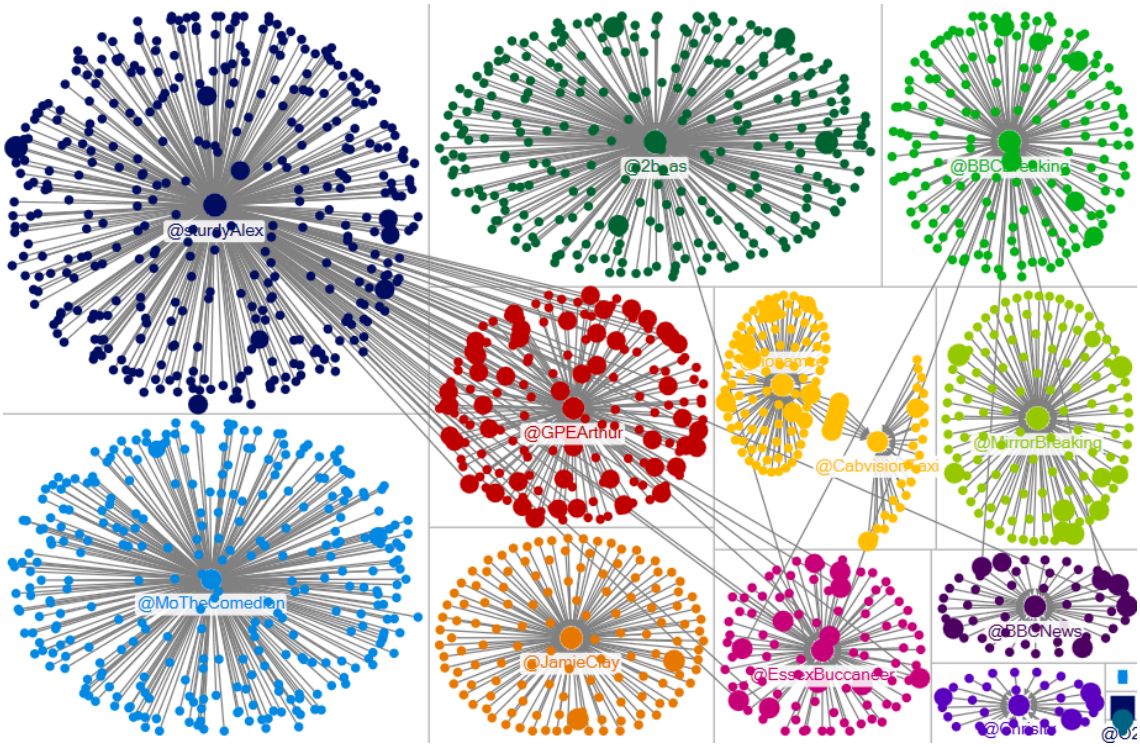


Table 5. the top 10 stakeholders based on in-degree, eigenvector centrality and betweenness centrality for the O2 UK Day-long Outage dataset

In-degree	Eigenvector Centrality	Betweenness centrality
@sturdyAlex(425)	**@sturdyAlex** (0.00252)	@tomthemac (2828340)
@MoTheComedian (299)	@Un1v3rs4L (0.00067)	@chriswb (1673679)
@2b_as (271)	@AshleyW12945493 (0.00067)	@ioniqman (1193729)
@BBCBreaking (159)	@kerrybroughton (0.00067)	@xa329 (995606)
@GPEArthur (147)	@HammerForLife (0.00067)	**@sturdyAlex** (838681)
@JamieClay (130)	@squired (0.00067)	@Shomer1Steve (838460)
@MirrorBreaking (114)	@A_Munn (0.00067)	@shellwinfrey (838460)
@fionamce (95)	@dentin_dentin (0.00067)	**@EssexBuccaneer** (618772)
@EssexBuccaneer (89)	@ruskin147 (0.00067)	**@2b_as** (572130)
@BBCNews (48)	@Jojobkk17 (0.00067)	@paracord_pete (555424)

Results and implications

The word count frequency presented in Table 2 provides the basic tweet information on each dataset, the results help to construct key topics, identify main stakeholders, compare relationships between incidents and lay down the foundations for later sentiment analysis. In Table 2, the top keywords from each dataset are those mainly used to describe the crisis

situations, the cause of the crisis and the public expectations. They form the main topics during the crises which link to the main stakeholders. For instance, the keywords used in the Fiat-Chrysler Dieselgate dataset are related to the RECALL due to the VEHICLES EMISSIONS CHEATING, and expecting SETTLEMET PAY. In Figure 2, these keywords are compared against 'DIESEL' problem and the 'DIESELGATE' crisis. It can be noted that stakeholders have mentioned more about whether or not AGREES have been given to SETTLE the DIESEL problem, compare the stakeholder in the DIESELGATE who are more concerned with the cost in MN (millions) to SETTLE.

Table 3 highlights the important and related keywords and how they form popular topics. For instance, tweets to describe the crisis incidents, provide information about the impacts are affected areas, products are focal topic groups in every datasets. However, there are also tweets, although less, that form topics to offer suggestions and give feedback (to reduce the crisis impacts), asking questions (to fix the problem). In addition, there are also tweets represent groups to express jokes (schadenfreude) and sending disappointed messages (blame).

From the results of the SentiStrength classifier illustrated in Table 4, the overall average sentiment of all between the band distribution of circa -1/+1, which may indicate that some tweets are not very affective (Mostafa, 2013) and suggest a more detailed analysis to look into the sentiment score of each topic group/stakeholder groupand at different timeframe for more meaningful explanations (Cao et al., 2018).

The results of the SNA to the O2 UK Day-long Outage dataset is illustrated in Figure 3 and explained in Table 10. Each of the three metrics used in this study indicate the influence of the tweeter users, such as a high in-degree indicates a high fluence of the account, a high eigenvector centrality represents a large number of connections with other influential accounts, and a high betweenness centrality shows an account with the most numbers of shortest connections with other non-neighbouring accounts. In this study, the key influential stakeholders are listed in Table 10. In particular, **@sturdyAlex** is the most influential stakeholder, as this account has the highest in-degree and eigenvector centrality, and a high betweenness centrality within the top 10 range. **@2b_as** and **@EssexBuccaneer** are two other important influential stakeholders.

Conclusion and recommendations

By adhering to Sedereviciute and Valentini's (2010) holistic approach to stakeholder mapping, within the context of several novel and important crises, this research has uncovered a few important research notes. These are:

i. Concerned and definitive stakeholders have the capacity to shape crisis-related conversations based on their position within social media networks. For example, **@sturdyAlex** was seen to influence the narrative through a central position.
ii. Once categorised as non-powerful, non-urgent, and illegitimate, these undiscovered online stakeholders require responses from crisis-stricken organisations in order to control and mitigate reputational damage, as was seen in the O2 outage case.
iii. The combination of SSM and SNA facilitates the identification of new, undiscovered online stakeholders, which are integral in the narrative, tone, and longevity of crisis situations and their manageability.

To advance this research effort, and to generate managerial implications, the authors call for

further research on online stakeholders, especially those on Twitter, to identify the timeframe in which they are *powerful, urgent, and legitimate.* This can then be mapped against company response. Scholarship could also compare online stakeholders with offline counterparts to review salience across channels.

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Operations Strategy

Understanding operating strategies for platforms and business ecosystems in Industry 4.0: Towards a conceptual framework

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Abstract

The Industry 4.0 concept proposes full flexibility of production environments to fulfil vastly individualized customer requests and requires increasingly digitized production settings. The future design and implementation of essential value-creation architectures will increasingly be based on standardized technological platforms. However, the operating strategies for the necessary platforms and multi-industry business ecosystems are not well understood. The purpose of this paper is to mitigate these limitations by introducing the emerging research stream on platforms and business ecosystems. It explicates the novelty and the usefulness of ecosystem-based approaches for production and operations management, to pave the way for a cumulative, interdisciplinary body of knowledge.

Keywords: Industry 4.0, platforms, business ecosystems

Introduction

The Industry 4.0 (I4.0) concept aims at fulfilling extremely individualized customer requests and moves away from predetermined supply chains towards highly flexible production environments. This flexibility challenges the role of the focal firm as coordinator and central decision maker in a production and supply network. Besides implementing the best real-time combination of actors for each individual order (Holweg & Helo, 2014, Stein et al., 2014) focal firms face managerial problems. The actors that contribute to the focal offer's value proposition increasingly operate via platforms and a growing number of complementary offers come from new partners outside the traditional industry settings (Gawer & Cusumano, 2014, Kapoor, 2018). These so-called business ecosystems bring their own set of rules and often ensuing loss of direct control for the focal firm over its production and supply network. In addition, the operating strategies for platforms and multi-industry business ecosystems are not well understood.

The purpose of this paper is to mitigate these limitations by introducing the emerging research stream on platforms and business ecosystems. It explicates the novelty and the usefulness of ecosystem-based approaches for production and operations management in order to pave the way for a cumulative, interdisciplinary body of knowledge. To achieve this purpose the author investigates the key tenets in research on platforms and business ecosystems in strategic management and in operations and production management literature and how they relate to established perspectives of value chains and of

production and supply networks. Based on this analysis the author proposes elements and constructs for a cumulative concept for operations and production management on platforms and business ecosystems for I4.0 settings.

The paper is organised as follows: the first section briefly describes the concept of I4.0. The following method section explicates information on the design and implementation of the literature review of operations and production management and strategic management research. The main part of the paper depicts the key tenets of the emerging research stream on platforms and business ecosystems and how they relate to established perspectives of value chains and of production and supply networks. Finally, the elements and constructs for a cumulative concept for operations and production management on platforms and business ecosystems are being derived for I4.0 settings. The paper closes with a conclusion and an outlook on future research.

The concept of industry 4.0

The term Industrie 4.0 (industry 4.0) was coined by the German government in their High-Tech Strategy Action Plan 2020 that addresses the increasing global competition on product quality and production costs faced by the German manufacturing industry. Nevertheless, even before the launch German manufacturing companies had started to exploit emerging technologies such as digitalization, the internet of things (IoT), internet of services (IoS) or cyber-physical systems (CPS) in search of new digital business models.

Although the concept Industry 4.0 is now widely discussed, neither academia nor practice has arrived at a generally accepted definition of what the concept comprises in terms of the actual objectives, the relevant technologies, or the applicability for different industrial sectors.

Following Baumann (2018) this paper defines industry 4.0 "as a concept in which companies, machines, devices and computers cooperate through digital technologies in horizontal and vertical networks to manufacture highly-individualized products. By connecting plants, equipment, machines, products and workpieces through information and communication technologies (ICT) into cyber-physical systems these networks continuously share information in real-time" (p. 2). The term smart manufacturing will be used interchangeably with I4.0 in this paper as it expresses the same ideas.

The I4.0 concept can be captured into four components: business models, enablers, information, and network management (see figure 1), which are briefly explained (see Baumann 2018 and the literature mentioned there for a more detailed description).

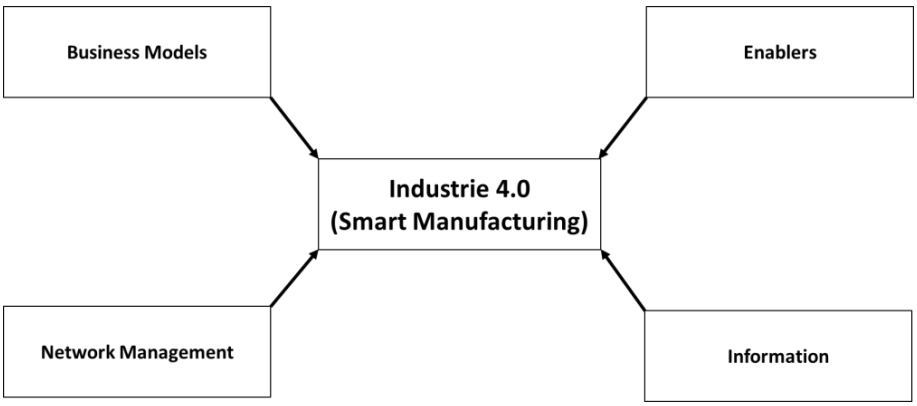

Figure 1: Components of the industry 4.0 and smart manufacturing concepts (Baumann 2018)

Business Models
I4.0 business models either address cost reductions or capturing new business opportunities such as innovative products and services. The majority of new digital business models is based on data analytics, for example predictive maintenance. Extended models move to service offers where the customer pays for equipment use, but no longer buys the equipment. From a cost reduction perspective I4.0 increases production flexibility and adaptiveness, speeds up reaction times or improves overall effectiveness of manufacturing equipment.

Network Management
The best real-time combination of actors regarding objectives such as timing, cost, quality levels, etc. for each individual order can only be achieved through extended vertical, horizontal, and lateral collaborations. Actors face a trade-off between installing efficient production and supply networks for particular products while being flexible enough to be part of alternative networks for required product differentiations. Furthermore, the role of the focal firm as principal coordinator becomes increasingly decentralized in I4.0 settings (see also the discussion of business ecosystems below).

Enablers
I4.0 grounds in a variety of enablers, such as *Cyber-physical systems (CPS), Internet of Things (IoT), Internet of Services (IoS),* and *Smart factory. CPS* connect computation with physical processes, so in manufacturing CPS refers to monitoring and controlling the processes via computer networks (through the use of multiple sensors, actuators, control processing units, and communication devices) and synchronising information related to the shop floor. Manufacturing execution systems (MES) link enterprise resource planning (ERP), production planning and control (PPC), and the actual shop floor to integrate all network participants. Thus, MES allow the shop-floor to become a marketplace where the allocation of capacity is self-coordinated with multi-agent systems. In *IoT* settings (physical) things connect to the internet with the use of RFID tags, sensors, actuators, or small computers. These "smart things" interact with each other and cooperate with their neighbouring 'smart' components in order to reach common goals. *IoS* makes services available through web technologies or software as a service (SaaS) and allows companies and consumers to access to the resources and service functions of another party. The idea of the *Smart factory* proposes a decentralised production network comprised of human beings, machines and resources. Digital connectivity enables an automated and self-optimised production and delivery free of human interventions or the customary central steering entity. Advanced data analytics derived from the operations of these connected systems provides decision support to both machines and humans.

Information
I4.0 grounds in extensive data collection, (big) data analytics and the implementation of efficient decision support and data-based self-coordination systems. The processes within the information processing chain in I4.0 systems also need to be evaluated from the perspective of value added by these processes, i.e. a detailed analysis of their accompanying value architectures in order to compare value propositions of competing I4.0 solutions (Wunck & Baumann, 2017).

Design/methodology/approach
IA content-analysis-based literature review is being completed, in which an inductive and multi-level coding procedure is applied on >120 articles on platforms and business

ecosystems, spanning the literature in production and operations management and strategic management. The following section shares the key tenets in research on platforms and business ecosystems in strategic management and in operations and production management literature and how they relate to established perspectives of value chains and of production and supply networks.

Cooperation and value creation scenarios

The cooperation of companies, machines, and computers through digital technologies is central to the provision of individualised products and services in I4.0 settings. These collaborations are realized by integrating technical and organisational processes into order-based value creation architectures that include all actors that contribute to the focal offer's user value proposition. Central elements of these value creation architectures are platforms and business ecosystems which are introduced in the following section.

Platforms

The concept of platforms is being discussed differently in economic (e.g., Rochet & Tirole, 2003 or Cennamo & Santalo, 2013) and engineering (e.g, Meyer et al., 1997 or Jiao, Simpson & Siddique, 2007) research. Economics investigates transactions on platform markets between different customer groups as well as the influence of network effects on competition. In contrast, engineering research regards platforms as technological designs that help firms generate modular product innovations (Brax et al., 2017; Gawer, 2014; Sköld & Karlsson, 2012).

Engineers interpret platforms as technological architectures that have been specifically developed (including their interfaces) so that their components can be utilised systematically across different products of a product family. Design and usage of these platforms allow for economies of scope in product development and production. Consequently, implemented platforms bear permanent structures while changes occur for newly developed or redeveloped modules, in order to achieve economies of scope through platform-based product development (Gawer, 2014; Jiao, Simpson & Siddique, 2007; Sköld & Karlsson, 2012).

In economic models platform competition is driven through the adoption of a platform through multiple user groups who themselves are being compelled through network effects. In the relevant literature network effects are distinguished into direct and indirect effects. Direct (or horizontal) network effects emerge through changes in the number of users of a platform (or a technology or a particular product): the higher the number of users, the higher the value for the users. Indirect (or vertical) network effects arise when the benefit of the platform (or technology or product) is not determined by the usage, but is determined by applications or complementary products that are based on or leveraged through the platform. Consequently, the influence on value is not determined by a direct relationship, but through a vertical network of interdependent complementary goods. It follows that it is not single products or components of the network that generate the value, but instead value is created through an inherent interdependency of the demand of two or more user groups. This mutual interdependency of two or more market sides in turn produces a self-supporting feedback loop (Hagiu & Wright, 2015; McIntyre & Srinivasan, 2017).

From the perspective of economic theory, value creation of platform relies on connecting user groups that would otherwise not be linked and could not transact with each other. The price settings of the platform operator coordinate these user groups. Developing the optimal price menu therefore is one of the central problems of platform management. Prices need to be set such that they motivate users from the relevant groups

to participate and transact on the platform. Specifically, attracting an increasing number of users from multiple user groups creates benefits for both the platform participants (increased value) and the platform operator (increased profits) because of the indirect network effects. This means that network effects are an essential attribute of platforms as they reflect the exogenous demand dependencies of different user groups and consequently shape platform competition. Thus, the economic perspective addresses the question under which conditions platforms could become dominant and or even drive out all other platforms in a „Winner-takes-all" rivalry (Eisenmann, Parker & van Alstyne, 2006; Rochet & Tirole, 2003).

Business ecosystems

Digitization not only provides data to develop new data-driven business models, but also requires collaborations with companies that have not been part of the traditional supply chain of an industry. Through these collaborations so-called Business Ecosystems emerge, i.e. company networks that link incumbents from different industries and on horizontal, vertical, and/or vertical level. Simply put a business ecosystem comprises the set of partners that contribute to the value promise of the focal firm (focal offer). The focal offer can consist of a product and/or service that has been created with or without a platform-based architecture. The biological term ecosystem conveys the mutual interdependency of the partners that together operate as a combined system. In addition the analogy suggests that the partners in a business ecosystem may well come from different industries and that the system persistently changes over time: partners compete with each other, new partners join and others leave the system, connections between ecosystem partners change (Kapoor, 2018).

Business ecosystem participants mutually influence each other because of simultaneously existing independencies and complementarities. Interdependencies between partners arise through the combination of their offers within the system architecture in the production of the final product and/or service. Opposed to that complementarities emerge because the combination of the partners' offers provides or increases value for the user/consumer. Economics investigates for how companies can survive competition in business ecosystems given these interdependencies and complementarities (e.g., Adner & Kapoor, 2010); Baldwin & Woodard, 2011); Hannah & Eisenhardt, 2017; Jacobides, Cennamo & Gawer, 2018 or Pierce, 2009).

The business ecosystems perspective differs from long-established concepts such as the value chain and the supply chain regarding focus and also the subject of investigation. Porter's value chain centers on the focal firm and investigates how the focal firm can derive competitive advantage in a specific market through organising its value creation activities to achieve cost leadership or differentiation (Porter, 1996). Supply chain research studies the efficient design and coordination of object flows (goods, information, values) along all stages of a supply chain through which a product is manufactured and then distributed to the final customers (MacCarthy et al., 2016). In particular, it investigates coordination problems in buyer-supplier-relationships along the entire supply chain (Pullman & Dillard, 2010). As the supply chain typically involves different companies and supply chain research consequently extends its emphasis beyond the focal firm. Compared to business ecosystems supply chain investigations do not consider complementarities of demand and the structure of interdependencies (Kapoor, 2018; Kapoor & Lee, 2013).

Management of value creation architectures in industry 4.0

The management of value creation architectures in I4.0 comes with a number of challenges. Particularly relevant are the integration of technological platforms, coordinating partners in business ecosystems with complementary offers and dealing with bottlenecks.

Bottlenecks

Bottlenecks can occur in any system that consists of more than one component. They limit the performance of the entire system (dominance of the minimum sector). Accordingly, partners in business ecosystems can constrain the performance and growth of the focal firm's offer due to their output, capacities or incurred costs. Similarly, interactions between components can be determined through the technological architecture such that improvements in the performance of one partner reduce or balance weaknesses of another partner and vice versa. Identifying and dealing with bottlenecks that result from technological innovations or business models therefore is one of the central problems of business ecosystem management. Besides developing value creation architectures with reduced bottleneck effects business ecosystem management concerns resource allocations between and mutual support of business ecosystem partners in order to resolve bottleneck situations (Adner & Kapoor, 2016; Kapoor, 2018).

Partners with complementary products and services

Providers of complementary products and services (complements) are central to business ecosystems, because they increase the value of the focal firm's offer (e.g., smartphone apps or infrastructure for charging electric vehicles). The function of the complements differs depending on how they contribute to the focal offer. A strict complementarity between two goods exists, if the goods have no usage value without each other (e.g. razor and blade). A super-modular complementarity describes a relationship where an increase in complements (availability, performance) increases the value of the focal offer (e.g., smartphone and number of apps, or electric vehicles and charging stations). Furthermore, complements can be generic or specialised regarding the focal offer (Jacobides, Cennamo & Gawer, 2018).

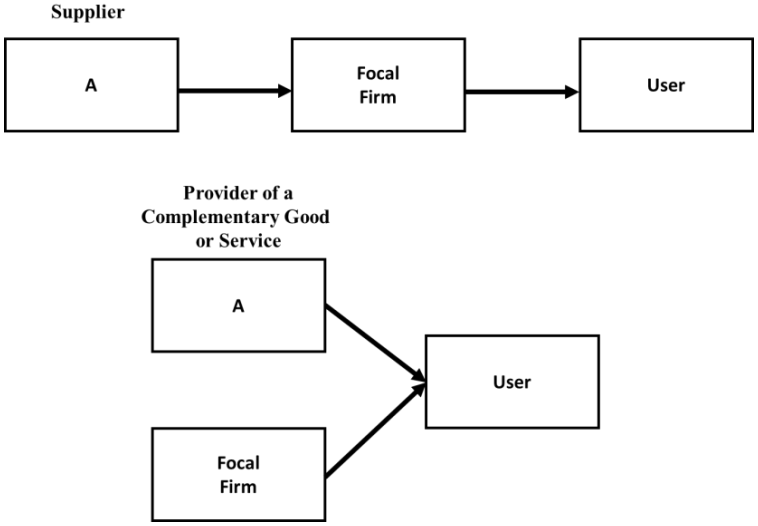

Figure 2: Roles in business ecosystems: supplier vs. provider of complementary goods (based on Kapoor, 2018)

The interdependency between providers of complementary products and services differs from that between a focal firm and its suppliers in the context of a supply chain. The latter concerns a sequential supply-side interdependency determined by the focal firm who decides how the supplied product or service is integrated into the focal offer. In the case of a complementary product or service offer (at the market level) the users of the focal offer decide on the integration of complementary offers. Figure 2 visualises the difference.

Compared to managing traditional supplier relationships the focal firm faces much higher operational challenges in business ecosystems. Relationships with suppliers are typically steered via bilateral contract-based formal mechanisms that regulate amounts, timing, and prices of supplies. Opposed to that the relationship with providers of complements concerns establishing multi-lateral alignment of offers with all relevant partners in the business ecosystem. This alignment relationship is about ensuring successful joint value creation (e.g. standards of cooperation, roles in business models) and the consecutive value appropriation across the partners, including rules to resolve conflict. In addition, the function of the complementary offer (strict, super-modular) poses significant alignment challenges, in order for the focal firm's value promise to be actually realised (Kapoor, 2018).

Platforms

Many value creation architectures organise the offer of complementary products and services via a central platform architecture. It is important to note that the management of product-based and platform-based business ecosystems differs considerably. Platform-based ecosystems are being orchestrated by the platform owner, who designs the platform architecture and determines the rules of participation. As such the platform owner also decides on the alignment structures with providers of complementary goods and services. In contrast, the rules in product-based business ecosystems are being determined jointly by the product company and the providers of complements.

In platform-based ecosystems the owner also defines the interface of the platform architecture through which providers of complements can access the platform as well as any changes over time (e.g., enhanced platform generation). Since every platform has its own specific interfaces providers of complements have to invest for their participation. They also have to decide in how many platform they want to participate (single- vs. multi-homing). Multi-homing provides them with a higher number of market opportunities, but increases costs through the necessary product adaptations for each platform. From the platform operator's perspective increased multi-homing reduces the relative value of their platform compared to competitors (Eisenmann, Parker & van Alstyne, 2006; Kapoor, 2018).

Product-based business ecosystem contain a single-sided market transaction between the focal product firm and the user. Platform-based ecosystems, however, relate to two- or multi-sided markets, on which the platform company interacts with complement providers and users that influence each other's platform benefits through mutual network effects (Rochet & Tirole, 2006). This multi-sided market interaction is a critical aspect of the necessary alignment structure, because it has to be designed such that it reinforces the platform value proposition through adequate price setting and subsidies (Rochet & Tirole, 2006, Rochet & Tirole, 2003; Eisenmann, Parker & van Alstyne, 2011).

In the context of I4.0 companies are expected to be able to develop and provide highly individualised products and service as participants of a value creation architecture. Depending on the order requirements the value creation architecture is assembled from a set of possible actors (Baumann, 2018). That means the architectures typically differ for

different orders. Ecosystem participants therefore have to take a number of strategic decisions. As focal firms they have to determine, for example, the structural design of the value creation architecture, the composition of the business ecosystem and which parts of the value creation they want to cover themselves (Kapoor, 2018; Pierce, 2009). Providers of complementary goods and services have different roles depending on whether they participate in product- or platform-based ecosystems. Their opportunities are limited by required technologies and necessary funds as well as their market position. Small and medium-sized enterprises (SME) in particular have to ensure that they are part of competitive value creation architectures, while competing successfully for orders in the business ecosystem. They face a trade-off between differentiation (unique selling proposition) and efficiency (e.g., cost minimisation, resource allocation). An increased degree of differentiation may allow for a higher share of value appropriation, but at the same time limits potential inclusion in a large number of value creation architectures. A higher standardisation improves connectivity, but with the danger of being easily replaceable (Baumann, Eulenstein & Wunck, 2017).

Conclusion

This paper elucidates the development and current state of platform and business ecosystems literature and synthesizes the strategic management and the operations and production management perspectives into a multifaceted view in I4.0 settings. A content-analysis-based literature review was completed on platforms and business ecosystems, spanning literature in production and operations management and strategic management. It was found that the number of studies in operations and production literature on business ecosystems is still low, while strategic management research is more advanced in their discussions. However, the latter often lacks the application perspective which is offered by the dynamic I4.0 settings. Exploring the ecosystem perspective in different research fields therefore helps to explain firms' manufacturing and supply strategies and to assess outcomes in I4.0 settings through the lens of complementarities and interdependencies. By identifying and defining key elements and constructs the paper introduced a first draft for a platform and business ecosystem framework for extending future production and operations management research.

The cooperation of companies, machines, and computers through digital technologies is central to I4.0. These collaborations are realized through so-called business ecosystems, i.e. sets of actors that contribute to the focal offer's user value proposition. The ecosystem perspective explicitly links supply-side and demand-side of focal offers and also considers contributions from multiple industries. It relates to traditional views of managing production and supply networks though investigating interdependencies between actors, because their offers are connected within a system-level architecture. In addition, it simultaneously considers complementarities between actors whose respective offers help to create or enhance the user value proposition. Consequently, interdependencies embody structural relationships between offers through their value contributions and the way changes in one offer affect the value contribution of other offers, whereas complementarities represent an economic value creation relationship between offers endorsed by the user.

However, business ecosystems come with a number of operational challenges. In the context of I4.0 the integration of technological platforms, coordinating partners in business ecosystems with complementary offers and dealing with bottlenecks are of particular relevance. These issues must be addressed on the level of the value creation activities, the perspectives of the different actors and the structure of the business ecosystem. Therefore additional research both in the production and operations

management and the strategic management fields is needed on three levels: the focal offer (innovation, technology), focal firm and the business ecosystem.

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Business model and modularity: a systematic literature review

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Abstract

Modularity has extended its application from product, process and organizational domains to newer ones such as services and business models. This growing literature has built up on the assumption that business models are complex systems and, as such, modularity could harness multiple benefits, such as business model innovation. In this sense, the aim of this article is to analyse the main theoretical insights towards the application of modularity principles to business model. Business model modularity is in exploratory phase, needing deeper theoretical refinements in order to identify main constructs and variables.

Keywords: Business model, Modularity, literature review

Introduction

Modularity, as a general systems concept, entails the "degree to which a system's components can be separated and recombined" (Schilling, 2000, p. 312). In this sense, modularity is an attribute of complex systems (Campagnolo and Camuffo, 2010) and architecture in one important concept as it refers to the allocation of functions to components and, as for a product architecture, the allocation of functions to physical components and the specification of interfaces among components (Mikkola and Gassmann, 2003; Ulrich, 1995). Therefore, as a design principle, modularity allows for complex systems to decompose complex tasks into simpler ones (Frandsen, 2017; Mikkola and Gassmann, 2003) and standardizing interfaces among components in order to enhance greater substitutability of components within an architecture (Mikkola, 2006; Voss and Hsuan, 2009).

Although the concept of modularity has been discussed for quite a long time in the literature, its application in the management literature has been particularly focused on product modularity, production systems modularity and organizational modularity (Campagnolo and Camuffo, 2010). On the other hand, research has been recently

discussing modularity in other domains such as service modularity (Aas and Pedersen, 2013; Avlonitis and Hsuan, 2017; De Blok et al., 2014; Brax et al., 2017; Kuula et al., 2018; Pekkarinen and Ulkuniemi, 2008; Voss and Hsuan, 2009) and business model modularity (Abdelkafi et al., 2018; Aversa et al., 2015; Gärtner and Schön, 2016; Hellström, 2014; Scannella, 2015; Snihur and Tarzijan, 2018; Tsvetkova et al., 2015; Tsvetkova and Gustafsson, 2012).

Applying modularity principles to business models build up on the considerations that business models are complex systems (Aversa et al., 2015; Foss and Saebi, 2017a), which are treated as an architecture for value creation and delivery in which specific functions are assigned to modules (Foss and Saebi, 2017b). As such, modularization allows for the decomposition, recombinability and manipulation of modules within a business model (Abdelkafi et al., 2018; Aversa et al., 2015; Gärtner and Schön, 2016; Tsvetkova and Gustafsson, 2012). As a consequence, modularization of business models has the potential to deliver multiple benefits for firms, such as enhance business model innovation (Aversa et al., 2015; Foss and Saebi, 2017b; Gärtner and Schön, 2016; Minatogawa et al., 2018) through modular innovation (Foss and Saebi, 2017b; Gärtner and Schön, 2016) and provides firms with strategic flexibility and adaptability (Aversa et al., 2015; Gärtner and Schön, 2016; Tsvetkova and Gustafsson, 2012), extends and adds to firm's value propositions (Hellström, 2014). Besides, modularity allows for cost reductions and smart use of resources (Abdelkafi et al., 2018) and also allows for the creation of platforms for solutions delivery (Cenamor et al., 2017; Kuula et al., 2018; Tsvetkova et al., 2015), specially in the cases of servitization, service-dominant logic or product-service systems (Brax et al., 2017; Cenamor et al., 2017; Kuula et al., 2018).

Despite the assumptions that modular business model are a mirror of modular product architectures (Najmaei, 2016), successful innovations of firms goes in parallel with business model innovation (Kodama, 2004). Although there has been a growing potential for future research opportunities in the business model modularity field, there is still a lack of fertilization between modularity and strategic concepts (Gärtner and Schön, 2016) and, due to its complex nature, there are number of several research possibilities (Aversa et al., 2015).

Therefore, the aim of this article is to analyse the main theoretical insights towards the application of modularity principles to business model field, looking to respond to the following research question (RQ): How are modularity principles being applied to business model in the literature? For answering this question, a literature review was performed, with an in-depth content analysis of 63 articles.

The article is structured in five sections. The first one corresponds to the introduction to the theme, highlighting the relevance of analysing this theme. The second section brings the research methods carried out in this research. The third section brings the main discussions and results of the systematic literature review. In sequence, the fourth section brings the main conclusions drawn from this research. Lastly, the references utilized are shown in section 5.

Research Methodology

The research design is a literature review applying qualitative content analysis. A codification scheme was developed and applied with the support of MaxQDA software. The sampling procedures comprised ISI Web of Science Core Collection (WoS) and Scopus databases. The following search query was utilized: "business model*" AND "modular*". The keywords were selected to appear in the articles' "title", "abstract" and "keywords" in both databases. Additionally, the filter applied in both databases aimed to select only "articles", "reviews" and "articles in press". In total, 119 documents were

found in WoS and 202 in Scopus, resulting in 59 and 84 articles only after the abovementioned filter was applied with an overlapping of 42 articles. In Scopus, out of the 42 articles that were not overlapping with WoS, 4 were also found in this database – but did not appear in the first research - and included in the final sample. Finally, 63 articles composed the final sample from WoS. This database was selected as it is regarded as having a higher quality (Chadegani et al., 2013).

In order to perform the qualitative analyses, the research protocol followed the recommendations of Tranfield et al. (2003) which are (i) planning the review with research question, search strategy and coding, (ii) conducting the review and (iii) reporting the results. All articles were read and analysed, but only those articles discussing modularity in the business model domain were discussed in this article. This criterion was utilized in order to achieve the goal of this article which is to analyse the main theoretical insights towards the application of modularity principles to business model. In addition, the codification scheme was developed and applied in order to carry out the systematic literature review.

The codification was crafted mixing deductive approach based on theoretical background extracted from the analysis of articles identified in the co-citation and keywords networks generated for this database through bibliometric analysis. Codes were related to modularity features such as degree of coupling, decomposability and substitutability (Mikkola, 2006, 2007; Mikkola and Gassmann, 2003; Schilling, 2000; Schilling and Steensma, 2001), pre-requisites and catalysts such as labor intensity, competitive intensity, technological change and availability of standards (Schilling, 2000; Schilling and Steensma, 2001) as well as drivers such as balancing standardisation and customization and reduce system's complexity. Also, business model building blocks proposed by Osterwalder (2004) were also used as codes, being (i) value proposition, (ii), target customer, (iii) distribution channel, (iv) relationship, (v) value configuration, (vi) capability, (vii) partnership, (viii) cost structure and (ix) revenue model. The codification was done using MaxQDA software, in which the codes we assigned to segments related to each topic and latter analysed in order to identify the main patterns and insights from this stream of literature.

Results and discussion

In the sample analysed, articles were discussing a diverse range of topics in which some of them, business model and modularity combined were not the object of study. In addition, in some studies, although modularity and modular approaches were proposed/applied, the theoretical elements of modularity were underspecified or missing or only mentioned in the article without proper theoretical backing. As such, these articles tend to assume modularity as a given, pre-conceived notion without specifying which features and elements of modularity were utilized.

On the other hand, a variety of articles discussed business model and modularity in a deeper and insightful manner (Aas and Pedersen, 2013; Aversa et al., 2015; Gärtner and Schön, 2016; Hellström, 2014; Khan et al., 2018; Kodama, 2004; Kuula et al., 2018; Meier et al., 2011; Najmaei, 2016; Richter, 2013b, 2013a; Scannella, 2015; Snihur and Tarzijan, 2018; Spring and Araujo, 2009; Tsvetkova et al., 2015; Tsvetkova and Gustafsson, 2012).

Within the business model literature, business models are seen as the architecture for the value creation, delivery and capture of firms (Amit and Zott, 2001, 2015; Teece, 2010; Zott et al., 2011; Zott and Amit, 2007), composed of elements, modules or building blocks built together in an interdependent fashion (Demil and Lecocq, 2010). Thus, defining business model modularity is one necessary step so as to evolve in identifying the main

features around this stream of literature. Business model modularity is defined as "sets of choices about their (business model) elements, their combination and coordination through which value is created and captured" (Gärtner and Schön, 2016, p. 41) or, as highlighted by Aversa et al. (2015), since business models are composed of sub-categories and elements in an interconnected fashion, business model modularity consists of the ability to manipulate their components, facilitating changes in their design.

In treating business models as a set of interconnected modules and components, modularization, as a process, becomes one central aspect for business model modularity. In the work of Aversa et al. (2015), modularization is aimed to understand complex systems, such as business models, in simplified models of interconnected elements, drawing from modularity principles to achieve this purpose. Through this, Aversa et al. (2015) points out that understanding business model in a modular fashion should consider four cognitive steps, such as (i) identifying functionalities in a business model, (ii) assign functionalities do business model elements, (iii) prioritize which elements are focus of attention and (iv) decouple the interdependencies of these elements.

This modularization refers to conceiving complex systems as simplified models of interconnected elements (Aversa et al., 2015) in which the benefits of this process goes beyond its application to traditional domains such as product or technological systems (Gärtner and Schön, 2016). For Aversa et al. (2015), along with modularization as a process for business model modularity, manipulation and manipulability are key elements as manipulability allows for changes in business model design through the understanding of their components and their interdependencies. Recognizing business models as manipulable instruments (Aversa et al., 2015) refers to the need of conceiving and understanding business models in modular terms (Aversa et al., 2015; Gärtner and Schön, 2016).

For AAversa et al. (2015), business models are manipulable instruments and manipulability is achieved through this modularization process and through understanding their components and their interdependencies. Manipulability, as a property of modular business models, relates to the changing of business model elements and their linkages (Aversa et al., 2015). Similarly, Tsvetkova and Gustafsson (2012) points out that manoeuvrability of business models for industrial ecosystems can be achieved through a modular approach. This ability to manipulate business model elements goes in line with the traditional feature of modularity of recombinability of components allowing for their mixing and matching (Schilling and Steensma, 2001) .

Reducing and managing complexity is both an outcome and a driver to the modularization processes. In this sense, complexity surges as an important topic for the modularization of business models. According to Aversa et al. (2015), business models are viewed as complex systems and, as such, modularity is perceived as a problem-solving approach in order to decompose business models into components and elements to be further manipulated. Gärtner and Schön (2016) also highlights that firm's business models are complex systems. In a different approach, Tsvetkova and Gustafsson (2012) and Tsvetkova *et al.* (2015) affirm that industrial ecosystems for biogas are complex and nearly-decomposable systems in which modularity serves as a way of managing and reducing complexity in which various business are considered modules in this ecosystem. Hellström (2014) discusses how a modularity-based solution business model contributed to manage the complexity in capital goods for power plant and shipbuilding cases. For Snihur and Tarzijan (2018), complexity is discussed in terms of managing multi-business models in a firm. In this sense, although the authors consider business model as complex systems, complexity is encountered within business model and between business models, entailing the complexity of managing various business models. As a result, modular

decentralization in organizational structure is necessary to manage low within complexity and between complexity as well as modular decentralization to manage high within and between complexities.

Within modularization of business models, balancing standardization and customization and the availability of standards within an industry surges as perceived drivers for business model modularity. In the industrial ecosystem approach for biogas, Tsvetkova and Gustafsson (2012) highlight that standardization in industrial ecosystem is necessary, but also needs to adapt to local business and material conditions, thus, customization is also required. It is noteworthy that Tsvetkova and Gustafsson (2012) propose a modular approach to business model for industrial ecosystem in which the modules corresponds to businesses and their functions in this ecosystem. In a subsequent article, Tsvetkova et al. (2015) argue that functions in industrial ecosystems are somewhat standardized, but requires degrees of customization to adapt to local conditions. In this sense, functional modularization in the business model for biogas industrial ecosystem may provide this balancing (Tsvetkova et al., 2015; Tsvetkova and Gustafsson, 2012) and also allows for the replicability of this business model (Tsvetkova et al., 2015).

Similarly, Hellström (2014) discussed the reasons behind modularization of two companies in the capital goods industry for integrated solutions business model based on functional modularity. In a power plant case, due to the high customization of each plant, economies of scale were not possible and, therefore, the company engendered modularity in order to standardize the content of sub-suppliers and manage demands for customization (Hellström, 2014). In terms of the availability of standards within an industry as pre-requisite/catalyst for modularity (Schilling and Steensma, 2001), Scannella (2015) highlights that sharing of standards reduces asset specificity and transaction costs, facilitating intra and inter firm transactions. In this sense, the author argues that standardization of information collection and processing acted as one very important driver for the vertical disintegration of the loan industry. Also, Scannella (2015) points out that modularity acted as a driver for new business models in the banking industry and allowed for the modularization of pricing strategies for information in the industry.

Through the analysed articles in the sample, it was evidenced that business model modularity may also entail a different level of analysis. On one hand, the modularization of business model building blocks was discussed in order to allows for their recombinability and flexibility (Aas and Pedersen, 2013; Abdelkafi et al., 2018; Aversa et al., 2015; Gärtner and Schön, 2016; Richter, 2013a). Abdelkafi et al. (2018) discussed how modular business model (and modular value proposition) allowed for the updates of building blocks in education services, cost reductions and a balance between standardization and customization. Aversa et al. (2015) transfer six modular operators from technology domain to business model domain in order to allow for changes in the business model architecture through the manipulation its elements. Gärtner and Schön (2016) discussed business model modularity based on five modular elements, such as (i) product and service modularity, (ii) channel modularity, (iii) pricing modularity, (iv) asset and capability modularity and (v) partner network modularity. In the case of German utilities, Richter (2013a) proposes a modular value for German utilities to overcome inhibiting factors to business model innovation and, therefore, seize a growing opportunity in solar photovoltaic energy. A modular value proposition enables bundling of product and services, enhances flexibility and allows for different combination of modules (Richter, 2013a). Finally, Aas and Pedersen (2013) describes that business modelling modularity in a specialized public service providers enhanced management control, service and client orientations and service innovation.

In addition, platform approach to businesses enabled by modularity were also a stream of analysis (Cenamor et al., 2017; Kuula et al., 2018; Tsvetkova et al., 2015). Interestingly, this discussion emphasized the use of platforms in systems composed of a bundling of products and services, such as servitization, product-service systems and service-dominant logic. In these domains, platform approach facilitates implementing services, enables efficient use of resources (Cenamor et al., 2017; Kuula et al., 2018), defines roles such as platform orchestrators and offering builders (Cenamor et al., 2017). In the biogas industrial ecosystem, platform approach allows for the replication of the business model (Tsvetkova et al., 2015).

Cenamor et al. (2017) highlight the role of platforms and information modularity in facilitating servitization through customized and flexible offerings in manufacturing firms. Kuula et al. (2018) discuss a solution platform consisting of different modules in co-creation of knowledge intensive business services. Lastly, in a different segment, Tsvetkova et al. (2015 and Tsvetkova and Gustafsson (2012) argues that modularity is an enabler to business model replication for biogas industry in which platforms are useful for this purpose.

Conclusion

The aim of this article is to analyse the main theoretical insights towards the application of modularity principles to business model field. This study contributed to understand the underlying theoretical insights behind the application of modularity principles to business model through the execution of a systematic literature review.

Current research has discussed business model as complex systems and how modularity can act as a tool for reducing this complexity, allowing for recombinability and manipulation of modules. In addition, different focus of analysis was also identified. While some discussions emphasized business models and their building blocks, other articles analyzed business model for industrial ecosystems in which other business acted as modules as well as the role of platforms (enabled by modularity) for the delivery of solutions in servitization, service-dominant logic and product-service systems domains. Widely accepted drivers for modularity in the literature, such as balancing standardization and customization and the availability of standards were also identified as driver for companies to pursue modularity in business models.

Business model modularity is a growing and recent research field with field research in its exploratory phase. In addition, deeper theoretical refinements are still needed, despite of the previous observable attempt to do it, in order to identify the main constructs and variables for business model modularity evolve and be consolidated as a research field. One of the main limitations of this research refers to the sampling process. It was considered only one database for analysis and, while being recognized as having better quality than other databases, interesting and insightful articles may be left out of analysis due to this sampling bias.

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Lean and Industry 4.0: empirical study on the impact of Lean in companies' digital transformation process

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Abstract

Existing researches focus mainly on how Industry 4.0 technologies affect the existing Lean practices in companies. On the other hand, the opposite perspective, concerning the impact that Lean Production can have on the Industry 4.0 transformation, presents few and very narrowed studies. This work intends to provide a contribution to the analysis of such perspective, hypothesising that differences in companies' Lean adoption level also reflect differences in the way they are transitioning to Industry 4.0. This research adopted a multiple-case study approach and several case studies have been conducted in companies operating in the low-volume high-variety metalworking sector.

Keywords: Industry 4.0, Lean, multiple Case-study

Introduction

The transition phase towards Industry 4.0 and the integration of new technologies are not free of interrogatives and doubts (Buer, et al., 2018). One of the most discussed issues is surely related to the mutual relationship and integration between Industry 4.0 and Lean Production, the most prominent paradigm in the existing industrial environment (Costa et al., 2019; Kundu and Portioli, 2018). Described as a technology independent approach, Lean Production can be generally considered as a complement to the technological perspective (Kolberg, et al., 2017). Indeed, some examples of successful integration between these two paradigms exist and are usually referred to the term Lean Automation (Kolberg, et al., 2017). However, it is still pending a clear definition about the mutual relationship and integration between Industry 4.0 and Lean Production (Buer, et al., 2018).

The aim of this research is to investigate the relationship between Lean Production and Industry 4.0. In doing so, particular attention is posed in the understanding of whether and how different Lean maturity level within companies can affect choices regarding the

introduction of Industry 4.0 technologies. This article presents the preliminary results of the research conducted by authors, obtained from multiple case studies conducted through the use of semi-structured interviews. All the companies involved in the study are based in Italy and operate in the production of either machinery or low-volumes, high variety metal products.

Literature review

A literature review has been performed, considering the framework from Buer at al. (2018) as a reference to classify studies. This framework identifies four different "theoretical lenses" through which it is possible to look at the relationship between Lean Manufacturing and Industry 4.0. Each study within this field of research concerns one (or more) of the following relationships:

- Industry 4.0 supports Lean Manufacturing;
- Lean Manufacturing supports Industry 4.0;
- The performance implications of an Industry 4.0 and Lean Manufacturing integration;
- The effect of environmental factors on an Industry 4.0 and Lean Manufacturing integration.

The first of the four perspectives is the only one that has already been assessed by a wide set of studies (69% of the sample). These researches investigate the possibilities, included in the Industry 4.0 paradigm, that may bring Lean tools and practices to a higher level. The application of Industry 4.0 technologies to Lean Manufacturing methods has been commonly defined as Lean Automation (Kolberg, et al., 2017). Analysing this set of papers, it is possible to find examples and models for the development, through Industry 4.0 technologies, of all the main Lean practices.

A small set of studies focuses on the opposite perspective, that is the support provided by Lean Manufacturing to Industry 4.0 implementation. Various experts believe that Lean can be considered a prerequisite or enabler for the introduction of Industry 4.0 (Dombrowski & Richter, 2018) (Prinz, et al., 2018) (Davies, et al., 2017), however, this statement is typically shortly analysed and motivated. A few studies have been performed on very specific aspects, such as the application of the 7 Muda paradigm in a digital context (Romero, et al., 2018) (Teixeira, et al., 2018). Only the research by Sony adopts a more comprehensive approach, though it bases on a narrative literature review and does not include empirical evidence (Sony, 2018).

The third set of studies evaluates the consequences, in terms of performance, of the integration between Lean Manufacturing and Industry 4.0. (Sanders, et al., 2016) point out that the combination of Lean Production and Industry 4.0 technologies may increase productivity, reduce waste and therefore reduce costs. (Kolberg & Zühlke, 2015) instead argue that smart modular working stations combined with SMED could strongly improve companies' flexibility. (Wagner, et al., 2017) state that the introduction of CPS in a JIT system may enhance reliability as well as reduce the inventory level. The study conducted by Tortorella and Fettermann, by targeting Brazilian companies, analyses the correlation between Lean level, Industry 4.0 implementation and operational performances (Tortorella & Fettermann, 2018). Furthermore, the research from (Rossini, et al., 2019), adopting a similar methodology and focusing on European companies, obtains results in agreement with those related to Brazilian firms. Despite of few exceptions, for both the second and third group of papers, there is a large adoption of qualitative methods and the focus is often directed towards specific aspects.

Finally, even though some researchers are starting to propose questions related to this topic, to the best of the authors' knowledge, no study entirely focuses on the effect of environmental factors on an Industry 4.0 and Lean Manufacturing integration.

The outcome of the literature review suggested that the research on the relationship between Lean Production and Industry 4.0 is not mature yet.

Research methodology

According to (Yin, 2014), the adoption of a specific research methodology over the others strongly depends on three main conditions: 1) the type of research question, 2) the researcher's span of control over behavioural events, 3) the degree of focus on contemporary or historical events. Given the study context and the defined research questions, the multiple case study was therefore selected as the reference methodology.

Each of the performed case studies was mainly characterized by two sources of information and data. The first one consists of a quantitative survey based on the model developed by Shah and Ward (2007). This instrument allowed to assess the state of Lean Production practices implementation in companies' plants and to group in clusters similar companies. The survey is composed of 41 questions evaluating, with a score ranging from one to five, the extent of implementation of Lean Production practices within a specific plant. The second source relates instead to the conduction of semi-structured interviews addressed to companies' managers involved in both Lean and Industry 4.0 projects. The interviews were based on a set of questions covering aspects related to Industry 4.0 and its integration with Lean Production practices. This way of conducting interviews allows to blend closed- and open-ended questions, often combined with follow-up "how" and "why" questions (Adams, 2015). Given the intrinsic nature of the method, interviews were carried out in a way to leave respondents enough space to expose aspects and opinions considered as important. A set of questions was predetermined and used to guide the respondent across the entire interview. Questions within each interview were organized to cover four Industry 4.0 macro-areas of discussion: the investment decision, the adopted technologies, the impact of technologies on the company and the relationship with Lean Production paradigm.

The results gathered through surveys and interviews were then integrated and compared with information coming from direct observation during sites visits, secondary sources and companies' publications. In performing the case study design, issues related to the final quality of the research were carefully considered. As suggested by Yin, the following four tests with the related tactics were performed during the whole development phase: construct validity, internal validity, external validity and reliability (Yin, 2014).

Companies taking part in the studies were accurately selected in a way to guarantee the highest possible homogeneity of the sample. The focus was directed towards Italian-based companies involved in the production and assembly of low-volumes high-variety metal products and machinery. A total of 85 e-mails were sent from December 2018 to March 2019, receiving the willingness to participate in the study from 19 of them. All these companies presented revenues from the previous years below 250 million Euros, with only one exception that was kept anyway in the sample due to not differentiating behaviours.

As suggested by (Eisenhardt, 1989), the data analysis was conducted following a two-step procedure: analysis within single case data and search for cross-case patterns.

Before starting analysing and synthesizing results across cases, a single-case perspective was adopted. Each of the transcribed interviews was analysed through the use of a two-cycle coding procedure (Saldaña, 2013). In order to analyse the pattern of data within cases, the results from the coded interviews were systematically organized in a standardized template. According to (Voss, et al., 2002), having information arranged in this way helps researchers to look for explanation and causality, and to reach valid conclusions on the single case. Furthermore, this way of conducting the analysis

determined the creation of a standardized case study protocol that increased and facilitated the comparability of all 19 cases.

The first action of the cross-case analysis consisted of the evaluation of the data gathered through the Shah and Ward's survey (Shah & Ward, 2007). In this phase, companies sharing a comparable level of Lean Production practices implementation were grouped in two different clusters by means of a cluster analysis. Out of a total of 19 companies, 10 presented a high average adoption level of Lean Production practices and were therefore labelled as High Lean (HL). The remaining 9 companies presented instead a low average adoption of Lean Production practices and were labelled as Low Lean (LL).

The obtained clusters, together with the results from the single case study analysis, allowed at this point to perform a cross-case synthesis of the results. According to (Voss, et al., 2002), the simplest and most effective method for this, is to construct an array, pick a group and to search for similarities and differences within the group. For that reason, five different matrixes were developed, one for each research question. The first dimension was filled with the observations and their related state of Lean implementation. The other dimension contained instead the variables describing the five research questions. By crossing observations and variables, the matrixes were therefore completed leveraging the results from the single-case analysis. In that way, patterns across cases were systematically identified and examined, enhancing the generalizability of the conclusions.

Preliminary Findings

The cross-case analysis helped in highlighting some shared patterns among companies belonging to the research sample. Even though some hybrid behaviours can be identified, each of the two clusters presented some unique and differentiating features.

Low Lean companies consider Industry 4.0 as a stand-alone phenomenon. They leverage this wave of technological innovation as an opportunity to reach results that are not necessarily overlapped with the Lean Production ones. In particular, substituting outdated machines, coping with saturated production capacity and filling gaps in the data are the key drivers for investments. For that reason, the most discussed performance improvements refer to productivity and efficiency, as showed in figure 1. On the other hand, High Lean companies mainly interpret the fourth industrial revolution as an opportunity for further pushing Lean Production to a higher level, commonly referred to as Lean 4.0. For that reason, the drivers and performance improvement associated with this path are the ones typically considered by Lean Production, such as flexibility, efficiency and quality increase (figure 1).

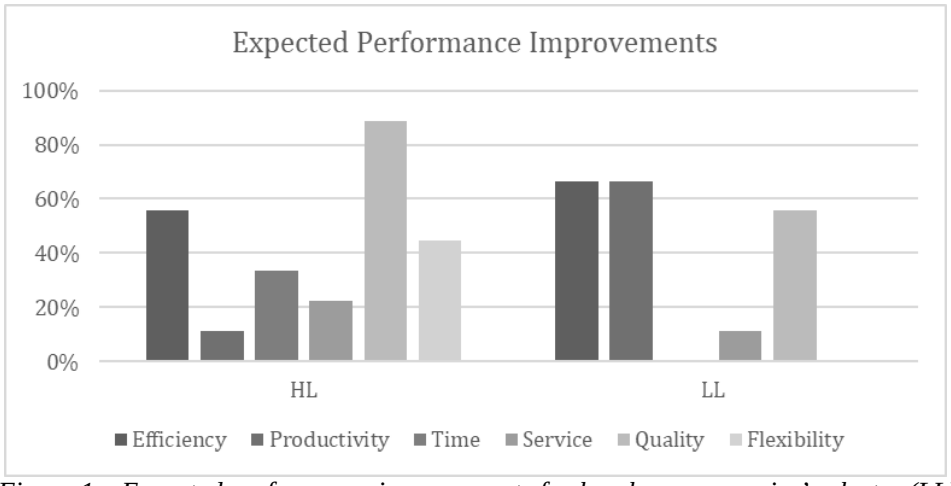

Figure 1 – Expected performance improvements for low-lean companies's cluster (LL) and high-lean cluster (HL)

Conclusions

In the authors' view, this study could create a step forward in understanding the impact that Lean Production could have on the Industry 4.0 transformation, therefore enriching the framework by (Buer, et al., 2018). Behaviours and choices of companies with different Lean implementation levels were analysed and compared on five Industry 4.0 dimensions, highlighting common patterns and differences. In addition to the theoretical contribution, the obtained results can also represent a possible guide for companies involved in the Industry 4.0 transformation for performing benchmark analysis and directing their investments.

The main limitations of this research are three. Firstly, due to the selected research methodology, there is a lack of statistical generalization capacity. Secondly, other variables influencing the choices of companies in terms of Industry 4.0 might have been neglected, such as external market conditions, macro-economic situations or specific cost-benefit analyses. In this case, an attempt to reduce the impact of this limitation was made by trying to consider a set of similar companies in terms of products, locations, sectors and volumes. Thirdly, besides secondary information sources and direct observation on the field, no multiple points of view were considered in performing each case study.

Future researchers could replicate the same study to compare the results obtained in different countries or sectors. Moreover, the case study could be enriched by considering other characteristics of the companies' behaviour in terms of Industry 4.0 transformation, such as quantitative information on the investments or a more disaggregated categorization of Industry 4.0 technologies.

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The protagonism of Cash & Carry in the supply chain in Brazil: fashion or trend?

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Abstract

New formats of retail stores continue to emerge, in order to better meet the needs of consumers. In Brazil, the Cash & Carry format occupied a leading position due to the high growth in number of stores and billing volume. This research aimed to characterize the value chain of the Cash & Carry format in Brazil, in comparison to the traditional physical stores in search of the justification for this phenomenon. Through a documentary research, the ten largest retail chains of the country and their brands of physical stores and wholesale stores were analysed, in order to construct the presented models.

Keywords: Supply Chain Management; Cash & Carry; Value Chain

Introduction

Retail organizations are diverse and new forms continue to emerge so that consumers can now buy goods and services in a wide variety of stores (Da Conceição, 2018). The idea of cash & carry, better known as "Cash & Carry" in Brazil, came into being in Europe and was more developed in the United States from 1980 onwards. The idea came from the following understanding: having a store capable of bringing the desired product to small retailers or objective consumers, without offering any services but with a more robust mix of products (Napoleão, 2017).

According to Abad (2016) and Napoleão (2017), Brazilian families has preferred the "Cash & Carry" to the supermarket and hypermarket. This research aims to characterize the chain of values and the format Cash & Carry, demonstrating the main advantages obtained by this business model in comparison to the traditional physical retail that justify its recent rise and its impacts in the retail supply chain in Brazil. The contribution of the results obtained here derives from the example of this operation in an emerging country.

Literature Review

Chain of Values For an examination of the activities performed and the way they interact, for a broad approach and identification of the main process flows of the company, the chain of values can be introduced as a systematic tool for such an evaluation.

According to Porter (1990: 31): The value chain disaggregates a company into its strategically important activities so that it can understand cost behavior and existing and potential sources of differentiation. A company gains competitive advantage by performing these strategically important activities at a cheaper or better way than the competition.

The performance of the value chain represents a process of differentiation between companies and their processes and the establishment of competitive advantages. Figure 1 illustrates the value chain model proposed by Porter (1990).

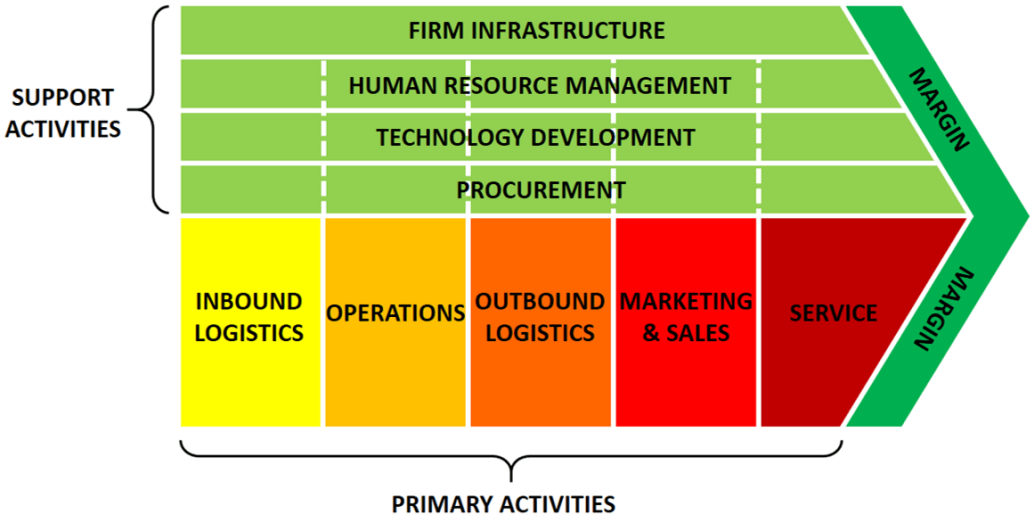

Figure 1 – Value Chain Model, Porter (1990)

Primary activities are those involved in the physical creation of the product and its sale and transfer to the buyer, as well as after-sales service. In any company, primary activities can be divided into five generic categories: (1) internal logistics: the activities associated with the receipt, storage and distribution of inputs in the product, such as material handling, warehousing, inventory control, fleet scheduling, vehicles and return to suppliers; (2) operations: the activities associated with the transformation of the inputs into the final product, such as working with machines, packaging, assembly, equipment maintenance, testing, printing and production operations; (3) external logistics: the activities associated with the collection, storage and physical distribution of the product to buyers, such as storage of finished products, material handling, delivery vehicle operations, order processing and programming; (4) marketing and sales: these are the activities associated with providing a means by which buyers can buy the product and induce them to do so, such as advertising, promotion, sales force, quotation, channel selection, channel relationships and pricing; and (5) technical assistance: these are activities associated with the provision of service to enhance or maintain the value of the product, such as installation, repair, training, parts supply and product adjustment.

Support activities can be divided into four generic categories. Like the primary activities, each category of support activities can be divided into a series of activities of

value that are distinct and specific to a particular company. The generic categories of support activities are:

(1) acquisition: refers to the function of purchasing inputs used in the company's value chain, not to the purchased inputs themselves. Inputs purchased include raw materials, supplies and other consumer items, as well as assets such as machinery, laboratory equipment, office equipment and buildings. Although these acquired inputs are commonly associated with primary activities, they are present in each value activity, including supporting activities;

(2) technology development: it consists of several activities that can be broadly grouped together in efforts to perfect the product and process. The development of technology related to the product and its characteristics can support the entire production chain;

(3) human resource management: consists of activities involved in the recruitment, hiring, training, development and compensation of all types of personnel. Human resource management affects competitive advantage in any company, through its role in determining qualifications and the cost of hiring and training; and

(4) company infrastructure: consists of a number of activities, including general management, planning, finance, accounting, legal, government affairs and quality management. Infrastructure, unlike other support activities, generally supports the entire production chain and not just individual activities.

Porter (1990) relates an advantage to value creation, that is, the competitive advantage arises from the value that a company can create for its buyers and that exceeds the cost of manufacturing the company and provides the difference between a firm's offer and that of others.

From the evolution of Supply Chain to Cash & Carry

When looking to analyse the dynamics and structure of the chain of supermarkets, it is necessary, at first, to understand some basic concepts that guide the actions of the products and services that are in networks. The need to understand the performance scenario is fundamental for assertive and optimized decision making throughout the chain.

By understanding the organizations and the ways that these are instituted, it becomes perceptible to understand the dynamics and structure of the business and therefore outline the strategies needed to gain competitiveness. The understanding of economic reality requires interpretations that are based on a systemic environment, which involves not only the parts, but the whole and their interrelations (Capra & Jakobsen, 2017).

Antonialli et al. (2016) infer that it is emphasized as the importance of studies on productive chains requires evaluations of both economic and technical operations throughout the stages of production and consumption of goods, ranging from (organizational, institutional, consumer) environments that permeate the production chain, essential for the construction of the competitive advantage of the chain (Antonialli et al, 2016).

Although dynamics is different from that of the Supermarket Supply Chain, these studies converge to the same point, being applied to all sectors, which are the structures of their respective chains (Zylbersztajn, 2005). By using the concepts of chains, production systems and coordinated subsystems, the expansion of volumes of empirical research volumes, both national and international, was evident from the 1980s to the present day. Whether in agro-industrial systems or in any other organization, they all employ the concept of continuous production steps, from the raw material to the finished product, in order to guide their analysis (Andrade, 2015).

The supply chain, according to the Supply Chain Council (2002), infers that "the supply chain covers all efforts involved in the production and delivery of an end product from the vendor supplier to the customer's customer" (Machline, 2011). Thus, typical transactions and the influence of institutional and organizational environments (which are defined as determinants of competitiveness) are common to all chains, regardless of the theoretical conceptualization (Zylbersztajn, 2000).

This relationship between supplier, producer and client creates and models the organizational and institutional environment, from which it is intrinsically linked to the cultural environment and the consumer environment, as shown in figure 1. Thus, the Supply Chain can be understood as the "main cell" in all production dynamics of products or services goods, since each chain link is affected, directly or indirectly, by any actions that affect one of its agents.

When we turn the perspective to retailing in the dynamism of information and interpersonal relations, new approaches emerge not only in the academic environment, but also in the commercial relations and the Cash & Carry is one of those results coming from the modifications in the organizational and institutional environments, as mentioned above.

Cash & Carry

According to Oliveira, Lima-Filho and Watanabe (2013), it is understood as Cash & Carry being the format of store known in Brazil for being a mixed operation of wholesale and retail, of which its actions are intended to serve preferentially, purchase (Silva, 2017).

In addition, it is important to note that the quality of the food service is not limited to the food service sector. According to Broud (2016) and Levy (2000), Cash & Carry is understood to be: The "Cash & Carry" is a phenomenon nowadays, mainly in Brazil, this model joins features of wholesale retail and aims to provide products with lower prices to the client to offer good services. This model does not have a refined structure, the design is low cost and its focus is on "pay and carry" (Broud, 2016; Levy, 2000).

Napoleão (2017) advocates that over the years, the development of this type of business has brought from new purchasing systems to adoption of new practices, such as the agglomeration of additional services added to the physical structure of the store, and in this way, it is possible offer not only cheaper products, but also, better quality services whose situation ends up adding more value to the enterprise.

Methodology

This work, in terms of its concept, is characterized as qualitative, through documentary analysis as scientific articles, as well as reports of specialized journals in the field, descriptive-exploratory. This infers that this type of research seeks to understand a reality that has not yet been studied, in which one can describe how the phenomena related to it occur (Gomes, 2006; Reis, 2018).

Pimentel (2001), shows us that studies based on documents as primordial material, be they bibliographic reviews or historiographical research, extract from them all the analysis, organize them and interpret them according to the objectives of the proposed research, giving them the specific treatment in order to corroborate with the object of study (Pimentel, 2001). Garcia Gutierrez (1984) apud Junior, Medeiros & Augusta (2017), reflects on documentary analysis as "all recognition and study that is made of a document, requiring an identification of the physical characteristics, which would be the form, and the intellectuals, the content". These elements corroborate the establishment of the best method to organize all the "information" expressed in the document (JUNIOR, Medeiros & Augusta, 2017).

It was applied in this work the analysis of documents such as scientific articles, books and reports in magazines or nationally recognized electronic sites that dealt with the theme of evolution and modification in the structures and dynamics of the retail chain and seek to understand what the current panorama of the transition traditional market of the hyper and supermarkets for the recent cards.

As a study delimitation, we opted to work on the analysis with the top 10 retail chains in Brazil's supermarket or hypermarket sector, according to the Brazilian Retail and Consumer Society (Sbvc, 2017). From the list obtained, company flags were tabulated in a spreadsheet and classified according to their size and sales format (small retail, super / hypermarkets, cash backs, etc.). In order to obtain a broad analysis specifically of the cash cards, the analysis of the discount cards that make up the Brazilian Association of Wholesale Carriers (Abaas, 2017) was included in the analysis. Below, the table 1 presents the flags chosen for the analysis.

Table 1: Retailers chosen for analysis

Flag *or* Brand	**Type**	**Flag or Brand**	**Type**
Carrefour	Super/Hyper	Assaí Atacadista	Cash & Carry
Pão de Açúcar	Super/Hyper	Atacadão	Cash & Carry
Extra	Super/Hyper	Comercial Esperança	Cash & Carry
Wallmart	Super/Hyper	Makro	Cash & Carry
G. Barbosa	Super/Hyper	Mart Minas	Cash & Carry
Prezunic	Super/Hyper	Maxxi Atacado	Cash & Carry
Bretas	Super/Hyper	Roldão Atacadista	Cash & Carry
Perini	Super/Hyper	Spani Atacadista	Cash & Carry
Dia%	Super/Hyper	Tenda Atacado	Cash & Carry
Smart Supermercados	Super/Hyper	Fort Atacadista	Cash & Carry
Super Muffato	Super/Hyper	Villefort Atacadista	Cash & Carry
Big	Super/Hyper	Carrefour Bairro	Small retail
Bompreço	Super/Hyper	Carrefour Express	Small retail
Mercadorama	Super/Hyper	Pão de Açúcar minuto	Small retail
Comper Supermercados	Super/Hyper	Extra mini mercado	Small retail
Supermercados BH	Super/Hyper	Todo dia	Small retail

From the choice of the sample, the electronic websites and news related to the respective flags were searched and the data obtained were classified in a spreadsheet, so that the specific characteristics of each company were allocated according to each activity of the value chain. Then, the data collected and classified were submitted to content analysis according to Bardin (1977), and the content analysis categorization was based on Porter's value chain proposal (1990).

Findings and Discussion

In analyzing the Brazilian retail supply chain over the last decades, it is notorious to realize that there has been a restructuring between distribution channels both among internal and external agents and, therefore, shaping the structure and dynamics of the latter. With this, several consumers have migrated their shopping environment, but mostly inserted in the super / hyper format for the retail and small retail formats.

This fact can be evidenced when it is observed that the largest retail groups operating in Brazil started to enter this market more intensively over the years, especially in the

infrastructure and locality models of their stores. To better elucidate this phenomenon, the section will be presented in three stages. The first presents the comparisons of traditional retail value chains versus the retail value chain. Subsequently, the traditional structure of the Brazilian retail chain is presented, followed by the characterization of the chain after the rise.

The retail versus retail chain of value - Traditional structure of the retail chain in Brazil
The Cash & Carry in Brazil, although recent, presents a highly dynamic and increasingly comprehensive structure. The distribution channels between the suppliers of inputs, products or services to the final customer, generate impacts at all levels of the chain.

The more complex and long the relationships between the agents that feed the chain, the more financial and managerial resources will be needed, and this is the dynamics of the traditional retail model in Brazil, where the acquisition, inventory, distribution and sale management of products of the supermarkets, presents in its great majority, like an extensive and pushed system. Figure 1 summarizes the distribution channels of the products in the traditional retail markets in Brazil.

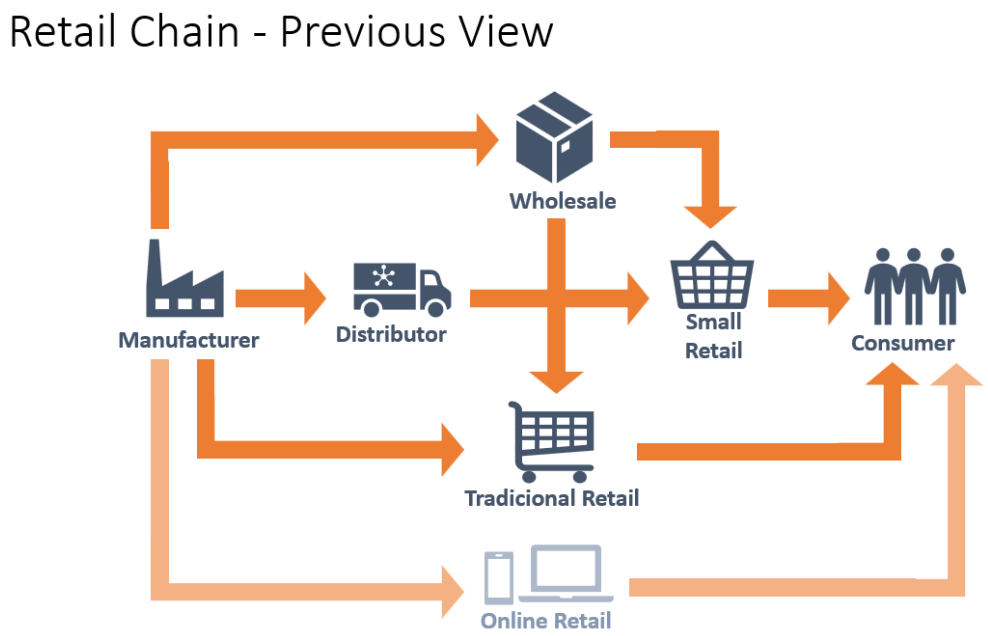

Figure 1 - Traditional structure of the retail chain in Brazil – By Authors

In this model, the product manufacturer presents itself not only as the one who produces a particular product, but also becomes a stockist (in this case, stockist would means the manufacturer as being the maintainer of the products in its own physical structure for later distribution) and sometimes acts as a distributor to the wholesale or traditional retailer. The Wholesale in turn supplies the small retailers that make the products available to customers, replacing them from time to time. The same happens with traditional retail, where the products are stored at the disposal of the final customer. In this model, the interfaces between the links in the supply chain show an increase in the final cost of the product, since each agent must receive a value for transportation, inventory and / or resale of the products to final customers.

Losses, low optimization of inventory management and costs, is recurrent in this type of marketing. Sometimes this commonly used structure has certain barriers that raise costs throughout the chain, as explained above. Linked to this favor, chain coordination

becomes fragile because it has several links between agents, which, due to the complexity of coordination conditioned to the various factors, can generate countless losses due to the organizational environment that this chain is inserted.

In addition, the operational costs of the distribution operations mean that the products that reach the end of the chain have an additional level of intermediation and consequently an added value that ultimately increases the final price of the product to the final consumer.

Current structure of the retail chain in Brazil

At Cash & Carry sector, dynamics and coordination of the chain become leaner, with the optimization of the distribution and storage of products. In the meantime, it is worth stressing with the performance of the chain is more dynamic, both the product outputs and the search for these products by the end customer. This coordination of the chain reinforces the considerations of the Value Chain proposed by Porter (1990) and demonstrate the impacts that the operations both internal and external, modify the organizational and institutional environment of the retail chain as a whole.

Thus, stores denominated Cash & Carry become the link between the manufacturer and final consumer, presenting not only as a retail store, but also as a wholesale center and as a Distribution Center (CD - It would be inferred that it is a warehouse whose purpose is to manage the inventory of goods in the fixed distribution (Abralog, 2016; Do Nascimento et al., 2018).). This changes the whole structure of internal logistics, operations and supplier, vendor and consumer relations. In this sense, Cash & Carry is a protagonist in relation to the position in the supply chain, since it occupies in a concentrated and strategic way, a new location in the structure of the chain. Figure 2 demonstrates the Chain Supply Chain and its structural arrangement differentiated from the traditional chain.

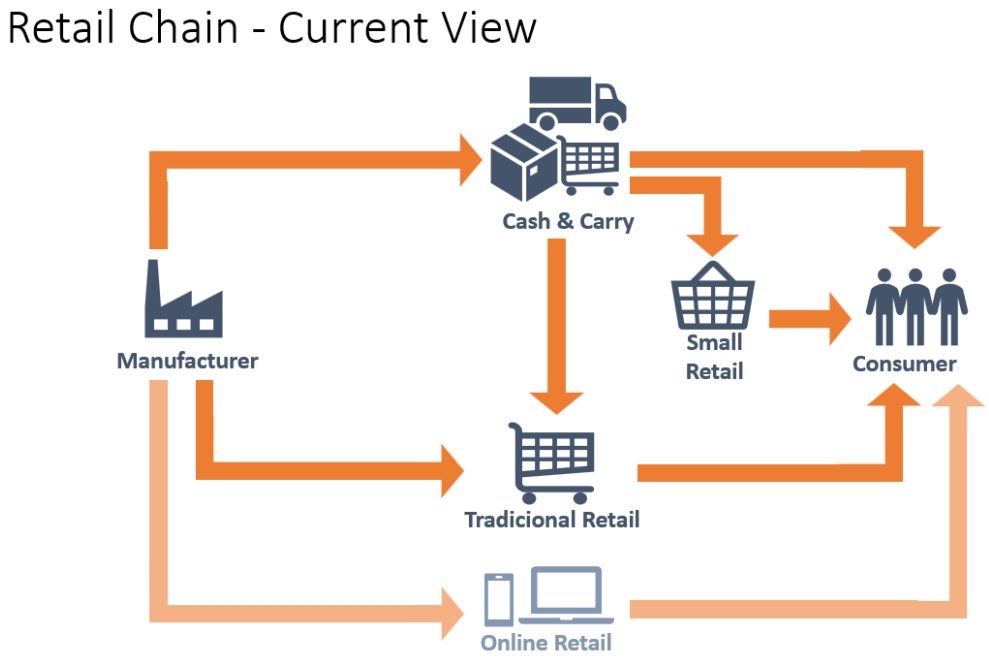

Figure 1 - Current structure of the retail chain in Brazil – By Authors

Notorious is the concentration of the agents under a single player that are nets of Cash & Carry. These, in turn, have the following characteristics: 1) attacked; 2) Retail and 3)

Distribution Center for himself as well as the small and medium retailers of the surrounding region. This explains the growth of this type of commercialization in recent years in Brazil, since in addition to reducing the costs of maintenance, personnel and charges with CD's, the cash cards provide a greater mix of products in a single structure and increase the capillarity of distribution of the products.

In addition to providing support to small retailers, the final consumer is also impacted by the quantity / price ratio, where more quantity, lower price than the cash cards provide and corroborates for the maintenance of small retail stores with quick purchases in small quantities and (which does not, on certain occasions, also exempt the consumer from purchasing small quantities in the card in certain situations or preferential).

This new arrangement solidifies the trend of the expansion of the Cash & Carry in Brazil, because it meets the assumptions of the Brazilian consumer (be it the final or internal consumer of the chain), which is the question of price. As the prices are better in the wholesale account, one can then refute, at first, that the card is a fad, but a new business model that emerges to consolidate over time.

Delimitations and Suggestions

This research was limited to a brief illustrative analysis of the structure and dynamics of the supply chain in Brazil, since the incipient studies are about this topic in depth and, thus, propose new perspectives and considerations about the Cash & Carry Brazilian. However, the limitation was only limited to some academic articles available and also focused on specialized magazines in Brazilian wholesale and retail.

As a suggestion for future research, it is the search for correlating international and national articles (if there is one) to understand the coordination of this chain and the economic, financial and social impacts that the attack provides to the region in which it is installed, such as employ ability, cost and inventory, logistic cost, among other determinants. Moreover, the authors of this work sought to demonstrate the Cash & Carry chain as a whole in its physical structure, but without neglecting or omitting, as shown in figures 2 and 3, the profound changes that online retailing causes and will cause in retail as a everything.

Thus, it is suggested that further studies are about what impacts online retailing can impact on the retail strategies, as well as, to understand the dynamics of Online Retail Supply Chain in the interfaces between supplier and buyer, restructuring the organizational and institutional environment of retail trade.

Conclusions

Cash & Carry, although widespread around the world for more than two decades, presents substantial growth in Brazil only from 2012 to the present day. However, the Brazilian retail sector is not in line with this expansion, since only large groups started to emerge for this new modality that is Cash & Carry. The perception of traditional retailers needs to be reviewed and, above all, studied and disseminated in their planning and management strategies so that there is no disappearance of traditional retails or even the bankruptcy of several of these, due to a strong and massive competition resulting from credit cards.

Since the Brazilian consumer is more closely linked to the prices of the products, the Cash & Carrys appear as an innovative and comprehensive business model, providing a more balanced inventory management between a push-pull management, since the latter occurs more strongly in the traditional retail. This leads to a reduction in the costs and concentration of the products in the own cards that not only replenish their stores in their gondolas, but also have their own stock at the same time, as well as serving as a CD for small retailers, that is, an anchor for other people in the chain.

This all leads to a reduction in costs and optimization of transactions across all interfaces, which today, is a matter of survival of most businesses. Thus, the exponential growth of Brazilian cash loans is more like a market trend than just fad or punctual actions of large corporations. The dynamics of the current relations are getting faster and faster and adapting to the new trends is and will be, in most cases, the threshold between the success or failure of the cash advance in Brazil.

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A NEW PRODUCT-PROCESS MATRIX: To explore why the ecosystem concepts are needed

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Abstract

The Product-Process Matrix (P-PM) as a strategic manufacturing analytic tool has been with us for forty years since it was published in Harvard Business Review in 1979. The model has soon become not only one of the essential theoretical foundations for manufacturing strategy but also one of the core practical factory design tools. This paper seeks to develop a new version of P-PM by combining it with Ansoff's corporate strategy model (1965) in order to demonstrate the new frontier of the discipline and the linkages of emerged and emerging industrial systems in the last forty years.

Keywords: Product-process matrix (P-PM), industrial systems, ecosystems, life cycle

Introduction

The Product-Process Matrix (P-PM) model scientifically synthesizes and systematically visualizes the compatible relationships between different types of products and various factory production systems (Hayes and Wheelwright, 1969). The model has soon become not only one of the essential theoretical foundations for manufacturing strategy but also one of the core practical factory design tools. Although the authors might not be the people firstly found the strategic compatible relationships between products and their production systems, the P-PM model was the first one systematically and concisely visualizes and details the relationships. The P-PM model has laid down a corner stone for the current production and operations management (P/OM) discipline, influencing basic textbook structures and knowledge organization. It even provides a strong hint guiding many followers to explore emerging types of industrial systems, such as international manufacturing networks, (global) supply chains, and global engineering networks.

However, the best way to celebrate an existing theory is to generate new vitality to it by extending it to new territories or linking it with emerging industrial systems. This paper seeks to develop a new version of P-PM based up the original one in order to demonstrate the new linkages of emerged and emerging industrial systems in the last forty years. Like the original P-PM, this paper is also keen to explore the deep science and various scenarios to design and govern the new industrial systems.

The original motivations to explore the new P-PM is inspired by three threads as the followings:

- In the last forty years, the industrial systems have been diversified and adapted from the traditional factory based system significantly and dramatically.
- In the last ten years, business ecosystem researches have emerged in many innovation and strategy related disciplines although the main stream of P/OM hasn't response in a very significant way.

- Ansoff's classical strategic management matrix (1965) has provided another key dimension in order to enrich the original P-PM model as innovation and strategic upgrading with different types of industrial systems.

These threads helped the paper set up its general research question as – "based on the original P-PM, could a new version of P-PM be developed in order to capture the main industrial systems and explore their product-process relationships?"

Literature Review

Classical Porter's value chain (1985) is a firm based industrial system with value-added input-transformation-output process supported by other company functions. This industrial system provides an essential foundation to ensure the outputs (products and/or services) can be delivered effectively and efficiently. The whole POM body of knowledge is about how to design/construct, operate/deliver, and improve/adapt the industrial system (value chain) (Slack et al, 2013). The value chain is the core part of the POM, but it has been usually neglected because POM people pay more attentions to its subsystems rather than its totality.

During the last two decades, however, the business globalisation has transformed manufacturing industry and its industrial systems completely. Many POM researchers have involved in the explorations and theorisation. The Figure 1 demonstrates the value chain based industrial systems' transformations, which diversifies linear input-output system into various types of networks. At this moment, the research scopes have been further extended into 3-dimensional space as illustrated in the Figure 2 as the manufacturing value chain has been considered.

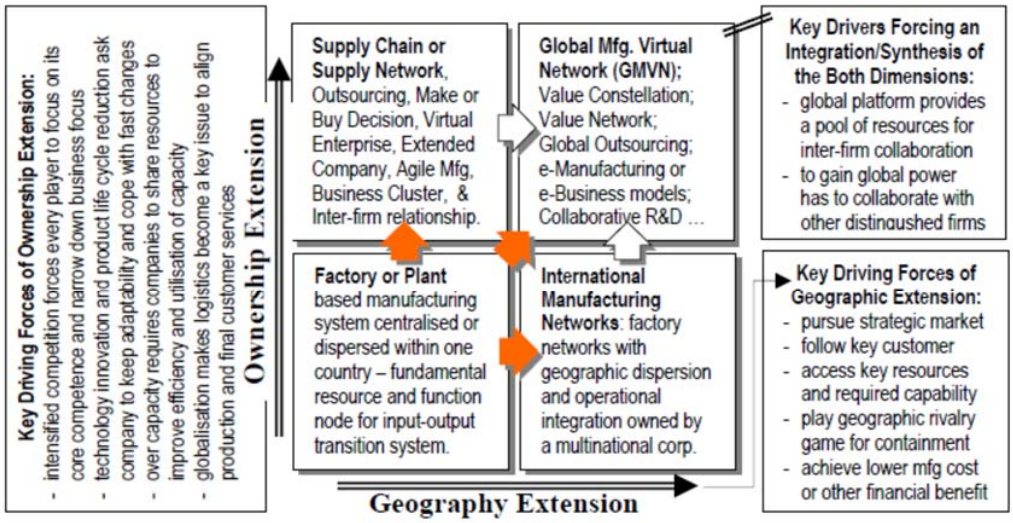

Figure 1: Manufacturing System Evolution Matrix and Key Drivers

Global Value Chain (GVC) research work (Gereffi, Humphrey, and Sturgeon, 2005) explores and enriches the understandings of different types of international and inter-firm collaborative networks (Figure 3) illustrating a spectrum from traditionally vertical integrated firm towards classical free market. Interestingly, more and more emerging configurations of GVC appear between the extreme ends of the spectrum. The research highlights extended and adapted value chains during the globalisation. And cross-firm collaborated value chains are emerging as the powerful competitive industrial systems.

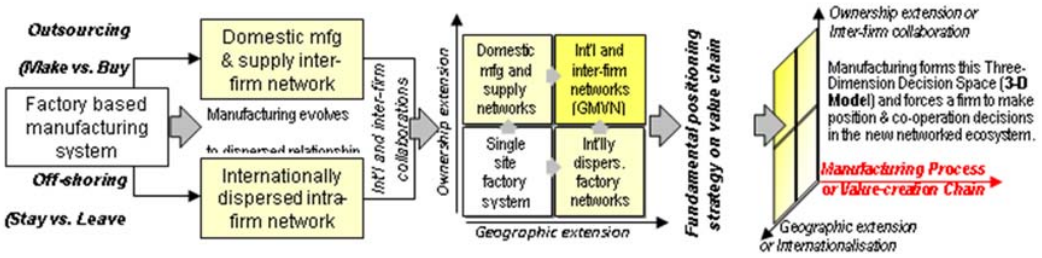

Figure 2. A Evolutionary Process of Manufacturing Systems towards the Three-Dimension Decision Space (the 3-D Model)

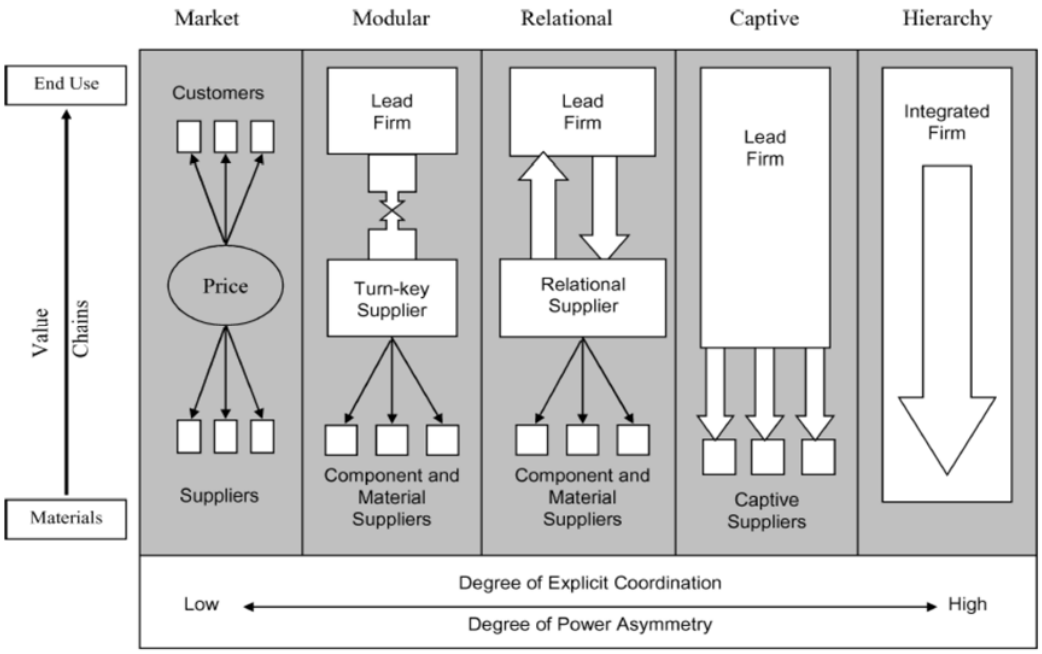

Figure 3. Global Value Chain (GVC) and its Different Configurations and Governance Types

Business globalisation triggers developing countries catching-up. China has been an excellent example, particularly in mobile phone industry. Zhu and Shi as well as other scholars have explored the Shanzhai phenomenon in the Pearl River Delta region (2010). Their observations demonstrates more dynamic pictures about industrial system formation and dissolution according to fast changing technology and product. The dynamics of industrial systems and their quick reconfigurations have inspired people pay more attentions to not only the value chain and its establishment but also its behind enabling infrastructures that strategically functions supporting system and nurtures emerging industrial systems. People give this new kind of supportive infrastructure a very imaginative terminology – business ecosystem. This term has further extended POM boundaries from industrial system towards its ecosystem or environment.

Business ecosystem concept was firstly suggested by Moore (1996). But, to certain degree, his vision as shown in the Figure 4 was not very far away from an extended supply chain model in POM. Even most recently, Adner and his colleagues seem to not strategically differentiate the fundamental distinction between supply networks and business ecosystems. Adner's complementor consideration only provides minor improvements to the existing supply chain management theories. The main streams of

studies about business ecosystems fail to breakthrough the principal supply chain boundary and to exploit the conceptual potentials of business ecosystem.

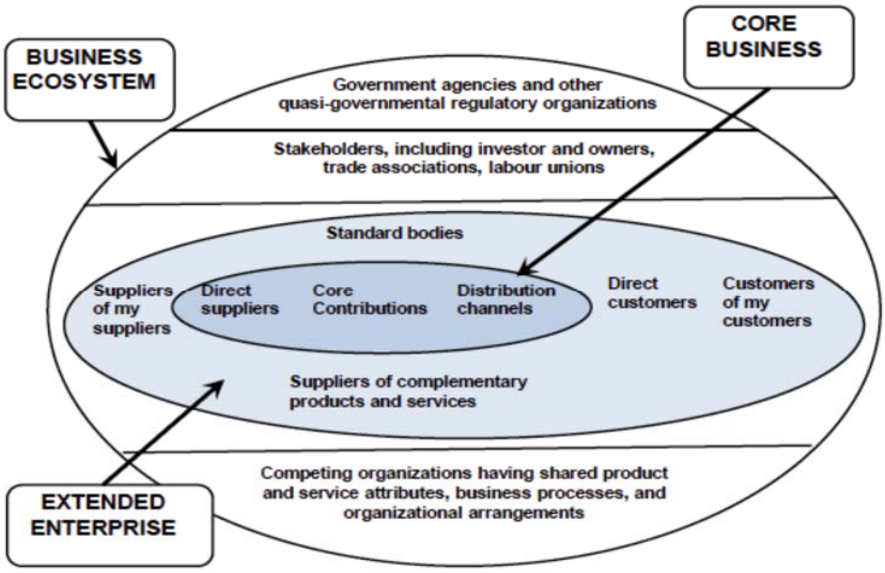

Figure 4. Moore's Business Ecosystem (1996)

In summary, the above brief literature reviews highlight the value chain or industrial system have been updating and transforming in the last thirty years. What are the implications of the manufacturing evolution to practitioners and academicians? Has the mission of value chain based industrial system been changed, or the value creation mechanisms and business principles changed? How many typical types of industrial systems are existing and can be identified to understand? One of the clear conclusions can be that there are many theoretical gaps in the new forms of value chains. We need to explore their evolutions and understand them more systematically.

Based on Ansoff's corporate strategy model considering the relationship existing and emerging customers and firms' products, the Figure 5 illustrates a new two-by-two matrix entitled with New Product-Process Matrix (NP-PM). The NP-PM horizontal dimension represents Products and their change from existing one (a certain state) towards a new one (usually an uncertain state). The vertical dimension represents Processes (in another term, an industrial systems) and their changes from existing towards a new. Both dimensions are quite similar to the Ansoff Model's dimensions seeking to capture the business changes or innovations.

The New Product-Process Matrix can be understood as dynamic transformations from the original P-PM (product-factory) state when a company has its established products and processes towards three very different directions.

- At the original circumstance (the bottom-left quadrant) with existing products and processes, the company can completely follow the classical P-PM model as it is from a factory oriented situation as a starting point.
- Along the vertical dimension upwards towards the up-left quadrant, it is a circumstance that the company changes its industrial systems based on its established products. In this quadrant, many researches have explored many different types of new industrial systems including international manufacturing networks and inter-firm supply chains and/or both international and inter-firm value networks (Rudlberg and Olhager, 2003; Shi, 2004).

- Along the horizontal dimension changing towards the bottom-right quadrant, the circumstance is that the company seeks to develop new products based on existing industrial systems (factory). The established new product development approach of course can be adopted within this quadrant. However, new mass customization approach also can be adopted to enrich the company's choices for competitive advantages (MacCarthy, et al 2003).
- The final up-right quadrant has both serious challenges from product and process with new and uncertainty characteristics. For mainstream P/OM community, it hasn't found any effective solution to cope with the challenges yet. However, is this the place for the new concept of business ecosystem that provides very interesting and inspiration to tackle the uncertainties?

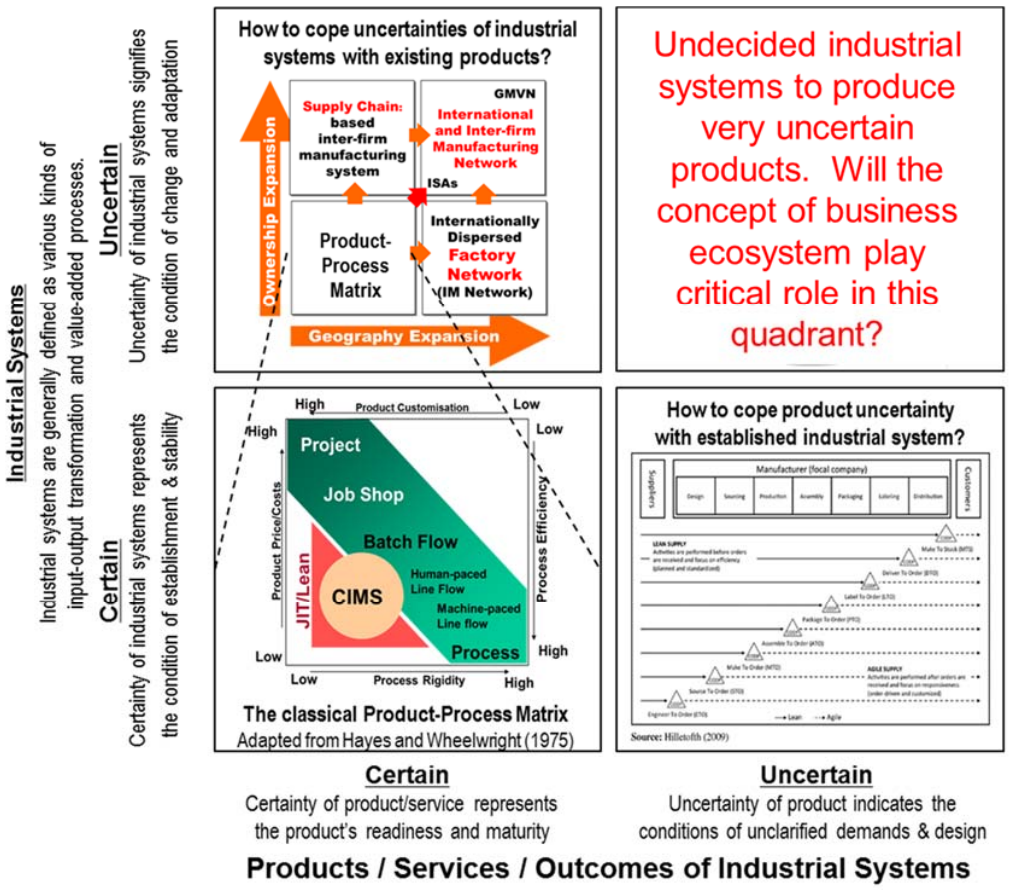

Figure 5. New Product-Process Matrix for Environemntal Uncertainties

Research Design: phenomenon capturing and analysis

In order to empirically explore the changes of value chain during the globalisation and inter-firm collaboration, a research programme was set up to address the following research question – "could the new version of P-PM illustrated in the Figure 5 be developed in order to capture the main industrial systems and explore their product-process relationships?". The answer could be very obvious and positive. However, the general research question actually aims to achieve two strategic objectives. The first is to understand more about the adapted value chain or industrial system in order to systematically understand why, what and how the value chains have evolved. The second

is to strategically integrate and analyse our existing industrial data set developed in the last 15 years based on continuous observations in several industrial sectors in China.

Considering its exploratory characteristics of the research question, insightful case observation approach is seriously considered. The essential criteria for case selection are: (1) the targeted case should be fast changing or adapting itself, which can potentially help to identify, capture, and understand significant changes of the value chain; (2) the case studies had better to be a relatively narrow in terms of region and sector, which can be convenient to observe and follow; (3) the observed value chains had better to have a larger industrial impact, which demonstrates the new value chains have their significances in both practice and theory.

Based on the above criteria, the mobile phone industry in China, particularly in its Pearl River Delta (PRD) Region, was selected. A serial longitudinal, in-depth regional based, and multiple dimensional case observations have been adopted since the year 2000 in order to a holistic view about the value chains and their evolutions. The key units of the case studies include the following three different levels:

(1) The Chinese regional evolutionary studies: Based on the mobile phone industry evolutions in China, the following four stages of industry development can be identified including:
    1) Multinational corporations foreign direct investments in China, like Motorola operations in Tianjin TEDA from mid-1980s to mid-1990s;
    2) Chinese domestic corporations catching-up, like Bird (BoDao) based in YRD from late-1990s to mid-2000s;
    3) Chinese Shenzhen Shanzhai Phenomenon in PRD from 2007 to 2012; and
    4) Xiaomi emergence from Zhongguancun High Tech Park after 2012;
(2) The four representative development phases and flagship companies are taken as the unit of analysis to explore each phase's key events and particularly the value chain statues and transformations;
(3) Each phase and the related representative company's key value chain partners and environmental supporting systems are also investigated in order to capture the comprehensive pictures of value chain formation and adaptations in an ecosystem context. The phases (2) and (3) form an ecosystem based holistic stories reflecting the value chain collaboration formation and adaptation in the phases.

By following the individual case and its value chain transformations as well as its regional and key organisational changes, a holistic picture about value chain transformations can be described and potentially further analysed. The four phase cross-case analyses along the time dimension can provide a longitudinal picture for better understanding the evolutionary journey of the value chain adaptations.

The detailed case descriptions and analysis have been deliberately omitted in order to concentrate on key findings and related discussions. The authors can be contacted for further information enquiries.

Research Findings

In the last 25 years, the global mobile phone industry has experienced three main transformations, and four different phases could be identified as shown Figure 6. Each phase has its very unique and dominant type of value chain:

In the very early phase (1990 – 2000), the global mobile phone industry was dominated by multinational corporations (MNCs) like Motorola and later Nokia and Samsung. Vertical integrated value chain model based on individual firm has been heavily adopted in the MNCs. Nokia as an emerging new star in the industry changed the traditional Motorola's internal vertical integrated value chain and started to focus more on the

downstream of the value chain by adopting wider range of components and modules outsourcing.

In the starting phase (2000 – 2005), when Nokia demonstrated its highly variety of end products and very efficient supply chain against Motorola, Chinese mobile phone pioneer companies such as Bird and later Jinli still mainly tried to learn from Motorola by adopting the vertical integrated value chain. They tries to achieve the transformation from imitation to innovation (like the secondary innovation methodology). There are some breakthroughs but not very significant. But this phase was still very critical for China because it laid down a solid foundation including all kinds of components and assembly as well testing capabilities.

In the middle phase (2007 – 2012), Chinese Shan-Zhai phenomenon transformed the global mobile phone industry fundamentally (Zhu and Shi, 2010). The so-called "blank brand" or "white brand" phones, contract manufacturing service providers, and quickly formed networks forced people rethink about Porter's value chain model. The Value Constellation Model (Normann and Ramirez, 1993) might be better for capturing the core of the emerging phenomenon.

In the current phase (2012 – 2015), it was very soon the industry moved to the smart phone or mobile computing age that nurtured more diversified business models and value chain patterns. Apple and Chinese similar version – Xiaomi – have pushed people's attentions a wider range of business scope for not only the value chain operations but its designs and creations. Our observations on Xiaomi have helped us to notice both a new type of value chain including three key building blocks – supply parts, demand parts, and intermediaries – as well as the formation or evolution of the value chain from more fragmented social networks. We tend to call this extended value chain as a business ecosystem that continuously creates innovative ideas and nurtures new value chains (or industrial systems) to deliver highly efficient products and services.

Based on the four stages observations, three key transformation processes have been also identified in Figure 4. They are entitled with:

- Global Outsourcing (Globalization);
- Specialisation and Reconfiguration (Global-localization); and
- From Social Networks to Industrial Systems (Ecosystemization).

The third transformation can be illustrated in the following diagram (Figure 7). The diagram also presents the 4th phase of value chain highlighting the dynamics and transformation in a business ecosystem. The holistic model of business ecosystem in the diagram offers an integrated representation of value creation mechanism in the currently uncertain and quick-changing world.

The four case studies representing the four evolutionary phases in the mobile phone industry development in China have clearly demonstrated very different types of value chains or industrial systems. The different types of value chain organisations or governances have demonstrated very different strategic capabilities to cope with industrial innovation and customer demand changes.

The clear phenomenon of industrial systems adaptions and evolutions have inspired us to have better understandings about the value chains and their relationship with the ecosystems:

(1) There are many different types of industrial systems; but the most fundamental one can be represented as the value chain.
(2) During the globalisation, the value chain has also adapted itself to various types of forms, such as Figure 1, 2, 3, 4 and 5 illustrate; however, the core part of value chain is always an input-process-output such kind if industrial systems.

(3) The core part of POM discipline is to design/construct, operate, and improve an industrial system that can deliver product and/or service effectively and efficiently.
(4) The current challenges that POM discipline is facing are:
   1) Industrial systems emerge and evolve too many diversified forms. It is more critical to understand the new types of industrial systems than to better operate the classical ones, particularly from research perspective.
   2) The POM priorities have been changed from operations and deliver towards industrial system (re)design, (re)configuration, and (re)constructions in a much faster way.
   3) Therefore, the business ecosystem emerges as a more essential unit of analysis or attention focus to reconfigure the new industrial system.
(5) More attentions focusing on business ecosystems implies that POM should have new extended system boundaries – not only industrial systems but also their ecosystems.

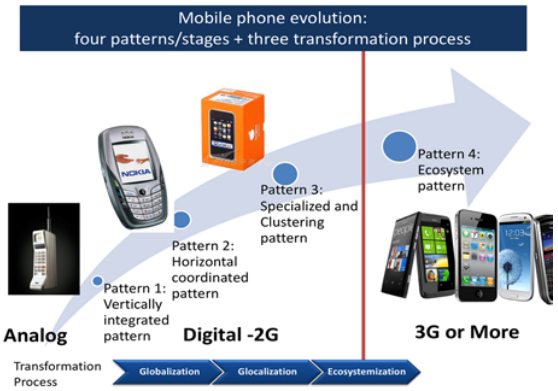

Figure 6. The evolutionary journey of mobile phone industry

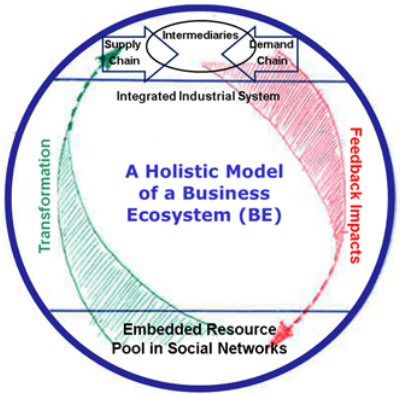

Figure 7: A Holistic Model Representing a Business Ecosystem

Discussions

Relationship between Industrial Systems and Business Ecosystems

Based on the observations of manufacturing system evolutions, the new system boundaries for the ecosystems can be recognized in order to cope with the uncertainties of both product and manufacturing system. A new generation of "product-process matrix" (Hayes and Wheelwright, 1975) can be proposed as the Figure 5 demonstrated to capture the new requirements. The business ecosystem as a solution for the new challenges is discussed to call for more research and understanding in POM community. The new matrix explains the role of the ecosystems in the POM body of knowledge.

From the Figure 5 – the New Product-Process Matrix, the business ecosystems do have their clear boundaries distinguishing from the classical industrial systems or value chains. In the top-right corner, it illustrates the Figure 5 dynamic characteristics. Both diagrams conceptually offer a new definition and vision about business ecosystem – a business ecosystem is an interconnected and interactive community and continuously nurtures new industrial systems to create business value.

New Research Directions and Approaches for Studying Business Ecosystems

POM has established very robust methodology to deconstruct and analyze a system. The similar approach and tools can be used for the business ecosystems. A simplified framework from the 6C Model (Rong, et al, 2015) can be used to address the following issues of business ecosystems (BEs):

- Context of BE: the purpose and boundary of BE
- Configuration of BE: including constructs/building blocks of BE, architypes of BE, and key dynamic mechanisms of BE
- Capability of BE: strategic functions, health status, and potential key performance indicators (KPIs) of BE
- Change of BE: the adaptation and evolution paths and mechanisms

The Framework provides a new target and logic relationship to systematically explore the emergence of business ecosystems.

New Priority of Production and Operations Management (POM)

Based on the case observations and business ecosystem emergence, the paper also suggests that POM research and education need to shift the priority from established industrial system operations toward new industrial system design and reconfiguration. Traditionally, POM pays too much attentions to existing system running and continuous improvement. The industrial trends show the changes are so unpredictable the radical now, especially in the emerging industries and developing regions. POM people no longer to have the previous luxury time to build up an industrial system and rely on it for a few decades without any significant restructuring. Business ecosystem concept and vision actually hint to all of us that it is much more critical for operations managers to continuously monitor the environmental changes and very quickly redesign and configure internal and external resources to form a new industrial system in order to capture the opportunity, take advantage of emerging technology, and/or exploit accessible resources.

This will fundamentally change POM body of knowledge, putting strategic thinking and system design as well as construction or configuration into much higher priority. The operations managers need new types of capabilities to satisfy the requirements.

Conclusion

The paper explores the new forms of international manufacturing networks. It finds business ecosystems are emerging to cope with the dramatic industry changes. In order to introduce the new pattern of industrial systems, this paper also systematically review and study the evolving value chain patterns with four stages and three transformative process. Such process includes 1) Global Outsourcing; 2) Specialisation and Reconfiguration; and 3) From Social Networks to Industrial Systems. The paper argues the evolved types of value chains provides new theoretical challenges in POM discipline and the new researches on business ecosystems as a new type of value chain can contribute management studies fundamentally. Besides the suggested future research directions in terms of business ecosystem theories, the paper alert the POM community that operations management task priority should be shifted from existing system operations toward new system strategic design and fast reconstruction. The NP-PM extends and original P-PM, captures the dynamics of product-process, and demonstrates different types of industrial systems and their relationships.

Acknowledgement

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Bricolage – managing operations in a resource constrained environment.

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Abstract

Even with good supply chain risk assessment and management processes, short-term resource shortages are not uncommon. Bricolage is an approach to dealing with managing in resource shortage environments, and has been widely studied in innovation, but not in operations. Although approaches such as inventory build-up and capacity planning to deal with such problems, we explore how the experience of bricolage can be applied in such contexts and what are the potential contexts in which they may be applied.

Keywords: Resource constraints, Bricolage

Introduction

The uncertainties in the United Kingdom have highlighted the possibility of temporary or longer term resource availability for both industry and individuals. This is potentially a particular issue for those organisations that have well developed lean supply chains. At the time of writing, companies, public sector organisations such as hospitals are beginning to stockpile parts, raw materials medicines etc., and some individuals are stockpiling medicines and food. Whether this will be necessary is not yet known.

We argue that it is important to explore what may be effective policies is such situations. One approach that has been studied in resource-constrained situations is bricolage. To date it has mainly been studied in the context of innovation (Witell Gebauer, Jaakkola, Hammedi, Patricio, and Perks, 2017; Linna, 2013). In this paper we examine how it might be more broadly applicable.

Bricolage

Bricolage is a term derived from the French verb bricoler (meaning "to putter about") and related to bricoleur, the French name for a jack-of-all-trades or handyman. Bricolage made its way from French to English during the 1960s. The concept of bricolage originated with the philosopher, Levi-Strauss (1966). He contrasted Engineers with Bricoleurs. An engineer follows set procedures and have a list of specific tools to carry out their work, in contrast, a bricoleur by definition is someone who uses ‘whatever is at hand’ and this repertoire of resource elements can be odd and heterogeneous (Lina 2013. Baker and Nelson (2005) describe bricolage as making do by applying combinations of whatever resources at hand to new problems and opportunities.

Bricolage is typically not a strategy that is chosen from alternatives, but one that is forced upon the organisation when there is constrained access or uncertain access to resources. Resources can include physical elements such as products, raw material, people and capability. There has been substantial research on the use and impact of bricolage in innovation. It has been argued that when confronted by resource scarcity, individuals can be more creative leading to innovation. Bricolage can enable the adaptive design process by making solutions to problems more achievable, by making critical resources more obtainable and by reducing costs (Vanevenhoven, Winkel, Malewicki, Dougan and Bronson, 2011). Baker and Nelson (2005) found that it explained many of the behaviours observed in small firms that were able to create something from nothing by exploiting physical, social, or institutional inputs that other firms rejected or ignored.

Contextual implications

Research on the impact of bricolage has focused on two main contexts. First, smaller firms who lack access to resouce. Guo, Zhang and Guo (2018) argue that that medium-sized firms benefit less from bricolage than SMEs because they are more formalized and can afford standardized resources. If they rely too heavily on bricolage, they can fail to adopt the optimal solutions for the exploitation of recognizable opportunities. The second context is at the country level where there are inherent shortages of resources, in particular less developed countries. It has been argued that a selective bricolage approach can break through resource constraints while also establishing a base for firm growth. Instead of deploying bricolage capabilities consistently and repeatedly across multiple service innovation projects and entire NSD processes, organizations should use it selectively (Baker & Nelson, 2005, Witell et al. 2017).

In operations, the risk of resource shortages can occur from two sources, (1) risks arising from the problems of coordinating supply and demand, and (2) risks arising from disruptions to normal activities (Kleindorfer and Saad, 2009). A particular problem in recent years has been the risk associated with financial crises (Blome and Schoenherr, 2011). With increased amounts of outsourcing, a financial crisis can lead to supplier failure leading to higher risks of resource shortage.

There has been substantial study of supply chain risk in multiple contexts. Much of this has been focused on risk identification and risk management. There are a number of ways of categorising risk, for example, they can be known risks or unknown risks. Known risks may include supplier problems, quality failures, industrial action, factory process problems etc. Unknown risks such as natural disasters are those that are very difficult foresee. Short-term and non-forecast disruptions are often known as Glitches. “A supply chain disruption is an unintended, untoward situation, which leads to supply chain risk. For the affected firms, it is an exceptional and anomalous situation in comparison to every-day business. Depending on its severity other terms might be applied, e.g. glitch, disturbance, or crisis. It is triggered by an underlying disruptive event (or a series of such events). Since the resulting detriment is usually a function of time, supply chain disruptions involve time pressure implying that decisions for mitigation must be made swiftly” (Wagner and Bode, 2006 p303).

Supply chain risk assessment and risk management approaches would seem to be able to address and mitigate much of the potential resource shortages that could result. Bricolage approaches would seem to be most applicable when resource shortages are unexpected, and

difficult to mitigate. In operations this consistent with what has been described as glitches and where risk mitigation has failed and there are still severe resource shortages.

Bricolage in operations

Despite the wide research in innovation, bricolage has been neglected in operations. I first encountered a bricolage approach to operations many years ago in a presentation by a senior Hungarian expert during the communist era. He argued that at that time, there were shortages and uncertainties as to what would be available and that rather use sophisticated production planning systems, production was scheduled based on what was available. With hindsight, this was a bricolage approach.

Dealing with temporary or long-term resource constraints is likely to be a problem that many organisations will experience. Dealing with short-term resource shortages in operations has been studied by Morrison (2015). As he points out, resource constraint is commonplace in organizations, but resourceful and dedicated people find ways to do with what is available. He argues that, due to resource shortages, pressure on the person increases to find a way of accomplishing more tasks in the same amount of time, and their way of responding is through workarounds. Maybe surprisingly, this works in the short term. However, Morrison (2015) found that this can have severe negative consequences. Workers generating way of working round constraints such as resource shortages signals to management that more personnel are not needed and counteract requests for more resource, locking the organisation into a continued contexts of resource shortage and over time potentially leading to an enduring regime of poor performance. This behaviour is clearly one aspect of a bricolage approach. It also illustrates in an operations context the strengths and weaknesses that have been found in innovation – it works in the short-term but can lead to sub-optimal solutions.

“Manufacturers can reduce the occurrence of glitches in their operations by building capabilities to prevent them, yet mitigation capabilities are also needed to contain the effects of the glitches that will still inevitably occur every now and then” (Tenhiälä and Salvador, 2014 p437). They point out that “operational glitches constitute a major concern for manufacturing managers: minor glitches like late raw material deliveries or machine breakdowns are fairly common in most manufacturing environments yet they have potential to transform into big disruptions, unless they are mitigated effectively” (op.cit. p 438). Although approaches such as inventory build-up can in part deal with such problems, Tenhiälä and Salvador (2014) examine interorganisational communication routines as a key glitch mitigation capability. They argue that although, consistent with Morrison’s (2015) work on workarounds, glitches should be dealt with as near as possible to their and point of origin, at the lowest possible level in the organisation, a local solution to a glitch is not always possible. Without effective communication of messages concerning the glitch it may not be possible to rapidly deal with it. They find that the use of formal communication channels mitigates the impact of glitches and this is supported by informal communication channels. This is consistent with one of the capabilities required for bricolage, networking with external partners, put forward by Witell et al. (2017).

Discussion

A useful analogy for bricolage in supply chains is supermarket delivery and cooking. Increasingly, many order from supermarkets for direct delivery to home. However, not

infrequently the items ordered are not in stock, so the supermarket substitutes something else or notifies the buyer that the item cannot be delivered. The result can be that plans for meals to be cooked have to be adjusted rapidly to reflect the actual supplies available. Alternatively other routes to supply could be sought such as visiting a different shop or just asking the next-door neighbour whether they have some of what is needed. This can be seen as a bricolage approach in the context of an unexpected supply failure.

Our review of Bricolage approaches and research on mitigation of short-term resource shortage shows a strong similarity between the two. This raises two questions, what can our knowledge of bricolage approaches add to what is already known about mitigating short-term resource shortage and second in what contexts should it be used.

Bricolage capabilities

Witell et al. (2017) argue that successful exploitation of bricolage in service innovation requires development of four capabilities: (i) actively addressing resource scarcity, (ii) making do with what is available, (iii) improvising when recombining resources, and (iv) networking with external partners (Baker & Nelson, 2005; Fisher, 2012; Linna, 2013). Morrison's (2015) work provides additional insights into what bricolage activities and outcomes can be in an operational environment, in particular the positive and negative outcomes associated with workarounds. Having these capabilities will enable superior performance to others operating with the same resource constraints. We argues that these capabilities apply equally to the management of short-term operational resource shortages and glitches. Capabilities (ii) and (iii) are most easy to implement in a make to order or make to stock context, but may be very difficult in high volume lean production contexts. They require capabilities of production planning and control systems to re-programme schedules based on what is available.

However, Seynard, Baker, Seffens and Davidson (2014) point out that bricolage is frequently associated with outcomes that leave a lot to be desired such as second best solutions, maladaptation, inefficiency and slowness, and as Morrison (2015) points out, approaches such as workarounds work, but lead to sub-optimal solutions.

In conclusion, bricolage approaches should not a strategy that is chosen from alternatives, but one that is forced upon the organisation when there is constrained access or uncertain access to resources. The outcomes of their use can be sub-optimal. Unfortunately, short-term resource shortages are common occurrences in organisations. Thus, organisations may have to resort to bricolage approaches in such circumstances. Thus although such problems may fall into the supply chain risk category of unknowns, it is important that an organisation should have the capabilities outlined above to so as to be able to deal with resource shortages effectively.

This area, mitigating short term unexpected resource capabilities is one that requires further research and in particular the capabilities needed in different operational contexts. Study of how firms in the UK are dealing with the current uncertainty and risk may provide interesting insights.

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Scale Development for Measuring Operations Strategy Processes

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Abstract

Slack and Lewis (2017) conceptualize Operations Strategy (OS) as reconciliation – i.e. recognizing the prima facie significance of both, the market- and the resource-perspective on strategy and aiming at harmonizing implications from the two. However, there is no study providing empirical data to understand if and how companies practically approach the goal of reconciliation in their strategy-process. This is both a practical as well as a theoretical problem. Addressing this deficit, in a first step this paper reports on the development of a scale for measuring the reconciliation process.

Keywords: Operations Strategy Process, Empirical Research in Operations Management

Introduction

Slack and Lewis (2017) conceptualize Operations Strategy (OS) as recognizing the prima facie significance of both, the market- and the resource-perspective on strategy and aiming at harmonizing implications from the two. They refer to their concept as reconciliation. From a practical point of view, reconciliation seems plausible since there is arguably no need for strategists, to strictly opt for only one approach to OS: a pure market- or pure resource-based perspective. Thun (2008) finds so-called hybrid strategy-types (i.e. strategies showing market- and resource-based characteristics) in the HPM-Database. Hence there is at least some empirical basis for the existence of reconciliation. The lack of insight on how to formulate a strategy that harmonizes the market- and resource-approach, however, is both a research deficit as well as a practical problem. This is in line with the general lack of a broad theoretical understanding for strategy processes (Chatha and Butt, 2015). In particular, there is no study, providing empirical data to understand if and how companies practically carry out reconciliation. Addressing this deficit in a first step this paper reports on the development of a scale for operationalizing the strategy process, particularly measuring the reconciliation process as conceptualized by Slack and Lewis (2017). Our main research question is: based on the existing OS process literature, how can the process of reconciliation be measured in a survey?

Literature Review

The body of OS literature is commonly divided into content ("what") and process ("how") studies (Dangayach and Deshmukh, 2001) (Chatha and Butt, 2015). Slack and Lewis (2017) prescriptive concept of a reconciling strategy approach refers to the goal of the content of strategy. Simply put, firms should make decisions in a way that best exploits the interplay between their competitive resources and the fulfillment of market requirements, leading to a sustainable performance advantage. This paper focuses on the question if there is also a process element to reconciliation, i.e. how companies try to approach this goal of a reconciled strategy. We refer to this as the process of reconciliation. The following review therefore focusses on relevant process contributions to the OS literature. Compared to the content literature, which is methodologically rich and split into many broadly discussed subthemes (da Silveria and Sousa, 2010), the theoretical foundations of the process theme are far less developed. In the latest review of OS articles in major journals, Chatha and Butt (2015) find that merely 15% of contributions deal with process topics. Barnes (2001) argues that the OS process literature tends to be prescriptive in nature, thus conceptually speaking about what should be done rather than empirically studying what companies do. Due to the generally increased use of quantitative and qualitative empirical studies in recent years (Chatha et al., 2018), the lack of descriptive studies has been addressed. However, there is still a lack of purely descriptive, empirical insights in the process literature (Jagoda and Kiridena, 2015) and especially regarding the specific concept of reconciliation. This presents a problem for theory building since practical issues and procedures are not considered, which, in turn, weakens academic relevance and input for practitioners. The specific aspect of the OS process we want to examine is strategy formulation, i.e. gathering and understanding information to come to a common understanding of a strategy. A large part of strategy formulation is constituted by research on alignment Chatha and Butt, (2015). Alignment comprises the sub-themes of aligning OS with business strategy (Joshi et al., 2003), aligning OS with other functional strategies (Weir et al., 2000) as well as alignment within the operations function, i.e. aligning strategic goal with operative actions (Choudhari et al., 2013). The rationale of all three alignment-concepts is that a harmonization between OS and the afore-mentioned elements leads to a sustainably improved business and manufacturing performance. We argue that Slack & Lewis (2017) reconciliation process differs from alignment in two dimensions. 1) the first two types of alignment refer to a harmonization between strategies (business strategy and other functional strategies respectively) and the third type to a harmonization of different levels of action (strategic versus operative). In contrast, reconciliation covers the harmonization of different approaches to strategy (market- and resource-based) within the same level of action (OS as functional strategy). 2) Particularly the first type of alignment implies directionality, i.e. OS is meant to align with business strategy, not vice versa. Reconciliation is balanced in that both strategy-approaches are initially equal and a focus on one or the other is only the potential outcome of the reconciliation process. Having stated these differences, the underlying rationale of harmonization is akin to both concepts. For operationalizing the reconciliation process we therefore draw on insights from alignment. The underlying rationale of harmonization is akin to both concepts. For operationalizing the reconciliation process we therefore draw on insights from alignment.

The positive effect of alignment on performance seems to be a commonly shared notion. (Anderson et al., 1991) (Weir et al., 2000) (Joshi et al., 2003) (Olhager et al., 2008). However, firms seem to struggle in reaching high overall levels of alignment reflecting the general difficulty of the strategy process as mentioned in the introduction of this paper. Weir et al., (2000), Sun and Hong (2002)and Hausman et al. (2002) show

that inter-functional harmony between OS and marketing strategy is caused by intensive communication between representatives from both functions as well the intensity of cooperation during their strategy process. Similarly, Weir et al., (2000) indicate the importance of inter-functional communication and cooperation to exploit benefits of alignment. Cheng and Musaphier (1996) out that reaching alignment is an iterative process of reviewing and validating information to come to conclusions regarding desirable strategic actions. We argue that the importance of communication and collaboration is that it fosters a learning process and facilitates that the access to information. This notion is supported by other contributions to OS (Berry et al., 1999) as well as older contributions to the management literature (Hambrick and Mason, (1984). To conclude, literature for serving as a basis for operationalizing the reconciliation process is scant. However, contributions to the field alignment yield preliminary insights into steps taken to harmonize different perspectives: i) communication with various information sources (to gather and validate information) and ii) cross-functional collaboration/decision-making (also to gather and validate information and create legitimacy for the potential strategy outcome). Referring to Slack & Lewis (2017) concept of reconciliation, we hypothesize that a process-element to reconciliation could materialize through gathering market- and resource-information (regarding an OS decisions problem) and validating this information with market- and resource-sources.

Methodology

Research Design Scale Development

Sound measurement development is critical for good survey-based science and is associated with numerous challenges (Forza, 2002). Addressing this, we follow an adapted, rigorous scale development approach designed by Menor and Roth (2007). As illustrated in figure 1, they report on a two-stage approach, with the 'front-end' designed to ensure face validity and inter-rater reliability and the 'back-end' leading to construct valid and reliable scales. The two stages are linked as face validity is a prerequisite of construct validity (Forza, 2002).

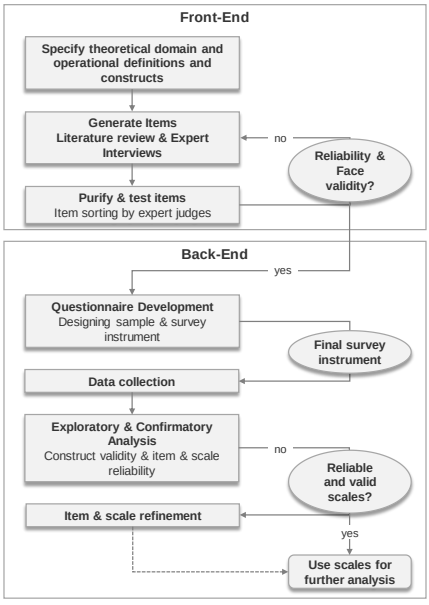

Figure 1 – scale-development process adapted from Menor & Roth (2007)

Just as with hypothesis testing, the basis for scale development is an analysis of the existing literature as discussed in the previous section. On this basis, we conducted expert interviews with five strategy professionals from three different manufacturing companies in Germany. We specifically asked them what their approach to the OS process has been in the past and how they carried out the steps they mentioned. According to the interviewees, the formation of OS is initiated by problem scoping (i.e. precisely describing the decision situation) followed by defining alternative courses of action (i.e. defining alternate scenarios) and finally by assessing the various scenarios. Problem scoping strongly relies on gathering and processing relevant qualitative and quantitative data on the strategic issue at hand. Defining and assessing scenarios is characterized as a highly communicative process, were stakeholders from various functions are involved to validate the data gathered in the first step. The experts' descriptions of OS formulation is similar to the simple illustration of Slack & Lewis (2017). Further, communication flows across functions and cross-functional collaboration were stressed by experts corresponding to the rationale of the alignment literature presented above. The expert's evaluation complemented these by adding the importance broad information from various sources. In sum, this led us to an operational definition of the reconciliation process: The balance of gathering and processing information on both, operations resources and market requirements to cross-functionally develop an understanding of the desired interplay between the two. Note that we combined the concept of alignment and harmonization with the concepts of market- and resource-based-strategies. Consequently, we hypothesize the reconciliation process to be measurable using six constructs:

- Market-Information: The significance of information regarding market requirements
- Resource-Information: The significance of information regarding operations capabilities
- Market-Source: The significance of market-related information sources
- Resource-Source: The significance of resource-related information sources
- Functional Collaboration: The extent of functional collaboration
- Cross-Functional Collaboration: The extent of cross-functional collaboration

Front-End (Prior to Data Collection)

Having defined our constructs, we generated items based on literature and expert interviews. Following Menor & Roth (2007) last 'front-end' step, we employed a modified Q-sort-method (McKeown and Thomas, 1988) to purify our items prior to sending out the questionnaire. In three rounds of item-sorting exercises we asked two subject-matter-experts (SMEs) in separate interviews to categorize a randomized list of items (Hinkin, 1998) based on their fit with the constructs. This led to nominal item-to-construct-mappings. Item-sorting allows for a quantitative measure of interrater reliability and face validity and has been advocated as a critical quality factor of survey research (Hardesty and Bearden, 2004). We interviewed representatives from academia in the first round and OS and supply chain professionals in round two and three. After each round, we calculated scores and based on these, refine definition, explanation or example of the items. First, we assess interrater reliability, i.e. the extent to which two SMEs agree on the classification of a specific item. Table 1 shows the results of our scores over all three rounds.

Table 1 – results of interrater reliability measures

Interjudge combination $C_{a/b}$	Round 1 $C_{1/2}$	Round 2 $C_{3/4}$	Round 3 $C_{5/6}$	Acceptable thresholds
Interjudge agreement percentage	76%	90%	98%	no established threshold
Cohen's *k*	0,7237	0,8997	0,9759	0,8 (0,7 for more exploratory designs)
Perreault & Leighs' I_r	0,5727	0,8289	0,9048	0,65

The interjudge agreement percentage is the ratio of pairwise agreements to the total number of pairwise judgements in one round. There is no established standard for this simple score, however a low percentage indicates confusion about the item. Cohen's *k* addresses the element of chance in the interrater agreement and Moore and Benbasat, (1991) note that a *k*-value greater than 0.65 is considered acceptable. Finally, Perrault and Leigh's I_r calculates with the number of categories an item was possibly mapped into. Here a value of 0.7 in exploratory designs is acceptable. As can be seen in table 1 threshold values are met after the second round of item-sorting. Note that values in all scores are comparably high, which is explained by item-sorting being carried out as an interview. Secondly, we checked for face validity on item-level (or substantive validity) (Anderson and Gerbing, 1991). We calculated the proportion of substantive agreement (P_{sa}) as well as the coefficient of substantive validity (C_{sv}). P_{sa} is the proportion of experts that have correctly mapped the items to the designated construct with 1 being the maximum proportion of agreement. C_{sv} additionally considers experts that have assigned the item to another construct, taking on values between -1 and 1. Each item not complying with threshold of values of 0.7 (P_{sa}) and 0.41 (C_{sv}) respectively were eliminated from the questionnaire. Finally, our initial pool of 42 items was reduced to 33 items representing the six constructs measuring the reconciliation process.

Using these items, we designed an online-questionnaire using freeonlinesurveys (https://freeonlinesurveys.com), containing not only our own items, but items inquiring about characteristics of the surveyed company, its contextual variables, its performance measures as well as its OS content. All these items are adapted from previous surveys, mainly the IMSS- or the HPM-survey, to ensure validity. Our unit of analysis is a manufacturing unit that has the autonomy to decide on strategy and, on an empirical level, a manufacturing plant. We sent out the questionnaire based on a convenience sample of 163 representatives of manufacturing plants involved in strategy-making, with a focus on the machine tooling- and automotive-sector. Each participant received a personalized e-mail along with a link to a survey that was open for eight weeks. We received 52 usable responses (32% response rate). We excluded three cases answering for non-German companies to avoid a country-bias and five cases due to sector (non-manufacturing), ending up with 44 cases. Three cases showed missing values which we estimated based on averages (Kaufman, 1985). 27 respondents represent the engineering sector (mainly machine tooling and automotive), 16 respondents other manufacturing companies (e.g. electronical devices) and 1 respondent is unclassified. Concerning positions of the respondents, 22 hold board executive positions (e.g. CEOs), 20 work in strategy-related positions (either as executive or task lead) and 2 are unclassified. The time a respondent is associated with the company she represents is on average 11 years and the time in the position indicated on average 8.6 years. One can therefore assume respondents to be experienced and knowledgeable about the surveyed content. 55% of responding companies have less and 45% more than 500 employees, making the sample

evenly split between small/mid- and large-caps (https://en.ifm-bonn.org/definitions/sme-definition-of-ifm-bonn/).

Back-End

Following Menor and Roth (2007) we analyzed the factor structure of our scale in an Exploratory Factor Analysis (EFA) and verified its internal consistency. EFA is an approach to structure data-sets through identifying groups of variables which are highly correlated with each other (Backhaus et al., 2018). Note that the precondition of both conventional EFA and Confirmatory Factor Analysis (CFA) is a reflective model. Following Backhaus et al. (2018), this means that the latent variable (e.g. market-information) influences the indicator variables (e.g. significance of customer requirements), rather than vice versa. Changes in the hypothesized construct thus also lead to changes in the measurement variables. For instance, the construct market-information is defined as the significance of market information during a strategy project. A firm values market-information because it (deliberately or not) addresses this information in its strategy process. Hence, this significance also drives the extent to which market-information is gathered. We therefore argue our model to be reflective. As discussed below, the high correlation among indicator variables empirically supports our rationale. We entered item sets per question (i.e. three models with 2 hypothesized constructs respectively) and explored the factor structure using SPSS 24. As example, results for the EFA of the first model are summarized in table 2.

Table 2 – results from EFA for model 1

Item	Market-Information	Resource-Information
Market-Info 1		0.70
Market-Info 2	0.76	
Market-Info 4	0.74	
Market-Info 5	0.67	
Market-Info 6	0.69	
Market-Info 8	0.81	
Resource-Info 1		0.92
Resource-Info 2		0.83
Resource-Info 3		0.65
Eigenvalue	4.99	1.90
Percentage of variance explained	36	14
Cumulative percentage of variance explained	36	50
Cronbach's α reliability measure	0.81	0.79
Notes: n=44		
Extraction Method: pricipal component		
Loadings below 0.65 not displayed		
Rotation Method: Oblimin with Kaiser normalization in 8 iterations		

Restricting to two hypothesized factors, we first checked for factorability by different means. The overall Kaiser-Meyer-Olkin (KMO) criterion of sampling adequacy yielded 0.72 which is above the recommended threshold (Hair et al., 2014) (Kaiser, 1970). Bartlett's test of sphericity was highly significant ($p<0.001$) indicating adequate correlations among the variables (Bartlett, 1950) (Hair et al., 2014). Next, principal component analysis with oblimin rotation was performed for the 14 items. We iteratively eliminated five items due to high cross or low factor loadings less than the recommended 0.65 (Hair et al., 2014). Interestingly, Market-Info 1 loads highly into Resource-Info, which is contrary to the hypothesized loading. This is addressed in the CFA. The remaining two sets of items have an Eigenvalue of at least 1.9 and explain 50% of the total variance, which is lower than the recommended value (Hair et al., 2014). With nine items and 44 observations, the observations-to-item-ratio is 4.9:1,

which is marginally below the recommended 5:1 rule of thumb (Bryant and Yarnold, 1995) (Hair et al., 2014). However, this ratio can be seen critically (Arrindell and Van Der Ende, 1985). Inter-item-correlations and item-to-total-correlations range between 0.3 and 0.62, exceeding the suggested threshold of 0.3 (Hair et al., 2014). Finally, Cronbach's α ranges from 0.79 to 0.81, which is above the required value of 0.7 (Nunnally, 1978). In conclusion, all of the above provides evidence that the items are reliable and that the constructs developed are internally consistent.

Analogous to the first model, we conducted an EFA with the second (market-source and resource-source) as well as the third model (functional and cross-functional). The results are briefly summarized in the following. In the second model values for the KMO (0.71) were again acceptable and so was the measure for sampling adequacy (Bartlett's test highly significant at $p<0.001$). Restricting the model to two factors lead to consistent loadings. We eliminated seven items due to high cross- or low factor loadings. Interestingly, resource-source 6 (quality management) loaded into market-source rather than its hypothesized construct. People seem to understand quality management not only as a source of information about the product's quality but also as a function translating quality requirements from the market into product requirements. We address this item specifically during the CFA. With seven remaining items, the observations-to-item-ratio was above the recommended 5:1 threshold (Bryant and Yarnold, 1995) (Hair et al., 2014). Inter-item-correlations and item-to-total-correlations are between 0.3 and 0.6 and therefore acceptable (Hair et al., 2014). Model three shows consistent and high factor loadings. No items were eliminated. With KMO at 0.66 and Bartlett's test highly significant ($p<0.001$) factorability and sampling adequacy is supported. Inter-item and item-to-total-correlations range between 0.54 and 0.89. Observations-to-item-ratio exceeds the recommended cut-off-value (Hair et al., 2014). However, the Eigenvalue of the second construct is relatively low (0.8) and Cronbach's α (0.67) is just below the threshold (Nunnally, 1978). This indicates issues with the second factor. Nevertheless, we decided to proceed with the two-factor-solution in the second model, due to consistent and high loadings.

In order to assess construct validity and confirm the factor structure resulting from the EFA, we conducted a CFA. We employed a structural-equations-modelling-approach using SPSS AMOS 24. CFA demonstrates that collapsing all items into one construct is empirically less sound than the respective a priori structure of a model. Construct validity is usually measured through convergent and discriminant validity (Campbell and Fiske, 1959). Convergent validity describes the degree of convergence of a set of items. Discriminant validity assesses if items, which are intended to measure different latent variables (constructs) actually do so (Bagozzi and Yi, 2012). We conducted three CFAs – one for each model with two latent variables and the respective indicator variables. The first model (market- and resource-info) was entered with nine items (five for market- and four for resource-info) resulting from the EFA. The first iteration showed relatively low loadings with market-info 6 not loading significantly. Moreover, the a priori model still had market-info 1 loading into the latent variable resource-info. We therefore decided to eliminate both items during a second iteration. This led to highly significant factor loadings ($p<0.001$) with average loadings per factor above 0.7. As can be seen in table 3 construct reliabilities (CR) are above the recommended 0.7 and the average variance extracted (AVE) are above 0.5 suggesting convergent validity. The maximum shared variance (MSV) and the average shared variance (ASV) for the two constructs is below the AVE, strongly indicating discrimination between them (Hair et al., (2014)) (Fornell and Larcker, 1981). Further exploring discriminant validity, we calculate the inter-construct-correlations and

compare to the square-root of the AVE. Inter-correlation marginally exceed the square-root of the AVE in the second decimal. In sum, all measures support that the two constructs are valid and capture unique aspects. To analyze the a priori specification of the resulting model, we compared several goodness of fit indices (Edwards, 2001) (Hu and Bentler, 1999). SPSS AMOS automatically calculates numerous indices, however, we focused on those most affected by sample size (Fan et al., 1999). The root mean square error of approximation (RMSEA) has a recommended value below 0.06. The comparative fit index (CFI) as well as the Tucker Lewis index (TLI), sometimes also referred to as the nonnormed fit index (NNFI), both have acceptable values larger than 0.95. These values are conservative, which addresses our relatively small sample size (Hair et al., (2014)). As shown in table 3 our final model meets these values.

Table 3 – results from CFA for final model 1 after eliminations

Construct	CR	AVE	MSV/ASV	RMSEA	CFI	TLI
1. Market-Info	0.82	0.54	0.13/0.13	<0.001	0.99	1,12
2. Resource-Info	0.79	0.56				

Notes: n=44

Hence, the first model showed a remaining seven items for the two constructs. Similarly, we conducted the CFA for models two and three. For Model two (market- & resource-source) we received low and non-significant loadings in the first iteration using the initially hypothesized structure. In the second iteration, we opted for the structure resulting from the EFA which meant that we linked resource-source 6 (quality management) to the market-source construct. Furthermore, we deleted another item due to low and non-significant loading. This improved factor loadings with all of them being significant at $p<0.05$ as well as CR and AVE. Merely the first construct indicated issues with convergence at an AVE of slightly below 0.5. Model-fit-indices were all above thresholds. Finally, model three (functional and cross-functional) was assessed using the structure provided by the EFA, resulting in overall acceptable values for validity and model-fit. Only the relatively high value for MSV and ASV indicate potential problem for discriminant validity. However, with AVE of both constructs still exceeding them, we argue this scale still captures sufficiently unique aspects.

Discussion

To conclude, our scale development approach resulted in six constructs with a total of 17 items (~40% of the initial pool). Figure 2 summarizes quantitative part of the scale development. The scales at hand have several limitations that the researcher needs to be aware of when using the scales for further analysis. First, due to low maturity of the subject, there is only a narrow range of literature available for the definition of constructs and generation of items. Second, we operate based on a convenience sample not a randomized sample representing all manufacturing or automotive companies in Germany. The robustness of scales needs to be validated based on a larger, randomized sample. Third and probably linked to the previous points, we do encounter minor issues, particularly with discriminant validity. This needs consideration in the interpretation of further analysis based on these scales. Despite all these limitations, we argue that we have developed first constructs to capture a potential reconciliation process rigorously and empirically supported. All threshold values are chosen conservatively to combat doubt regarding our sample adequacy and our scales meet these recommended values. Finally, we argue that the contribution of these scales also lies in their simplicity and

relatability for practitioners. All items used as indicator variables are practical realities strategists are confronted with regularly.

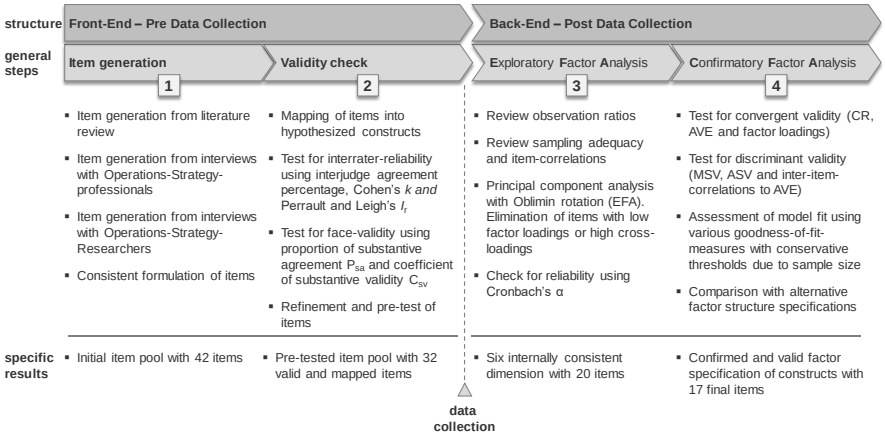

Figure 2 – summary of quantitative part of scale development. Own illustration based on (DeVellis, (2016))

Outlook

The contribution of our study is twofold. First, we contribute methodologically, by developing a sound and easily reproducible scale for measuring some aspects of the OS-process in general and the relevant aspects of the reconciliation process in particular. Second, the presented scale-development serves as a first step in a larger work empirically testing the concept of reconciliation more extensively. Slack & Lewis claim that companies ought to pursue a harmonization of market- and resource-based perspectives. In other words, they posit that successful companies balance both elements, consciously and deliberately weighing them against each other. Based on our work, the next step is to conduct a statistical analysis, e.g. hierarchical cluster analysis, to empirically test whether companies in fact address the goal of a reconciled strategy in their strategy-process.

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The impact of CEO stock options on supply chain stability and the moderating role of a powerful COO

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Abstract

Supply chain disruptions (SCDs) remain one of the most significant threats to firms' performance. In this study we investigate chief executive officer (CEO) stock options as an antecedent of SCDs. Based on an eleven-year sample of more than 2,000 disruptions in U.S. S&P 500 firms we conceptually and empirically explain an inverted U-shaped relationship between CEO stock options and SCDs. We contribute to research the investigation of a previously neglected antecedent of SCDs, a more nuanced view on the strategic impact of CEO stock options, and insights on the moderating effect of relative chief operating officer (COO) power.

Keywords: Supply chain disruptions, CEO stock options, COO power

Full Paper

Introduction

Business interruption risks remain a significant threat to firms' performance. Despite the high importance of SCDs for academia and practice, their causes are neither conclusively identified nor empirically well understood. Moreover, even though their decisions directly influence the supply chain, the impact of decision makers in charge of operations management is also neglected in operations management research (Hendricks, Hora, & Singhal, 2014). In this context, stock options are supposed to evoke more aggressive risk-taking by otherwise rather risk-averse executives in alignment with the shareholders' interests. The concept of stock options allows executives to participate from the potential upsides of high-risk decisions with limited downside risks due to their optionality. This also comprises an increased willingness to take risks with regards to supply chain

management. Recent studies are ambiguous regarding the effectiveness of CEO options and call for further research on contingency factors impacting managerial risk taking (Benischke et al., 2019; Wowak, at al., 2015).

By contrasting agency and behavioral agency theory, we investigate the impact of CEO options on SCDs and the moderating effects of relative COO power and market uncertainty (see figure 1). We draw upon a unique, hand-collected sample of more than 2,100 firm-year observations over the years 2006 to 2016 with more than 2,000 SCDs in 223 S&P 500 firms. To support our manual sampling process, we used a machine learning algorithm to identify potentially relevant SCDs from more than 450,000 press announcements.

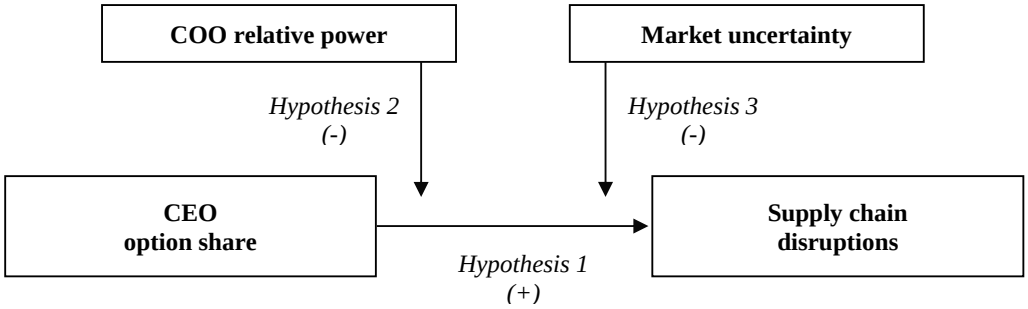

Figure 1 – Simplified research model

Our study contributes to operations management research in multiple ways. First, we identify and empirically investigate CEO options as a widely neglected organizational antecedent of SCDs. Second, we establish an inverted U-shaped relation between CEO options and SCDs enhancing research on CEO options with a more nuanced perspective on the effects of CEO options. Third, our study highlights the importance of having a powerful COO in the top management team with regards to supply chain stability. Fourth, we emphasize the necessity of adopting a contingency perspective when assessing CEO options and SCD risks. Finally, we introduce machine learning as a supporting technique to empirical secondary data research in operations management.

Theoretical background

SCDs

Prevailing research on SCDs emphasizes their harmful consequences: Hendricks & Singhal in several studies found, that SCDs diminish stock returns, market and shareholder value, and reduce sales over several years following a disruption (1997, 2003, 2005). In line with Hendricks & Singhal (2003) we define SCDs as unexpected events in the supply chain or its environment that threaten the normal business operations of a firm. Existing studies on SCDs vary strongly in the events being considered. Based on related supply chain risk literature, we use a dichotomous classification to cluster the SCDs used in our study. First, we separate micro- and macro-SCD-risks being in- and external to the organization (Wu et al., 2006). As we in this study investigate the effects of CEO stock options on SCDs, we exclusively focus on micro-disruptions which can directly be influenced by the firms. Loosely following the meta-analysis by Ho et al. (2015), we consider the following micro-disruptions in our study: demand and supply mismatches, delays, outages (of machinery or production), strikes, product quality issues, recalls, infrastructural problems, and issues of adverse business conduct. In line with Hendricks

& Singhal's understanding of supply chain management and its subsystems, we assume that executives either indirectly (through negligence of important operations processes) or directly (through active strategic decisions or conscious misconduct) effect SCDs (2014).

(Behavioral) Agency Theory and CEO Options

The basis of agency theory and research on CEO options is the separation of ownership and management in firms, leading to potentially diverging interests between shareholders (principals) and managers (agents) (Jensen & Meckling, 1976). Principals delegate the management of the business to the agent (i.e. the CEO), who is assumed to act in their best interest. In this context, agency theory assumes, that agents are risk-averse. Stock options are supposed to reduce the CEOs' risk-aversion by offering the CEO the opportunity to profit from firm success while not suffering from potential loss (Wiseman & Gomez-Mejia, 1998). Since CEO options are meant to influence a CEO's behavior, behavioral agency theorists pronounce the need to combine agency with behavioral decision theory to fully explain its effects (Martin et al., 2016). Behavioral agency theory enhances agency theory by prospect theory to explain managerial risk-taking (Wiseman & Gomez-Mejia, 1998). Prospect theory postulates that managerial decision behavior depends on individual valuation of potential gains and losses to the personal wealth (Kahneman & Tversky, 1979) with wealth being understood as current, just-received, and fully anticipated wealth. Accordingly, agents weigh anticipated future wealth against declines in current endowed wealth (Benischke et al., 2019).

Development of hypotheses

CEO options and SCDs

If not in charge of operations themselves, CEOs have a strong impact on strategic decision-making regarding initiatives that affect company operations, such as cost-reduction programs, process-oriented programs (e.g. quality management, working capital management), or budgeting (e.g. R&D spending) (Wowak et al., 2015). Overly risky decisions in pursuit of stock performance optimization, thus, have the potential to evoke SCDs. Whereas agency theorists postulate a linear relation between CEO options and managerial risk-taking, based on the behavioral agency theory we assume that the relation between stock options and risk-taking is more nuanced and driven by two latent interacting forces: the perceived benefits in case of success and the perceived costs in case of loss associated with higher risk-taking by the CEO. CEOs with a low stock option share have little incentive to take risky decisions, as they only limitedly benefit from increasing share prices if the high-risk initiative achieves anticipated results. However, they have much to lose in terms of non-financial wealth or imminent penalties. With an increasing but still moderate CEO option share, the financial incentive to take risks increases, as the fully anticipated wealth assigned to high-risk initiatives becomes more compelling. As risk-taking preferences of an agent vary depending on the executives' framing of the situation and anticipated effects on the personal wealth (Sitkin & Weingart, 1995), the CEO will constantly weigh benefits and costs of risky decisions against his current endowed wealth. Up to a certain point depending on the personal risk-taking preference, the incremental benefits of taking additional risks will overweigh the perceived incremental costs and will cause CEOs to ignore indications of project failure, to be negligent about risk mitigation, or to ignore downside risks of their decision (Wowak et al., 2015). As a consequence, we assume SCDs to increase. Following our logic of decreasing marginal benefits and increasing marginal cost of taking high-risk

decisions, we argue that with a high option share relative to the CEOs total compensation, risk-taking decreases as the CEO considers a large part of his prospect wealth at risk.

Hypothesis 1 (H1): CEO options exhibit an inverted U-shaped relationship to the frequency of SCDs, such that firms with low and high CEO option shares will experience fewer SCDs than those with medium CEO option shares

CEO options, market uncertainty, SCDs

When analyzing managerial risk-taking behavior, market uncertainty being defined as the extent to which a CEO faces an unpredictable and unstable environment (Finkelstein & Boyd, 1998) is arguably of special interest. Uncertain markets are characterized by constant variations in customers, preferences, and competition and increased supply chain risks per se (Trkman & McCormack, 2009). This will enhance the perceived costs of additional risk-taking by the CEO. Moreover, research suggests that with increasing market uncertainty firms face higher complexity in their task environment and an increased need to review and adjust strategies continuously (Miller & Friesen, 1983). This increases the alignment efforts within the top management team (TMT), which restricts the CEO in making high-risk decisions. Finally, with less predictability of the market and a growing amount of personal wealth being linked to firm performance, CEOs tend to become increasingly risk-averse and seek to preserve personal wealth (Wiseman & Gomez-Mejia, 1998). As the marginal costs increase as compared to the marginal benefit related to additional risk-taking, the U-shaped relationship between CEO options and SCDs is flattened, thus SCDs decrease.

Hypothesis 2 (H2): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter in markets where uncertainty is high and (b) steeper in markets where uncertainty is low.

CEO options, relative COO power, SCDs

Past research suggests that the increasing marginal cost curve counteracting the marginal benefits of CEO options might increase in the presence of a powerful COO. Power is defined as the extent to which the COO can influence the behavior of others and has the discretion to shape and implement strategic decisions in his interest (Finkelstein, 1992). The COO frequently is delegated responsibilities usually held by the CEO. He, thus, reduces power distance in the TMT and constrains the power otherwise centralized in the position of the CEO (Worrel et al., 1997). With increasing power of the COO, the CEO needs to more closely involve him when initiating strategic changes in a firm's operations. By creating a task-oriented conflict between CEO and COO, decisions are made in a process of social interactions that reveals differing assumptions and expectations (Marcel, 2009). This alignment process will arguably constrain the CEO's tendency to disproportionally focus on upside potential of high-risk decisions with regards to operations and, in turn, increase the CEOs perceived risk to be blamed with a negative outcome of a high-risk initiative if pursued against opposition. Second, power structures in TMTs can create conflicts among executives. By contending the power of the CEO, the COO takes a monitoring role towards the CEO. This is based on an inherent competition between the CEO and COO and the fact that a weak performance of the operations function being visible to the external labor market might harm future employment opportunities of the COO (Fama, 1980). Third, the functional backgrounds represented in the TMT influence the salience of certain organizational objectives and performance drivers (Marcel, 2009). While Hayward & Hambrick show that CEOs – a

role rather focused on output-oriented than internal processes – tend to be more risk-seeking with higher individual power (1997), COOs will presumably act in the foremost interest of their functional responsibility and, thus, will challenge overly risky decision based on a profound understanding of the operations function.

Hypothesis 3 (H3): The inverted U-shaped relationship between CEO options and SCDs is (a) flatter, when the relative power of the COO is high and (b) steeper, when the relative power of the COO is low.

Data and methods

Sample

To empirically test our hypotheses, we gathered more than 2,000 SCDs from PR Newswire press announcements in the Factiva database from 223 publicly traded S&P 500 firms in the U.S. between 2006-2016. Based on the taxonomy developed above, we identified key search terms to identify first relevant disruption announcements per category, following the procedure of Hendricks & Singhal (2005). To handle the number of announcements and support our manual coding process, we developed a supervised machine learning algorithm, using python 3.6 & scikit-learn libraries, to automatically identify potentially relevant announcements based on both, title and body of the announcements. We re-read all announcements tagged as potentially relevant by the algorithm to judge the appropriateness, discussed unambiguous announcements. We, then, clustered the announcement into the SCD categories introduced above, using triple coding technique and regularly testing for intercoder reliability (Daniel & Harland, 2018). We then merged this SCD sample with TMT data from S&P Capital IQ's ExecuComp and firm characteristics from S&P Capital IQ's Compustat.

Measures

We operationalized our dependent variable (DV) *supply chain disruptions* as count variable (i.e. the number of recalls of firm i in year t), ranging from 0 to 8 in our sample. Our independent variable (IV) *CEO options* was operationalized as the share of stock options granted relative to the total compensation of the CEO as reported by ExecuComp. Following prior research, we calculated this variable as a two-year weighted average (Wowak et al., 2015).

With regards to our moderating variables, we put our focus on the presence of the COO role rather than on the title as such, following Hambrick & Canella (2004). We operationalized COO relative power as the COO's total compensation relative to the total compensation of the highest paid TMT member (the CEO). This definition implies that higher relative compensation ratios indicate higher power in the TMT (Daily & Johnson, 1997). We operationalized market uncertainty as the coefficient of variation of sales per industry on four-digit SIC code level in a given year (Tosi et al., 1973).

To increase robustness of our research model we included multiple control variables on firm-, industry- and TMT-level. On firm-level, we controlled for *firm size*, *financial slack*, *operating performance*, past financial performance using *Tobin'sQ*, *R&D intensity*, and *capital intensity*. On environmental-level, we controlled for *market uncertainty*, *technological turbulence*, and *technological sophistication*. On TMT-level we considered *TMT size*, *TMT ownership structure*, *CEO duality*, and *COO relative power*.

Since firms with a history of SCDs may be more likely to subsequently encounter problems, we included lagged DVs in all models. Finally, all research models contain *year* and *industry dummies*. We lagged all variables in our model (except for the DV) by

one year to account for the fact, that strategic decisions based on information in a given year, will take time to become effective (Souder & Bromiley, 2012). All continuous variables are winsorized at the 1.0% level to avoid bias from outliers.

Model

We use STATA's generalized estimating equation (GEE) model to analyze our unbalanced and pooled cross-sectional time-series data, following structurally similar studies based on longitudinal data (Wowak et al., 2015). GEE measures the effect on the DV "population-averaged" across all units in the data set, thus, considering both, within- and between-unit variation. Unlike alternative approaches (e.g. random- or fixed-effect models), GEE can deal with potential heteroscedasticity and serial correlation as it accounts for both inter- and intra-firm variations (Shah et al., 2016). Moreover, GEE does not (wrongfully) omit "zero SCD" firms (Sine et al., 2003).

Results

Table 1 provides descriptive statistics (unstandardized) and correlations (standardized) for all variables used in our models. The top right part of the matrix shows Spearman's rank-order correlations, the bottom left values show Pearson's product-moment correlations. The fact there is no significant correlation between CEO options and SCDs might be a first indication that the relationship might indeed not be linear rather curvilinear / U-shaped.

Table 1 – Descriptive Statistics and Correlations

Variables	M	SD	Min	Max	1.	2	3.	4	5	6	7.	8	9	10	11	12	13	14	15	16
1. Supply chain disruptions	0.77	1.52	0.00	8.00	1.00 (0.00)	0.49 (0.00)	0.00 (0.92)	0.00 (0.92)	0.29 (0.00)	0.20 (0.00)	0.29 (0.00)	-0.04 (0.08)	0.02 (0.33)	0.14 (0.00)	0.00 (0.68)	-0.02 (0.36)	0.02 (0.32)	0.05 (0.02)	0.08 (0.00)	0.05 (0.03)
2. Supply chain disruptions (lagged)	0.77	1.51	0.00	8.00	0.63 (0.00)	1.00 (0.00)	-0.03 (0.19)	-0.03 (0.19)	0.29 (0.00)	0.21 (0.00)	0.29 (0.00)	-0.04 (0.05)	0.03 (0.14)	0.14 (0.00)	0.01 (0.54)	-0.01 (0.63)	0.04 (0.08)	0.03 (0.10)	0.06 (0.01)	0.05 (0.02)
3. CEO options	0.22	0.19	0.00	0.84	-0.03 (0.16)	-0.05 (0.02)	1.00 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.02)
4. CEO options squared	0.08	0.12	0.00	0.71	-0.04 (0.02)	-0.05 (0.03)	0.91 (0.00)	1.00 (0.00)	-0.07 (0.00)	-0.05 (0.01)	-0.04 (0.04)	0.06 (0.01)	0.05 (0.03)	-0.04 (0.09)	0.02 (0.27)	0.04 (0.05)	0.08 (0.00)	-0.03 (0,13)	-0.48 (0.00)	0.05 (0.01)
5. Firm Size	9.70	1.11	7.57	12.51	0.34 (0.00)	0.35 (0.00)	-0.08 (0.00)	-0.08 (0.00)	1.00 (0.00)	0.64 (0.00)	0.92 (0.00)	-0.35 (0.00)	-0.05 (0.03)	0.08 (0.00)	0.10 (0.00)	-0.01 (0.75)	0.05 (0.03)	0.03 (0.11)	0.18 (0.00)	0.19 (0.00)
6. Financial Slack	7.21	1.47	3.56	10.82	0.26 (0.00)	0.27 (0.00)	-0.04 (0.04	0.01 (0.65)	0.65 (0.00)	1.00 (0.00)	0.61 (0.00)	0.03 (0.18)	0.34 (0.00)	-0.18 (0.00)	0.24 (0.00)	0.33 (0.00)	0.35 (0.00)	0.02 (0.25)	0.17 (0.00)	0.05 (0.03)
7. Operating Performance	7.81	1.11	5.59	10.67	0.34 (0.00)	0.34 (0.00)	-0.07 (0.00)	-0.07 (0.00)	0.92 (0.00)	0.63 (0.00)	1.00 (0.00)	-0.11 (0.00)	-0.05 (0.03)	0.18 (0.00)	0.10 (0.00)	-0.03 (0.11)	0.03 (0.14)	0.02 (0.48)	0.16 (0.00)	0.22 (0.00)
8. Financial Performance	2.09	1.03	0.57	8.64	0.01 (0,73)	-0.02 (0.43)	0.07 (0.00)	0.12 (0.00)	-0.33 (0.00)	0.04 (0.09)	-0.12 (0.00)	1.00 (0.00)	0.30 (0.00)	-0.14 (0.00)	0.13 (0.00)	0.23 (0.00)	0.15 (0.00)	-0.04 (0.07)	-0.05 (0.03)	-0.06 (0.00)
9. R&D Intensity	0.03	0.05	0.00	0.68	0.03 (0.13)	0.05 (0.03)	0.09 (0.00)	0.16 (0.00)	-0.14 (0.00)	0.27 (0.00)	-0.12 (0.00)	0.33 (0.00)	1.00 (0.00)	-0,37 (0.00)	0.41 (0.00)	0.90 (0.00)	0.67 (0.00)	0.02 (0.22)	0.03 (0.09)	-0.06 (0.00)
10. Capital Intensity	0.49	0.36	0.03	1.61	0.12 (0.00)	0.13 (0.00)	-0.08 (0.00)	-0.11 (0.00)	0.14 (0.00)	-0.18 (0.00)	0.20 (0.00)	-0.17 (0.00)	-0.32 (0.00)	1.00 (0.00)	-0.09 (0.00)	-0.45 (0.00)	-0.42 (0.00)	0.00 (1.00)	0.07 (0.00)	0.19 (0.00)
11 Market uncertainty	2.60	1.74	0.32	8.21	0.03 (0.10)	0.04 (0.11)	0.04 (0.06)	0.10 (0.00)	0.10 (0.00)	0.23 (0.00)	0.13 (0.00)	0.16 (0.00)	0.36 (0.00)	0.01 (0.67)	1.00 (0.00)	0.50 (0.00)	0.40 (0.00)	0.06 (0.01)	0.14 (0.00)	-0.12 (0.00)
12 Technological turbulence	0.04	0.06	0.00	0.49	0.04 (0.07)	0.06 (0.01)	0.06 (0.00)	0.13 (0.00)	-0.00 (0.86)	0.36 (0.00)	0.10 (0.61)	0.26 (0.00)	0.74 (0.00)	-0.38 (0.00)	0.50 (0.00)	1.00 (0.00)	0.73 (0.00)	0.02 (0.49)	0.05 (0.01)	-0.10 (0.00)
13 Technological sophistication	0.31	0.46	0.00	1.00	0.00 (0.83)	0.02 (0.31)	0.11 (0.00)	0.15 (0.00)	0.03 (0.10)	0.34 (0.00)	0.02 (0.26)	0.12 (0.00)	0.58 (0.00)	-0.40 (0.00)	0.31 (0.00)	0.72 (0.00)	1.00 (0.00)	0.01 (0.80)	0.03 (0.16)	-0.08 (0.00)
14 TMT size	5.62	0.88	4.00	9.00	0.05 (0.03)	0.34 (0.11)	-0.02 (0.31)	0.00 (0.84)	0.04 (0.08)	0.02 (0.42)	0.01 (0.70)	-0.05 (0.02)	0.02 (0.31)	0.00 (0.91)	0.06 (0.01)	0.3 (0.19)	0.01 (0.66)	1.00 (0.00)	0.05 (0.01)	-0.07 (0.00)
15 TMT ownership structure	0.36	0.22	0.00	0.95	0.11 (0.00)	0.10 (0.00)	-0.49 (0.00)	-0.39 (0.00)	0.20 (0.00)	0.20 (0.00)	0.19 (0.00)	-0.04 (0.04)	0.05 (0.01)	0.09 (0.00)	0.18 (0.00)	0.11 (0.00)	0.04 (0.08)	0.06 (0.01)	1.00 (0.00)	-0.05 (0.03)
16 CEO duality	0.62	0.48	0.00	1.00	0.06 (0.00)	0.07 (0.00)	0.02 (0.26)	-0.02 (0.36)	0.19 (0.00)	0.03 (0.23)	0.21 (0.00)	-0.05 (0.01)	-0.15 (0.00)	0.15 (0.00)	-0.14 (0.00)	-0.16 (0.00)	-0.08 (0.00)	-0.07 (0.00)	-0.06 (0.00)	1.00 (0.00)

Notes: Table exhibits Spearman's rank-order correlations top right and Pearson's product-moment correlations bottom left with ρ values in parentheses; $N = 2{,}134$

As we have COO presence in only 53.6% of all firm-year observations we shrink our sample size by 990 observations with the inclusion of the COO power moderator and control variable. Accordingly, we tested hypotheses 1 and 2 ex ante in separate models without the COO power variables. We repeated the tests in a second group of models including the COO power moderator and variables to test hypothesis 3. This approach allowed us to test hypotheses 1 and 2 without a potential COO presence selection bias

(which we separately tested for as described below) and served as a first robustness test for the effects investigated in hypotheses 1 and 2. Table 2 exhibits the results of the regression analysis. Model 1-1 contains control variables only. Model 1-2 tests the main effect and model 1-3 includes the main and the first interaction effect without the COO power variables. Models 2-1 to 2-3 are identic in structure to models 1-1 to 1-but include the COO power variables. Model 2-4 additionally contains the second interaction term. Model 2-5 is the full model with the main and both interaction effects. All models are highly significant (p<0.01) and show increasing Wald χ^2 statistics with inclusion of the IV and additional moderators. Despite the drop of 990 firm-year observations between model 1 and 2 all results remain constant for both, the main and interaction effect, indicating a high robustness.

Table 2 – Regression Results: Effect of CEO options on Supply Chain Disruptions

	Model 1			Model 2					Robustness Tests					
Independent variables	**(1-1)**	**(1-2)**	**(1-3)**	**(2-1)**	**(2-2)**	**(2-3)**	**(2-4)**	**(2-5)**	**(3-1)**	**(3-2)**	**(3-3)**	**(3-4)**	**(3-5)**	**(3-6)**
CEO options		0.319**	0.423**		0.341*	0.504**	0.358**	0.507**	0.229**	0.227*	0.580**	0.402**	0.533**	0.502**
		(0.100)	(0.101)		(0.137)	(0.135)	(0.131)	(0.137)	(0.077)	(0.103)	(0.142)	(0.135)	(0.140)	(0.138)
CEO options squared		-0.270**	-0.401**		-0.349*	-0.555**	-0.371**	-0.556**	-0.240**	-0.238**	-0.751**	-0.380**	-0.577**	-0.554**
		(0.101)	(0.104)		(0.138)	(0.148)	(0.131)	(0.150)	(0.069)	(0.079)	(0.160)	(0.129)	(0.149)	(0.149)
Firm Size	0.347†	0.377†	0.356†	0.483*	0.501*	0.459*	0.493*	0.457*	0.298**	0.284**	0.498*	0.487*	0.524**	0.479*
	(0.196)	(0.193)	(0.192)	(0.221)	(0.222)	(0.214)	(0.219)	(0.213)	(0.298)	(0.055)	(0.209)	(0.216)	(0.201)	(0.202)
Financial Slack	-0.008	0.001	0.011	-0.046	-0.032	-0.015	-0.036	-0.023	-0.021	-0.020	-0.038	-0.034	-0.014	-0.027
	(0.084)	(0.083)	(0.083)	(0.109)	(0.110)	(0.109)	(0.109)	(0.109)	(0.054)	(0.057)	(0.106)	(0.107)	(0.107)	(0.110)
Operating Performance	0.159	0.127	0.134	0.061	0.032	0.042	0.019	0.027	0.030	0.044	-0.025	-0.003	0.017	0.007
	(0.194)	(0.195)	(0.191)	(0.223)	(0.224)	(0.216)	(0.219)	(0.212)	(0.107)	(0.041)	(0.209)	(0.215)	(0.203)	(0.200)
Financial Performance	0.030	0.043	0.231	0.068	0.084	0.052	0.060	0.034	0.066†	0.061*	0.048	0.034	0.012	0.027
	(0.059)	(0.062)	(0.061)	(0.077)	(0.095)	(0.075)	(0.066)	(0.064)	(0.035)	(0.031)	(0.072)	(0.074)	(0.067)	(0.070)
R&D Intensity	0.094	0.108†	0.107†	0.149†	0.173*	0.173*	0.183*	0.182*	0.058	0.058	0.193*	0.170*	0.227**	0.177*
	(0.064)	(0.032)	(0.627)	(0.077)	(0.074)	(0.076)	(0.073)	(0.074)	(0.053)	(0.040)	(0.079)	(0.076)	(0.072)	(0.081)
Capital Intensity	0.149*	0.150*	0.152*	0.116	0.113	0.109	0.113	0.111	0.046	0.045*	0.109	0.119	0.116	0.114
	(0.070)	(0.070)	(0.070)	(0.085)	(0.085)	(0.083)	(0.085)	(0.083)	(0.042)	(0.021)	(0.080)	(0.083)	(0.086)	(0.082)
Market uncertainty	0.089	0.100	0.103	0.051	0.075	0.069	0.087	0.081	-0.001	-0.002	0.040	0.048	0.066	0.097
	(0.098)	(0.094)	(0.966)	(0.113)	(0.111)	(0.108)	(0.113)	(0.110)	(0.053)	(0.033)	(0.100)	(0.103)	(0.111)	(0.109)
Technological turbulence	0.100	0.084	0.101	0.055	0.026	0.058	0.017	0.049	-0.006	-0.006	0.072	0.077	0.043	0.052
	(0.078)	(0.076)	(0.079)	(0.098)	(0.095)	(0.095)	(0.093)	(0.094)	(0.069)	(0.051)	(0.093)	(0.095)	(0.095)	(0.098)
Technological sophistication	-0.016	-0.008	-0.033	-0.153	-0.142	-0.151	-0.173	-0.178	-0.047	-0.048	-0.119	-0.184	-0.190	-0.174
	(0.206)	(0.199)	(0.199)	(0.217)	(0.214)	(0.212)	(0.212)	(0.211)	(0.118)	(0.067)	(0.200)	(0.208)	(0.215)	(0.212)
TMT size	0.060†	0.615†	0.602†	0.070	0.065	0.072†	0.073	0.079†	0.065	-0.063	0.076†	0.081†	0.106*	0.080†
	(0.034)	(0.034)	(0.034)	(0.045)	(0.045)	(0.044)	(0.045)	(0.044)	(0.035)	(0.031)	(0.042)	(0.044)	(0.485)	(0.044)
TMT ownership structure	0.013	0.518	0.054	0.067	0.099*	0.097†	0.073†	0.095†	0.084	0.086**	0.091†	0.107*	0.101†	0.092†
	(0.041)	(0.043)	(0.044)	(0.046)	(0.050)	(0.053)	(0.049)	(0.051)	(0.041)	(0.031)	(0.050)	(0.496)	(0.051)	(0.052)
CEO duality	-0.944	-0.892	-0.095	-0.097	-0.125	-0.122	-0.118	-0.115	-0.088	-0.086*	-0.081	-0.098	-0.117	-0.144
	(0.097)	(0.010)	(0.097)	(0.138)	(0.142)	(0.136)	(0.135)	(0.132)	(0.070)	(0.042)	(0.127)	(0.131)	(0.133)	(0.141)
Supply chain disruptions (lagged)	0.248**	0.246**	0.248**	0.252**	0.257**	0.273**	0.273**	(0.286**	0.606**	0.606**	0.282**	0.276**	0.274**	0.286**
	(0.043)	(0.044)	(0.044)	(0.053)	(0.053)	(0.528)	(0.049)	(0.049)	(0.061)	(0.032)	(0.047)	(0.047)	(0.050)	(0.049)
COO relative power				-0.059	-0.050	-0.059	-0.081	-0.087	-0.047	-0.047†	-0.105*	-0.106*	-0.107†	-0.087†
				(0.056)	(0.056)	(0.056)	(0.051)	(0.052)	(0.036)	(0.027)	(0.051)	(0.053)	(0.057)	(0.053)
Market uncertainty x CEO options			-0.205*			-0.347**		-0.327**	-1.44*	-0.140†	-0.5117**	-0.391**	-0.323**	-0.336**
			(0.090)			(0.125)		(0.123)	(0.072)	(0.082)	(0.127)	(0.132)	(0.121)	(0.127)
Market uncertainty x CEO options squared			0.204*			0.355**		0.338**	0.158*	0.153*	0.526**	0.356**	0.338**	0.347**
			(0.087)			(0.106)		(0.106)	(0.063)	(0.068)	(0.120)	(0.114)	(0.105)	(0.110)
COO relative power x CEO options							-0.340**	-0.316**	-0.197*	-0.198**	-0.267	-0.343	-0.314**	-0.310**
							(0.102)	(0.098)	(0.079)	(0.050)	(0.108)*	(0.117)**	(0.097)	(0.097)
COO relative power x CEO options squared							0.277**	0.243**	0.176**	0.179**	0.124	0.235*	0.243**	0.237**
							(0.097)	(0.082)	(0.062)	(0.036)	(0.103)	(0.104)	(0.081)	(0.082)
Inverse Mills ratio (IMR)													-0.106	
													(0.080)	
CEO options (predicted)														0.160
														(0.332)
CEO options squared (predicted)														-0.144
														(0.247)
Observations	2,134	2,134	2,134	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144	1,144
Number of firms	223	223	223	205	205	205	205	205	205	205	205	205	205	205
Wald χ^2 / R^2	1920.16***	2036.03***	2151.58***	467.69***	551.63***	630.06***	570.21***	654.27***	0.377**	0.377**	748.17**	572.10**	662.28**	710.75**

Notes: Robust standard errors in parentheses. Industry and year dummies included but not shown
† p<0.10; * p<0.05; ** p<0.01; two-tailed tests

Hypothesis 1 theorized an inverted U-shape relationship between CEO options and supply chain disruptions. Necessary condition for such a curvilinear relationship is a negative second-order effect of the IV in our regression model. In support of Hypothesis 1, model 1-2 shows that CEO options have a highly significant effect on supply chain disruptions and the second-order effect is significantly negative. In hypotheses 2 and 3 we theorized a flattening in the inverted U-shape relationship between CEO options and supply chain disruptions by our interaction effects. A flattening (or steeping) of a quadric relationship requires the regression coefficient between the interaction effect and the squared IV to be significant and positive (negative) (Haans et al., 2016). As depicted in our full model 2-5 the coefficients of both interaction terms are significant and negative, with their corresponding second-order effects being significantly positive. H1, H2, and H3, thus, are strongly supported.

Given the stable results of the main and the first interaction effect in both the model with the COO variables (N = 2,134) and the model without the COO variables (N = 1,144), our estimations show high robustness. Still, we conducted multiple additional checks to ensure a high robustness of our findings. Our main analysis was conducted using a

negative binominal distribution best fitting our count data DV. To ensure our results are not driven by model specifications, we reran the analysis with an ordinary least square (OLS) random effects model with robust standard errors (model 3-1) and with Driscoll-Kraay standard errors to rule out cross-sectional correlation (model 3-2) (Shah et al., 2016). Both models confirm the results presented above. Next, we reran our main model with two different specifications of our IV using an unweighted average in model 3-3 and annual values in model 3-4. Again, our estimations are confirmed.

Firms with COOs might be substantially different from firms without COOs. Unobserved factors (e.g. operations management experience of the CEO) might influence both, the decision to have a COO and supply chain related outcomes and bias the results of our study. To test for this potential sample selection bias, we applied a Heckman two-stage selection model (1979) in line with prior TMT research (Kim et al., 2016) and included an inverse Mills ratio (IMR) predicting COO presence in all our models 2-1 to 2-5. As the IMR is insignificant and all other results remain robust, our analysis does not suffer from a sample section bias. The results including the IMR are shown for the full model in model 3-5. Moreover, we drew on multiple means to lower the risk of potential endogeneity in our study. Among other measures, we created an endogeneity control by regressing CEO options in $t-1$ on eleven of its potential firm-, industry-, and TMT-level antecedents in $t-2$ and including this predicted IV as endogeneity controls in our models 2-1 to 2-5. Again, the results remained robust in all models. We show the results for the full model in model 3-6. Given the results of the tests above, reverse causality and endogeneity do not appear to be a problem in our study.

Discussion

Theoretical Implications

Our findings have important implications for research on SCDs and the extensive literature on the impact of CEO options on executive behavior. First, we extend operations management research by investigating CEO options as an organizational antecedent of SCDs. We empirically show, that CEO options – especially at medium levels – increase the frequency of SCDs. Second, we contribute to strategic management research which investigates the effects of executive stock options. While research on this topic has long been dominated by two schools of thought – agency theory expecting more risky decisions and behavioral agency theory expecting less risky decision as consequences of stock options – our research conceptually and empirically adds a more nuanced assessment of CEO options to prevailing literature. Third, this study identifies both organizational and environmental factors that have significant impact on CEO option-induced risk-taking. Both, market uncertainty and relative COO power have a flattening effect on the relationship between CEO options and SCDs, thus, diminishing the CEOs willingness to take disproportionate risks with regards to operations management. As of today, research on performance effects of COOs is ambiguous (Hambrick & Cannella, 2004; Hendricks et al., 2014). Our findings underline the importance of a COO at equal terms with regards to supply chain stability and further confirms research underlining the importance of operations capabilities in the TMT as a source of competitive advantage.

Finally, our study advances strategic and operations management research from a methodological standpoint. As the algorithm is not limited to a predefined dictionary of relevant terms but constantly evolves based on the growing training data set, this approach might be an interesting alternative to dictionary-based approaches. Especially in times of "big data" that can hardly be managed manually anymore and for relatively new areas of research where no established dictionaries exist, this approach can become increasingly relevant.

Practical Implications

Our findings bring about two important implications for decision makers. First, we advise decision makers to carefully select and combine different tools of executive compensation. Whereas CEO options might not be the best incentive used by itself, they still might be a valuable tool to induce additional risk-taking if required. However, this decision needs to be made very deliberately, keeping in mind potential risks. We, thus, recommend decision makers to balance CEO options with other means of executive compensation such as stock that also have a downside potential and reward sustainable decision making. Second, if using CEO options, we advise decision makers to embed their usage in an organizational setting that either does not facilitate strategic individual actions by the CEO or, as this study has proven, has a relatively low power distance in its TMT to enable mutual control among executives.

Limitations and Avenues for Further Research

Our study is subject to certain limitations that provide interesting avenues for further research. First, while our study focuses on the effects of CEO options, future research should investigate the interplay of CEO options with other prevailing means of executive compensation (e.g. stock ownership) in predicting supply chain stability. Second, whereas we focused on CEO compensation, it might be of interest to investigate effects of additional TMT characteristics on supply chain stability. Third, research has a strong focus on the CEO when investigating the effects of stock options. Future studies could expand this scope to other TMT members' roles and strategic outcomes in their areas of responsibility to better understand potentially diverging interests between different functional strategies.

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Interplaying internal and external mechanisms for the operational capabilities development

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Abstract

This study analyses the impact of internal and external mechanisms on the process of operational capability development. While internal mechanisms comprise a set of operational resources used by companies in order to improve their performance, external ones refers to the influences coming from external players. High Performance Manufacturing database composed the sample with 263 companies from fifteen countries. The results suggest that internal mechanisms influence positively operational capabilities development. Furthermore, external aspects like supplier development and customer alignment create a feed-back process nurturing organizational knowledge.
Keywords: Operational Capabilities, Coevolution, Operational Performance.

Literature Review

Operational Capabilities

Operational capabilities have been understood also as a set of interrelated routines of companies for performing through their resources base (Peng et al., 2008), including the role of external players, such as supply chain partners (Raddats et al., 2017; Vanpoucke et al., 2014), and professional network (Zhang, Gregory, and Neely, 2016). Beside a conceptual convergence of the prior literature, prior studies present an absence of consensus of the antecedents of operational capabilities, because it has been understood as a phenomenon composed by multiple elements (tangible and intangible). Capability development has been studied from two main approaches. Some authors have pointed out organizational knowledge as an intangible element of the organizational capabilities regarding their value for decision-making, and identifying new opportunities and threats (Grant, 1996). Similarly, a body of empirical studies shed light on the role of tangible factors, such as operational practices and new technologies on capabilities development (Wu et al., 2010).

As one of the most important internal resource of companies, organizational knowledge has internal and external perspectives. While internal knowledge is considered as a way in which companies explore their internal resources, external knowledge refers to identify a set of opportunities and threats in the market (Paiva, Roth, and Fensterseifer,

2008). Previous studies have pointed out market knowledge as a way to detect proactively changes in the market (Alfalla-Luque et al., 2018; Lee, 2004). Thus, we may state that market knowledge is one of the sources that influence companies' operational activities adaptability (Alfalla-Luque et al., 2018; Paiva et al., 2008).

We combine internal and external mechanisms in our proposed framework. Therefore, we consider customer and supplier market knowledge, effective process implementation, continuous improvement, and anticipation of new technologies as antecedents of operational capability. On the other hand, operational capability influences positively operational performance. In the sequence, customers and suppliers adapt their processes according to the performance target defined by the company. Finally, both customers and suppliers influence company's organizational knowledge in a looping process. The same looping is identified between operational performance and internal mechanisms of effective process implementation, continuous improvement, and anticipation of new technologies.

Co-evolution theory

Co-evolution theory is originally from Biology. Ehrlich and Raven (1964) demonstrated a joint evolution between butterflies and some species of plants This approach was brought to Social Sciences by Lewin and Volberda (1999) for mentioning simultaneous interactions among managerial actions, industry, and institutional and government environments. Currently, co-evolution in Social Sciences is a macro-theory that integrates several theoretical approaches. It is considered as a promising theory to reduce the dichotomy between determinism and voluntarism view in management studies. Thus, while determinism emphasizes external factors as determinant of the company's adaptation, voluntarism cover factors from managerial action (i.e., internal scope) (Abatecola, 2012).

Five properties support coevolution theory: multilevelness and embeddedness, multidirectional causalities, nonlinearity, positive feedback, and path and history dependence. In order to characterize a co-evolutionary phenomenon, all properties should meet together at the same time (Lewin and Volberda, 1999, 2009).

Hypothesis development

Paiva et al. (2008) empirically found a positive impact of external knowledge on value creation resulting from manufacturing resources. Considering that external knowledge enable proactiveness, Alfalla-Luque et al. (2018) found a positive effect of adaptability capacity of companies on the operational and financial performances. Those studies suggest that market knowledge influence internal processes and thus companies may adapt to continuous changes in the environment. Based on these arguments, we hypothesize:

Hypothesis 1 – Market knowledge influences positively companies' internal processes.

Resources and operational practices are accessible for the companies, but there are idiosyncrasies related to how to evaluate and reconfigure those practices over time. Teece (2007) proposed the 'seizing' and 'reconfiguring' mechanisms to identify opportunities and threats, and to implement them in companies' activities. We argue that continuous development of the internal factors by companies lead to operational capability development.

Hypothesis 2 – Internal processes positively influence operational capability.

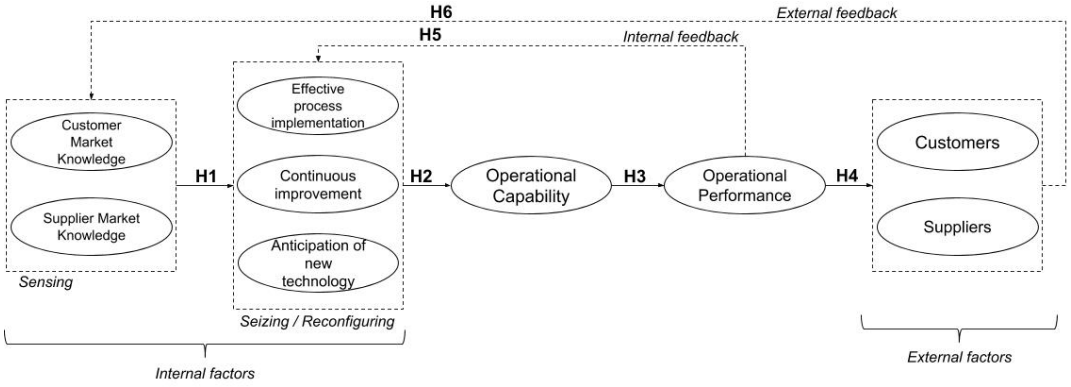
Operational capabilities has been defined from different perspectives, such as based on trade-off concept (Boyer and Lewis, 2002), cumulative capabilities (Ferdows and De Meyer, 1990; Schroeder et al., 2010), and combinative capabilities (Rosenzweig and Roth, 2004; Roth and Miller, 1992; White, 1996). All of them understand operational performance related to the company's heterogeneity. Prior studies have also emphasized the positive effect of operational capabilities over performance, measured by quality, delivery, flexibility and manufacturing costs (Peng et al., 2008, 2011; Schoenherr and Narasimhan, 2012; Tan et al., 2007; Wu et al., 2010). Thus, we hypothesize:

Hypothesis 3 – Operational capability influences positively operational performance.

Regarding the process of operational capability development, we consider that companies influence external players through their performance, which characterizes an external adaptation. Empirical studies have used co-evolutionary theory to illustrate this aspect. For example, Dieleman and Sachs (2008) showed political changes in the Indonesian institutions caused by Indonesian Salim group. Braguinsky and Hounshell (2016) highlighted the influence of Osaka company's performance on industrial policies changes in the Japanese textile industry, as well the competitors' efforts in order to keep in the market. From this, we hypothesize:

Hypothesis 4 – Operational performance of companies influences positively interactions with external players.

Figure 1: Operational framework



Fifthly, according to the internal feedback mechanism from co-evolutionary theory, the company's operational performance may help managers to adapt their manufacturing tasks. Therefore, we argue that operational performance influences positively internal factors of companies: effective process implementation, continuous improvement, and anticipation of new technology. (Peng et al., 2008, 2011; Schoenherr and Narasimhan, 2012; Tan et al., 2007; Wu et al., 2010)

Hypothesis 5 – Operational performance positively influences tangible internal factors.

We state that companies develop their operational capabilities within a dynamic process, in which the companies and other players exert influence and are influenced by each one other continuously. Based on previous studies, we hypothesize that when the

company's market knowledge is influenced by external actors, it adapts its internal factors (Alfalla-Luque et al., 2018; Paiva et al., 2008). Based on this argument, we present the last study's hypothesis:

Hypothesis 6 – Higher the integration with external players, higher the market knowledge of companies.

Methodology

This study uses data from the fourth round of the High Performance Manufacturing (HPM). The fourth round data collection started in 2012 and it contains 330 respondents at the moment from fifteen countries: Brazil, China, Finland, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Switzerland, Twain, United Kingdom, United Stated, and Vietnam. These countries were selected due to the composition of high performance and traditional manufacturing companies, and its distinct institutional characteristics, such as cultural, industrial politics and economic development. Additionally, the project contains data from machinery, electronics, and transportation components industries to cover distinct contexts – stable and dynamic environments (Schroeder and Flynn, 2001).

All measurement items in this study are from the HPM database. Nine latent variables and forty-four items with a five-point Likert's scale were used in this study. As the first step, we cleaned data for checking missing values. Full data with 330 respondents presented 9.43% of missing values. We removed incomplete responses until to reach 263 useful respondents (2.53% of missing values). As an acceptable condition (less than 5%), we proceed with a mean replacement according to the most appropriate treatment suggested by experts.

The nine scales of this study are: customer market knowledge, supplier market knowledge, effective process implementation, continuous improvement, anticipation of new technology, operational capability, operational performance, customers and suppliers. Customer and supplier market knowledge states an ability of companies to detect trends or changes from the market in which they operate (Alfalla-Luque et al., 2018). Effective process implementation refers to the ability of companies to develop and implement new processes (Huang et al., 2008). While continuous improvement scale seeks to provide a set of proactive adaptation ability of companies (Bortolotti et al., 2015; Peng et al., 2011), anticipation of new technologies scale evaluates the ability for moving technological structure early than rivals (Garrido-Vega et al., 2015). Operational capability scale refers to a broad ability of companies for performing their full manufacturing task (Wu et al., 2010). In turn, operational performance is measured by the traditional OM variables: cost, quality, delivery, and flexibility (Bortolotti et al., 2015; Peng et al., 2008). Finally, customer alignment and supplier development scales refer to external players that may influence and be influenced by the focal company; therefore, both scales seek to measure interactions level in their processes and services.

In order to analyse common method bias, we used procedural and statistical remedies (Lee, and Podsakoff, 2003). First, we got data from five distinct respondents for the dependent and independent variables. Secondly, personal identity of respondents were not revealed. Thirdly, respondents answered self-administered questionnaires without any external influence. Fourth, data matches the perception of two respondents per company. Fifth, Harman's one-factor revealed no emergence of a single factor with variables used in this study, in which the first factor represented just 17% of the whole variance. These results suggest no concern about common method bias in the study.

Data Analysis and Results

Followed two stage analytical procedures of structural equation modelling; we treated measurement model (reliability and validity tests), and then a path analysis model for testing the hypotheses. Table 1 provides a descriptive analysis of the latent variables, including means, standard deviations, correlations, and square roots of AVE in diagonal (remaining data after model purification).

Table 1 - Descriptive analysis

Construct	Mean	SD	1	2	3	4	5	6	7	8	9
Customer market knowledge	3.850	.679	.803								
Supplier market knowledge	3.894	.676	.346	.778							
Effective process implementation	4.040	.590	.268	.238	.788						
Continuous improvement	4.192	.555	.239	.214	.264	.755					
Anticipation of new technology	3.683	.749	.248	.271	.729	.192	.806				
Operational capability	3.703	.661	.211	.257	.298	.202	.288	.807			
Operational performance	3.765	.606	.223	.241	.268	.095	.269	.693	.733		
Customers	3.847	.702	.463	.297	.292	.252	.289	.334	.324	.846	
Suppliers	3.956	.625	.151	.488	.272	.069	.285	.275	.253	.176	.789

Initially, we analysed validity and reliability. Standardized indicators loading and p-values were used as criteria to remove items with low loadings. Remaining items presented a satisfactory composite reliability, and convergent and discriminant validities. Firstly, the values of composite reliability ranged from .799 to .848, showing an adequate fit (>0.7). Secondly, convergent validity was addressed by the average variance extracted (AVE), which ranged from 0.538 to 0.716, higher than the recommended value (>0.5). Thirdly, discriminant validity also is identified because squared root of AVE are higher than contructs correlations (Hair Jr. et al., 2014). Overall, the overall results suggest a good internal consistency of data.

We ran a path analysis with the Amos18 software. The indices for goodness fit of the structural model are highly satisfactory (table 2).

Results from the structural model indicate a positive relation among customer market knowledge and supplier market knowledge with effective process implementation. Only Effective process implementation did not present a statistically significant result. Nevertheless, considering the positive relation between Anticipation of new technology and Effective process implementation, the results support hypothesis one.

Regarding hypothesis two, we found a positive relation among effective process implementation, continuous improvement, and anticipation of technology and operational capability. However, only one presented a statistically significant result. Thus, hypothesis two was only partially supported. We also found support to confirm third hypothesis, in which operational capability has a positive influence on operational performance of companies. (See table 3)

Table 2 – General statistics for goodness-of-fit

Stand Alone Indices

Chi-Square	45.66
Degrees of Freedom (df)	15
Probability Level	.000
Goodness of Fit (GFI)	.964
Adjusted Goodness of Fit (AGFI)	.892
Standardized RMR	.033
RMSEA	.088
Incremental Indices	
Normed Fit Index (NFI)	.935
Incremental Fit Index (IFI)	.956
Comparative Fit Index (CFI)	.954
Tucker-Lewis Coefficient (TLI)	.890

Our results indicate that operational performance positively influences customers and suppliers interactions. Therefore, it confirms the fourth hypothesis. The fifth and sixth hypothesis tested the feedback effect on the internal mechanisms. In this case, operational performance is positively related only to anticipation of new technology and negatively to effective implementation. Thus, the results only confirm partially the fifth hypothesis. The sixth hypothesis evaluates the influence of external players on the organizational knowledge. The results showed a positive result between customer interaction on customer market knowledge and supplier interaction on supplier market knowledge. Therefore, these results confirm the last hypothesis.

Discussion

The results found indicate that customer and supplier market knowledge positively impact internal mechanisms (Alfalla-Luque et al., 2018). It refers to checking opportunities and threats present in the market. Furthermore, internal resources when related to effective processes implementation (Huang et al., 2008; Morita and Flynn, 1997), continuous improvement (Bessant and Francis, 1999; Coltman and Devinney, 2013), and anticipation of new technology (Matsui, 2007) strengthen operational capabilities.

Also, the results suggest that companies with stronger operational capabilities may achieve higher operational performance including costs, quality, delivery, and flexibility. In addition, operational performance is considered a 'managerial control point' in which managers define their functional targets. At the same time, operational performance works an internal feedback process that positively influences the internal mechanisms (antecedents of operational capabilities). This aspect present a clear connection to the co-evolutionary theory, which considers feedback effect as a property that lead companies jointly evolve over time (Lewin and Volberda, 1999).

Table 3 – Coefficients of Total Effects

	Loading
Effect of Customer market knowledge	

Effective process implementation	.074 (n.s.)
Continuous improvement	.147
Anticipation of new technology	.178
Effect of Supplier market knowledge	
Effective process implementation	.015 (n.s.)
Continuous improvement	.120
Anticipation of new technology	.226
Operational capability	.116
Effect of Effective process implementation	
Operational capability	.157
Effect of Continuous improvement	
Operational capability	.115 (n.s.)
Effect of Anticipation of new technology	
Effective process implementation	.543
Operational capability	.099 (n.s.)
Effect of Operational capability	
Operational performance	.630
Effect of Operational performance	
Customers	.357
Suppliers	.207
Effect of Customers (Feed-back)	
Customer market knowledge	.386
Effect of Suppliers (Feed-back)	
Supplier market knowledge	.488
Effect of Operational performance (Feed-back)	
Effective process implementation	.147
Continuous improvement	-.106 (n.s.)
Anticipation of new technology	.014

On the other hand, operational performance may influence changes in external environment, influencing external players and partners. Our results indicate that higher operational performance increase customers and suppliers interactions. This result is in consonance with previous studies that have showed a joint evolution between companies and industry players (Braguinsky and Hounshell, 2016; Chen et al., 2017; Raddats et al., 2017; Rodrigues and Child, 2003). Changes in the external environment or companies lead to a new organizational forms or to the adaptation of existing ones, according to the basic premise of co-evolutionary theory (Lewin, Long, and Carroll, 1999). Based on that premise, our results indicate a positive influence from customers and suppliers' interactions on the market knowledge. This result suggests that adaptations in the resources portfolio caused by external influences at the end influence the process of operational capability development.

Table 4 indicates three main mechanisms identified by this study. The internal factors are related to the influence of tangible and intangible resources on the operational capabilities development. Furthermore, internal factors receive influences from operational performance (named as internal feedback) and external players (named as external feedback) mechanisms. Internal feedback refers to the causal effect of an outcome reached by managers; in other words, regarding the outcome achieved, it provokes internal adaptations in order to achieve managers' goals. In turn, external feedback represents the effect of adaptation of external players on companies' internal

factors; it implies an internal adaptation to improve companies' processes. Consequently, companies will be able to develop their operational capabilities through a cyclical process for monitoring external players. Therefore, there is an 'interactively developed capabilities' (Raddats' et al., 2017) between dyads based on internal and external mechanisms simultaneously.

Table 4 - Mechanisms for the operational capability development

Category	Mechanism	Effects on operational capability
Internal	Internal factors	Indirect effect of customer and supplier market knowledge
		Direct effect of effective process implementation, continuous improvement and anticipation of new technology
	Internal feedback	Indirect effect of operational performance
External	External feedback	Indirect effect of customers and suppliers

Conclusions

This study brought new insights to the process of operational capability development. For doing so, we underline co-evolutionary theory as the support for our analytical framework. The framework considers capabilities development as a cyclical process among internal and external mechanisms. Thus, the results suggested a direct influence of internal mechanisms on operational capabilities. In turn, operational performance and external players influence companies' internal resources, and, at the end also influence operational capabilities.

More than theoretical implications, this study provides some managerial contributions. First, managers should pay attention to the company's strengths, monitor and manage internal and external sources in order to respond to the changes in the environment. Second, managers should monitors external environment (players and partners) constantly in order to adapt their internal resources when looking for developing their capabilities. Third, as a cyclical process of operational capabilities development, managers should pay attention to what aspects from the environment and external players are more relevant.

We may list some limitations present in this study. Firstly, we used only customers and suppliers as external actors to analyze the co-evolution process among companies, however, according to the theory many others external players should be considered, such as competitors, consumers, entities, institutions, among others. We also used cross-sectional analysis but co-evolutionary processes also needs a longitudinal research approach to be fully analyzed (Breslin, 2016). Future studies can extend this debate by analyzing the effect of other set of external players, as well as considering a longitudinal approach in order to understand distinct effects along the time.

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Appendix A –Measurement Items

Effective Process Implementation	We pay close attention to the organizational and skill changes needed for new processes
	We search for continued learning and improvement, after the installation of new equipment
	Our processes are effectively developed and implemented
Continuous improvement	We strive to continually improve all aspects of products and processes, rather than taking a static approach
	If we aren't constantly improving and learning, our performance will suffer in the long term
	Our organization is not a static entity, but engages in dynamically changing itself to better serve its customers
Anticipation of New Technology	Our organization is not a static entity, but engages in dynamically changing itself to better serve its customers
	We pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs
	Our plant stays on the leading edge of new technology in our industry
	We are constantly thinking of the next generation of manufacturing technology
Customer	We are comfortable sharing problems with our customers
	We emphasize openness of communication in collaborating with our customers
Supplier	We hold regular meetings to exchange improvement ideas with our suppliers
	We encourage our suppliers to continuously improve their production processes
	As our suppliers strive to improve their processes, we provide assistance
Customer Knowledge	In order to find potential new markets, we monitor economies around the world
	We are concerned about the needs of both our immediate customers and our ultimate consumers
	We understand the marketing strategies of our customers
Supplier Knowledge	In order to find potential new suppliers, we monitor economies around the world
	Understanding our supplier's production processes is a high priority for us
	It is important for us to have a good understanding of our suppliers' R&D activities

Developing problem-solving capabilities for sustainable solutions: A dynamic capabilities approach

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Abstract

Continuous improvement is a premise for a firm's competitiveness over time. Problem-solving activities are a way to continuously improve the operations of a firm. However, not every problem-solving activity leads to sustainable improvements. The problem-solving literature promotes systematic behavior to cope with problems (systematic problem-solving or SPS). Although the effectiveness of SPS is well-documented in the literature, many firms fail to fully reap the benefits of this behavior or struggle to sustain its outcomes over time. Motivated by field work at a manufacturing firm, this study aims at understanding the major reasons of failures for SPS-based programs, from a dynamic capability perspective.

Keywords: Systematic problem-solving, dynamic capabilities, case-study

Introduction

In today's fast-moving and global business environments, characterized by unpredictable changes and uncertainty, creating new capabilities by which organizations approach and respond to problems seems necessary to achieve continuous improvement and stay competitive in the long-term (Helfat & Peteraf, 2015; Teece, 2007). However, not all problem-solving activities result in sustainable outcomes. The literature on problem-solving promotes a systematic approach to deal with problems (e.g. Choo et al., 2015; Repenning & Sterman, 2002), called systematic problem-solving (SPS). SPS is a multistage process encompassing different activities (i.e. problem definition, problem analysis, and solution design) before a final decision is reached whose main objective is to constantly improve operational processes (Repenning & Sterman, 2002). Although many firms implement improvement-oriented programs (e.g. Lean, Kaizen, Six Sigma DMAIC), they cannot fully reap the benefits of SPS-based opportunities or struggle to sustain the outcomes over time (Netland & Ferdows, 2014; Bateman, 2006).

This study addresses the need for long-term and sustainable success in the context of operational problem-solving. We propose that the theory of dynamic capabilities (DC) sheds light on the major reasons of failures in SPS-based programs. Teece (2007) defines DC as the firm's capacity to (1) identify opportunities (sensing), (2) make investments to

seize those opportunities (seizing), and (3) reconfigure enterprise's assets and capabilities to maintain competitiveness (reconfiguring). DC theory indicates that solving problems fundamentally with the help of structured actions, i.e. SPS, requires continuously and systematically developing sensing, seizing, and reconfiguring capabilities.

Based on insights from a case-study company, we identify different modes of problem-solving behavior. Accordingly, we propose that not every problem-solving behavior could be considered as a DC and hence contribute to sustainable improvements. Then, we identify and discuss two groups of impediments for successful SPS adoption. One is a cognitive bias defined as a natural tendency of problem-solvers to jump to a solution. The second one is a set of organizational impediments for SPS adoption namely: (a) time pressure, (b) resource constraints, (c) individual problem-solving and lack of collaborative culture, and (d) insufficient leadership practices. We demonstrate how these factors curb problem-solver's capabilities for sensing, seizing, and reconfiguring as three components of the DC.

This study contributes to a body of literature where a systematic approach is emphasized for dealing with complex problems and decisions. Despite all the attention to design SPS and promote techniques for this mode such as lean manufacturing and Six Sigma DMAIC in the operations management literature, a clear picture of the conditions by which SPS-based programs succeed or fail is missing. The theory of DC sheds light on realizing behavioral and organizational impediments of SPS.

This work also has considerable implications for managers. It provides insightful information to address the circumstances through which problem-solving activities pay off successfully.

Design/ Methodology/ Approach

To understand problem-solving activities in companies, we conducted a case-study. The research site was a manufacturer of gardening equipment and supplier of agricultural products. This setting is of particular relevance for two reasons. First, operational problems related to cost, quality and delivery of the products occurred frequently and we could realize how different problem-solving behaviors contribute to sustainable development. Second, the plant manager of the firm started emphasizing improvement-based programs (e.g. lean manufacturing and its bundles such as JIT or TQM) due to an increasing trend of customer complaints together with reports about the low efficiency of the assembly line (e.g. a high defect rate and warehousing problems). Therefore, it is assumed that the firm previously faced difficult times fundamentally solving problems.

All in all, the case-study company provided a good opportunity to observe problem-solving activities (before and after the implementation of improvement-based activities). We gathered data, over a period of three months, on the actual problem situation. This included several days shadowing the managers and roaming the shop-floor employees as well as conducting semi-structured interviews to understand how problems were overcome in the company. We also relied on the memory of interviewees to provide historical information concerning different problems, their frequency, and the problem-solving actions.

Data analysis began with reviewing the observational data and analyzing the notes recorded during the interviews. We identified a sample of problems that were resolved differently. Hence, different levels for problem resolution and their potential impacts on operational performance are highlighted. In order to ensure having a comprehensive

understanding of problem-solving activities and sharpen its generalizability, we double-checked the proposed levels and their effects to see whether, or not, they are also supported by the literature, i.e. theoretical triangulation (Eisenhardt, 1989).

Explication of Building Blocks

Based on insights from the case-study and in line with the literature, we propose three levels for problem-solving and present the main characteristics of each.

Level 1: Intuitive Problem-Solving (IPS)

Level 1 occurs when problem-solvers employ prompt remedies to temporarily solve the problem. In the literature, it is interpreted as jumping to a solution where intermediate steps of comprehensive problem-solving such as problem definition, problem analysis, and solution design are skipped or abbreviated (Baer et al., 2013). Adopting the cognitive perspective of the dual-processing theory (Evans & Stanovich, 2013), this level could be labeled intuitive problem-solving (IPS) as it relies on heuristic reasoning of problem-solvers while confronted with complex problems. Although IPS results in short-term and minimal improvements as problems are temporarily solved, there is a high likelihood for problems to recur. Moreover, it might lead to type III errors, i.e. solving the wrong problem because IPS is a solution-mindedness behavior mode and problem-solvers work around the problems by focusing just on problem symptoms rather than its major causes (Smith, 1989). A sample problem from the case company is briefly explained in Table 1 and it is highlighted why the problem-solving efforts represent IPS adoption.

Table 1- IPS Adoption (Level 1 Problem-Solving)

<table>
<tr><th colspan="2">Evidence for IPS adoption</th><th>Theoretical Triangulation</th></tr>
<tr><td>Sample Problem</td><td>IPS Characteristics</td><td rowspan="2">A high rework rate to correct defects (Repenning & Sterman, 2002) or to increase pressure on front-line employees to get work done (Morrison, 2015) is a common response to just remove the problem symptoms rather than exploring the major sources of problems (i.e. process problems).</td></tr>
<tr><td>In many cases, front-line employees are behind the defined schedule to meet the daily production target.</td><td>• <u>Temporary Solution:</u> Low productivity is mostly covered by a high rework rate.
• <u>Operational Performance:</u> Although this solution is helpful in the short-term as the production target is met, the same problem occurs again as insufficient attention is put on a root-cause analysis.</td></tr>
</table>

Level 2: Semi-Structured Problem-Solving (SSPS)

Level 2 problem-solving, from dual-process theory (Evans & Stanovich, 2013), could be interpreted as a rational reaction to fundamentally solve the problem. Problem-solvers, on this level, are required to go through a set of steps (i.e. problem detection, problem formulation, and solution design and implementation) to take structured actions (Baer et al., 2013). Although, deliberate and reflective efforts are employed to link the observed problem to a diagnosis, and eventually an appropriate solution, it fails to produce a positive change in production processes. Activities of level 2 are limited to an action, although helpful to solve the problem, cannot contribute to sustainable and long-term

developments. Indeed, a problem is solved but the effects are still short-lived and hence radical improvements in operational processes are less likely to occur. This level is called semi-structured problem-solving or SSPS. Table 2 summarizes the main characteristics of SSPS based on our data.

Table 2- SSPS Adoption (Level 2 Problem-Solving)

Evidence for SSPS adoption		**Theoretical Triangulation**
Sample Problem	SSPS Characteristics	
Unbalanced workloads	• Root-Cause Analysis: ▪ Production planning is not based on customer demand. • Solution: ▪ To balance the production line, production planning is taken as an action to collect rich information regarding the most (least) demanded products. • Operational Performance: ▪ Problem-solving activities end with the proposed solution. However, solutions do not lead to positive change. In this case, production planning is done whenever assembly line is either over-utilized or under-utilized. ▪ Improvements are still short-lived and mostly incremental in nature.	• Problem-solving should be stressed in such a way that problems remain solved with a low probability of recur (Argyris, 1976). This should be done through constant monitoring and standardization of the operational processes. • Process changes should be routinized for further improvements (Anand et al., 2009). Otherwise, problem-solvers are less likely to establish repeatable processes in order to prevent re-occurrence.

Level 3: Systematic Problem-Solving (SPS)

In essence, level 3 problem-solving corresponds to a situation where problem-solvers rely on rational reasoning and employs a systematic approach to deal with problems. Similar to level 2, it begins with problem detection, goes through problem formulation and analysis and concludes with the best applicable solution. However, in contrast to level 2, level 3 is more complete and leads to the modification of production processes. We label this level as systematic problem-solving (SPS). The problem-solving literature promotes SPS as a behavior mode that is more likely to create and retain a positive change in operating routines (Itabashi-Campbell et. al, 2011; Tucker & Edmondson, 2003). Indeed, SPS is not limited to the right problem to detect and the best solution to take based on root-causes. Standardization or routinization (i.e. systematically incorporating positive changes) also matters for sustainable solutions. Once the fundamental solution is identified and the positive change is implemented as a result of cyclical investigation through (formal) improvement initiatives, there is a lower likelihood that problems recur. Table 3 summarizes SPS adoption in the case-study company.

Table 3- SPS Adoption (Level 3 Problem-Solving)

Evidence for SPS adoption		**Theoretical Triangulation**
Sample Problem	SPS Characteristics	
High Holding Cost	• Root-Cause Analysis: ▪ Warehousing is limited to just counting stocks. ▪ Lack of a plan to store and to move stocks in a structured way (products are not positioned in the right place at the right time). This causes inconsistencies when counting the products and also when sending them out to end-users. • Fundamental Solution: ▪ Just in Time (JIT) to reduce the high dependency on the warehouse. ▪ The layout manager together with the warehouse manager start attempting to improve the warehouse (spacing and timing). ▪ Inventory management techniques such as LIFO (last in first out) and FIFO (first in first out) are suggested under different conditions. • Positive Change: ▪ Fundamental proposed solutions are incorporated within production process in form of positive changes (e.g. appropriate stocking becomes routinized and part of warehousing operations). • Operational Performance: ▪ Problems are fundamentally solved with lower probability to recur. ▪ Lower cost is imposed to the system in the long-term after incorporating the solutions in operational processes.	• Relying on valid information about the problem structure results in double-loop learning as explicit knowledge is generated and used to fundamentally solve the problems (Tucker et al., 2002; Argyris, 1976). This can, eventually, improve the manufacturer's ability to attain improvements in both the short and the long term (Choo et al., 2015). • Problem-solvers focus on process rather than just problem symptoms (Repenning & Sterman, 2002). Accordingly, SPS results in positive changes in operational routines (Itabashi-Campbell et al., 2011; Tucker & Edmondson, 2003).

Characterizing level 3 as a dynamic capability (DC)

As described earlier, Teece (2007) defines DC as the capacity (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, and reconfiguring the business enterprise's assets. DC is linked to human cognition by Helfat and Peteraf (2015) where managerial dynamic capabilities of sensing, seizing, and reconfiguring are recognized as necessary elements that lead to a change and an amelioration of firm-level performance. Along with this definition, Zollo and Winter (2002) propose DC is "a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness" (p. 340). In the context of operational problem-solving, to constantly modify and update existing routines and implement positive changes in production processes seem to be substantial characteristics of a DC in order to seek continuous improvement (Eisenhardt & Martin, 2000).

Building on proposed definitions for DC, we claim that just level 3 problem-solving or SPS could be considered as a DC, necessary to achieve sustainable solutions and address continuous improvement. We stipulate that SPS not only highlights the right problem to detect (sensing), and emphasizes a course of actions to appropriately respond to the problem (seizing), but also should lead to the constant modification of operating routines and implementation of positive changes in production processes (reconfiguring). Figure 1 shows that the main activities for SPS match sensing, seizing, and reconfiguring capabilities.

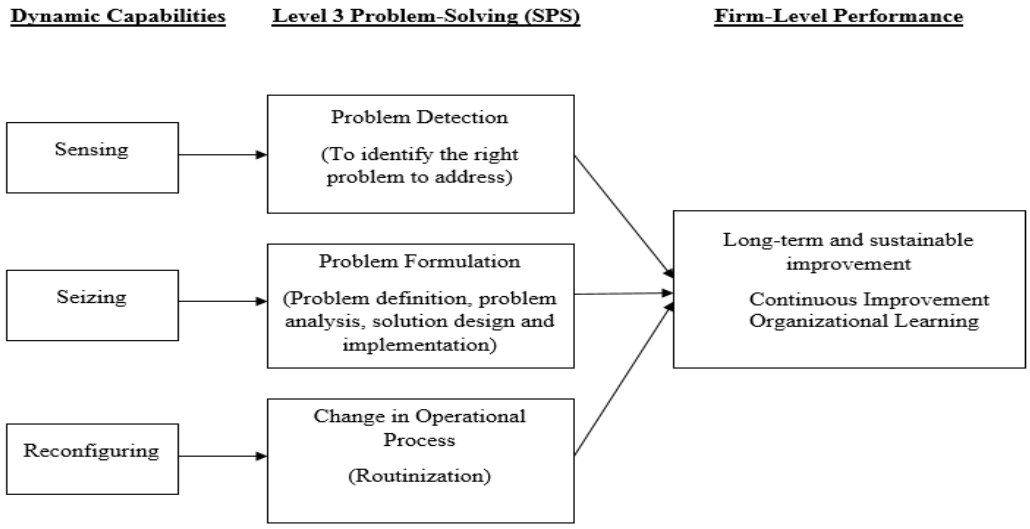

Figure 1- SPS as DC

Major Reasons of Failures

To systematically structure our data and address our research question, i.e. to extrapolate the impediments of SPS, we followed a research strategy suggested by Rerup & Feldman (2011). First-order and second-order concepts are used to organize the data units, develop the themes and refine the patterns among the identified concepts.

It began with identification of first-order concepts that are simple descriptive phrases based on our observations or language used by problem-solving informants in the case-study. Then, common elements and similarities among first-order concepts were highlighted to develop a higher-order construct, i.e. second-order concepts. Finally, similar themes from second-order concepts facilitated the recognition of aggregate themes, introduced also as the major groups of SPS impediments (Table 4).

Table 4 - SPS Impediments

First-Order Concepts	Second-Order Concepts	Aggregate Themes
• In many cases, shop-floor employees fail to consider different solution alternatives as they simply jump to the solution. • "As an experienced person, I've faced different types of problems and I know how to deal with them successfully" (Assembly line supervisor).	Cognitive Bias	SPS Behavioral Impediment

• Relying on just previous personal experiences leads to heuristics and shortcuts associated more with irrational sphere of making choices. • Firm and its managers mostly care about tangible outcomes (e.g. financial indicators, production capacity and sales). Hence, the attention is moved from problem and its causes to problem symptoms, i.e. IPS.		
• Problem-solvers mostly adopt level 1 problem-solving or IPS due to an extreme time pressure (e.g. Crisis or customer's pressure). • "Sometimes, we must immediately react to a problem" (Plant manager) as a sense of urgency overtakes comprehensive problem formulation (e.g. to keep the production running). • Increasing pressure to front-line employees (e.g. assembly line is over-utilized in some cases; rework) seems to be common to reach the daily production target.	Time Pressure	SPS Organizational Impediments
• Lack of valid information regarding the problem structure derives problem-solvers to rely just on pre-existing hypotheses to jump to a solution. • Although the effectiveness of SPS is well-realized by the plant manager, he claims that "improvement activities are costly". • Without organizational resources (i.e. information, money, and human resources), SPS is less likely to succeed.	Resources Constraints	
• Even after emphasizing the improvement-based activities and encouraging team-work, in many cases, errors in shop-floor are rarely reported to the assembly line supervisor. Therefore, problem status becomes hidden and information is not shared across different levels (Still, in some cases, individual problem-solving is dominant rather than team-work). • One employee highlights dysfunctional conflicts based on personal relationships during the problem-solving sessions. • Participation of lower-level employees is rarely observed (group problem-solving sessions is mostly limited to upper managers sessions). Hence, shop-floor employees as the important problem-solving informants are neglected.	Individual Problem-Solving and Lack of Collaborative Culture	
• "I only inform my supervisor about a failure when I cannot solve it by my-self" (a front-line employee). One potential reason could be that employees are afraid to be blamed by supervisors. • Upper-level managers are responsible for resource allocation, training problem-solvers, encourage team-work and participation of employees, and establish collaborative culture for group problem-solving. • Upper-managers also are required to provide an environment where SPS can flourish (i.e. culture for continuous improvement, organizational learning, and change). • Lack of attention from top managers for aforementioned tasks prevents level 3 and leads to levels 1 or 2 problem-solving.	Insufficient Leadership Practices	

Based on insights from the case-study, this study discusses two aggregate themes for the failures of SPS-based programs: (a) behavioral and (b) organizational impediments. We claim that both groups prevent level 3 problem-solving, i.e. lead to level 1 or level 2,

and hence can be considered the major factors by which sustainable problem-solving outcomes are less likely to achieve.

The behavioral theme refers to a cognitive bias of individuals while confronted with problems. Drawing from the idea that humans are cognitive misers, Evans and Stanovich (2013) argue that most of human behavior is controlled by rapid autonomous responses (intuitive mode) unless reflective reasoning (systematic mode) is triggered. This natural and instinctive tendency to jump to solutions limit sensing, seizing, and reconfiguring capabilities of problem-solvers. The sensing capability is limited as problem-solvers focus on a wrong problem that is more likely to recur and hence cannot contribute to sustainable development. Quick recognition of the problem which is not based on adequate problem analysis and employing workarounds based on subjective prior beliefs is a result of the inability of problem-solvers to interpret problem-structure data. Therefore, seizing and reconfiguring capabilities of problem-solvers are distorted, problems cannot be appropriately responded to, and long-term success seems difficult to be achieved.

For the second aggregate theme, organizational impediments, we identify four factors namely (a) time pressure, (b) resources constraints, (c) individual problem-solving and lack of collaborative culture, and (d) insufficient leadership practices.

Time pressure: SPS takes time and becomes effective only with a delay (Repenning & Sterman, 2002). When time pressure is high (i.e. either external pressure such as intense competition and customers' pressure or internal pressure from top managers for "Don't bring me problems, bring me solutions" type of culture), problem-solvers act as quick satisfiers by just eliminating problem symptoms. Rushing into solutions prevents problem-solvers to get involved in SPS (Tucker et al., 2002) and limit sensing, seizing, and reconfiguring capabilities of problem-solvers.

Resource constraints: knowledge-based theory (KBT) proposes that information is the main dimension of SPS (Nickerson & Zenger, 2004). When problem-solvers fail to obtain the relevant information, they just rely on their knowledge on prior successful solutions that are devised according to their personal experience. However, information gathering is costly and requires a considerable investment on organizational resources (Mintzberg et al., 1976). From a DC perspective, identification of a right problem (sensing), making investment to transform it into an opportunity to grow (seizing), and adopting positive changes based on rich information (reconfiguring) seem difficult when either organizational resources (strategic such as information or other resources such as money and human resources) are not available or a firm's understanding is limited on potential resources to invest on.

Individual problem-solving: the problem-solving literature promotes team-work to facilitate SPS (Morrison, 2015). Individual problem-solving, compared to group-problem-solving with heterogeneous team members where a problem could be viewed through multiple perspectives with different cognitive structures of participants, is less effective (Baer et al., 2013). From a DC perspective, when the problem and its structure are not perfectly shared, problem-solvers are less likely to shape a problem as an opportunity to learn from and to employ a course of actions to fundamentally overcome the problem.

Insufficient leadership practices: senior executives play the most critical role not only for resource allocation and training problem-solvers, but also to create a supportive context

where SPS can fully flourish. Leaders should emphasize team-work and encourage front-line employees to participate in SPS by making incentives, create commitment, and trigger the culture of continuous improvement, change and learning (Bruccoleri et al., 2019). This type of leadership is known as transformational leadership in the literature (Lopez-Cabrales et al., 2017). Transformational leadership is concerned with the encouragement of SPS adoption through exploring new ideas (sensing), establishing an environment where problem-solvers can formulate the problem faced (seizing), and constantly improving the operational processes (reconfiguring) for the successful SPS adoption.

Discussion and Conclusion

First, we demonstrated that not every problem-solving behavior serves as a DC. We illustrate that, among identified levels, level 3 problem solving or SPS could be considered a DC to improve and maintain operational performance over time. The main activities of SPS match sensing, seizing, and reconfiguring capabilities. Problem detection refers to the sensing capability as it includes the detection of a value-creating opportunity or addressing a right problem. Problem-solving activities should focus on the problem that brings value and leads to the opportunity to learn from. Problem formulation (i.e. problem definition, problem analysis, and solution design) emerges as the seizing capability which means to invest on organizational resources to fundamentally respond to the problem. Finally, routinization is recognized as the reconfiguring capability to constantly refine and make positive changes in operating routines of the firm.

Second, we also show that activities for level 1 and level, although helpful for short-term improvement, might undermine level 3 or SPS and usually fail to result in sustainable outcomes. This study also determines two themes as the major reasons of failures for improvement-based activities. One is a behavioral factor that refer to a cognitive bias, i.e. a natural tendency of problem-solvers to jump to a solution. This, indeed, leads to levels 1 and 2 problem-solving with tangible and certain outcomes. The second theme is a set of organizational impediments in particular time pressure, resource constraints, individual problem-solving and lack of collaborative culture, and insufficient leadership practices. We claim that these factors distort sensing, seizing and reconfiguring capabilities of problem-solvers where DC cannot be developed and SPS adoption is less likely to take place or its effect is minimized in long-term.

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Implications of production movements on manufacturing firms' financial performance

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Abstract

This paper examines the effects of production relocations on manufacturing firms' financial performance, by employing survey data and financial statement of 229 Finnish manufacturing companies. Comparison groups are built of companies that have relocated their production and those that have not done so. The paper employs information directly from the financial statements to understand real performance implications. It was found that labor intensity is not always related to production movements, and, significantly, companies that relocated their production maintained their profitability better than those that did not do so. This result implies further studies with both theoretical and practical relevance.

Keywords: Production, Relocation, Financial performance, Profitability

Introduction

Manufacturing companies have been actively looking for new manufacturing locations throughout the last decades in their search for lower production costs, new markets and customers, and best capabilities for future success. The importance of manufacturing industries for national economies is significant because of jobs and tax incomes. Therefore, there have been increasing concerns among policy makers to re-attract production that has been moved abroad. Relocation of production has been extensively studied from different perspectives during recent years (the most recent ones being Baraldi et al., 2018; Barbieri et al., 2018; Bailey et al., 2018; Di Mauro et al., 2018; Heikkilä et al., 2018a and 2018b; Johansson et al., 2018). However, there are not many studies available (cf. Stentoft et al., 2018) in which the performance effects of production relocations are directly studied. This study aims to contribute to this research by analyzing the financial implications of production movements. The data used for the analysis combines survey data and financial statement data of 229 Finnish manufacturing companies during the time period of 2010 to 2015.

Several studies examine the objectives and expected benefits of the production

relocation. However, these studies typically exclude the actual outcomes of the relocations from the studies or they use survey instruments to examine perceived performance outcomes. Stentoft et al. (2018) are among the few studies that address the performance outcomes of the production relocations, with their focus on cost performance and operational performance, and also cost accounting capabilities, which can be considered as a prerequisite for anticipating and managing cost-related performance outcomes. Their study was based on Danish survey data which was collected at the same time as our data in Finland, using the same survey instrument.

In order to provide more support to the findings on the production relocation performance, Stentoft et al. (2018) mention use of return on capital employed (ROCE) figures (as averages) from the studied companies. However, they do not report any significant associations or influences of the production relocations to those figures. In other words, as a clear motivation for this study, despite the highlighted need for understanding the production relocation performance, as perceived by the managers or reported as financial performance, the extant literature has not been able to provide evidence on such a link.

Indeed, thorough understanding of the companies and their production relocation cases is required for unveiling production relocation performance, in contrast to similar companies that did not make production relocations. In order to enable such comparison, one has to be careful in designing the research setting accordingly. Wagner (2011) is among the very few who have compared the performances of the relocating and non-relocating firms. He used propensity scoring to establish a sufficient basis for the comparisons. As Wagner (2011) argued, there is no data available about the same companies both relocating and not relocating under the same circumstances, and therefore, one has to find matches of similar companies to enable comparisons. Wagner (2011) reports his analysis on the relocating company characteristics and relocation performance effects in the German context, but the examination in his surveys is limited to the effects on human capital intensity and productivity, with only small or not significant performance effects.

In this study, we argue that understanding the effects of relocation on firm performance would require an extensive analysis of the production relocation decisions, compared with non-relocation and supplemented with an analysis of longitudinal performance data from the financial statements. Such analyses need to be conducted by matching the relocating companies in sufficient detail with those companies that did not relocate their production (Wagner 2011). These analyses would help in unveiling the possible differences between the actual performance outcomes, i.e. the long-term profitability of the companies, in the companies that did make production relocation decisions and those that decided to stay at home. Such possible differences have not been empirically examined, thus outlining the contribution potential of this study.

In order to examine the production relocation performance, it is important to analyze the conditions under which the production relocations could be more likely done. Overall, cost benefits are desired in offshoring decisions, and thus cost accounting capabilities are associated with offshoring, as was found in the study by Stentoft et al. (2018). Such capabilities both enable analyses prior to production relocation and unveil potential for savings and other financial benefits from production relocation. If the cost accounting reveals potential for labor cost savings, this could support production relocation considerations. More broadly, the labor intensity, or human capital intensity, as Wagner (2011) described, could encourage companies to continuously analyze production location and their effects on firm performance and profitability.

Design/methodology/approach

The premise for this study is to find an objective view on the performance of companies relocating their production. The following two propositions were addressed, grounded on earlier research:

- Proposition 1: Lower capital intensity (higher labor intensity) supports production movements (cf. Canham and Hamilton, 2013; Dachs et al., 2006).
- Proposition 2: Production movement activity has a positive effect on financial performance (cf. Bertrand, 2011; Jiang et al., 2007; Lu and Beamish, 2001; Massini et al., 2010; Moser et al., 2009; Wagner, 2010).

The empirical analysis consists of two parts. First, the production movement activities were studied using logistic regression. Second, the effects of production movements were analyzed using propensity score method. Two groups were formed to control the influences of the production movements. The first group consisted of companies that had made production movements and the second group was a control group with similar characteristics but with no production movements. The groups were compared for production movement activity and characteristics, financial performance and operational working capital.

The study combined two data sources. The data regarding manufacturing relocations came from a survey consisting of manufacturing offshoring and backshoring by Danish, Finnish and Swedish firms during 2010-2015, collected in the autumn of 2015 (Heikkilä et al., 2018a, Heikkilä et al., 2018b, Johansson et al., 2018). The second data source was the financial statements of all the 229 Finnish firms that responded to the survey, for the years 2010-2015 (six years), providing a view on the evolution of the financial figures.

Literature on production relocation performance

Only few articles have studied the actual performance effect of the production relocation (Stentoft et al., 2018). Surprisingly, relocation in general associated with firm performance has not been extensively studied either. Knoben and Oerlemans (2005) analyzed firm relocation research and concluded that research on the effects of the relocation decisions remained scarce, despite the interest in the relocation decisions and their antecedents. More particularly, some research on the relocation outcomes focused on stock prices (e.g. Brandon-Jones et al., 2017), possibly neglecting profitability effects at multiple performance effects on business operations, measured by return on assets and its components, as well as the effects on the innovation possibilities.

Since then, Wagner (2011) has explicitly studied the relocating firm characteristics, as well as the effects of those relocations. Similarly to this study, Wagner also used propensity scores on his survey data, in order to find a comparison group for the relocating companies among those companies that did not relocate their production. In his study on German manufacturers, Wagner (2011) concluded that relocating firms are “larger and more productive, more human capital intensive, and have a higher share of exports in total sales”. Regarding the performance effects of the production relocations, Wagner (2011) focused on the employment and productivity effects of the relocations, and found only small negative effects to the employment and positive effects on the productivity, the latter limited to the companies that had long experience on offshoring relocations. In contrast to Wagner (2011) study, uniquely, this study supplements the survey data with financial statement analyzes, to analyze the effects of relocations to the financial performance of the firms by employing return on assets and its components.

The advantage of this approach is to provide the overall performance effects, neither limited to the effects related to the labor and costs nor to the effects perceived by the survey respondents. Instead, the approach enables the view on the broader competitiveness of the

companies under examination.

On decision-making and performance

Overall, managers tend to assume rational decision-making, based on the financial figures and forecasts available. However, financial information often fails in actually supporting decision-making, which may hinder the performance effects of those decisions. Wouters and Verdaasdonk (2002) argue that managers find financial information useful "(1) when they must make a significant, new or rarely taken decision, (2) when they must take new considerations into account, and (3) when operational knowledge is distributed across various people from different parts of the organization". All these characteristics tend to apply production relocation decisions, which should then benefit from financial information available before the relocation decisions. Indeed, financial information would be needed to understand the decision-making situation and thus support the decision-making process. More particularly, cost accounting capabilities may help making relocations decisions (Stentoft et al., 2018), but it is noteworthy that the companies need to understand if they seek to keep their current performance with the relocation or improve it from certain perspectives. This requires more extensive analyses than cost accounting on the labor-intensive operations, and thus support the choice of analyzing long-term profitability and its trend over time, in contrast to the comparison group.

Bals et al. (2016) outlined a theoretical framework on different options of production relocation decisions. They also highlighted the need for understanding the decision-making processes of production relocation and eventually the performance outcomes of those decisions. In their agenda for further studies, they brought up the distinction between the strategic relocations and reactions to earlier relocation failures. Indeed, seeking for cost savings, for instance, may be in these two cases a remarkably different issue. Besides, they placed an emphasis on the organizational readiness for production relocation decisions (also well beyond the cost accounting capabilities) and the need for examining units of analysis on different levels with respect to the production relocation decisions. In response to this need for understanding production relocation decisions, the present article examines long-term profitability outcomes of the production relocations in contrast to similar companies that did not make production relocations, which provides an overview of the outcomes that could be thus detailed from different perspectives of the framework of Bals et al. (2016).

Analysis

Logistic regression analysis is performed to find out if capital intensity is connected with relocation activity. Respondents in our survey research stated that savings in labor costs were the most important reason to offshore (Heikkilä et al., 2018a and 2018b; Johansson et al., 2018). This would imply that labor costs are significant part of companies cost structure and savings in there would be significant enough to justify production movements. Finding out if more labor and less capital-intensive companies move production more often would be in-line with survey results.

Analysis is performed using SPSS binary logistic model. The chosen explanatory variables are total assets to revenue for capital intensity. The financial indicators from the beginning of the examined period (2010) are used. The assumption is that bigger companies and companies in certain types of industries move production more often. Controlling effects of industry and company size is done using control variables from the survey data. Companies answered to which industry their focal plant primary belongs. The industries are classified into a 1-5 scale based on the technology intensity. The total number of employees in companies operationalizes the company size in the analysis.

The production movements are separated into three different analysis. Table 1 presents the sample data for the analyses. The probability for offshoring, backshoring and any production movement are compared to no-movement group of companies. The limit for the sample sizes is often 50 or 100 with minimum observation-to-predictor ratio of 1:10 (Peng et al., 2010). All of the analyses fulfill the criteria of 50 observations with adequate observation-to-predictor ratio. The requirement for logistic regression analysis is that the conditional mean of the binary outcome is binomially distributed (Peng et al., 2010). It is assumed that the production movements are independent of each other, even if it is possible that some companies follow the example of others when making production movements. Thus, the assumption of the binomial distribution is robust (Peng et al., 2010).

Table 1: The three logistic regression analyses and their sample sizes.

Outcome of interest and sample size for each analysis	Y = 1	Y = 0
Analysis 1	Offshoring (N = 52)	No movement (N = 131)
Analysis 2	Backshoring (N = 27)	No movement (N = 131)
Analysis 3	Any movement (N = 69)	No movement (N = 131)

Overall, the prediction of production movement is difficult with the use of logistic regression and the information from the chosen financial measures. The evidence on the effects of labor intensity to production movement activity is not clear (Proposition 1), so the model does not support the survey results. The number of employees and the technology-intensity of a company seem to be relatively good predictors for production movement activities. Companies with higher number of employees and companies in industries with higher technology-intensity seem to move production more often than others do.

Propensity score analysis for financial performance

When analyzing effects of production movements, it is not possible to examine the same company with and without production relocations using the same time period. Therefore, companies with production movements are compared to companies with no production movements. The problem is that companies who are active in production movements tend to have certain characteristics more often than others, as was seen in the results for the logistic regression analysis. Bigger companies and companies in higher technology-intensive industries seem to relocate production more often. This often leads into research settings where groups of companies in the comparison are different, and these differences are not controlled for analysis of, e.g., differences in performance.

The situation in which uneven selection of the participation makes the focused group and control group different is called selection bias. In this study, the companies that have moved production tend to be bigger and they are not evenly distributed across industries. The bias rises from the possibility that size and industry type affect the financial performance of companies. To control the effects of industry and size the control group needs to be as similar as possible compared to the focused group of companies, i.e., in our study those companies that have done production movements. To do this, each company that has moved production need to be matched with a similar non-moving company (ideally identical) at the time of production relocation (Caliendo & Kopeinig, 2008).

Production movement companies can be matched to its no-movement pairs by using the propensity score method (PSM). It has become a popular approach to examine effects

in situations where selection bias is a potential problem. Moser et al. (2009) and Wagner (2010) have analyzed the effects of offshoring using PSM and focusing on the effects in employment and productivity.

Taking into account relevant differences between units when selecting the control group can yield an unbiased estimate of the treatment impact. According to Caliendo and Kopeinig (2008), PSM should include the following five steps:

1. Propensity score estimation
2. Choose matching algorithm
3. Check overlap/common support
4. Matching quality/effect estimation
5. Sensitivity analysis

Step 1 includes choosing the propensity score model that calculates probabilities for the units to be selected in the treatment group. When the final purpose of the product is to select a suitable control group, not to estimate accurate structural coefficients, the given models yield similar results (Caliendo & Kopeinig, 2008). In this study, the chosen statistical computing program (SPSS) is used to calculate propensity scores. Variables that affect simultaneously the selection and the outcome should be chosen and only the variables that are unaffected by the participation should be included (Caliendo and Kopeinig, 2008). In this study, the chosen variables are company size (number of employees) and industry (two-digit SI-codes). The attempt is to keep the number of variables as low as possible due to the small sample size and to minimize the variance in propensity scores.

In Step 2, after the estimation of propensity scores, the actual matching of the treated and untreated units takes place. One of the most common and straightforward ways of matching, also used by Wagner (2010) and Moser et al. (2009), is to use the nearest neighbor matching method (Thoemmes 2012). The decisions can be considered as trade-offs between bias and efficiency. In here, due to the relatively small sample size but still sufficient number of untreated control units, one-to-one matching was applied. The caliber shows how far the nearest neighbor is from its treated pair. Increasing caliber adds chance for weaker matches. Increasing caliber causes bias but choosing small caliber can cause units to be excluded from the analysis. Here, the analysis was performed using different calibers to validate the sensitivity of the results.

The purpose of Step 3 is to ensure that for each treated unit a close untreated unit can be found. This is called common support. In a lack of common support, observations can be discarded if the chosen caliber is small, resulting in some regions of the propensity score distribution consisting of only treated or non-treated units. When the number of discarded units is increasing, it raises the question if the remaining units represent the sample well enough.

In Step 4, matching quality is verified by comparing distributions of the selected variables and means of estimated propensity scores. Independent t-test is performed in order to compare the difference between the means of the estimated propensity scores for the production movement and control groups. There should not be found any statistically significant differences in the mean after the matching is done or otherwise the matching quality is inadequate. At this point, it is still possible to go back and try different variables or matching methods. If the matching quality is sufficient, it is possible to calculate average treatment effect on treated (ATT). The treatment effect is here considered as the difference of the arithmetic means using independent t-test. When using matching method without replacement and the amount of discarded units is small, we assume that p-values from the t-test are approximately correct.

The objective of Step 5 is to verify assumptions that all the covariates are taken into

account and the results are not sensitive to discarded units because of lack of common support. The first assumption is strong and difficult to test. The rest of the analysis assume that all of the relevant covariates that affect matching are taken into account. The assumption of common support is tested by including also bigger calibers in matching (if possible) to ensure that discarded units do not significantly affect the results.

Testing proposition 2 with the propensity score method

The effects of production relocations were tested for financial effects of any relocation decision (offshoring or backshoring) against companies with no movements. Any production movement group and no-movement groups both had 55 companies in the analysis. Table 2 below shows the distribution of company size for the two groups and Table 3 shows the distribution of industries in the two groups.

Table 2. Distribution of company size for any production movement and no-movement control groups.

Number of firms across company size	Caliber 0.1		
	Any movement	No move-ment	Total
51-100 Employees	13	12	25
101-250 Employees	20	19	39
251-500 Employees	8	8	16
Over 500 Employees	14	16	30
Total	55	55	110

Table 3. Distribution of industry for any production movement group and no-movement control group.

Number of firms across industry	Caliber 0.1		
	Any movement	No movement	Total
Food industry (10)	4	4	8
Textile and clothing industry (13,14)	1	1	2
Paper industry (17)	2	1	3
Graphical industry (18)	1	1	2
Chemical industry (20)	4	5	9
Pharmaceuticals Industry (21)	0	1	1
Rubber and plastics industry (22)	3	2	5
Other non-metallic mineral products in-dustry	1	2	3
Basic metals industry	2	1	3
Fabricated metal products, except machin-ery and equipment (25)	6	8	14
Computer, electronic and optical products (26)	3	5	8
Electrical equipment (27)	8	4	12
Machinery industry and equipment (28)	17	17	34
Transport equipment industry (30)	1	1	2
Furniture industry (31)	0	1	1
Other Manufacturing (32)	1	1	2
Total	55	55	110

The overall distributions are relatively even for both groups and matching was, therefore, considered successful even with the low number of no movement firms and electrical industry (SI code 27) being over-represented in the any movement group and fabricated metals (SI code 25) and computer, electronic and optical products (SI code 26) being over-represented in the no movement group. Analysis of means of discarded variables in Table 4 support that matching quality is sufficient even for the variables that were left out of the matching. No statistically significant differences between the groups were found, even if any movement companies are bigger in terms of revenue.

Table 5 presents the results for effects of any production movements in terms of profitability and operational working capital. The difference between the comparison groups (ATT value) for change of OROA (4,30 percentage points) imply that any movement group has been able to maintain the profitability much better than the no-movement control group. Therefore, proposition 2 is supported with 5 % risk level in one-way testing ($p < 0,023$). As OROA can be calculated as gross profit multiplied by asset turnover, the relocating firms have performed better especially regarding the profits (income statement).

Table 4. Means of discarded variables for any production movement group and no-movement control group (t-test).

Means of discarded variables	**Caliber 0,1**		
	Any movement	No Movement	p-value (2-tailed)
OROA (2010)	7,68 %	7,17 %	0,87
Financial Leverage (Equity-to-debt (2010))	2,37	2,83	0,64
Revenue (2010)	220 MEUR	137 MEUR	0,48

Table 5. Effects of production movements on financial performance.

Effects of Production movement	N	Any movement	No movement	ATT	p-value (2-tailed)
Caliber 0.1					
Operating return on assets %	103	-0,24	-4,54	4,30	0,06
Revenue	103	24,59 %	5,86 %	18,73 %	0,13
Gross profit %	103	0,23	-3,07	3,29	0,03
Asset turnover %	103	-7,23	1,51	-8,74	0,46
Net trade cycle %	92	-0,24	-0,24	0	1,00
Absolute operational working capital (trimmed)	99	0,72 %	6,60 %	-5,88%	0,62
Inventory to Revenue %	102	1,20	-1,35	2,55	0,04

The effects in operating working capital are seen in the absolute change of operating working capital (-5,88 %, with no statistical significance) but the effect disappears when the change in revenue is taken into account in the net trade cycle. The change of inventories shows a statistically significant change in the ATT. The results for the change of inventory are more reliable in terms of more companies included in the analysis.

Findings and conclusions

The paper examined the effects of production relocations on manufacturing firms' financial performance, by employing survey data and financial statement data of 229

Finnish manufacturing companies. Uniquely, the study employed financial information directly based on the financial statements, to understand the overall financial performance implications in a longitudinal manner (2010-2015 in this study).

Regarding proposition 1, the findings of the study suggest that labor intensity does not always predict production movements, although a weak relationship between less capital-intensive companies and production movement activity was identified.

Regarding proposition 2, the most important finding of the study is a positive relationship between the production movement activity and the financial performance. A statistically significant difference of 4.30 percentage points in the change of OROA was found between the comparison groups, especially due to the better maintained gross profits of the relocating companies. Indeed, companies with movement activities were able to maintain their profitability better than companies in the control group with no movements, during a weak economic cycle.

The contribution of the paper lies only partly in the identified effects on the financial performance. Besides, the approach of the paper provides the following benefits to the scholarly discussion in this area, to be further examined and tested in the forthcoming studies:

- The article addresses directly the performance effects of the relocation to provide a operationally solid basis for comparisons.
- This article, quite uniquely, brings up the profitability to the discussion (cf. Stentoft et al., 2018), and can show an effect of the relocation on the profitability, to foster discussion on the actual performance effects of the production movements.
- This article is among the very few articles that is able to compare the effects of the relocation with the companies that did not relocate, with a methodology suggested and used by Wagner (2011).

It is noteworthy that in its analyses on the financial performance effects, this study included long-term profitability and profitability trend in the analysis and was thus able to show the companies' ability to maintain the profitability (in contrast to non-relocating companies, in response to the challenging economic situation). This is a relevant approach also for the further studies. One should not only focus on the financial performance positive or negative trends in the pure numbers, but the analyses should enable recognizing the possible negative effects of not making any decisions about the production locations.

Finally, production movements are in an important role in the strategy and profitability of manufacturing firms. Investigating more specific mechanisms behind the positive effects offer interesting opportunities for future research. As a limitation, the article, of course, cannot state that maintaining the profitability was only due to the relocation. Instead, relocating companies might be more active also in their other choices and decisions in managing their profitability. Thus, in-depth cases studies are suggested to unveil these dynamics underlying the positive financial performance effects.

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Ship Breaking Industry in Bangladesh: Operations Management Perspective

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Abstract:

Ship-Breaking Industry is contributing to the Development of Bangladesh since the 1960s. This research argues that theories of Operations management would help this industry not only to manage in a better way but also to overcome the criticism about this sector around the world. Grounded Theory as the methodology has been adopted with Negotiated Entry into three Ship-breaking Yards. Having analyzed the fictitiously named cases, Hill Model and HW Model emerged instrumental to explain the operations activities of the ship-breaking Industry. This finding may be considered as an extension of the Operations Management theory. Future researches can be directed to the path of Supply chain management, Financing, and recycling of product of ships.

***Keywords*:** Ship-breaking; Operations Management; Circular Economy; Hill Model and HW Model

Background:

Although there has been enough attention on Ship-breaking Industry in Bangladesh by the Environmental activities, Non-governmental organization (NGO), legal practitioners and journalists (Print and Electronic), academic and research attention is relatively inadequate to this growing and important sector of Bangladesh. Ship-breaking industry possesses economic importance and peril to the environment at the same time as previous researchers noted. Most of the ship breaking yards are situated in Sitakund by the side of Bay of Bengal. The location and the availability of cheap labor rate have acted as the biggest competitive advantage to establish itself as one of the biggest ship scrapping market (Zakaria, Ali & Hossain, 2012).

Ship breaking industry has enjoyed subsistent growth over the years in Bangladesh. This industry was found to be the unique source of scraps for small rerolling industries in Bangladesh for years. Their output in 2008 rose to become more than doubled as compared to that in 2005 (Sujauddin et al., 2015). Ship breaking industry helps to meet 60% demand for the raw materials required by the local steel industry. Around 1.5million tons of scrap steel is produced from ship breaking. This contributes to national steel production to 50% and contributes to national steel consumption to as much as 25%. Domestic vessels are mostly made out of steel and equipment from the dismantled ships in Bangladesh (Hossain, Iqbal, Zakaria, 2010). These findings align with the thinking of circular economy which is based on the idea of "the economy being restorative and regenerative" (McDonough & Braungart, 2010). Ship breaking industry also contributes to a huge extent for the national economy. Around 10 billion Taka of import duty, yards tax, and other taxes are earned by the government. Also, the ship breaking industry creates employment for a large number of people (Rabbi & Rahman, 2017). According to the World Bank, around 1.5million new jobs have to be created for the next 20 years (Rahman, 2017).

Disassembling of ship bears great economic value, but grave environmental concerns (Talukder, Fakhruddin & Hossain, 2015). Pollution of environment by emitting toxic materials, being cause of different diseases of the workers, causing death of workers although the most is occurred by the carelessness of the workers- could be stated as the major adverse impacts of ship-breaking in Bangladesh (Rahman, 2017; Jobaid, Khan, Haque & Shawon, 2014; Muhibullah, 2013; Sikder, Bhuiyan, Ghosh & Rabin, 2016).

The Environment Conservation Rules, 1997 requires that each ship breaking yard must develop an environmental management plan. Then a clearance certificate from the Department of the Environment, Ministry of Forest and Environment is required. The new rule states that the exporter has to certify that the ship to be disposed of in Bangladesh has to be environmentally safe. Although it is hard not to pollute the environment around ship breaking yards, the impact on the environment can be minimized by adhering to international conventions (Rabbi & Rahman, 2017).

Though every organization posits various prescriptions to make the ship-breaking industry less detrimental for the environment and people, very less has been talked about how the process of ship-breaking can be carried out complying with the well-proven theories of operations management. This paper particularly focuses on the process choice and infrastructural part of the process of breaking the ship into useful pieces. This research argues that theory and Concepts of Operations management would help this industry not only to manage in a better way and become competitive but also to overcome the criticism about this sector in Bangladesh and around the world.

CHOICE OF FRAMEWORK OF OPERATIONS MANAGEMENT

Skinner's (1969) idea on manufacturing strategy has been developed and extended by a number of researchers and among them two frameworks have provided 'real alternative emphasis' to the original idea (Anderson, Cleveland and Schroeder, 1989:137). One is Terry Hill's framework (1985) and the other is the Hayes and Wheelwright (1984) stages of developing a manufacturing strategy. Although these models are regarded as classic models, they were chosen because of their relevance to this study. The discussion begins with the Hill framework named the 'Hill Model' and is followed by the Hayes and Wheelwright Model that is titled as the 'HW Model'.

HILL MODEL OF OPERATIONS MANAGEMENT

Terry Hill (1985) gives attention to the strategic and contingency issues of manufacturing policies. He put forward a framework of Manufacturing Strategy (Figure-1). This model is widely recognised both by academicians (Anderson et al., 1989; Adam and Swamidass, 1989; Ward, Leong and Snyder, 1990) and by practitioners (Voss, 1992). There are five steps in this model. These are: Corporate objectives, Marketing strategy, Order winning criteria, Process choice and Infrastructure. This model is relevant to this study because of its special attention to the organisational and HRM issues in developing a manufacturing strategy. The main advantages of this model are: identification of strategic role played by manufacturing, links between the marketing and manufacturing, identification of order winning criteria and the separate steps of developing a manufacturing strategy.

1	2	3	4	5
Corporate objectives	Marketing strategy	How do products win orders in the market place	Manufacturing Process choice	Strategy Infrastructure
• Growth • Profit • Return on investment • Other financial measures	• Product markets and segments • Range • Mix • Volumes • Standardisation versus customisation • Level of innovation • Leader versus follower alternatives	• Price • Quality • Delivery speed reliability • Colour range • Product range • Design leadership	• Choice of alternative processes • Trade-offs embodied in the process choice • Role of inventory in the process configuration	• Function support • Manufacturing systems • Control and procedures • Work structuring • Organisational structure

Figure-1: Hill Model of Manufacturing Strategy; Source: Hill (1985:41)

However, there are some weaknesses in this model. First, there is inadequate attention to the implementation of manufacturing strategy. Voss (1990) suggested a three-phase model of manufacturing strategy development. The first phase is equivalent to Hill's first three steps and the second phase is equivalent to Hill's last two steps. The third phase is the implementation. Although implementation is considered as those activities undertaken after setting the strategy, it clearly shows the inadequacy of the Hill Model on the implementation.

Second, there is incomplete consideration of the organisational and human resource management issues. The relationship of these issues with manufacturing strategy has received attention in some studies in the recent past. For example, Misterek and his colleagues (1990) examined the links between manufacturing strategy and organisational culture, Tranfield and his colleagues (1990) examined the relationship between the manufacturing strategy and organisational design. The importance of human resource issues in manufacturing strategy was highlighted by some researchers (for example, Goodridge, 1986; Oliver, 1990; Prabhu, 1990).

Hill (1985:158) believes that all these issues are part of the manufacturing 'infrastructure' that comprises 'the controls, procedures, systems and communications combined with the attitudes,

experience and skills of the people involved'. All these comments on the Hill Model will be examined in the light of a Comparative case studies on Ship breaking Industry in Bangladesh..

HW MODEL OF OPERATIONS MANAGEMENT

Hayes and Wheelwright's (1984) stages model of manufacturing strategy has attracted the attention of academicians and practitioners around the world (e.g. Anderson et al., 1989; Adam and Swamidass, 1989; Ward et al., 1990; Misterek et al., 1990; Schroeder et al., 1992; Mills, Platts and Gregory, 1995). This notional framework has particular relevance to the present research. The HW model has highlighted the progression of developing manufacturing strategy and the present research has adopted a comparative case study on Ship breaking Industry in Bangladesh. Figure-2 shows the HW Model of manufacturing strategy.

STAGE-1	**STAGE-2**	**STAGE-3**	**STAGE-4**
INTERNALLY NEUTRAL (Mininize Manufacturing's negative potential)	***EXTERNALLY NEUTRAL*** {Achieve Parity (Neutrality) with competitors}	***INTERNALLY SUPPORTIVE*** (Provide Credible Support to the Business Strategy)	***EXTERNALLY SUPPORTIVE*** (Pursue a Manufacturing -Based Competitive Advantage)
• External experts are used in making decisions about strategic manufacturing issues. • Internal management control systems are the primary means for monitoring manufacturing performance. • Manufacturing is kept flexible and reactive.	• "Industry practice" is followed. • The planning horizon for manufacturing investment decisions is extended to incorporate a single business cycle. • Capital investment is regarded as the primary means for catching up to competition or achieving a competitive edge.	• Manufacturing investments are screened for consistency with the business strategy. • Changes in business strategy are automatically translated into manufacturing implications. • Longer-term manufacturing developments and trends are systematically addressed.	• Efforts are made to anticipate the potential of new manufacturing practices and technologies. • Manufacturing is centrally involved in major marketing and engineering decisions. • Long-range programs are pursued in order to acquire capabilities in advance of needs.

Figure 2-2: HW Model of Manufacturing Strategy; Source: Hayes and Wheelwright (1984:396)

The HW model has a number of advantages. These are: it identifies the four roles that manufacturing can play in achieving competitive advantages; it suggests a continuum that contains four stages for developing manufacturing strategy; it highlights the growth and incrementalism for developing manufacturing strategy; it shows the influence of contextual factors, both internal and external, on manufacturing strategy.

However, certain comments can be made on this model. First, it gives inadequate attention to the infrastructural and organisational issues for developing manufacturing strategy. A number of researchers have highlighted the importance of these issues in developing manufacturing strategy. Akkermans and Aken (1991:9) mention that 'so-called "soft" issues like organizational culture, organizational politics and organizational learning are often not seen as essential for the operations manager's job. Yet they constitute the major challenge in developing a successful operations strategy'. Secondly, it appears that the process of implementing manufacturing strategy has received inadequate attention in this model. Although Hayes and Wheelwright (1984:30) believes that the development of a manufacturing strategy is an interactive process of planning and execution, a good number of researchers have highlighted the need for separate research attention to the process of implementing manufacturing strategy (Voss, 1988; Leonard-Barton, 1988; Miller and Hayslip, 1989; Barker, 1990;

Marucheck et al., 1990; Kinnie and Staughton, 1991). Finally, the HW model has considered the corporate and business level of an organisation but did not consider the plant level for developing manufacturing strategy. All these observations on the HW Model will be pursued in this research.

Method:

Ship breaking activities appears to be very restrictive and very difficult to get access in to the yard. The main focus of this study is to understand the ship breaking activities. Without having knowledge of how ship breaking activities are taking place, it would be difficult to conceptualize the problem & suggest any advice for the problem. The nature & realities of field indicates the appropriateness of research methodology to be adopted (Denzin 1978; Glaser and Strauss 1967).

Considering this realities, research team decided to adopt naturalistic paradigm (Lincoln and Guba, 1985) for this research. Moreover, in order to get access, the lead researcher had to use official position (Director, Government Bank of Bangladesh). The lead researcher had to visit all three ship yard as a part of a "Negotiated Entry" into the yards. In addition, research team had to explain the academic rationale of this study & this help the research team to establish trust between the owner & researchers. It took more time to apply this approach and access was negotiated and only for academic purposes. The problems associated with gaining access and developing trust are well established in the research methodology literature (Bogdan and Taylor, 1975; Whyte, 1984; Lincoln and Guba, 1985: Johnson, 1975).Then a detail discussion broadens our understanding about the phenomenon of ship breaking activities & becomes difficult to concentrate on one particular area. Based on the observed realities, research team discussed & concentrated on operations management. From ground of ship yard, we gradually move upward, ship broker & finally to the highest level of the relevant authorities of Government of Bangladesh.

The Methodology adopted was qualitative and Grounded theory (Glaser and Strauss, 1967) approach. On Grounded theory, Discussion meeting, Observations, Open ended questions, access to the documents and recording some the discussion and allowed to take photo of work activities. Once the owner trust the research team, everything become open and very elaborate and the meeting times of 10 minute becomes 2 hours. The nature of ship –breaking activities in the Yard indicates the Grounded Theory Methodology is appropriate in this research (Rahman, 2016). The duration of this research project is about six months from July 2018 to December 2018. Three field visits took place during this period. After the successful key informant interviews, the research team reviewed necessary documents and found out the parameters on which the comparisons among the three ship-yards can be made.

The Naturalistic Paradigm:

The naturalistic paradigm is the alternative way of understanding the organisation from the social perspective. Its focus is to get insights into the social processes of an organisation. A number of researchers have highlighted the theoretical and substantive dimension of the naturalistic paradigm (Bogdan and Taylor, 1975; Lincoln and Guba, 1985; Denzin, 1978; Morgan and Smircich, 1980; Walker, 1985; Reason, 1988). Its main assumptions are: multiple realities, interaction between the researcher and subject, generating hypothesis, use of qualitative research techniques such as observation, in-depth open-ended interviewing, ethnography, holistic view of the organisation and the subjective interpretation of the experience. As Walker (1985:13) mentions 'there can be no absolute objectivity but only agreements on truth and validity shared by people who hold the same meaning'.

The Grounded Theory:

Glaser & Strauss (1967) mentioned in their classic book on "The Discovery of grounded Theory" that in order to understand the realities, an inductive research methodology in particular 'Grounded theory Approach' (Glaser and Strauss, 1967) has been deployed. This method is appropriate becausesome of the theories are 'too remote or abstract to offer much detailed guidance and assistance' (Martin and Turner, 1986:142). On Grounded theory Glaser and Strauss (1967:6) mention that "Generating a theory from data means that most hypothesis and concepts not only come from the data, but are systematically worked out in relation to the data during the course of research". Turner (1983) has applied grounded theory approach in the organisational behaviour area. On the use of this research approach in organisational research, Martin and Turner (1986:143) mention that "An emerging

grounded theory primarily justifies itself by providing a detailed and carefully crafted account of the area under investigation. The theoretical account not only aids the investigator's understanding, but provides a means of communicating findings to those in the area studied, either as a basis for discussion or as a vehicle for implementing change".

Furthermore, it is almost established phenomenon that use of voice-recorder during interview greatly beneficial for the researcher (Whyte, 1984). Lead author of this paper has used voice-recorder elsewhere to conducting a field work (Rashid, 1997). Now-a-days, with the development of technology, in many organisations' videos is being used to examine the movement of people and parts within the studiedarea. Video can provide the details of movement along with the descriptions though it is very expansive mechanism. It can provide an insight into the shipbreaking processes of an organisation without physically visiting that particular plant. Moreover, observation and document review technique of data collection were used to study the ship-breaking in the yard. All the collected data were systematically analysed to make sense about the ship-breaking activities. On the basis of field work, this framework has been developed.

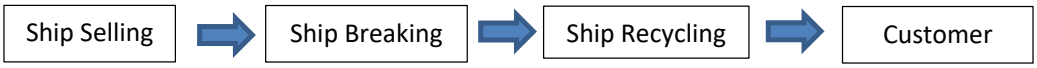
Framework Emerged from Fieldwork

International: International Maritime Organization (IMO), Basel Convention-1989, United Nations, Hong Kong Convention 2009- European Ship.

National: Bangladesh Bank, Bangladesh Government, NGO, GOB, Environmental activities, Legal aspect, Tax, Ministry of Shipping, ministry of Environment, Ministry of Commerce, Ministry of Industry.

Apex Body: Bangladesh Ship Breaking Recycling Association (BSBRA).

Plant Level:



Structure	Infrastructure

Source: The Authors

Interview:

Interview is one of the important techniques for collecting data (Yin, 1984). It may take various forms and can be placed on a continuum with unstructured interviews at the one end the semi-structured interview in the middle and the structured interview at the end (Berg, 1989; Robson, 1993). The unstructured interview is free from scheduling of questions but controlled through the researcher's interview framework (Burgess, 1982). It may be used to validate the observation and also to develop trust with the key informants. The semi-structured interview comprises pre-determined lists of questions using the words familiar to the subject. It allows the researcher to understand the subject's view and this can be accomplished through the unscheduled queries that arise during the interview process. The structured interview is the fixed schedule of questions developed by the researcher. It may be used to validate researchers 'ideas about the subjects' actions (Berg, 1989: 16).

The researcher was allowed to use a voice-recorder during the interviews. It is a symbol of a high level of trust (Whyte, 1984) in the researcher. The length of interview varied from manager to manager and also between levels of managers. The average length of recorded interview was one and one quarter of an hour

The Document Review:

The document review is another technique of collecting data. It is an acceptable technique in qualitative research (Marshall and Rossman, 1995; Lincoln and Guba, 1985). This technique may be used to get information on the historical background of the field, to broaden understanding about the nature of the business, and also to validate the observation. In addition, it can be used to resolve differences of opinion that are generated through the interview. The documented sources can also help to reconstruct the past activities. The documents are classified into two categories such as primary and secondary (Yin, 1984). The primary document is a document on which decisions are taken and most often it contains financial and personal information.

Comparative Case Study:

Turning to the comparative case study, a large number of researchers have used this method. This method helps to develop a new theory or a model (Walton and Susman, 1987) and also provides the opportunity to test findings of one case against other cases (Leonard-Barton, 1988). It reveals that multiple data collection techniques, such as observation, interview and document review, have been commonly used in comparative case studies. Wilkinson (1983) is the exception who has provided a detailed description of research method and also pointed out some of the problems relating to the access to some of the sources. The review of comparative case studies reveals that time frame has not been considered. The main advantages of this method are that it provides the basis for comparison of data and also the opportunity to demonstrate the similarity and differences of the findings (Voss, 1992). The main disadvantages of this method are that it fails to capture the process of change and also the depth of all the cases may not be the same. Level of access to the data sources in all the studied cases may vary. In addition, this method requires more funding than a single case study.

Brief Case Descriptions:

In order to maintain the anonymity as agreed with the owner of shipyard, Case-1, Case-2 and Case-3 has been used. Moreover, all case materials have been presented in a tabular form instead of descriptive format.

Case -1 is a small Yard and mostly manual system operating system. Yard appears to be not well structured. In the process of breaking a ship, it was identified that there are some hazardous materials inside the ship and overall quality of the ship was poor. Cleaning the hazardous materials from the ship was difficult task and took long time, although there was no major accident. As a result owner has failed to pay bank loan on time and become bank defaulter. Owner has to close down the yard.

Case-2 is a medium sized yard. This yard is primarily manual system with some automated equipment. This yard is in running condition but no attention to improve and follow the compliance issues. International price fluctuations put this yard in a losing condition. Moreover, big tidal wave has put huge raw materials into the sand. Taking out all those material and selling is a very difficult and long term task. Little employee accommodation was found.
Case-3 is a medium sized yard and growing at a faster rate. This yard is a mix of manual and automated. This Yard is following all the rules and regulations of the Government of Bangladesh. Moreover, new automated structure will be developed soon to satisfy international compliance. Regarding employees separated multistoried dormitories with all facilities has been developed. This Yard is operating round the year.

Case Number	Name of the Ship-breaking Yard
1.	DSY
2.	MSBY
3.	KRSY

Studied Cases

Serial No	Focus	Case-1	Case-2	Case-3
1.	Time Period (First Date of Visit)	August 2017	January 2018	December 2018
2.	Ownership	Single Owner	Family Ownership	Single Owner
3.	Experience	New	Long Experience	But New
4.	Size of Yard (Capacity of Beaching Ships, At a Time)	2 Ship	3 Ship	4 Ship
5.	Structure	Manual Activities	Manual but Some Automated Equipment	More Automated Equipment & Green Yard is In-process
6.	Employee Issues	No Employee Accommodation	Little Employee Accommodation	Employee Dormitories
7.	First Aid	Very Little	Some Medical Facilities	First Aid Room with Equipment
8.	Compliance	Little attention	Some Attention	Special Attention
9.	Running Time	Seasonal	Round the Year with Small Scale Activities	Round the Year with Regular Activities
10.	Notice Board	No Notice Board	Small Notice Board	Safety Notice Board with Bangla & English
11.	Inside Structure	Not Available	Around the Office, only Pathway	Walking Pathway with Hard Solid, cannot Move beyond Pathway
12.	Research Technique	-In-depth Observation -Interview with Owner, Manager & Employees	-In-depth Observation -Interview with Owner, Manager & 2 Employee	-In-depth Observation -Detail Discussion with Owner -Documents Review -Yard is Internet Connected
13.	Green Yard Certification	No	No	No
14.	No of Time Visited	3	2	1
15.	Sources of Fund	Bank Loan (Defaulter)	Bank Loan (Regular)	Bank Loan (Regular)
16.	Suffering Due to International Market Price Volatility	Yes	Yes	No
17.	Proper Utilization of Tidal Wave	No	No	Yes

DISCUSSION AND IMPLICATION:

Ship breaking industries in Bangladesh started its voyage in Bangladesh in 1960s when Chittagong Steel House brought and scrapped "MD Alpine", a cyclone-struck ship stranded in the shores of Sitakund, Chittagong (Hossain, Iqbal & Zakaria, 2010). In 2014-15, there were around 150 registered ship breaking yards, some of which has a capacity of scrapping 4 ships simultaneously. A significant number of ship breaking yards are ISO and other quality management certified, and many others have applied for it (Shameem, 2012). According to Greenpeace (2005), cheap labor cost, frail environmental regulations and weak safety issues are the main reasons behind pursuing ship breaking in Bangladesh. In 2015, there were around 80 companies were operating, with around 200000 workers working in this industry (Dunn, 2015). Maximum numbers of ships are scrapped in Chittagong,

Bangladesh and Alang-Sosiya, India. These are also known as capitals of the ship breaking. However, they are also known as sacrifice zones or toxic hot spots (Steve, 2010).The sub-continental ship breaking yards use beaching method for disassembling ships, as this region has huge tidal range and extensive mudflats (Pasha, Mahmood, Rahman, Hasnat, 2012). Bangladeshi ship breaking yards are not different from this. The ships are cut at small pieces using gas cutting. Bangladesh recently has scrapped some of the biggest deactivated ships of the world. Bangladesh scrapped around 30% of the world's LDT from 2000 to 2010. According to www.shipbreakingbd.info, Bangladesh held the first position in scrapping the highest number of ships from 2004-2009, and still holds a top position in ranking.

From the comparative case study, it can be easily extracted that the yard with automated structure is growing rapidly in terms of business volume. This very yard, namely KRSY, is providing better facilities for the employees and has a First-aid room with enough equipment. KRSY operates its business round the year with activities more regular compared to its counterparts. Moreover, KRSY is resistant to the volatility of International Market Price of Steel and not a loan defaulter. KRSY conforms more to the theories of operations management i.e. Hill's Model and HW Model than the other yards. Thus the general conclusion can be drawn that the yard which breaches itself more to the theories of operations management, will enjoy more success than others who remain far from the textbook operations theory.

On the basis of this study, the government of Bangladesh is financially benefited by getting tax and socially this industry will be contributing for the infrastructure development of the country. Theoretical implications are that Terry Hill (1985) model and Hayes and Wheelwright (1984) Model can help to explain the development of ship breaking industry of Bangladesh. Practically, the managers can get better insights by using these two models for their work and can also satisfy international compliance relating to this industry. At a higher level, this study contributes to the theory of circular economy.

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A bio-inspired solution for operations strategy

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Abstract

Operations strategy deals with tasks that manufacturing function has at the strategic level. Our purpose was to answer a classical question in a novel way: How corporate strategy can be translated into implications and terminology that are meaningful to manufacturing? A qualitative research perspective was followed, prompting to emerging results that follow an inductive approach. A Colombian manufacturing company participated in this project. OS representation was proposed by the participants through an "Operational Excellence Tree" to answer de question. We found that this novel result could be called bio-inspired solution and bio-inspired strategies is a good opportunity for further research.

Keywords: Operations strategy, bio-inspired strategy.

The knowledge gap and research question

This investigation contributes to research in operations strategy field. Operations strategy (OS) deals with tasks that manufacturing function has to fulfill in order to meet current and future challenges of the company (Slack and Lewis, 2011). According with Hayes and Wheelwright (1984, p. 398), companies that provide significant and credible support to their overall competitive strategy: "*Translate the business strategy into implications and terminology that are meaningful to manufacturing*". How to do it is a classical problem that remain open in the literature (Vivares, 2017) because there is not a universal OS that is good for all the companies (Miltenburg, 2009).

To verify the knowledge gap around this topics, a systematic review was performed (Bartels, 2013; Kitchenham, 2004). 395 references were found using two search equations. After their analysis, it can be concluded that there is a novel contribution to answer the following research question:

How corporate strategy can be translated into implications and terminology that are meaningful to manufacturing?

Design/methodology/approach

A qualitative research perspective was followed, prompting to emerging results that follow an inductive approach. An action research (AR) process was carried out to answer the research question. AR should contribute both to academic and practical fields (Avella and Alfaro, 2014). AR can be considered experimental research (Styhre and Sundgren, 2005). In this investigation, the experiment can be described as follows: 1) designing a procedure to guide the discussion required to answer the research question; 2) application of the procedure, and, 3) evaluation of results to validate the contribution to the OS.

A Colombian manufacturing company participated in this project. A group of 14 employees related to the production system administration participated in a workshop aimed at providing the structural bases to translate the company corporate strategy (CS) into the OS. The workshop followed the procedure in Figure 1, using open questions and discussion among the participants.

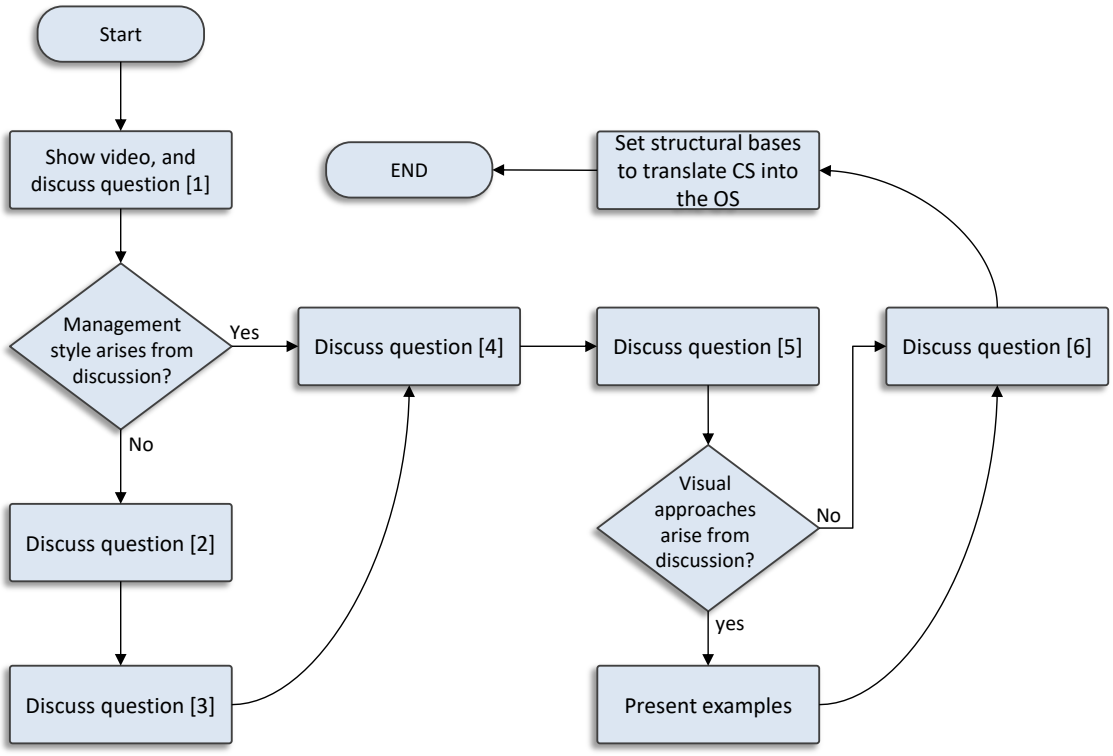

Figure 1- General procedure to identify the structural bases of OS

Question [1] was related to the company strategic needs. Questions [2], [3] and [4] were oriented on guiding the participants towards understanding the importance of translating the CS into OS, and question [5] on how to do it. Finally, the question [6] aims to define the specific application in the company.

Findings

As an emergent result from the process a bio-inspired solution was proposed by the participants. Specifically, OS representation was proposed through an "Operational Excellence Tree" (Figure 2), which contains the precise terminology for the company OS.

Figure 2- Bio-inspired operations strategy tree

Analog to the biological process, the roots support the whole tree and keep it erected, while absorbing water and nutrients from the soil, as OS is supported and nurtured by principles. The trunk holds the crown and keeps it firm, so, it allows connecting the OS with the company business strategies (BS). Branches represent each of the different BS, which helps to provide the fruits expected by the CS. Finally, sap circulates through the entire tree, being defined, in this case, as a renovating and revitalizing energy that keeps people motivated inside the company.

To test the suitability of the resulting tree as a tool to translate CS into OS, the workshop participants and the company management team were asked separately (Table 1), obtaining a high level of agreement and good acceptance by the management.

Table 1- Utility and suitability test

The resulting tree is accurate and useful to translate corporate strategy in into implications and terminology that are meaningful to manufacturing*	**Avg.**	**Median**	**Std. Dev.**
Workshop participants	4,4	4,250	0,459
Management team	4,2	4,000	0,274
Overall	**4,3**	4,000	**0,408**

* 1 (totally disagree), 5 (totally agree).

Discussion

A bio-inspired approach to OS alignment with CS and BS was obtained to answer the research question, specifically by analyzing the behavior of the trees. According to Vivares et al. (2018, p.1): "Bioinspiration is to solve problems taking lessons inspired by the behaviors of nature". The systematic literature review performed allowed us to confirm novelty of this approach since few articles were found regarding bio-inspired strategies, and none of them studied the problem addressed in this research.

From the reviewed works in the state of the art, some works have made bio-inspired contributions. For example, Peralta et al. (2017) presented a bio-inspired framework for sustainable fractal manufacturing, Kuznetsova et al. (2016) adopted the concept of industrial symbiosis to improve an Eco Industrial Park performance, while McCullar et al. (2016) propose bio-inspired design as a strategy to enhance sustainable products development. However, none of these contributions are however related to OS or CS.

For this reason, we state a novel hypothesis for further research:

Bio-inspired solutions are meaningful to translate corporate strategy into OS implications and terminology.

Furthermore, the aforementioned reasons suggest a more extensive field for research: bio-inspired strategies or bio-inspired management. This is a kind of framework in which we have an entrepreneurial problems and researchers can look for lessons from the behaviors of the nature to solve them. This approach has been used in other sciences but is not used yet in the OS field.

Conclusion

A bio-inspired approach to OS alignment with CS and BS was obtained to answer the research question, specifically by analyzing the behavior of the trees. The systematic literature review performed allowed us to confirm novelty of this approach since few articles were found regarding bio-inspired strategies, and none of them studied the problem addressed in this research. From a practice perspective, the proposed approach was well evaluated, and accepted by the company as a valuable contribution to translate CS into OS, in a didactic and easily understandable way to all levels of the workforce. Action research was a useful paradigm.

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Operational capabilities and business performance: the role of absorptive capacity and management practice

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Abstract

This paper investigated the role of the absorptive capacity and management cost control in the relationship between operational capabilities and business performance. We conducted a survey in the automotive and food industry and ran a structural equation modeling as analysis method. We found that different nature of operational capability impact on different type of performance. Additionally, we found that traditionally advocated benefits of management cost control on performance is mediated by operational cost efficiency. Finally, our results suggest investigations of some other potential capabilities that could mediate the absorptive capacity and performance.

Keywords: Capabilities, performance, practices

Introduction

The relationship between organizational capabilities and performance has been a lot studied, however, there are still plenty more to be done since this relationship could be analyzed from different dimensions of the performance (Kafetzopoulos et al., 2014). In addition, different assumptions while building the theoretical mechanism relating capabilities to performance also made this topic still open for research. For some scholars, operational capabilities are antecedents of performance (Wu et al., 2010), while others suggest differently (Jansen et al., 2005; Fosfuri and Tribó, 2008).

Schroeder and colleagues (2002) advocated that operational capabilities are positively related to manufacturing performance when incorporating both external and internal learning. Therefore, we started our study by adopting a similar rationale. In our manuscript, we operationalized information and knowledge acquisition and incorporation as absorptive capacity (Zahra & George, 2002).

Based on the literature of management control and practiced based view (Bromiley & Rau, 2016; Chenhall, 2003), we hypothesize that management control process might mediate the relationship between absorptive capacity and operational capabilities. Then, the latter might manifest on business performance. Among several operational capabilities, we explored the flexibility and operational cost efficiency and we adopted both financial and non-financial performance (Tatikonda & Montoya-Weiss, 2001)

From our results, we reinforced some of the existing studies about operational capabilities and performance. However, our results also suggested some controversial insights regarding the antecedents of these capabilities and the role of managerial cost control with performance.

Our research aimed to contribute in three big points. First, to improve the understanding of the impact of operational capabilities on the business performance. Second, to determine impact of absorptive capacity on the business performance and operational capability development. Third, to evaluate the role of managerial control on business performance and capabilities development.

Next, this work is structured in the following way: in section two we present a literature review on capabilities, absorptive capacity and management control. In section three, we described the research methodology. In section four, we present and discuss the results. And in section five, we conclude the paper.

Theoretical background

Capabilities

The study of the company's capabilities is a recurrent theme in the operations literature, as well as in strategy. The definition of capability is still a subject of study due to the profusion of is meanings and the most recurring conceptualization of capabilities relies on ideas of resources, routines, and skills. Pandža et al., (2003) and Amit and Schoemaker (1993) defined the capabilities as the idiosyncratic processes arising from tangible or intangible knowledge developed through the interrelationship of company resources and history. More specifically, some other authors suggested that capability is as bundle of the repetitive organizational routines and procedures and it represents a pattern of an organization behavior to solver problem and achieve a certain pre-defined goals (Dosi et al., 2000; Winter, 2003; Ray et al., 2004; Peng et al., 2008). Wu et al., (2010) propose capability as a set of skills, processes, and routines aiming at the alignment of resources in response to specific problems. These routines represent the strength or proficiency of a set of skills and competencies to manage resources for task execution.

Flexibility, cost efficiency and performance

There are several types of organizational capabilities, such as production, logistics, R&D, continuous improvement, innovation, project management, among others (Schmenner and Vastag, 2006). In the literature, the capabilities are often used as synonyms of how well organizations is performing in cost, quality, flexibility, deliveries (Ferdows and De Meyer, 1990; Flynn and Flynn, 2004; Rosenzweig and Roth, 2004; Schroeder et al., 2011; Skinner, 1969). or "environmental protection" (Avella and Vázquez-Bustelo, 2010).

By studying capability and performance, Swink et al. (2005) observed that cost efficiency and flexibility influence business performance through strategic integration of operational processes. However, some other studies demonstrated cost efficiency and flexibility might not impact in the same manner on all the business performance. For example, Rosenzweig, Roth, and Dean (2003) have argued that process flexibility has a positive influence on customer satisfaction, but did not confirm the same impact on sales.

As for the leadership in cost, they observed a positive relationship in sales, but did not ratify the same direction in customer satisfaction.

By turning the attention to the capability of cost efficiency, it is almost straightforward to infer that this capability is positively related to the organizational performance (Peteraf and Barney, 2003). Thus, while observing the role of cost efficiency in the supply chain, we can infer that cost efficiency creates values, but the value generated could be appropriated either by the supplier or by the customer depending on the power of these agents in the chain (Brandenburger and Stuart, 1996). Therefore, based on the rationales above, we declare the following hypotheses:

H1: Operational capabilities have a positive relationship with business performance.

H1a: Cost efficiency has a positive relationship with financial performance.

H1b: Cost efficiency has a positive relationship with customer satisfaction.

H1c: Process flexibility has a positive relationship with financial performance.

H1d: Process flexibility has a positive relationship with customer satisfaction.

Absorptive capacity

The seminal articles by Cohen and Levinthal (1989, 1990, 1994) described that the prior knowledge and relevant skills of a company are those that enable the assimilation of new knowledge and, in a way, do things in other configurations. In order to express this ability, Cohen and Levinthal (1989, 1990, 1994) proposed the term absorptive capacity (AC), which represents the ability of a company to recognize the value of new information and then to assimilate it and apply it for business purposes.

Based on the similar rationale, Zahra and George (2002) emphasized the dynamic aspect of this capacity and advocated that AC corresponds to the set of routines and processes of the company, which allows the acquisition, assimilation, transformation, and exploitation of external knowledge aiming to the generation of a dynamic organizational competence. Narasimhan, Rajiv, and Dutta (2006) also corroborate the dynamism of AC. These authors suggest that the process of absorption of know-how is essentially one of the most valued and uses a series of knowledge assets, which are sometimes not structured.

To better structure the AC as organizational routine, Tu et al., (2006) suggested AC as set of organizational mechanisms that enable the identification, communication, and assimilation of relevant external and internal knowledge. They suggest four dimensions of AC such as relevant prior knowledge, communications network, communications climate, and exploration. By noting the dependency of the new knowledge on the previous one, Tsai (2013) emphasized on the cumulative characteristic of AC, then on the routines of prolonged process of accumulation of investment and knowledge.

Potential and realized absorptive capacity

Zahra and George (2002) proposed two complementary dimensions of AC: (a) Potential Absorptive Capacity (PAC) that is based on acquisition and assimilation; (b) Realized Absorptive Capacity (RAC) based on transformation and exploitation. According to these authors, these two dimensions when properly managed, companies might experience superior performance, since it can change and reshape the base of the resource to fit to the market demand.

According to Zahra and George (2002), PAC provides the company's flexibility and freedom to adapt quickly to the environment. This capacity provides an increase in the company's ability to exploit the relevant external information (Fosfuri and Tribó, 2008). However, Jansen et al., (2005) also suggest when the firm focuses on PAC, it continually refined the knowledge stock, but increases its costs in order to reach a new level of

learning, therefore the decreasing its marginal contribution to performance (Brettel et al., 2011).

On the other hand, some studies suggested that RAC is the primary source of performance improvements, which means when the company focuses on RAC, it tends to make a profit in the short term (Jansen et al., 2005). RAC captures the new insights and results from the combination of current and newly acquired knowledge in operations and employ it to improve the organizational practices, routines and capabilities (Leal-Rodríguez et al., 2014). In other words, it represents the capacity to leverage acquired knowledge and transform it into innovation results (Zahra and George, 2002; Fosfuri and Tribó, 2008). According to Zahra and George (2002), these two subcategories (PAC and RAC) have complementary roles. Considering the discussion pointed out in the literature, we declare the following hypotheses:

H2: Absorptive capacity is positively related to organizational practices and capabilities;

H2a: Absorptive capacity is positively related to cost management control of the organization;

H2b: Absorptive capacity is positively related to cost efficiency capacity of the organization;

H2c: Absorptive capacity is positively related to flexibility capacity of the organization;

H3: Absorptive capacity is positively related to organizational performance

H3a: Absorptive capacity is positively related to financial performance

H3b: Absorptive capacity is positively related to customer satisfaction

Management control system – Cost control

The literature defines management control system (MCS) as the control process in which companies execute to implement and support their business strategies (Otley, 1994; Simons, 1994; Langfield-Smith, 1997). Therefore, we could infer that MCS has a close relationship with performance.

Similar to organizational capabilities, MCS could also be seen as routines and procedures to maintain or adjust the organizational activities, such as planning, budgeting, cost control, environmental analysis, competitive process analysis, performance evaluation, resource allocation, and incentives (Simons, 1987). Moreover, Henri (2006) understands that MCS acts as an antecedent of the organizational capabilities, that is, it represents the mechanism of influence of the company's competencies. In this sense, Henri (2006) suggests that the MCS impacts, through the diagnostic and interactive tools, on the generation and maintenance of organizational capabilities. Following this line of reasoning, it is observed that the literature presents evidence of the positive influence of the management control tools on capabilities and performance (Govindarajan and Gupta, 1985; Marginson, 2002; Chenhall, 2003; Nisiyama *et al.*, 2016).

Additionally, Merchant and Otley (2007) advocated that the control systems is a broad process that comprises the strategic development, strategic controls, and learning processes. These controls contribute to achieving organizational goals, consequently, impacting positively on organizational performance.

Malmi and Brown (2008) when analyzing MCS as a package of managerial artefacts, they argue that these artefacts can contribute to the understanding of how the definition of control systems can support organizational activities. In a complementary manner, Chenhall (2003) points out that the control systems are more related to the set of activities inherent to the processes, for example, statistical quality control, just-in-time system,

among others. Consistent with this view, (van Veen-Dirks, 2005) argues that management accounting and the control system support managerial behavior to meet the production strategy

Base on this rational, we suggest that:

H4: The cost control has a positive relationship with operational cost efficiency.

From another perspective, the cost control could be seen as a set of process that is part of the MCS that aims to identify, control and reduce the organizational expenses based on a given budget (Langfield-Smith, 1997). Therefore, in several occasions, it is possible to observe a positive impact of this managerial tools on business performance measures captured by ROI, ROA, market share, among others (Ketokivi and Schroeder, 2004).

However, by observing the supply chain configuration, the bargaining power of the customer and/or supplier could impact severely on the business performance of the focal firm (Porter, 1992). Therefore, we could expect that even having a significant cost control process in the organization, if the supplier and/or the customer has a greater bargain power than the focal firm, then, the value created might be appropriated by these other agents, consequently not manifesting on the focal firm's performance. In other words, the cost control is a sine qua non condition for the firm to compete; consequently, Thus, we declare the following hypotheses:

H5a: The cost control does not impact on the financial performance for companies in the industries that suppliers normally have greater bargain power than the focal firms.
H5b: The cost control has a positive relationship with customer satisfaction for companies in the industries that suppliers normally have greater bargain power than the focal firms.

The figure 1 could summarize our theoretical discussions and hypothesis.

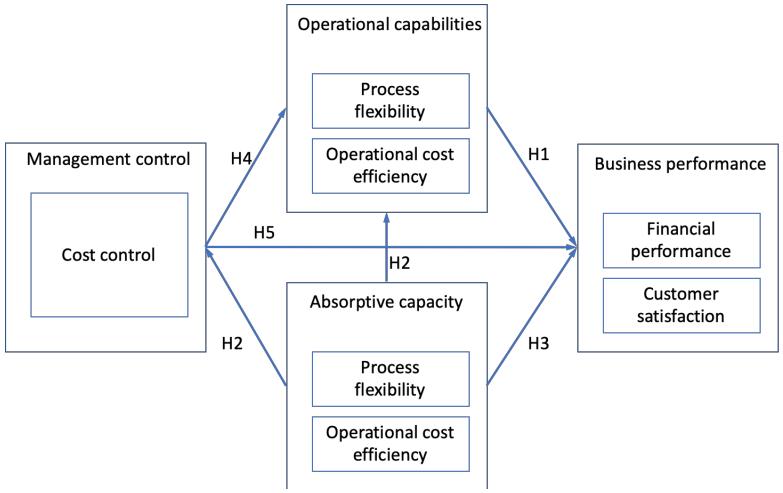

Figure 1 – Proposed conceptual model

Survey Methodology

We designed our questionnaire by adapting from existing literature in operational capabilities, absorptive capacity, management control and performance. The questionnaire was first designed in English, then translated to Portuguese. The

questionnaire was first assessed by academics and practitioners to correct problems concerning distortions (problems with assertive, lack of objectivity, among others). They suggested small corrections that were done for the final questionnaire. After that, we ran a pre-test with a small sample from the target industries, and we found no major issues.

The questionnaire has four main blocks. The first block collected data regarding the operational capabilities (cost efficiency and process flexibility). The second block gathered the info concerning management control (cost control). The third block aims to evaluate the absorptive capacity (potential absorptive and realized absorptive capacity). And finally, the fourth block seeks to assess business performance (financial performance and customer satisfaction).

We conducted our study in São Paulo (Brazil) from April to December 2017. We successfully contacted 387 firms from a random sample of 449 companies of the National Association of Auto Parts Manufacturers and 924 companies of Brazilian Association of Food Industries. From those contacted companies, 299 accessed the questionnaire, and we obtained 161 valid answers (81 food sector, 61 auto parts, 19 did not indicated the sector). As part of common method variance mitigation strategy, we maintained the confidentiality of the respondents and companies' names

Variables description

Operational capability – Cost efficiency

We used two 7-points scale items to assess it where we asked respondents to indicate how cost-efficient operational practices are executed in the organization. From the scale, the higher the rating, the more intensive are the practices in the company. The three items were adapted from Boyer and McDermott (1999) and Swink et al. (2005)

Operational capability – Process flexibility

We used four 7-points scales items to assess it where we asked respondents to indicate how flexible operational practices are executed in the organization. The higher the rating, the more intensive are those practices in the company. The questions were based on the existing studies of Boyer and McDermott (1999), Machuca and Álvarez-Gil (2003)and Rosenzweig et al., (2003)

Absorptive capacity

This variable was measured as second order latent variable that was composed by the *Potential absorptive capacity* and *Realized absorptive capacity.* This first dimension was measured by three 7-points scale items based on the study of Leal-Rodríguez et al (2014) and Jansen et al. (2005). The latter was also based on the same literature and it was measured with five 7-points scale items.

Performance

The literature characterizes the performance as multidimensional construct (Kafetzopoulos and Gotzamani, 2014) and it could be analyzed from financial and non-financial measures (Kaplan and Norton, 1992, 2001, 2007, van Veen-Dirks, 2005, 2010). A set of dimensions to measure the performance could be used such as return on investment (ROI), profitability, sales, market share, contribution to technological leadership, contribution to the retention of employees, and the degree of customer satisfaction. From this perspective, our study assessed the business performance construct based on two dimensions: customer satisfaction and financial performance.

Financial performance

This variable is measured by four self-evaluated items where we asked respondents to rate how the company performed in the last fiscal year in each of the financial dimensions. We employed a 7-point scale where higher the rating, better the performance. These items were based on the existing studies of Tatikonda and Montoya-Weiss (2001), Swink et al. (2005).

Customer satisfaction

This variable was based on the study of Shenhar et al., (1997). We used four items to assess it where we asked respondents to indicate how the company positions itself about its customer satisfaction. We employed a 7-point scale where the higher the rating, the higher is the customer satisfaction.

Measurement and construct validation

We performed the confirmatory factor analysis to assess the reliability and validity of our variables. All the constructs demonstrated reliable (CR>0.7; AVE>0.5) and discriminant validity (square root of AVE > correlations of each pair of variables – See Table 1). Our CFA model demonstrated a regular fit given the sample size ($\chi 2$=476.89; DF=282; p-value=0.000; CFI=0.913, RMSEA = 0.067) (Hair *et al.*, 2014, p. 584). Regarding the common method variance, we assessed its impact using unmeasured latent method factor (Podsakoff et al., 2012). This common method factor is equally loaded on all the observed variable. Then we computed the chi-square difference between the CFA model and the common method variance method and no statistically difference was found between the both models (p=0.16). Therefore, we inferred that the common method variance is not a concern in our study. However, for our hypothesis assessment, we computed the composites using the factor scores obtained from the CFA model with the unmeasured common latent factor. Hence, our composites could be considered as been common method variance adjusted. To assess our hypothesis, we ran the structural equation modelling (SEM) using the composite calculated previously.

Table 1 - Variables reliability, discriminate validity and correlations

	CR	AVE	(1)	(2)	(3)	(4)	(5)	(6)
Customer Satisfaction (1)	0.835	0.560	**0.748**					
Financial (2)	0.869	0.625	0.385	**0.791**				
Cost Efficiency (3)	0.847	0.735	0.448	0.360	**0.858**			
Process Flexibility (4)	0.825	0.546	0.419	0.362	0.492	**0.739**		
Cost control (5)	0.912	0.723	0.452	0.324	0.433	0.406	**0.850**	
Absorptive (6)	0.955	0.914	0.668	0.512	0.479	0.588	0.625	**0.956**

Results and discussions

By observing the significant regression coefficients in the Table 2, we noted that absorptive capacity is necessary to develop operational capability, more specifically, the process flexibility. The absorptive capacity is also positively related to the management cost control process, which supports our hypothesis H2a. The absence of the relationship between absorptive capacity suggests this direct relationship might be mediated by the management cost control.

Surprisingly, observing the effects of our variables on the business performance, we could note that the management cost control process did not impact on the performance, which is counter intuitive. According to the literature mentioned in the theoretical section, the management cost control impacts positively on the performance, however,

the absence of direct effect on financial performance suggested in the H5a is supported, and could be caused by the bargain power of the customers. However, the absence of effect on customer satisfaction did not support the hypothesis H5b. The impact of management cost control process on financial performance seems to seems to be mediated by operational capability, more specifically, the cost efficiency capability. This finding suggested that by practicing cost control process, it will not necessarily manifest in performance, but it will impact positively if it develops cost efficiency capability, consequently, on the performance. This rationale could be support by the concept of cumulative capability (Ferdows & De Meyer, 1990) and support our hypothesis H4.

We observed that different nature of operational capabilities can impact on business performance in a different manner. While flexibility is positively related to customer satisfaction, operational cost efficiency affected positively on financial. This finding suggested that industries that suffer cost reduction pressure such as food and auto parts, the operational cost efficiency might be necessary but not enough to satisfy the customers (Spring & Boaden, 1997). We also noted that absorptive capacity is positively impacting on financial performance, this result support our hypothesis H3a, but not the H3b.

Table 2 – Coefficients and standard errors of the conceptual model

Independent variable	Dependent variable				
	Customer satisfaction	Financial performance	Process flexibility	Cost efficiency	Cost control
Cost efficiency	0.019 (0.071)	0.166** (0.079)			
Process flexibility	0.172 ** (0.077)	0.024 (0.086)			
Absorptive capacity	-0.072 (0.096)	0.428*** (0.108)	0.527*** (0.078)	0.07 (0.098)	0.618*** (0.081)
Cost control	0.052 (0.075)	-0.075 (0.084)		0.219*** (0.083)	
Obs.: *** p-value < 0.001; ** p-value < 0.05; * p-value < 0.1					

Final considerations

Managerially, we demonstrated that effect of management cost control process on process might be mediated by the capacity of operational cost efficiency. This finding made us believe that simply implementing the cost control process will not improve the business performance, unless, this control process develops the cost efficiency capacity. If the organizational objective is the long-lasting operational cost efficiency, then sand cone model might be considered.

Theoretically, we contributed by demonstrating the different operational capabilities can bring different type of contribution to the business performance and the role of absorptive capacity as antecedent of these capabilities.

Our results suggested that absorptive capacity could improve the flexibility capability of the company, since, this capacity could reconfigure the company and adapt it to the external environment. However, to exploit the company, the effect of the learning on cost efficiency capacity is mediated by the management cost control.

Our study did not fully and exhaustively explore the effect of absorptive capacity on performance. We found that there is a direct relationship between these two concepts, hence suggesting that there might be some other capability that could mediate the learning towards the business performance. We also suggest studies using other industries, since we focused on two ones that are known by great customer bargain power.

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Digital Strategy and Transformation: a Systematic Literature Review

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Abstract

Nowadays, manufacturing companies have been facing a complex phenomenon of technological advance, often named Industry 4.0, that is reshaping companies' strategy and organization, products and services, supply chains and operations. At the best of our knowledge, the academical panorama lacks an exhaustive literature review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems. Accordingly, this paper carries out a systematic literature review with the aim of mapping the publications and systematizing the often-fragmented literature on this field to propose directions of future inquire that could inspire scholars and support practitioners.

Keywords: Digital Strategy, Digital Transformation, Literature Review, Industry 4.0

Introduction

Nowadays technologies progress like a dense avalanche of advancements pouring into the environment (Brynjolfsson and McAfee, 2014). The rhythm of growth has been exponentially hastening in recent times indeed, and this has been provoking shocks in the realm of management (Westerman et al., 2014; Brynjolfsson and McAfee, 2017; Venkatraman, 2017). This complex phenomenon, often named Fourth Industrial Revolution or Industry 4.0, is reshaping companies' strategy and organization, products and services, supply chains and operations (Porter & Heppelmann, 2014). The concept of Industry 4.0 (I4.0) was initially introduced in Germany in 2011 (Lu, 2017), referring to the integration of physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries, with the aim of realizing a system in which all the processes are integrated and information is shared in real time (Hozdić, 2015).

This wave poses an important challenge to companies that more and more are required to deal with the opportunities offered by the digital technologies which are at the core of

the Fourth Industrial Revolution. Aware of both the limited financial resources as well as of their level of digital readiness, companies need to make some strategic choices, selecting and exploiting the set of digital technologies that better fit with their own context (Hess, 2016).

In other words, to remain competitive companies are called to strategically govern the digital change by formulating and executing a clear strategy to keep pace with the new digital reality (Matt et al. 2014).

Since the beginning of the 2010s, a large proliferation of papers on this subject matter has been observed, but often in a quite fragmented fashion and using an ample variety of terminology. At the best of our knowledge, the academic panorama lacks a complete and exhaustive literature review on how companies can strategically govern the digital change provoked by technology advancements and occurring in business systems. To date indeed, the newness of the topic and the wideness of the combined domains blur the knowledge on the company ground and torment researchers and experts across their affairs by creating overlaps between words and meanings, constructs and definitions, and by fostering unuseful varieties of vocabulary, and diverse perspectives on the same objects and phenomena.

Accordingly, this paper carries out a systematic literature review (SLR) on this field, with the aim of charting the map of the publications and systematizing the often-fragmented literature on this field into a comprehensive body of organized knowledge, underlining the different perspectives and proposing some directions of future inquire that could inspire scholars and support practitioners.

In pursuance of these targeted objectives, the SLR has been guided by the following research questions:

- RQ1: Which are the perimeter and the current state of the art in the field of research?
- RQ2: Is there a way to frame and organize the knowledge belonging to this field?
- RQ3: Which are guidelines to drive future researches on this field?

Findings of the research contribute to systematize the often-snipped literature on how to govern the change provoked in companies by digital technology advancements. Results of the literature review show that the field under investigation may be framed into four blocks, namely: Digital Transformation Strategy; Digital Transformation Execution; Leadership & Culture; and Models. Hence, our review will depict the nature and the main contents of these blocks, to what extent they are intertwined, and which are the leverages managers may employ to govern the change. Along this line, in the final part of the paper, a discussion on the current detected gaps is carried out, and some avenues of future researches are spelt out.

Methodology

Towards achieving our aim and answering the research questions, a systematic literature review on how to strategically govern the digital change provoked by technology advancements occurring in companies has been carried out. The field under investigation, which concerns the process followed by companies to strategically select the most prominent digital technologies and then drive their implementation within the companies, revolves around two main key areas. From one side the opportunities offered to the companies by the set of digital technologies and the Fourth Industrial Revolution, and, from the other side, the strategic process they have to follow to govern within the company this change. Accordingly, two different groups of keywords have been selected to carry out the literature review on the ISI Web of Science Database (core collection):

- Group 1: it contains the keywords to intercept the papers referring to the Fourth Industrial Revolution (i.e. "Industry 4.0"; "Industrial Revolution"; "Smart Factory"; "Smart Manufacturing") and the ones referring to Digitalization or Digital Transformation (i.e. "Digital*").
- Group 2: it contains the keywords related to the investigation of how firms can strategically cope and manage these digital technology advancements which is the baseline of the studied field. The focus has been given to the governance of this kind of transformation ("Strateg*"; "Transformation*"; "Change"; "Roadmap"; "Cultur*").

We combined a) the terms belonging to group 1 and group 2; and b) the terms belonging to group 1 with each combination of two terms belonging to group 2. a) and b) where searched respectively in titles and topic (i.e. abstract, title and keywords). In this way, we were able to capture most of the papers covering the field under investigation.

The queries that were accomplished on the 12th of March 2019, returned 10.114 results at first, reduced to 508 by applying some basic filtering options proposed by ISI as the research area (i.e. Management, Business, Operations Research Management Science), the English language, and the document type. Duplicates have been subsequently removed. The application of these criteria provides us with 459 papers, that were subsequently analyzed by the authors.

Consequently, in order to check the pertinence of these papers with the field under investigation (e.g. how to strategically govern the digital change provoked by technology advancements occurring in companies), we read the abstracts of these articles and we excluded those articles that were not pertinent, and 168 relevant articles remain. The reading of the full articles made it possible to identify the 59 most pertinent articles.

At the end, after 16 papers and 8 books have been added via a snowball process, the final dataset was composed by 83 contributions. It may be argued that the final database is made up in most part by ISI ranked journals (i.e. the queries searched on ISI-WoS Database), while the snowball process added mostly practitioners' articles. We believe that this balance is valuable, bearing in mind the topicality and the hype of the theme discussed.

Finally, all the selected articles have been carefully mapped in a structured spreadsheet with different dimensions, namely: - the field, - the topic and the purpose of the article, - the construct/s under investigation and its definition (when provided), - the description of the theoretical ground, - the methodology, - the main findings. The analysis of this spreadsheet made it possible to develop a framework that organizes the contributions of the literature on the field and sheds some light on the state of the art on the theme as well as on gaps and avenues for further researches.

Field of research

Giving a general overview of the papers, the overall counter of publications per year on the field has been growing exponentially and the curve has just reared in the last three years (max[1996-2015]: 5; 2016: 8; 2017: 10; 2018: 28). The mounting interest around the topic witnesses its relevance and renews the necessity of this work.

The large part of the publications empirically test their arguments on real cases (Figure 1), interviews and surveys, secondary data analysis or action research, but the analysis of the papers also shows the presence of a consistent set of papers (i.e. "Opinions") which expound findings without the backing of a proper scientific methodology – and this principally happens with the articles dealing with strategical matters.

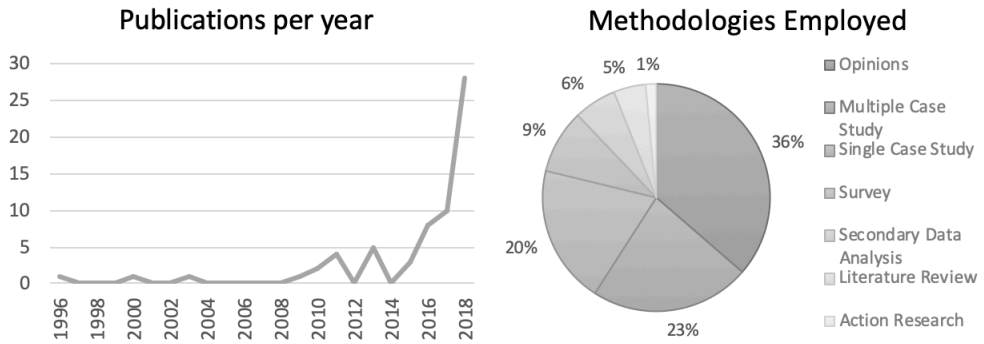

Figure 1 Publications per year and methodologies employed

The deep analysis of the papers shows that the articles on the field are quite fragmented and they deal with different aspects of the phenomenon, thus making it difficult to get a clear picture of it. To try to systematize the variety of these contributions, we develop a framework meant to integrate the different dimensions that shape the research field on how to govern the transformation provoked in companies by digital technology advancements. This framework (see Figure 2) is composed of four blocks.

The first two blocks – Digital Transformation Strategy (DTS) and Digital Transformation Execution (DTE) - constitute the backbone of the field and describe the process of digital transformation process (DT) triggered by the injection of digital technologies into companies. The second two blocks instead revolve respectively around the technical skills, Leadership and Culture companies need to be equipped with to be successful in the change process, and the Models literature supplies to comprehend these kinds of transformations. In this view, these latter two blocks sustain the field's backbone providing knowledge and tools to the people enlisted in the digital transformation process.

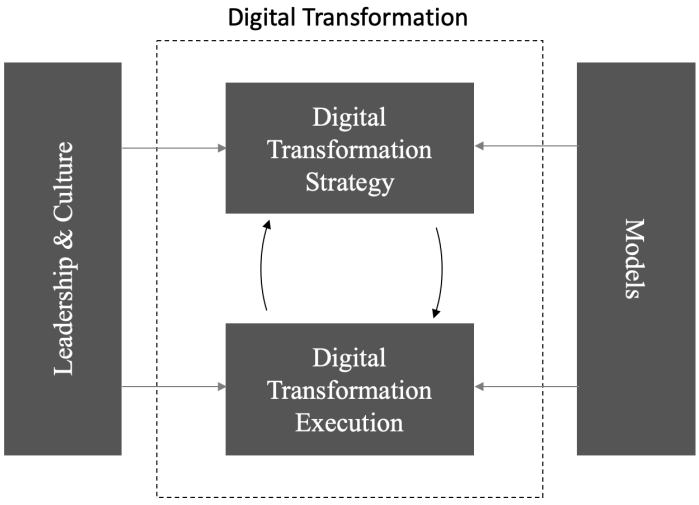

Figure 2 The architecture of a Digital Transformation Process

The Digital Transformation

The backbone of the field describes the process of governing the transformation of the company triggered by the injection of digital technologies. This process may be broken down into two diverse blocks, referring respectively to its strategical conception (i.e. Digital Transformation Strategy) and its execution (i.e. Digital Transformation Execution). More neatly, inside the concept of Digital Transformation there is one set of papers that concern Digital Transformation Strategy (DTS), where a company needs to explore the opportunities offered by technology (Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Konlechner et al., 2018) to select which to invest on (Mithas et al., 2010; Ardolino et al., 2018; Ghobakhloo, 2018; Pappas et al., 2018; Ross et al., 2018) and how to organize and control the strategical change (Tichy, 1983; Bharadwaj et al., 2013; Andriole, 2017; Davenport & Westerman, 2018). DTS papers conceptualize the path to be executed, argued in the second group of papers, which instead deal with the practical deployment of strategy into actions to transform the business model (Ross et al., 2016; Gobble, 2018) or with the management of the business-system-technology integration (Woodard et al., 2013; Agarwal & Brem, 2015; Teubner, 2018; Gastaldi et al., 2018). Consequently, as Digital Transformation Strategy lies in abstraction by the very nature of strategies, as its operations are made in the land of representations and models of reality (Gavetti and Levinthal, 2000), it has concrete effects on reality only through the Digital Transformation Execution (DTE) block (Gavetti and Rivkin, 2007). The proposed distinction comes out by the analysis of the aim and main constructs presented in the analyzed papers and will be clearly described in the subsequent sections.

Digital Transformation Strategy

Papers within this block deal with how to strategically address the opportunities and risks that originate from digital technologies, planning the company journey towards being digitally transformed (Singh &Hess, 2017). In order to refer to this concept, authors often employ different labels (i.e. digital transformation strategy, digital strategy, digital business strategy). A part from the different labels, the common features, which delimitate the boundary of the concept, relay on the fact that it governs the digital transformation: a) by defining objectives and priorities to provide directions (Mithas et al., 2010; Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Ardolino et al., 2018; Ghobakhloo, 2018; Konlechner et al., 2018; Pappas et al., 2018; Ross et al., 2018); b) by organizing the structure to enable the execution of digital initiatives (Agarwal & Brem, 2015; Hess et al., 2016; Sia et al., 2016); and c) by gauging progress to reroute efforts or investments when required (Sebastian et al., 2017).

Moreover, authors who use the label digital business strategy (Mithas, 2010; Kettinger, 2011; Bharadwaj et al., 2013; Grover and Kohli, 2013; Markus and Loebbecke, 2013; Mithas et al., 2013; Woodard et al., 2013; Sia et al., 2016) emphasize the integration between information technology (IT) function strategy and business strategy, which has its root in the need to achieve a peaceful and effective co-existence between IT and business strategy, thus suggesting a juxtaposition of their purposes and plans (Henderson & Venkatraman, 1992).

Beyond the definition of the concept of DTS, papers show that firms might craft their digital strategy to achieve two main objectives:

Value Propositions. A company can transform its value proposition to elevate "the performance implications of IT strategy beyond efficiency and productivity metrics to those that drive competitive advantage and strategic differentiation" (Bharadwaj et al., 2013). Ross et al. (2017) draw how companies use to pursue either a Customer

Engagement Strategy, whether they decide to focus on boosting their customer experience (Lanzolla & Giudici, 2017; Haenninen et al., 2018; Kotarba, 2018; Subramaniam et al., 2019), or a Digitalized Solution Strategy, if they bet on R&D chances to innovate their value proposition by combining products, services and available data (e.g. new smart and connected product, platform, analytics service-based) (Woodard et al., 2013; Porter and Heppelman, 2014; Echterfeld and Gausmeier, 2018).

Processeses. A company, pursuing an Operational Excellence Strategy (Ross et al., 2017) may decide to transform its processes. The matter is how to invest on the redesign of the way activities to deliver value propositions are performed, taking advantage of technology to generate more outputs employing less inputs (Zuehlke, 2010; Erol et al., 2016; Dremel et al., 2017; Sanders, et al., 2016; Szozda, 2017; Gastaldi et al., 2018; Kaidalova et al., 2018; Mittal et al., 2018). Moreover, authors sustain companies are required to consider adapting their processes whenever a change in their value propositions occur (Benner, 2009; Ross et al., 2016; Dremel et al., 2017; Lanzolla and Giudici, 2017; Ross et al., 2017).

Digital Transformation Execution

Digital Transformation is the product of the execution of a Digital Transformation Strategy (i.e. Digital Transformation Execution - DTE), where strategies transform the reality towards their exploitation by mean of actions (Gavetti and Rivkin, 2007; Ross et al., 2016). Accordingly, the overall subject matter of the second block is how to exploit the strategical transformations of value propositions and/or processes by leveraging on technologies (Day-Yang, L. et al., 2011; Gastaldi et al., 2018; Wagner et al. 2018; Weill and Woerner, 2018). Comparing to the previous block, here the knowledge is much more fragmented due to the absence of a referential theory and also because researches mostly and simply describe use cases of technology and how they have just been implemented (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018). Despite the complexity in navigating the knowledge of this block, the analysis on the research aims and the findings of each paper contained into the dataset allowed us to identify three patterns on DTE, regarding Industry 4.0, Lean Management and Project Management.

DTE & Industry 4.0. As salient detail, the contributions referring to the construct Industry 4.0 (i.e. The Fourth Industrial Revolution) mainly focus and prioritize the digital transformations of manufacturing operations and supply chains, and the way an Operational Effectiveness strategy (Ross et al. 2017) may be executed. (Hozdić, 2015; Lee, et al., 2015; Lu, 2017; Bienhaus & Haddud, 2018; Yin et al. 2018).

DTE & Lean Management. Going inside the contributions referring to the digital transformation of Supply chains and Operations, we notice a niche of contributions inquiring the relationship between Lean Management (LM) (Womack and Jones, 1997) and Digital Transformation, and we can outline two outlooks. On one side, Bortolotti et al. (2014) claim the effective execution of a Digital Transformation cannot avoid laying on already efficient and streamlined processes. This is the reason why tracking LM may lead to an operational readiness to change (Sanders et al., 2015; Mrugalska and Wyrwicka, 2017; Besser Freitag et al., 2018). On the other side, Kolberg and Zühlke (2015) overturn the concept, arguing that LM is enabled by Digital Transformation, because technology is broadening the chances for manufacturing and service companies to reinforce their efficiency by solving problems in ways afore unthinkable.

DTE & Project Management. Indeed Digital Transformation Executions are often described as a package of digital coordinated projects, (Erol et al., 2016; Goelzer and

Fritzsche, 2017; Dremel et al., 2017; Singh & Hess, 2017; Bertoncel, 2018), and this opens a question on the role of Project Management in the Digital Transformation process, although few publication refers explicitly to the issue (Schüritz et al., 2017; Teubner, 2018).

Leadership & Culture

The third block considers the academical interest on the impact of the organizational and cultural variables into a Digital Transformation (i.e. DTS and DTE). Compared to the rest of the papers, this block presents a dissonant peculiarity on the methodologies employed by scholars, that is the preponderance of hypotheses tested by surveys and statistic techniques, while case studies are the rule in the other papers. In this niche of knowledge results figure out two main topics discussed by scholars: technical skills, leadership, and cultural background requirements.

From the analysis, these requirements seem a prerogative to make a Digital Transformation effective, mainly for two reasons: first, they must to be fostered whatever the DT will be (Ross et al. 2016; Sia et al., 2016; Westerman, 2016; Dremel et al., 2017); second, it is "difficult, rather impossible, for a network of typical manufactures to achieve them in a short run" (Ghobakhloo, 2018)

Technical skills. Some publications claim that a Digital Transformation to survive in time without having a negative impact on performances need people to be equipped with some technical skills (Weizi et al., 2016). These are required to understand, deploy and manage the opportunities offered by technologies and the dynamics of the change their introduction involves Sia et al., 2016; Davison and Ou, 2017; Ross et al. 2017). Such skills are hybrid skills (Weizi et al., 2016; Schwarzmueller et al., 2018), for example, the ability to perceive week signals of disruption (Bertoncel, 2018) or to handle the analysis and conversion of big amount of data to make decisions above valuable information (Davenport and Patil. 2012; McAfee, Andrew, et al., 2012; Schallmo et al., 2017).

Leadership. Literature maintains the central role leadership plays in the Digital Transformation process, and in particular the interaction between leadership and technology advancements that is baptized as e-leadership (Avolio et al. 2014). Weizi et al. (2016) divide the construct of e-leadership in two layers, where at micro level it deals with the abovementioned skills requirements, and, at a macro level, e-leadership challenges the redesign of company's governance to allocate responsibilities to tackle a DT. On this account, the analysis on the dataset pinpoints a stream of research on the relationship between Chief Information Officers and Chief Executive Officers (Weizi et al., 2016; Hansen et al., 2011; Oberer & Erkollar, 2018), and the opportunity/possibility of introducing a new referential profile the Chief Digital Officer – CDO to supervise the DT (Singh & Hess, 2017).

Cultural Background. Some contributions address the theme of which kind of organizational culture is more suited to engage a Digital Transformation. From the analysis, two significant features emerge: agility and innovation (Ross et al., 2017; Dremel et al., 2017). In particular, Schwarzmueller et al., (2018) state "organizational culture should be transformed to a culture of involvement, in which decisions are taken together, a culture of innovation, that ensures agility based on the acceptance of suggestions, and a culture of training, in which staff is constantly developed (Patterson et al., 2005)." Furthermore, other authors hint companies need to pursue openness to change (Ghobakhloo, 2018) to adapt more quickly and shorten adaptation time to new working habits (Weizi et al., 2016), and, eventually, create a culture of decision making based on data instead of experience and intuition (McAfee et al., 2012; Dremel et al., 2017).

Models

The Models block collects the contributions which provide knowledge on the opportunities offered by technology advancements and on guidelines companies may follow to implement a Digital Transformation They are divided into three different groups: Frameworks, Roadmaps and Methodologies, and Assessment Tools.

Frameworks. As defined in the introduction of the paper, Digital Transformation is a consequence of the technological evolution which companies wrestle along their journey. Literature maintain diverse publications that try to build knowledge around this phenomenon (Porter & Heppelmann, 2014; Rometty, 2016; Westerman et al., 2014), inquiring how technologies progress, and/or their social impact, and/or the types of mutations they are provoking on companies (Brynjolfsson and McAfee, 2014; Porter & Heppelmann, 2015; Weill and Woerner, 2015; Brynjolfsson and McAfee, 2017; Venkatraman, 2017).

Roadmaps and methodologies. In this group are contained all the contribution referring to methods (i.e. standards and steps) (Bibby & Dehe, 2018; Mittal et al., 2018), guidelines, roadmaps and tools (Westerman, 2016; Andriole, 2017; Gobble, 2018) which a company could use for architecting and standardizing its Digital Transformation (Liu, Day-Yang et al., 2011; Porter & Heppelmann, 2015; Matt et al., 2015; Erol et al., 2016; Parviainen et al., 2017; Dremel et al., 2017; Ghobakhloo, 2018; Weill and Woerner, 2018). Methodologies can be applied to any type of digital transformation, and their focus ranges from the entire company to a specific project. Literature is rich of anecdotal cases of successful integration of technologies towards a digital transformation (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018), but a thorough reference methodology to handle the problem of Digital Transformation still lacks (Nwaiwu, 2018).

Assessment tools. This stream of papers provides contributions on instruments which support managers or companies in measuring and evaluating the degree of technological integration into company's processes. This results in a seminal provision to position companies into a reference system that can better drive the digital transformation process (Plomp and Batenburg, 2010; Bibby & Dehe, 2018; Heavin & Power, 2018; Kontic & Vidicki, 2018).

Conclusion

Although this is a preliminary review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems, some contributions to both research and practice have been provided. On the academic side, the paper systematizes the knowledge on the field and provides a framework to orient future researches. On the managerial side, our research offers some insights on the strategic aspects of the digital transformation that endeavour and supports organizations and managers that are tackling the challenges offered by the new digital era.

The paper has also some limitations, that can drive further developments. Results maintain that literature on the field is still in its infancy, suggesting that future research should go more in depth in comprehending how digital transformation can be developed and executed. The performed queries are more focused on the digital strategy conceptualization rather than its exploitation. So, additional research could be performed through a wider sample to validate and enrich the considerations addressed on Digital Transformation Execution subgroup.

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Antecedents of a Firm´s Supply Chain Agility: The Roles of a Transactive Memory System and Supply Network Flexibility

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Abstract

This paper describes how firms can develop Firm Supply Chain Agility (FSCA) and its benefits for operational performance (OP). The purpose of this research is twofold. First, to analyze the role of transactive memory system (TMS) and supply network flexibility (SNF) as potential antecedents of FSCA, also evaluating the moderating role of TMS; and, second, to evaluate the relationship between FSCA and OP, also examining the possible mediating effect of FSCA. The relationships are tested with survey data from 190 Spanish high-tech firms using structural equation and linear regression models.

Keywords: Firm's supply chain agility, transactive memory system, supply network flexibility.

Main subject text

Theoretical background

Today's hypercompetitive environment – characterized by demanding customers, short product life-cycles, volatile supply and demand, global supply chains, and rapid advances in technology – has pushed firms towards finding new ways of competing (Swafford et al., 2006; Chiang et al., 2012). Indeed, research suggests that developing a firm's supply chain agility (FSCA) can be key to improving competitiveness in the current environment (Christopher, 2000; Gligor et al., 2015; Kim and Chai, 2017). FSCA has been conceptualized variously as a comprehensive strategy, a paradigm, a management system or practice, and even as a capability (Shin et al., 2015). In this study, we adopt

Braunscheidel and Suresh's (2009, p. 126) definition of FSCA as *"the capability of the firm, internally, and in conjunction with its key suppliers and customers, to adapt or respond in a speedy manner to a changing marketplace, contributing to the agility of the extended supply chain".*

Given the importance of FSCA, an investigation of how such a capability can be built and the performance outcomes is of utmost importance (Blome et al., 2013; Gligor et al., 2015). The literature has identified some antecedents of FSCA by recognizing, for example, that FSCA depends on: the flexibility of the procurement/sourcing, manufacturing, and distribution/logistics processes (Swafford et al., 2006); internal and external integration of the firm (Braunscheidel and Suresh, 2009); coordinating, cooperative, and communicative mechanisms in the supply chain (Gligor and Holcomb, 2012); and the development of supply- and demand-side competences (Blome et al., 2013). Research has also identified outcomes associated with FSCA. For example, FSCA enables a firm to be more market-sensitive, have greater capacity to synchronize supply with demand, better manage disruption risks, achieve shorter cycle times, ensure uninterrupted service to customers, and accelerate the introduction of new products (Braunscheidel and Suresh, 2009; Blome et al., 2013; Gligor et al., 2015). However, due to limited research in this field, there have been a number of recent calls to explore new antecedents of FSCA and to further scrutinize the effect of FSCA on performance (Chiang et al., 2012; Blome et al., 2013; Gligor et al., 2015; Chan et al., 2017; Fayezi et al., 2017). Swafford et al. (2006) indicated that agility requires competitive strategies based on both the development of knowledge and the generation of flexible processes so firms can respond to changing circumstances in the environment. Building on this, our study evaluates a variable related to knowledge – transactive memory system (TMS) – and a variable related to flexibility – a firm's supply network flexibility (SNF) – as potential antecedents of FSCA.

Our first variable, TMS, *"is the shared division of cognitive labor with respect to the encoding, storage, retrieval, and communication of information from different domains that often develops in close relationships"* (Lewis and Herdnon, 2011; p. 1254). This variable, related to the creation, maintenance, transfer, and coordination of knowledge in work teams (Argote and Guo, 2016; Heavey and Simsek, 2017; Huang and Cheng, 2018). has been applied to various types of dyadic relationships (Hammedi et al., 2013; Argote and Guo, 2016), work groups (Liang et al., 1995; Argote and Guo, 2016), organizations (Heavey and Simsek, 2015; Huang and Cheng, 2018), and even contexts that transcend organizational boundaries, such as the development of TMSs between supply chain partners (Obayi et al., 2017). Although TMSs have received little attention in the operations management field, this variable could contribute greatly to the development of FSCA. For example, it has been recognized that uncertain environments require the rapid generation and coordination of new knowledge (Gligor et al., 2015; Argote and Guo, 2016). Further, firms like Honda, Apple, Zara, and Amazon have all succeeded in developing supply chain agility because they have teams that are motivated to develop creative solutions to unexpected problems (Gravier, 2016).

Our second variable, SNF, is related to an organization's ability to effectively and efficiently reconfigure its supply base (Liao et al., 2010), enabling the firm to maintain a sufficient set of alternatives and responses to possible changes in the environment (Liao and Marsillac, 2015). Although the extant literature has recognized the importance of different types of flexibility in achieving FSCA (Chan et al., 2017), SNF is a relatively new concept that remains underexplored in the FSCA literature (Liao et al., 2010; Purvis et al., 2014; Liao and Marsillac, 2015). As Lummus et al. (2003) argued, supply chain design must take change into account. When the market changes, competitive priorities

also change, making it necessary to find new supply chain partners with the required capabilities. Finding such partners is necessary for high levels of flexibility in supply networks (Purvis et al., 2014). Cisco, for example, uses three different supply networks to manufacture its products (depending on the type, volume, and customization required). When the need arises, it can switch manufacturing from one network to another, achieving rapid response to changes in the environment (Lee, 2004). It is thus reasonable to expect that having different strategic options for product supply would facilitate higher levels of FSCA.

Given the need to further evaluate the effect of FSCA on performance (Gligor et al., 2015), we also examine the relationship between FSCA and a firm's operational performance (OP). Supply chain managers must know what results to expect from the implementation of FSCA-focused strategies, yet prior studies have evaluated only some measures of operational performance (e.g. Gligor and Holcomb, 2012; Blome et al., 2013; Eckstein et al., 2015; Gligor et al., 2015). Our study expands these measures by exploring the relationship between FSCA and OP in four specific areas – delivery, production cost, product quality, and production flexibility – that reflect the four key capabilities of a focal firm in responding to competition (Wong et al., 2011).

Based on the above, our study has two main goals. First, to analyze the role of TMS and SNF as potential antecedents of FSCA, evaluating the moderating role of TMS in the SNF-FSCA relationship; and, second, to evaluate the relationship between FSCA and OP, examining the possible mediating effect of FSCA on the relationship between SNF-OP. These goals are summarized in the following two research questions:

RQ1. What is the relationship between TMS, SNF, and FSCA?

RQ2. How does FSCA affect OP, either directly or by mediating the relationship between SNF and OP?

The relationships to be empirically investigated are illustrated in the theoretical model in Figure 1.

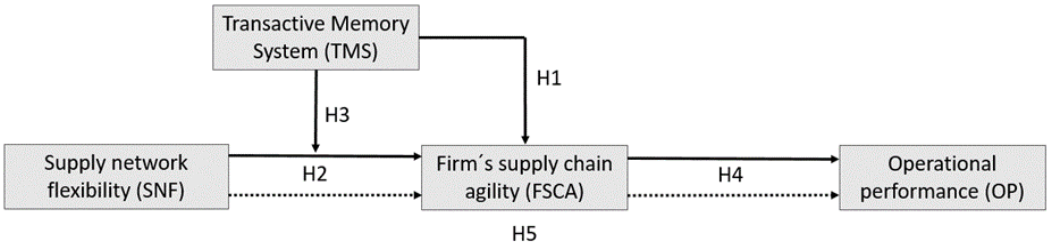

Figure 1. Theoretical Framework of the Study

Design/methodology

In order to provide empirical evidence for the proposed research hypotheses, Spanish companies belonging to the high technology sector were selected from the Iberian Balance Sheet Analysis System (SABI) database. Once the total population was defined, a survey was conducted to obtain specific information for our research, following Dillman's (2000) prescriptions. The unit of analysis was the firm, and the preferred respondents were senior managers with knowledge of the processes and activities of the firm´s operations department and who had the capacity to make decisions in that department. The procedure for data collection was through the computer-assisted telephone interview (CATI) system. Finally, we obtained a final sample of 190 usable surveys and a final response rate of 12.45 percent.

The main constructs used in our model were: TMS, SNF, FSCA, and OP. The measurement scales for these variables were adapted from prior studies: TMS (Lewis,

2003), SNF (Liao et al., 2010), FSCA (Swafford et al., 2006), and OP (Wong et al., 2011). A seven-point Likert scale survey was designed to capture managers' perceived levels of these variables (1 = maximum disagreement; 7 = maximum agreement). Moreover, we considered other contextual factors that might have an influence on operational performance such as firm age and firm size.

We examined the reliability and validity of the measurement scales following the procedure developed by Kaynak and Hartley (2006). We also studied all indicators of the measurement scales' goodness of fit by analyzing the absolute and incremental goodness of fit and the model's parsimony. In all cases, the indicators are within the levels recommended as acceptable in the literature (Hair et al., 2010).

The theoretical model was tested using the methodology of structural equations and regression analysis. In order to test H1, H2, H4 and H5, we employed structural equation modeling (SEM) to estimate the proposed research model. Results indicate a good fit for the measurement model with a Chi-square of 862 and 549 degrees of freedom, CFI of 0.90, IFI of 0.90, BBNNFI = 0.90 and RMSEA of 0.05. The standardized coefficient weights for each causal path are provided in Figure 2 for the main effects, being all factor loadings significant. The analytical approach outlined by Hayes (2013) was used to test the hypothesis related to moderation (H3). A summary of the moderation analysis results is available in Table I. In addition, Figure 3 presents the moderating effect of TMS in the SNF-FSCA relationship, for low, moderate and high TMS values. The empirical evidence suggests FSCA achieves its optimum when companies have high values of TMS and SNF. However, higher values of TMS weaken the relationship between SNF and OP. In other words, the existence of a highly developed TMS leads to SNF becoming less important in the consecution of FSCA.

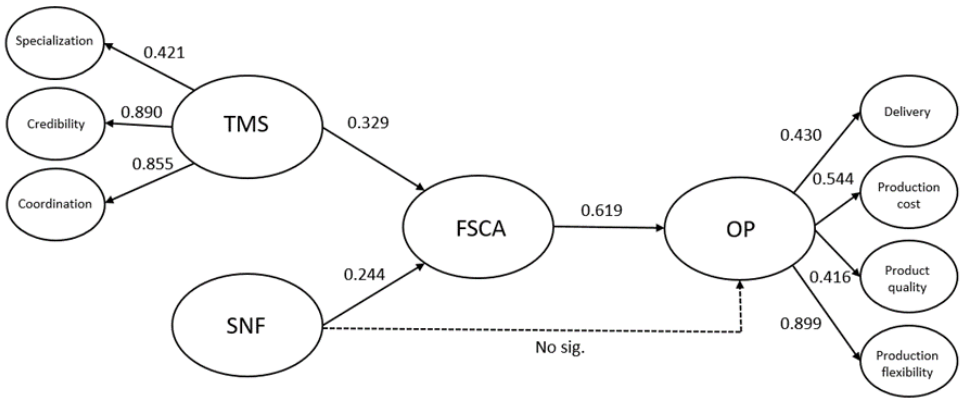

Figure 2. Main Effect Results

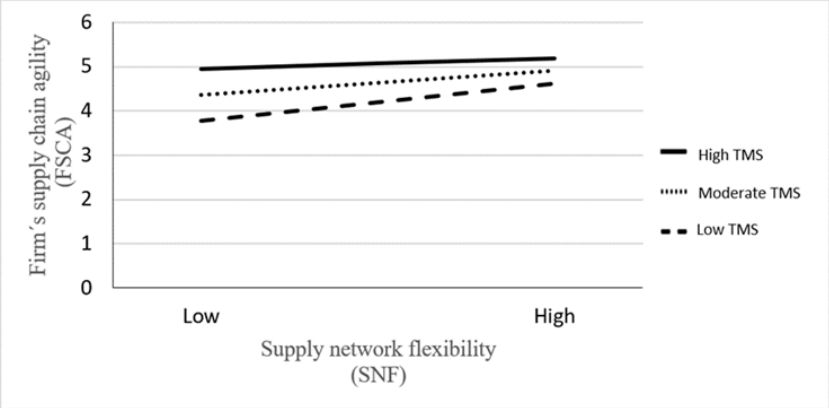

Figure 3 - Moderating Role of Transactive Memory System

Table 1. Moderation Results

	Firm´s supply chain agility		
	Coefficient β[a]	SE	95 percent CI
Constant	4.611***	0.084	4.444; 4.779
Independent variable			
SNF	0.230***	0.066	0.099; 0.361
Moderator			
TMS	0.507***	0.087	0.335; 0.680
Interaction			
SNF × TMS	-0.011**	0.054	-0.215; -0.002
R	0.468		
R^2	0.219		
F	17.424		
p	0.000		

Notes. Confidence intervals (CI). Significance *** p < 0.01; ** p < 0.05; * p < 0.10

Findings

The study makes three important contributions to Operations Management research, Supply Management Orientation and the Resource-Based View (RBV). First, in response to suggestions by Swafford et al. (2006), it contributes to the literature on Operations and Supply Chain Management by evaluating the role of TMS and SNF as possible antecedents of FSCA. These antecedents have not been considered before in the literature on agility. On the one hand, finding evidence of a positive relationship between TMS and FSCA (H1) supports the conclusion that the presence of high levels of TMS in the operations department encourages FSCA. This is a novel contribution to the literature in the field. Although the benefits of TMS and the use of knowledge in other areas of the organization are recognized (Zheng and Mai, 2013; Peltokorpi, 2014; Argote and Guo, 2016; Heavey and Simsek, 2017), there has been almost no exploration of these benefits in operations management. Therefore, our study adds to pioneering studies like that of Obayi et al. (2017), which have begun to explore the role of TMS in the field of operations, supply chains and their role in OP. Obayi et al. (2017) considered the TMS generated among the partners in the supply chain. Our study extends the knowledge of the area, by considering the TMS in the firm's operations department and exploring the benefits that this can have on the FSCA. On the other hand, evidence of a positive relationship between SNF and FSCA (H2) reinforces the need to reconfigure the supply

base in the face of changes in the environment. This finding is not only consistent with the operations management literature that recognizes the importance of different types of flexibility to achieve FSCA (Swafford et al., 2006, Swafford et al., 2008, Braunscheidel and Suresh, 2009, Chan et al. al., 2017), but also improves our knowledge on the flexibility-agility relationship, by exploring a particular type of flexibility, practically unexplored in this field: SNF. Firms that have different strategic options for product supply and can properly reconfigure their supply base will have a better position to develop the FSCA.

Both antecedents, in turn, highlight the need to develop intra- and inter-organizational competencies to achieve FSCA. FSCA depends on issues related not only to internal management of the firm (such as the presence of high levels of TMS in the operations department) but also to external management of the firm, such as relationships with suppliers (SNF). This need has been suggested by prior studies such as those performed by Braunscheidel and Suresh (2009), Gligor et al. (2015), and Fayezi et al. (2017). This study empirically confirms these assumptions.

Evidence of the moderating role of TMS in the relationship between SNF and FSCA (H3) is also important. In contrast to previous proposals, we find a negative moderating effect of TMS. That is, when the firm has high levels of TMS in the operations department, the relationship between SNF and FSCA weakens. One possible explanation for this finding may lie in the firm's capability for internal management. A high level of TMS grants the firm greater internal management capability, which facilitates its adaptation or response to market changes using its own mechanisms. Thus, based on survey data collected from 137 start-ups in China, Zheng and Mai (2013) found that forming teams of start-ups that were operating in highly uncertain environments and that had high levels of TMSs did not have to resort to external sources when responding to surprises in their environments. Rather, they responded to surprises by improvising using their own knowledge. Improvisation requires integrating and applying new and preexisting knowledge in real time, and the existence of a high level of TMS in the team facilitated this task.

As a firm's operations department develops its TMS, the probability of resorting to its supply base to improve FSCA decreases. In other words, the solutions for managing rapid changes can be forged internally. The ability to create, maintain, transfer and coordinate knowledge in operations departments with high levels of TMS enables the firm to draw on its own abilities instead of consulting external players to solve problems (Carney et al., 2008). Further, improving FSCA through the firm's internal processes encourages quick response and eliminates the costs associated with seeking new suppliers and generating commercial transactions (Williamson, 1975). SNF involves finding the best strategic combination for product supply. Such searches require not only the presence of suppliers available on the market but also the time, cost and knowledge necessary to perform a search and to select suppliers effectively and efficiently. Firms with a high level of TMS in the operations department will thus be more inclined to invest in themselves to respond to uncertainty instead of delegating this responsibility to external agents.

Second, the study makes a key contribution to the agility literature by examining the association between FSCA and OP. The evidence of a positive relationship between FSCA and OP (H4) confirms the importance of developing FSCA to improve the firm's operating measures. Consistent with prior research (Gligor and Holcomb, 2012; Eckstein et al., 2015; Gligor et al., 2015; Chan et al., 2017), this finding also enables us to extend knowledge in the field by considering four key dimensions of OP: delivery, production cost, product quality and production flexibility. To the extent of our knowledge, prior studies that explore the relationship between FSCA and OP have considered only some

of these dimensions (Blome et al., 2013; Eckstein et al., 2015; Gligor et al., 2015; Chan et al., 2017). Our study provides a more complete view of the operating measures improved by FSCA.

Finally, the study contributes to developing the literature supporting the relationship between flexibility and agility as a competency-capability relationship (Swafford et al., 2006; Braunscheidel and Suresh, 2009; Swafford et al., 2008; Chiang et al., 2012; Blome et al., 2013). However, this study extends past research considering an aspect of external flexibility, related to supply management. Normally, the studies have evaluated the flexibility relative to the internal processes of the firm. There is few research that extend the flexibility beyond the limits of the focal firm. Our findings suggest that the variable FSCA mediates the relationship between SNF and OP (H5). That is, while SNF is a competency, FSCA is a capability. According to the RBV, competencies in themselves do not lead to sustainable competitive advantage. Rather, they must be combined and managed to develop capabilities. Thus, SNF in itself does not generate greater OP per se, but requires FSCA to obtain operational benefits.

This study also has important implications for managers. The empirical evidence obtained highlights the value of investing in FSCA as a tool to build a sustainable competitive advantage. FSCA enables the firm to compete in an increasingly dynamic and changing environment by improving some of the firm's operational aspects, such as increasing product quality, decreasing production costs, improving issues related to product delivery and/or encouraging production flexibility.

At the same time, the study allows managers to understand how FSCA can be strengthened. We stress that FSCA depends not only and exclusively on internal aspects of the firm but also on parties external to it, which involve different agents in the supply chain. Managers should thus develop both intra- and inter-organizational resources to encourage FSCA. First, managers could focus on the intra-organizational possibility of developing a solid TMS in the operations department. That is, they could build work teams that prioritize collaboration and trust among the group's members, with members who specialize in a specific area and are willing to share and coordinate individual knowledge. Such teams not only enjoy greater response capability but can develop creative solutions to unexpected problems (Akgün et al., 2006) in the area of operations, increasing FSCA. Second, managers could develop the inter-organizational possibility of SNF by building a network of suppliers flexible enough to adapt to changes in the environment and thus able to respond quickly to new demands from the firm's customers. For example, in environments with highly competitive and dynamic markets, short product lifecycles and rapid new product introductions, maintaining these flexible networks reduces the firm's dependence on its suppliers and increases its capability to adjust supply and demand.

However, it should be noted, in the face of the need to prioritize one option over the other, investment in internal resources in the firm seems to be the more effective response when developing FSCA. Specifically, developing TMS in the operations department could be especially valuable when uncertainty is high as with the high-tech industry, because TMS provides a knowledge base that can be coordinated to better address uncertain conditions in the environment (Argote and Guo, 2016) without facing the costs associated with the search for new suppliers and the generation of new commercial transactions.

It is also important to note that while managers can develop SNF to strengthen FSCA, SNF does not improve the firm's operational aspects directly. A firm that has different strategic options for product supply, has a greater capability to adapt to changing market

requirements which increases its FSCA. This FSCA will lead to improvements in operational measures.

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An Empirical Analysis on Factors Influencing Smart Product Development from Industry 4.0 in Indian Context

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Abstract

Smart product development (SPD) in industry 4.0 facilitates decision making during different activities involved in development process. Contextual evidence shows such activities are influenced by several factors; however there remains little understanding on factors influencing SPD from industry 4.0 in Indian context. Present study aims to identify and develop perception based prediction model to investigate critical factors influencing SPD. Two dimensions extracted viz. “technological” and “strategic” factors have significant positive impact while out of five identified critical factors three have significant positive impact i.e., technology & innovation, system integration and collaborative engineering. Thus, increasing quality of industry 4.0 can be accomplished with proper integration of technologies.

Keywords: Critical factors, India, Industry 4.0, Smart product development

Introduction

With the advancement of digital technologies and a paradigm shift to industry 4.0 manufacturing industries have been found to be in major transformation towards adopting smart manufacturing (Feeney et al., 2015). This new industrial trend affects organizational structure and customer’s demand (Gilchrist, 2016) which resulted into development of complex and smart products with new capabilities thus influence product life cycle that is somewhat different from conventional product development approach (Nunes et al., 2017; Ahmed et al., 2019). Industry 4.0 is an integration of “intelligent systems, machines, production and processes to form a well-defined network” (Kagermann et al., 2013, cited in Ahmed et al., 2019). It is a concept that involves combined components of “cyber physical systems (CPS)”, “internet of things

(IoT)" with cloud based models as disruptive technologies (Wang et al., 2015; Dalenogarea et al., 2018). It produces new types of products with intelligent systems embed in it. Despite the recognition of the term "smart" as extensively used by many organizations and researchers, still today there is no consensus of consistent definition. The concept of "smart product" is a network based integrated approach that spans entire manufacturing process and control production stages/processes autonomously (Nunes et al., 2017). It is characterized by its computation and data-storage facilities and its way of interaction with other objects. From developing economy like India manufacturing industry resembles high priority sector in terms of wealth creation and employment generation. However, such development initiative is still in its concept phase and has got immense potential to bring positive effects in terms of cost, quality, productivity, time, flexibility and innovation. Traditional product development approach consisting of multiple processes and sub-processes that interferes decision making information and knowledge capture (Ahmed et al., 2019) and hence real time decisions cannot be taken (Wasim et al., 2013). This becomes an imperative for development of frameworks for smart products so as to offer unprecedented customer insights. In-spite of several advantages in combining industry 4.0 and SPD, majority of the Indian industries are in state of dilemma with respect to its adoption and implementation. Contextual evidence indicates that factors that influence traditional product development approach may not be same as in case of smart product development. Thus the purpose of this paper is to identify the critical factor dimensions that affect smart product development from Indian industry 4.0 perspective. Accordingly the following objectives have been considered.

Objectives: (i) To identify and predict the influence of critical attributes or indicators on SPD; (ii) To identify critical factor dimensions and its influence on SPD.

Hypotheses Development

Technology and Innovation

With high-technology development influenced by innovation facilitates product design and development process. Such innovation led technological development engenders substantial changes in existing market that leads to successful product development. Quality of the product can be improved with technology intervention as organizations are moving towards digitalization in context of industry 4.0. Development process of smart product entails diffusion of advanced technologies and equipment, advanced production procedures with upgraded software and databases. Thus it is expected that 'technology and innovation' would increase the process flow by focusing on process innovation. Accordingly the following hypothesis is proposed.

H1: Technology innovation has positive influence on smart product development

Collaborative Engineering

Collaboration, in terms of human interface perspective, aids towards execution of series of activities which provides channel for team. Collaborative product development from

engineering perspective is a technology oriented process that is used to design innovative and improved products by exploring new markets so as to gain competitive advantage (Büyüközkan and Arsenyan, 2012). From the literature it is evident that collaborative process is followed in many industries those are involved in complex product and service development including research and development (Feller et al., 2005). Collaborative engineering also focuses in handling problems in relation to partner selection and evaluation which is critical for product development success. Thus following hypothesis is proposed.

H2: Collaborative Engineering has positive influence on smart product development

System Integration

Pertaining to SPD from Industry 4.0 perspective, SI refers to cyber physical systems that interconnect physical systems and communication infrastructure (Baheti et al., 2011). Integration of cyber technologies make products internet enabled that generates lots of data and communicates with other interconnected products. These facilitate product development process which can be achieved in cost effective and effectual manner. With system integration approach flexible operations could be performed by adjusting combination of standardized modules that speed up the product development process and reduces time to market. Thus following hypothesis is proposed.

H3: System integration has positive influence on smart product development

Sustainability

Sustainability is considered to be a critical attribute that strategically addresses the risk management in product development. With reference to environmental perspective issues pertaining to sustainability related to smart products focuses on reducing wastes, resources and energy thus moving towards green products. Reducing series of activities pertaining to traditional product development approach would eventually make the process efficient and eliminate any special causes of defects which ultimately lead to product development success. Moreover, economic sustainability facilitates agility and smooth flow in smart product development with objective to maximize profit and minimize costs. Thus the following hypothesis has been proposed.

H4: Sustainability issues have positive influence on smart product development.

Lean Operating System

Lean implementation is initiated by cyber physical system (CPS) which results in elimination of wastes by maximizing productivity. Such implementation produces products at low production costs, with good quality, better accessibility to market and customer satisfaction. Lean aspects of product development include knowledge based engineering focusing on smart technology, mistake proofing, and continuous improvement as core enablers for process development (Khan et al., 2013). Knowledge based platform proposed in work of Ahmed et al. (2019) demonstrates the influence of

advanced lean technology in product development process using knowledge-based engineering. Thus the following hypothesis is proposed.

H5: Lean Operating System issues have positive influence on smart product development.

Methodology

In order to address the research objective the present study adopts qualitative and quantitative approaches. A comprehensive search on related literature has been conducted to identify critical attributes of SPD in context of industry 4.0. To carry out qualitative based approach a semi-structured questionnaire was prepared in understanding the contextual attributes and accordingly an in-depth interview is carried out from ten manufacturing organizations where respondents were from top management and managers who have got experiences of working in domain of product development. Criteria for selecting respondents were such that they should have atleast served for minimum of eight to ten years as senior manager category with respect to design, R&D, marketing aspects of product development. Organizations involved in manufacturing products that includes consumer based household appliances and intelligent medical devices are considered in this study. Overall five critical attributes have been finalized to be taken into consideration from industry 4.0 perspectives. With identification of critical attributes of SPD attributes a structured questionnaire is developed and respondents were asked to give their opinion for each attributes on 5 point Likert scale ranging from “5= strongly agree” to “1= strongly disagree”. A structured questionnaire was sent to around 250 organizations, out of which 200 organizations responded. Out of 200 questionnaires received 35 found to be with missing data thus total 165 questionnaires were taken into consideration for further data analysis. Overall 165 respondents’ opinion is finally captured for data analysis. SPD is taken as dependent variable in terms of product development success considering operational performance measures. To establish link between predictor and dependent variables proposition have been drawn considering literature and contextual understanding (Büyüközkan and Arsenyan, 2012; Hermann et al., 2014; Kiel et al., 2016; Jianfan et al., 2017; Mrugalska and Wyrwicka, 2017; Kamble et al., 2018). Thereafter, a step-wise multiple linear regression modelling is performed to study the influence of all the five models on SPD. Secondly, factor analysis with PCA (principal component analysis) is done on five attributes to extract and identify the critical dimensions. Third, the extracted critical dimension is further subjected to regression analysis to predict and understand the relationships between extracted factor dimensions and dependent variable (SPD success). In this study SPD is taken as dependent variable which is measured by both operational and quality performance.

Data Analysis and Results

This research is exploratory in nature. From quantitative perspective firstly a step wise multiple linear regression modelling is executed which shows all five models are statistically significant with positive and significant impact on SPD. The data being

captured were further subjected for corroboration to see whether it could be analyzed through factor analysis or not. Accordingly, we performed the following analysis: (i) Correlation Analysis: Correlations were high among the practices; (ii) stepwise regression model of critical attributes on SPD (iii) Bartlett's Test of Sphericity: Found to be significant ($p < 0.05$), this shows the acceptability of data; (iv) Kaiser Meyer Olkin Test (KMO): KMO test has been found to be 0.752, which is well above cut-off range; (iv) cronbach alpha: overall is 0.791, F1 is 0.823 and F2 is 0.696. Therefore based on analysis it can be concluded it is appropriate to conduct factor analysis (Meyers, 2006; Pallant, 2007). Before conducting factor analysis we performed univariate and multivariate statistics of the variables and discovered no apparent outliers (Jun et al., 2006). To further confirm the existence of normality we conducted two tests i.e. Kolmogorov-Smirnov and Shapiro- Wilks tests, which shows p value to be greater than 0.05 and therefore revealed normal distribution.

Table 1. Correlation Matrix

	SPD	TI	SI	CE	LOS	SUST
SPD	1.000					
TI	0.686	1.000				
SI	0.639	0.651	1.000			
CE	0.537	0.554	0.619	1.000		
LOS	0.334	0.321	0.370	0.224	1.000	
SUST	0.333	0.365	0.370	0.253	0.554	1.000

Table 2. Stepwise Multiple Linear Regression Model

Models	Predictors	β Coefficients	Std. Error	t statistics	Adjusted R^2	R^2 Change	Std. Error	F value	VIF
1	Constant	1.207	0.214	5.646***	0.468	0.471	0.769	145.064***	
	TI	0.676	0.056	12.044***					1.000
2	Constant	0.732	0.225	3.259***	0.530	0.065	0.722	93.352***	
	TI	0.462	0.070	6.645***					1.734
	SI	0.343	0.072	4.744***					1.734
3	Constant	0.582	0.239	2.435**	0.535	0.009	0.718	64.017***	
	TI	0.430	0.071	6.030***					1.852
	SI	0.287	0.079	3.642***					2.084
	CE	0.133	0.076	1.738*					1.733
4	Constant	0.311	0.317	0.981	0.537	0.005	0.716	48.641***	
	TI	0.419	0.072	5.845***					1.879
	SI	0.264	0.081	3.275***					2.189
	CE	0.136	0.076	1.788*					1.736
	LOS	0.104	0.080	1.300					1.175
5	Constant	0.300	0.322	0.933	0.535	0.000	0.719	38.691***	
	TI	0.417	0.073	5.746***					1.913
	SI	0.263	0.081	3.237***					2.204
	CE	0.136	0.077	1.782*					1.736
	LOS	0.094	0.091	1.039					1.514
	SUST	0.015	0.070	0.219					1.541

Note: *Dependent Variable is Smart Product Development (SPD); TI: Technology and Innovation; SI: System Integration: CE: Collaborative Engineering; LOS: Lean Operating System; SUST: Sustainability*

Durbin Watson value: 1.987 ; ***p value < 0.001; **p value < 0.05; *p value < 0.10

Factor analysis is performed on five critical indicators as identified from review of literature and contextual understanding based on qualitative study. We conducted factor analysis on explanatory variables/indicators with objective to determine minimum number of factors that accounts for maximum variance in data. The factors were extracted using principal component analysis (PCA with varimax rotation). The objective of deploying PCA is to reduce the number of variables (Jolliffe, 2002). PCA is used to "extract maximum variance from the data set with each component thus reducing large number of variables into smaller number of components" (Tabachnick and Fidell, 2007), which facilitate easier interpretations. Table 3 exhibits rotated component matrix which shows all the five variables having factor loading of more than 0.5 and further could be reconfigured into two factor dimensions as being extracted. Factor dimensions extracted are labeled as "Technological" (F1) and "Strategic" (F2).

Table 4. Factor Analysis

Variables	Factor Loadings		Total Variance	KMO
	F1	F2		
TI	0.811		75.80	0.752
SI	0.837			
CE	0.864			
LOS		0.869		
SUST		0.850		

Note: Rotation Method: Varimax with Kaiser Normalization

The overall reliability analysis shows Cronbach's alpha to be 0.791 which validates the reliability of the study. Further reliability analyses show Cronbach's alpha values for factor dimensions F1 and F2 to be 0.823 and 0.696 respectively, which validates the reliability of the factors being extracted. Regression analysis is performed on two extracted factors. The model explains the variance ranging between 46.8% to 53.5% i.e. the predictors explains the variance in the dependent variable well which is more than the standard 40%. Durbin- Watson index suggests that there is no problem of autocorrelation in data. F-value and VIF indicates that overall model has no multicollinearity problem.

Table 3. Coefficients Target: SPD

Model Term	**Coefficient**	**Sig.**	**Importance**
Intercept	3.678	.000	
FAC_1_transformed	0.717	.000	0.883
FAC_2_transformed	0.273	.000	0.117

Note: F value: FAC1_1 is 141.5 and FAC2_1 is 20.557

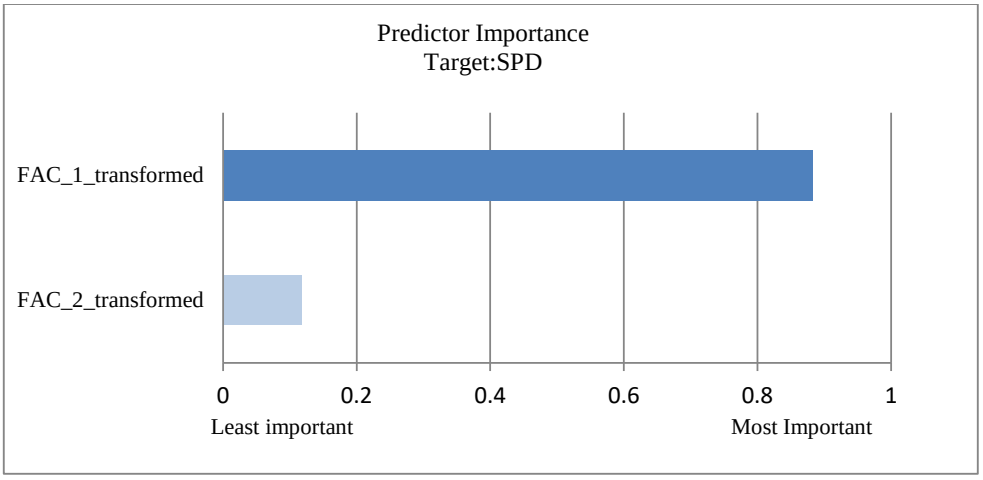

Figure 1. Predictor Importance

Overall, analysis (Figure 1) indicates the importance of technological factors which can be regarded as critical dimension for SPD. It is expected that from industry 4.0 perspective, IoT could have capability to offer transformational solutions for solving the complex digital issues in complex digital environment. In our opinion smart India in future would add value to realisation of industry 4.0 by deploying cloud manufacturing / manufacturing-as –a- service (Maas) which is gaining importance in manufacturing industry. Cyber-physical systems resemble a significant technological enabler for smart product development.

Findings and Discussions

The stepwise regression analysis reveals that attributes like technology and innovation (TI), system integration (SI) and collaborative engineering (CE) have significant positive impact on SPD whereas attributes like lean systems (LS) and sustainability (SUS) have insignificant impact on SPD. The impact analysis of technological innovation indicates that Indian industries are moving towards digital manufacturing where product development process will be executed through organised application of scientific knowledge and is consistent with Hecker (2005). With intervention of advanced technologies it is also likely that developmental process is driven by innovations that add value to the products which facilitates market demand. Here, SI resembles critical significance of cyber physical systems (CPS) where organizations would be able to generate large chunks of production data for real time analysis and decision making. Perception of respondent's towards SI also confirms the rapid move of manufacturing organizations to adopt IoT (internet of things) based approach where objects/ entities are virtually interconnected with lots of data being generated. CE approach also shows the significance of concurrent engineering management on the developmental process of SPD. As SPD from industry 4.0 perspectives is in its stage of infancy thus it would take some time to apply lean systems management and to develop a sustainable framework. Although TI, SI and CE models have been found to be statistically significant however impact of TI, SI found to be strong and CE to be moderate. This shows the lack of prominence in teamwork and human resource

practices. Exploratory factor analysis extracted two factor dimensions which are referred to as constructs namely“technological” and “strategic” factors respectively. Based on analysis performed, automatic linear modelling shows that both technological and strategic factors have significant impact on SPD which is interesting and thus exhibits paradox. The paradox itself gives an impression that strategic factor alone could not significantly impact SPD when acting alone but can significantly influence when combined effect of each technological attributes (TI, SI and CE) is deployed which shows complementarity effect with other resources. The results indicate that Indian industries with respect to Industry 4.0 anticipate better digital adoption with reduced operational costs and productivity improvement. The significant influence of strategic factor indicates the importance of triple bottom line (3BL) with lean initiatives as critical strategic components towards successful SPD initiatives. The perceptual measures from technological perspective expected to exhibit digital automation with integrated sensor systems as one of the most implemented technologies. The results obtained based on analysis gives an overall impression that increasing quality of industry 4.0 can be accomplished with proper integration of technologies and strategy. The integrated application of technological and strategic factor dimensions indicates that when products embed with advanced technology it increase intelligence and play strategic role. From lean initiatives the results indicate the possible dominance of design engineers to hide unwanted and irrelevant features and reduce environmental impact of product. Findings exhibit an overall impression that strategic/ intelligent product information is likely to be utilized as part of user-centered design process, where industrial designers can take advantage of smart product’s life cycle management. Overall the perception based findings show that advances in semantic and sensing technology can change approach of user interaction with products which eventually leads to product development success.

Contribution of the Study

In this study attempt has been made to analyze the perception of Indian organizations which are involved in product development in order to measure the impact of factor dimensions on SPD in terms of expected implementation benefits. Since the concept of smart product development from industry 4.0 in Indian context is in its stage of infancy and the scarcity of literature available in the said context clearly shows the prominence of the present study and its contribution. Results demonstrate the emergence of two constructs (technological and strategic) which are positively associated to expected benefits in terms of SPD success. The main contribution of this paper is identification of emerging constructs (herein referred to as factor dimensions) of SPD and how these factor dimensions are seen in emerging economy context like India, since most of the studies have been done from developed nations perspective. In this regard the present study showed how technological and strategic factor dimensions are associated with projected benefits of SPD. The designated approach using quantitative model for industries 4.0 gives industries the opportunity to learn regarding solutions from techno-strategic aspect which may be deemed to be a novel contribution from Indian context since Industry 4.0 is still in concept development phase.

Conclusions

In this paper the current industrial development on smart products from industry 4.0 in Indian context has been represented. The attributes and factor dimensions influencing SPD gives a preliminary overview regarding developmental process based approach for smart products. SPD from industry 4.0 perspective in Indian context being relatively new thus there is always a possibility of high degree of uncertainty and technological know-how for real time implementation. Hence, present study would be beneficial for its application based findings which could be taken up by the industries as partial guidelines to undertake implementation procedures from both technology and strategic perspectives.

Practical Implications

Results derived from this study can be beneficial to operations manager and industry policy makers to execute decisions at all levels from strategic, tactical and operational aspects. From operational perspective the results exhibit which attributes are critical for successful implementation of SPD. Considering the present industrial scenario the results would provide partial guidelines to the industries who wish to adopt the strategy of industry 4.0 and think which attributes should be considered. Accordingly based on competitive priorities industries can develop and design their implementation strategies. On other hand industrial policy makers can use the findings of this study to initiate policy level decisions as to what technology and strategic dimensions need to be considered during developmental phases of smart products in order to achieve competitive advantage. For example technological attributes like TI, SI and CE could be strong trending patterns followed by strategic attributes like lean systems and sustainability. Results and findings derived from this study can be beneficial to operations manager and decision makers to design their implementation strategies.

Limitations and Future Scope

In this study five critical attributes of SPD have been considered and there is a scope to explore more number of attributes from industry 4.0 perspective. From statistical perspective the study has some limitations since we considered perceptual measures based on respondent's opinion from industry 4.0 context, thus there may be possibility of respondent's bias. Secondly, there is a scope to increase number of respondents to generalise the findings. Future research can incorporate multiple variables and attributes along with control variables for advanced statistical learning. Furthermore, advanced prediction modelling could be initiated in future to investigate the role of contextual variables. Researchers can even think of bringing design management aspects into the entire process flow methodology to make smart products highly flexible and quality oriented.

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Performance Measurement and Management

Optimal screening policies in an Economic Production Quantity model

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Abstract

A manufacturing process with two stages of quality control is considered. Initial screening is performed following some critical operations that generate a high proportion of defections. This allows us to discard the defective items at an early production stage and increases the productivity downstream in the production line. The initial screening cost, as well as the defect detection rate, depend on the screening speed. A mathematical model is developed and the optimal production parameters are analytically determined. We provide numerical examples and sensitivity analysis to illustrate the results and to derive managerial insights and implications.

Keywords: Optimal lot sizing, Screening time, Imperfect quality

Introduction

For many companies – e.g. those in electronics and semiconductor industries – it is reasonable to have an initial screening after some initial processing, especially, critical operations such as chemical or mechanical handling like chemical etching, drilling, etc. The reason for this is that the proportion of defections at that particular stage of the process is relatively high, and the remaining production steps are time-consuming and costly. Discarding the defective items at an early production stage increases the productivity downstream in production line and improves the overall performance measures of the system. Therefore, companies sometimes have even more stages of quality checking than one. Cao et al. (2012) provide methods for optimal allocation of inspection stations. Bouslah (2018) provide a model with two stages and joint control of production, inspection and maintenance. The reason for the two stages is the existence of two machine lines. Even though, adding initial inspection to the system might be reasonable for a company because they want to check the parts or input materials from their suppliers. Of course, the extra effort of initial screening has its own costs, and we aim to optimize the time spent with this activity in order to minimize overall costs. The optimization is carried out in the framework of the classical models of inventory analysis.

Cárdenas-Barrón et al. (2014) stated that Harris (1913) published the first inventory model. A special issue of the International Journal of Production Economics celebrated the hundred years' anniversary of this seminal paper. Among the papers published in this issue, Cárdenas-Barrón et al. (2014) contains a broad overview of the extensions of the original model as well as an extensive bibliography. Andriolo et al. (2014) provide a comprehensive summary on papers in the field, followed by Glock et al. (2014) with a survey on literature reviews in the area of lot sizing. We restrict our attention here on the papers closely related to our topic.

Our model belongs to the extensions of the Economic Production Quantity (EPQ) model, originally developed by Taft (1918) which assumes that the production rate is finite. The other research field we would like to join is focusing on imperfect quality items. A related Economic Order Quantity (EOQ) model is proposed in Salameh and Jaber (2000). It assumes that every single finished item is screened, and the imperfect ones leave the system at the end of the screening period in a batch. The authors draw up the explicit formula to calculate the economic lot size quantity and found that it is increasing with the growth of the average proportion of imperfect quality items. Khan et al. (2011) reviewed the extensions of this model where none of them considers the speed of the screening as a decision variable. Additionally, our paper is adding another stage of quality control to the EPQ version of the model.

Al-Salamah (2016) states that inventory models with imperfect quality can be classified in two categories: predictable and unpredictable identification, the former one being more often found in literature. The author considers imperfect inspection, destructive and non-destructive acceptance sampling. Reviewing most cited papers in the stream of imperfect quality, we found that perfectly reliable quality control is more often assumed which is more or less equivalent to the assumption that every single item is checked at the end of the production process. Alamri et al. (2016) argue that exhaustive inspection may eliminate the return service cost caused by defections, and the impact of letting through defective items could be severe. Instead of sampling techniques, exhaustive screening is more commonly applied in the industries we would like to analyse in this paper. Based on Sahling and Hahn (2019), the biopharmaceutical manufacturing does also belong to the stream of the possible examples with their flexible flow and very strict quality check requirements.

Moussawi-Haidar et al. (2016) were the first who integrated screening time into their production model with rework. Previous literature assumed either that all items are perfect or that screening is carried out continuously, making it possible to rework imperfect items immediately after detection. The authors provide closed form expressions for the optimal production lot size in a framework where inspection is finished later than production, and all defections are repaired. Chiu et al. (2007) consider a proportion of defections to be repairable and the remaining ones to be scrapped, and investigate the joint effects of stochastic machine breakdowns, scrap, and rework on the optimal production run time.

The speed of screening was first considered as a decision variable in Hauck and Vörös (2015). The authors built EOQ models to find the optimal lot size, screening speed, and level of investments to increase the speed of quality control. In this paper, we rather focus on the initial screening time. We assume that the defect detection rate depends on this time, i.e. the more time is spent on the screening, the higher proportion of initial defections are found. The detected defective items are discarded at this stage, saving energy and cost in the subsequent production steps.

Jaber et al. (2008) extended the model of Salameh and Jaber (2000) with the assumption that the proportion of defective items is lowering from cycle to cycle due to learning. Konstantaras et al. (2012) have further developed this model with the possible

occurrence of shortages, and managerial insights helping companies to choose suppliers. The ideas of both papers are applicable as possible extensions to our model.

Model description

A production process with two stages of screening is considered as illustrated by Figure 1. We face a deterministic, known and constant demand of rate d. At the beginning of each cycle, we lunch the production of a lot of size Q (decision variable).The production rate is P and on average, a proportion a $(0 < a < 1)$ of the production is defective after an initial processing step. Since this proportion is typically relatively high, a screening stage is added right after, to the process. We decide on the amount of time $(0 \leq \sigma \leq \bar{\sigma})$ is spent on the screening of each unit. Both the screening cost and the defect detection rate depend on σ. To avoid creating a bottleneck at this stage, the screening rate must be higher than the production rate and consequently the maximum time that could be devoted to the screening is $\bar{\sigma} = 1/P$ (unit of time per item). We assume that a proportion $p_1(\sigma)$ of the defections $(0 \leq p_1(\sigma) \leq 1)$ can be detected at this stage, and we get rid of the defect items at the end of the processing period. Initial screening cost is $c_1(\sigma)$ per unit. It is natural to assume that if no time is spent on the screening $(\sigma = 0)$ than $p_1(0) = 0$ (no defects are detected) and $c_1(0) = 0$ (no costs are incurred). We assume that $p_1(\sigma)$ and $c_1(\sigma)$ are continuous functions of σ and at least twice differentiable.

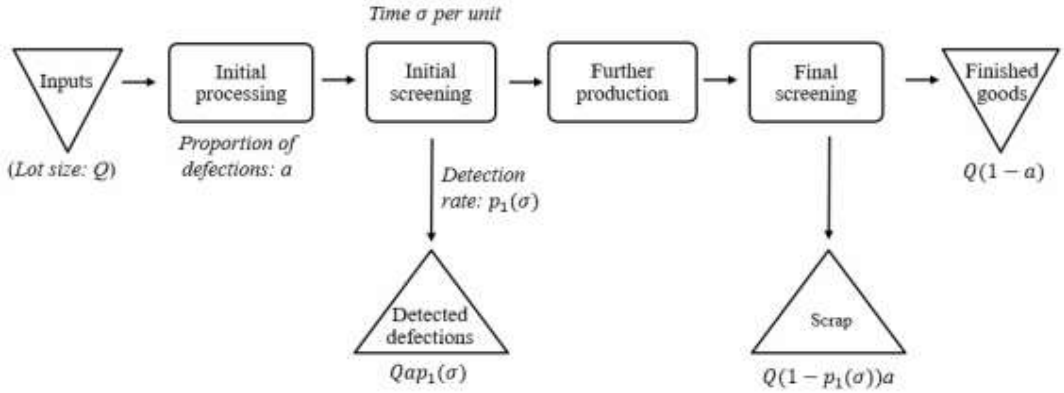

Figure 1. The production process with two stages of screening

After having separated the defects detected during the initial screening, the production continues with more expensive but reliable operations, followed by the final screening stage. At this stage, all kinds of defects are detected so only the good output is shipped. The defective items found at this step are removed from the inventory at the end of the cycle, without rework. The time spent on final screening is fixed and its cost is c_2 per unit. We assume that no backlog arises, and there is no excess inventory at the end of the cycle. In order to satisfy the demand, the defection rate has to be accounted for. The defect compensated demand rate is $d/(1-a)$ which must remain lower than the production rate (if not, the demand cannot be fully satisfied). We denote by $S = \frac{1-a}{d} - \frac{1}{P}$ (it can be interpreted as the idle production time per unit).

Notations used in this paper are listed in Table 1, and the inventory build-up diagram of the deterministic EPQ model is shown in Figure 2. During the production period, the inventory raises at rate $(P-d)$, i.e., the production rate minus the demand rate. At the end of the production cycle $R_1 = Q/P$, the company gets rid of the initially detected defections, i.e. $Qap_1(\sigma)$ items. The defective items detected later at the final screening

stage ($Qa(1-p_1(\sigma))$ items) leave the system at the end of the cycle. The total cycle length is $R = Q(1-a)/d$. The average inventory level is $I_1 = \frac{1}{2}(P-d)R_1$, during the screening period and $I_2 = \frac{1}{2}[(P-d)R_1 - 2Qap_1(\sigma) + Qa]$ during the remaining time of the cycle.

Table 1. List of notations

d	demand rate
P	production rate $(P > d/(1-a))$
a	proportion of defective items in the production, $0 < a < 1$
S	average idle production time per unit.
Q	production lot size, decision variable
R_1	production cycle length
R	cycle length
σ	time of initial screening per unit, decision variable
$p_1(\sigma)$	proportion of defective input detected at the initial screening
K	setup cost (arising every cycle)
k_1	initial processing cost per unit
$c_1(\sigma)$	initial screening cost per unit, depending on speed
k_2	second stage production cost (per unit)
c_2	final screening cost per unit
h	holding cost, per unit of product and per unit of time

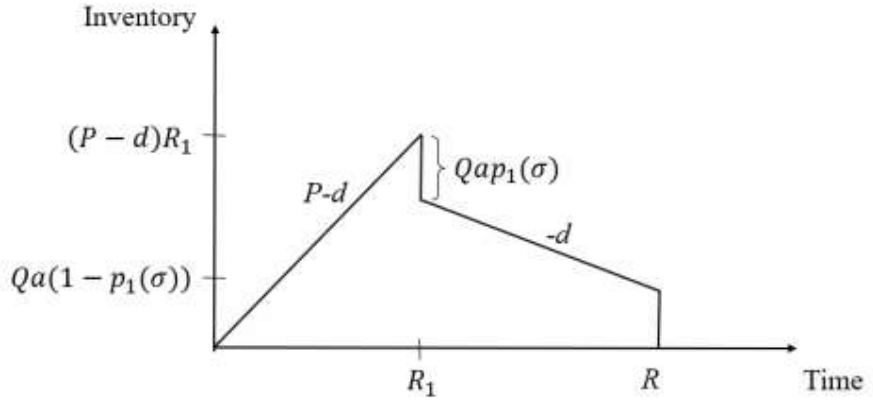

Figure 2. Inventory diagram of an EPQ model with two stages of screening

Processing, screening and holding costs are considered at both stages as listed in Table 2. The initial processing cost contains the cost of initial production for every item, whereas final stage processing cost does only consist of production costs of the items that passed the first screening (good and undetected defective items). Speeding up initial screening (spending less time with this process) saves some cost. However, it does also result in a lower proportion of defective items detected. The undetected defective items go through the second stage of production as well as the final screening, which results in higher processing and screening costs in the second-stage.

Table 2. Variable costs in a cycle

Costs	processing	screening	holding
initial stage	$k_1 Q$	$c_1(\sigma)Q$	$hR_1 I_1 = h\frac{Q^2}{2}\frac{P-d}{P^2}$
final stage	$k_2 Q\big(1-ap_1(\sigma)\big)$	$c_2 Q\big(1-ap_1(\sigma)\big)$	$h(R-R_1)I_2 = h\frac{Q^2}{2}S\left(\frac{P-d}{P}+a-2ap_1(\sigma)\right)$

Additionally, a fixed setup cost K is incurred once in every cycle. Thus, the total cycle cost writes:

$$TC(Q,\sigma) = K + k_1 Q + c_1(\sigma)Q + k_2 Q\big(1-ap_1(\sigma)\big) + c_2 Q\big(1-ap_1(\sigma)\big) + hR_1 I_1 + h(R-R_1)I_2 \quad (1)$$

Dividing the total cost in (1) by the cycle length, we obtain the average cost $C(Q,\sigma) = \frac{TC(Q,\sigma)}{R}$. After some reduction we obtain the following formula:

$$C(Q,\sigma) = \frac{d}{(1-a)}\left[\frac{K}{Q} + k_1 + c_1(\sigma) + k_2\big(1-ap_1(\sigma)\big) + c_2\big(1-ap_1(\sigma)\big) + \frac{1}{2}hQ\frac{P-d}{P^2} + \frac{1}{2}h\,QS\left(\frac{P-d}{P}+a-2ap_1(\sigma)\right)\right] \quad (2)$$

and hence, the optimization problem can be formulated as:

$$\min_{Q,\sigma} C(Q,\sigma) \qquad \text{s.t. } 0 \le \sigma \le \frac{1}{P}. \quad (3)$$

The average cost has to be minimized under the constraint that the initial screening should not be the bottleneck in the process, i.e., the screening rate must be higher than the production rate.

Convexity of the cost function

Let us suppose now that one of the two functions p_1 and c_1 is nonlinear but satisfy the assumptions A0-A1 and B0-B1:

Assumption A0: $c_1(0) = 0$ and $c_1'(\sigma) \ge 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption A1: $c_1''(\sigma) \ge 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption B0: $p_1(0) = 0$ and $p_1'(\sigma) > 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

Assumption B1: $p_1''(\sigma) \le 0,\ \forall\sigma \in \left[0,\frac{1}{P}\right]$.

The convexity of the cost function ensures that a stationary point is a global minimum which is also unique if the objective function is strictly convex.

Calculating the Hessian matrix:

$$H = \begin{bmatrix} \frac{\partial^2 C(Q,\sigma)}{\partial Q^2} & \frac{\partial^2 C(Q,\sigma)}{\partial Q \partial \sigma} \\ \frac{\partial^2 C(Q,\sigma)}{\partial Q \partial \sigma} & \frac{\partial^2 C(Q,\sigma)}{\partial \sigma^2} \end{bmatrix}$$

$$\mathrm{H} = \frac{d}{(1-a)}\begin{bmatrix} \frac{2K}{Q^3} & -hSap_1'(\sigma) \\ -hSap_1'(\sigma) & c_1''(\sigma) + (-k_2 - c_2 - hQS)ap_1''(\sigma) \end{bmatrix} \quad (4)$$

The Hessian is positive definite if and only if the Hessian determinant is positive (see, e.g. Chiang, 1984), and $\frac{2K}{Q^3}$ is positive as well. The latter condition is true. Thus, the condition (H1) must be satisfied.

$$\frac{2K}{Q^3}[c_1''(\sigma) - (k_2 + c_2 + hQS)ap_1''(\sigma)] - [hSap_1'(\sigma)]^2 > 0. \quad \text{(H1)}$$

A more explicit form of Condition (H1) could be obtained for particular c_1 and p_1 functions under few assumptions.

Optimal parameters

We solve the above optimization problem under condition (H1) that guarantees the convexity of the objective function.

The Lagrangian writes

$$L(Q, \sigma, \mu_1, \mu_2) = C(Q, \sigma) + \mu_1\left(\sigma - \frac{1}{P}\right) - \mu_2\sigma, \qquad \mu_1, \mu_2 \geq 0.$$

The Karush-Kuhn-Tucker points (KKT) are obtained from the following conditions:

$$\frac{\partial L(Q,\sigma,\mu_1,\mu_2)}{\partial Q} = \frac{\partial C(Q,\sigma)}{\partial Q} = 0 \quad \text{(L1)}$$

$$\frac{\partial L(Q,\sigma,\mu_1,\mu_2)}{\partial \sigma} = \frac{\partial C(Q,\sigma)}{\partial \sigma} + \mu_1 - \mu_2 = 0 \quad \text{(L2)}$$

$$\mu_1\left(\sigma - \tfrac{1}{P}\right) = 0 \quad \text{(C1)}$$

$$\mu_2\sigma = 0 \quad \text{(C2)}$$

$$\mu_1, \mu_2 \geq 0. \quad \text{(P1)}$$

Condition (L1) implies

$$-\frac{K}{Q^2} + \frac{1}{2}h\frac{(P-d)}{P^2} + \frac{1}{2}hS\left(\frac{(P-d)}{P} - 2ap_1(\sigma) + a\right) = 0$$

$$Q^* = \sqrt{\frac{2K}{h}\left[\frac{(P-d)}{P^2} + \mathrm{S}\left(\frac{(P-d)}{P} - 2ap_1(\sigma^*) + a\right)\right]^{-1}}. \quad (5)$$

From the formula (5) we can see that higher detection rate $\left(p_1(\sigma^*)\right)$ makes the optimal lot size increase.

Now, according to complementarity conditions (C1) and (C2), we have ($\sigma - \frac{1}{P} = 0$ or $\mu_1 = 0$) and ($\sigma = 0$ or $\mu_2 = 0$). These define four cases, from which $\sigma - \frac{1}{P} = 0$ and $\sigma = 0$ cannot be true at the same time. Hence, three possible solutions remain:

(a) $\sigma - \frac{1}{P} = 0$ which gives $\sigma^* = \frac{1}{P}$ and $\mu_2 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}\left[c_1'\left(\frac{1}{P}\right) - k_2 a p_1'\left(\frac{1}{P}\right) - c_2 a p_1'\left(\frac{1}{P}\right) - a p_1'\left(\frac{1}{P}\right) hQ^* S\right] + \mu_1 = 0$$

from which

$$\mu_1 = \frac{-d}{(1-a)}\left[c_1'\left(\frac{1}{P}\right) - k_2 a p_1'\left(\frac{1}{P}\right) - c_2 a p_1'\left(\frac{1}{P}\right) - a p_1'\left(\frac{1}{P}\right) hQ^* S\right] \quad (6)$$

which must be positive in order for this solution to be feasible.

(b) $\sigma^* = 0$ therefore $\mu_1 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}[c_1'(0) - k_2 a p_1'(0) - c_2 a p_1'(0) - a p_1'(0) hQ^* \mathrm{S}] - \mu_2.$$

Hence

$$\mu_2 = \frac{d}{(1-a)}[c_1'(0) - k_2 a p_1'(0) - c_2 a p_1'(0) - a p_1'(0) hQ^* S] \quad (7)$$

which must be positive in order for this solution to be feasible.

(c) $\mu_1 = 0$ and $\mu_2 = 0$. In this case, condition (L2) implies

$$\frac{d}{(1-a)}[c_1'(\sigma) - k_2 a p_1'(\sigma) - c_2 a p_1'(\sigma) - a p_1'(\sigma) hQ^* S] = 0.$$

Hence, σ^* is obtained from the solution of the following equation

$$c_1'(\sigma) - k_2 a p_1'(\sigma) - c_2 a p_1'(\sigma) - a p_1'(\sigma) hQ^* \mathrm{S} = 0 \quad (8)$$

which must satisfy feasibility conditions.

Note that if the initial screening cost is small and increases moderately with respect to the screening time, then we have case (a), which means that the maximum possible time should be spent on the initial screening. On the other hand, sharp increase in the initial screening cost makes zero initial screening time (case b) optimal. If initial screening cost is neither very high nor very small compared to second-stage screening, processing and holding costs, then the optimal screening time comes from equation (8) in case (c) which balances all the costs.

The condition (H1) is sufficient to guarantee the optimality of any feasible KKT point among the above.

Numerical examples and sensitivity analysis

In this section, we provide numerical examples to illustrate the computation procedure and to derive managerial insights from various scenarios regarding the shape of the underlying functions and the values of the different parameters of the model.

Assuming 40 working hours per week, the number of working minutes per year is $T = 125000$. Based on the production constraint, the maximum time that can be devoted to initial screening is 1 minute per unit. All the time related parameters are converted to minutes.

Table 3. General parameters to be used in the numerical examples

d	demand rate	80,000	units/year
P	production rate ($P > d/(1-a)$)	125,000	units/year
a	proportion of defective items in the production, $0 < a < 1$	0.04	
K	setup cost (arising every cycle)	1000	\$/setup
k_1	initial processing cost per unit	10	\$/unit
k_2	second stage production cost (per unit)	20	\$/unit
c_2	final screening cost per unit	10	\$/unit
h	holding cost, per unit of product and per unit of time	30	\$/unit/year

Additionally, to the parameters above (Table 3), we define multiple scenarios in which we consider various levels of the screening cost and/or detection rate. Furthermore, we vary the proportion of the defective items in the production (a) and observe the effect on the optimal parameters and total cost of the system.

We consider the parameters of the nonlinear detection function to be unchanged while calculating the optimal level of initial screening for cheap, moderate, and expensive parameters of the linear screening cost function. If the proportion of defective items is 4%, then parameter values that are lower than $\beta = 0.3$, the optimal initial screening time is 1, and for values higher than $\beta = 2.5$, screening is not reasonable, i.e. $\sigma^* = 0$.

Table 4. Optimal values of initial screening for various cost levels and defection rates

	Parameters, Variables	Values #1	Values #2	Values #3
Nonlinear detection function: $p_1(\sigma) = \alpha(1 - \exp(-\xi\sigma)),\ \alpha, \xi > 0$	α	1	1	1
	ξ	2	2	2
Linear cost function: $c_1(\sigma) = \beta\sigma,\ \beta > 0$	β	0.3	0.9	2.5
Level of the initial screening cost		low	medium	high
Proportion of the defective items in the production $a = 0.04$				
Optimal initial screening time	σ^*	1	0.5	0
Optimal lot size (units)	Q^*	3982	3948	3858
Optimal total cost (\$/year)	$C^* \times T$	3,313,716	3,349,839	3,376,538
Proportion of the defective items in the production $a = 0.11$				
Optimal initial screening time	σ^*	1	1	0.49
Optimal lot size (units)	Q^*	4214	4214	3915
Optimal total cost (\$/year)	$C^* \times T$	3,408,649	3,462,581	3,641,421

As to be seen in Table 4, the cheaper the screening, the more time should be spent with it. For rather low proportion of defective items in the production ($a = 0.04$), we have shown the two extremes when initial screening is so cheap that the optimal value is the possible maximum ($\sigma^* = 1$, see #1), and when it is so expensive that no time should be spent with it at all (see #3). The optimal lot size increases with the higher optimal values of σ. The minimum of the total cost decreases as the optimal initial screening time gets higher. The minimum of the total cost is higher if the proportion of defective items increases, and the differences are also bigger.

Let us also note that an increased proportion of defections, i.e. higher value of a makes initial screening more crucial. In the example above, it is optimal to do spend time with initial screening even if the costs are high and the maximal value is the optimum for a

moderate cost level already. As illustrated by Figure 3, the minimum of the total cost is increasing with both the initial screening cost and the defection rate.

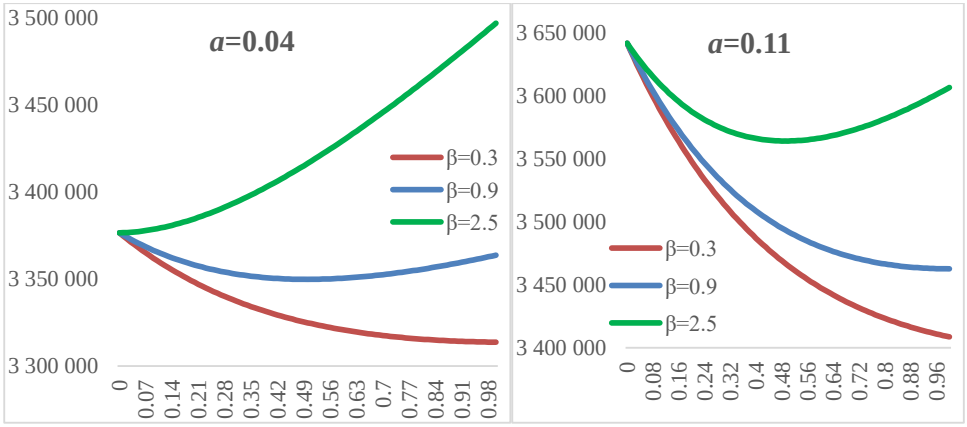

Figure 3. The total cost function with respect to σ, with low, medium and high initial screening costs, and higher defection rate in the second case

Conclusion

This paper presents an inventory model with two stages of quality screening. Jointly with the production lot size, the time allocated to the initial screening is a decision variable as well. This problem is relevant for many companies that have complex operations and many defections in the first stage of the production process.

The time of initial screening determines the related costs but also the proportion of detected defections in linear or nonlinear form. With the objective of minimizing the total production cost, we proposed a procedure to calculate the optimal lot size jointly with the optimal time of initial screening.

There are several results with high relevance for managerial implications. Firstly, the decision regarding the screening time affects the total cost of the system and modifies the optimal lot size. We found out that if the cost of screening in the first stage is too high then it is more reasonable to avoid it and bear the second-stage holding, processing and screening costs. Vice versa, if first stage screening costs are small enough compared to the other types of costs, then the maximal time should be spent on initial screening to allow the detection of a maximum number of defective items. In many other cases, the optimal screening time allows us to balance the various cost components. Other parameters that can influence the decision regarding the screening time include the proportion of the defections in the production (reliability of the production process in the first stage). The findings show that doing quality control in the optimal manner and in the right time reduces the overall system cost while ensuring the desired quality level.

The model in this paper can be extended in several directions. Possible extensions include additional defections in the second production stage, backlogging or rework, random defections, errors in screening and learning effect.

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A proposed framework for monitoring and evaluating national logistics performance: the case of Cambodia

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Abstract

The purpose of this paper is to propose a monitoring and evaluation (M&E) framework for national logistics policy based on Banomyong et al. (2008)'s macro-logistics model. The M&E framework was populated by using data from published macro-level indicators and actual performance data of national logistics system users. An identified list of key performance indicators is provided as reference. Cambodia was used to validate the proposed framework and how the framework can support the development of national-level logistics policy. Findings show that the indicators are first used to obtain national baseline logistics performance.

Keywords: Logistics performance, Monitoring and evaluation system, Cambodia Logistics Master Plan

Introduction

Logistics is important to national competitiveness (Arvis et al., 2018). Countries have increased their interest in data related to national-level logistics performances as these will help them not only improve their competitiveness but also support the development of their national policies (Rantasila and Ojala, 2012). Considering the national-level perspective, logistics encompasses both micro and macro levels (Havenga, 2018). At the micro level, this involves firms' own performance such as reducing logistics costs. At the macro level, the scope is on the national logistics systems (Gleissner and Femerling, 2013), the macroeconomic context (Havenga, 2018) and policy perspective (Banomyong, et al. 2008).

Based on these different scopes, the framework proposed by Banomyong et al. (2008) appears to cover a more holistic view of macro-logistics and micro-logistics issues. However, recent updates are lacking with regards to the present global business context that might impact national logistics performance.

The purpose of this paper is to provide countries with an approach for their national-level logistics policy development. Banomyong et al. (2008)'s initial framework is hereby refined with updated information gathered from both macro- and micro-level

sources. In order to validate the refined framework, Cambodia was selected as an illustrative case.

Literature review

Logistics development policy can be referred to as: "the policy that involves the planning, facilitating, implementing, integrating and controlling the efficient, effective flow and storage of freight, people and information within and between logistics systems, for the purpose of enhancing traders' competitiveness in order to increase national and/or regional competitive advantage" (Banomyong, 2008, p. 45).

Havenga and Simpson (2018) suggested that policy lifecycle consists of stages related to issue identification, analysis, consultation, development and adoption, implementation, monitoring and evaluation as well as adjustment. Thus, it is evident that monitoring and evaluation (M&E) is an integral part of logistics policy deployment that provides a link between the planning and implementation stages. M&E is a stage that keeps decision-makers informed of the policies implemented as well as provides evidence of what adjustments need to be made to current policies given shifts in the country's indicators (Havenga and Simpson, 2018).

While monitoring focuses on activities and outputs, evaluation focuses on the outcome and goals (Unicef, 1991). Considering the role of M&E in the development of national-level logistics policy, monitoring should be initiated during the conceptual phase of a country's logistics master plan. This will link the design of the assessment with the planning phases of logistics development strategies of the country. Furthermore, monitoring will help track and evaluate the implementation of those strategies. This is a continuous process of gathering logistics and strategy deployment information to measure against pre-determined set of key performance indicators, benchmarks or previously referenced data which would keep a country in alignment with the goals and objectives of its national logistics master plan.

Logistics at the national level has gained much attention from many countries and at the global level, there already exist a number of global logistics related indicators developed by institutions such as the World Economic Forum or the World Bank to broadly measure logistics quality and performance across the board. These macro-level indicators can capture logistics performance, reflect logistics improvements and can be used as a benchmark for national competitiveness (Havenga, 2018). However, these indicators are not defined for use in a more comprehensive country specific framework. As an example, the Logistics Performance Index (LPI) can measure a country's logistics performance perceived by external respondents but it is not a reflection of its actual logistics performance (World Bank, 2016; Havenga, 2018). Thus, indicators used in tracking and evaluating policy implementation will need to be derived not only from the existing macro level references but also collected empirically at the national level. Key performance indicators at the sector/firm level are important as these measures can reflect the actual logistics performances of a country. The logistics performance of a country will be based on the performance of national logistics system users.

To propose an M&E framework for logistics policy deployment, this paper uses the Banomyong et al. (2008)'s framework for two reasons. Firstly, this framework has already been used to assess logistics situation in ASEAN and the GMS. Secondly, the scope of the framework includes both micro-logistics and macro-logistics dimensions as suggested in the literature. Figure 1 describes that the framework is composed of four logistics system components. Infrastructure is the backbone of the logistics system while the institutional framework involves the regulatory and institutional environment

that affects the operation of national logistics users i.e. the service providers and shippers.

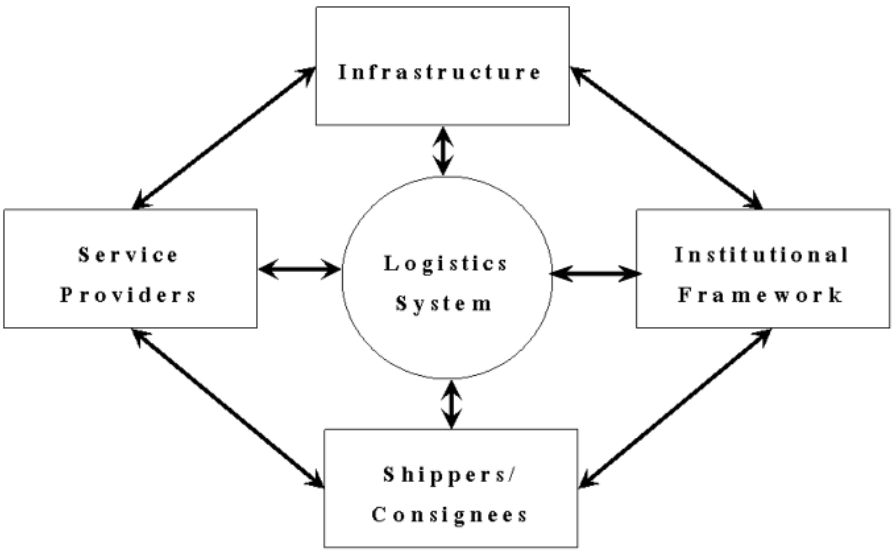

Figure 1 – Logistics System Components (Source: Banomyong et al., 2008)

Methodology

Since the framework does not provide specific details within each dimensions, the purpose of the paper is to propose a more refined Banomyong et al. (2008)'s framework. The refined framework was developed based on data from two levels. At macro level, there are major internationally recognised databases which include the Global Competitiveness Report by World Economic Forum (WEF), the World Competitiveness Yearbook by International Institute for International Development Management (IMD), the Logistics Performance Index (LPI) by the World Bank and Doing Business (DB) by the World Bank. These provide some basic measurements to define macro-level indicators for the logistics M&E framework of a country. At the micro level, data need to be collected from service providers and shippers related to their actual performances.

The logistics and supply chain literature suggests many key performance indicators (KPIs) that could be used to measure a firm's logistics performance (Gunasekaran and Kobu, 2007; Banomyong and Supatn, 2011; Banomyong and Varadejsatitwong, 2016). These KPIs derived from the literature can help in the design of questionnaires focused on observing national logistics system users' logistics performances. The data obtained from these two levels will serve as a country's logistics performance baseline and can be further used in the development of a national logistics policy.

To explore if such an approach could be used for national-level logistics policy development, a case study research method was used to help the authors validate their proposed framework (Voss et al., 2002; Yin, 2013). Cambodia was selected as an illustrative case. Compared to others in the region, the country faces challenges in logistics performance and needs a proper M&E system to support transport and logistics strategic planning, evidence-based policy making and the monitoring of the implementation of policies related to logistics (Banomyong, 2010).

Indicators in the M&E framework for Cambodia were separated into two groups. The first group, defined as high-level indicators, was based on existing macro-indicators available from secondary sources. Indicators already used by countries around the world

for benchmarking purposes were reviewed. These were set up in order to populate the four dimensions of the national logistics system framework (see Table 1).

Table 1 – High Level Indicators

Dimension	Indicator	Source
Infrastructure	Quality of Overall infrastructure	WEF
Institutional & policy framework	The efficiency of customs and border clearance	LPI
Logistics Services Providers	The competence and quality of logistics services	LPI
Shippers/Consignees	The ease of arranging competitively priced shipments	LPI
Overall	LPI Score	LPI

The second group focused on the actual logistics performance in the country. A baseline was obtained from actual empirical data i.e. logistics services users and logistics service providers capability in Cambodia. The rationale for collecting empirical data for baseline performance was based on the lack of existing data in the country.

In order to establish the baseline, a pilot survey was conducted. There were two sets of questionnaires. The first set was designed to capture an overview of manufacturing firms' logistics performance and costs. Respondents included garments, electronics, electrical components and agro-processing. The second set was designed to capture an overview of freight forwarders and logistics service providers' own logistics capability. KPIs in the surveys were adapted from Banomyong and Supatn (2011) and adjusted to the local context (see Table 2). The selected KPIs focused on the performance of key logistics activities based on cost, time and reliability.

Table 2 – Micro-Level Key Performance Indicators

Target Respondents	Key Performance Indicator
Users of Logistics Services	Logistics Cost/Sales, Weight of Logistics Performance Dimensions, Delivery in Full & On Time, Damage rate, Customer complain rate, Ratio of returns, Forecast accuracy, Cash conversion cycle, Outsourcing ratio, Service level agreements, Warehousing, storage and inventory costs
Logistics Service Providers	Weight of Logistics Performance Dimensions, Average Order Cycle Time, Transportation Lead time, Delivery in Full & On Time, Damage rate, Cash conversion cycle, Most common problems

Source: Banomyong and Supatn (2011)

Data collection involved manufacturing, agro-processing firms and logistics service providers in Phnom Penh, Cambodia. The majority of respondents were small and medium size enterprises (SMEs). Data was collected via a workshop format during September 2017 and December 2017. The workshops were facilitated with strong support from the Cambodian Chamber of Commerce (CCC), Cambodia Freight Forwarders Association (CAMFFA), Cambodia Trucking Association (CAMTA), Garment Manufacturers Association in Cambodia (GMAC), Rice exporters' association etc. Respondents were approached focusing on the key strategic sectors of Cambodia. Representatives from key professional organisations including GMAC, CAMTA and CAMFFA were also involved in the validation and collection of the empirical data.

Cambodia baseline score

Identified indicators both at the macro and micro logistics levels in all four dimensions can reflect Cambodia's national logistics system performance. For a rapid assessment of the logistics performance of the country, it is not necessary to compile all of the proposed indicators. The high-level indicators that need to be compiled and monitored

are described hereunder in Table 3. These indicators are sufficient to provide a snapshot of the current logistics capability of Cambodia without being submerged by too many KPIs. Table 4 describes the baseline of Cambodia's current logistics performance as reflected by the users of Cambodia's logistics system.

Table 3 – High-Level Baseline Scores for Cambodia

Infrastructure	
The indicators from WEF (out of 7)	**Baseline (2017)**
Quality of Overall Infrastructure	3.4
Quality of roads	3.2
WHO/MPWT: Road fatality rate (%) (2013)	17.4
WDI: CO2 emissions from transport (% of total fuel combustion) (2014)	63.61
Quality of railroad infrastructure	1.6
Quality of port infrastructure	3.7
WDI: Container port traffic (TEU: 20-foot equivalent units: thousand)	482
Quality of air transport infrastructure	3.7
The indicators from LPI (out of 5)	
The quality of trade & transport infrastructure	2.36
Institutional	
The indicators from WEF (out of 7)	
Irregular payments & bribes	3
Burden of government regulations	3.4
Efficiency of legal framework in settling disputes	2.9
Efficiency of legal framework in challenging regulations	2.8
Transparency of government policy making	3.2
Prevalence of trade barriers	4.1
Trade Tariffs (% duty)	9.3
Prevalence of foreign ownership	4.5
Business impact of rules on FDI	4.4
Burden of Customs procedures	3.2
The indicators from Trading Across Borders	
Time to Export (Border Compliance-Hours)	48
Cost to Export (Border Compliance)	375
Time to Export (Documentary Compliance)	132
Cost to Export (Documentary Compliance)	100
Time to Import (Border Compliance)	8
Cost to Import (Border Compliance)	240
Time to Import (Documentary Compliance)	132
Cost to Import (Documentary Compliance)	120
The indicators from LPI (out of 5)	
The efficiency of customs and border clearance	2.62
Logistics Service Providers	
The indicators from LPI (out of 5)	
The competence and quality of logistics services	2.6
Timeliness	3.3
Shippers/Consignees	
The indicators from WEF (out of 7)	
Local supplier quality	3.6
State of cluster development	4
Nature of competitive advantage	3.2
Value chain breadth	3.6
Control of international distribution	3
Production process sophistication	3.1
The indicators from LPI (out of 5)	
The ease of arranging competitively priced shipments	3.11
The ability to track and trace consignments	2.7

Table 4 – Micro-Level Baseline Scores for Cambodia

Target Respondents	Indicators	Baseline (2017)
Users of logistics services	Logistics Cost/Sales	20.52%
	Delivery in Full & On Time (DIFOT)	82.32%
	Damage rate	3.46%
	Customer complaint rate	5.80%
	Ratio of returns	3.68%
	Forecast Accuracy	81.25%
	Cash Conversion Cycle	9.49 days
	Outsourcing ratio	68%
	Warehousing and storage costs	9.69%
	Service Level Agreements	26%
LSPs	Average Order Cycle Time	6.48 days
	Transportation Lead time	4.16 days
	Delivery in Full & On Time (DIFOT)	85.84%
	Damage rate	2.86%
	Cash Conversion Cycle	6.03 days

The proposed M&E framework for Cambodia's National Logistics Master Plan

High-level indicators and empirical KPIs need to be aligned with the developed logistics strategies. Thus, the indicators obtained from the previous section were further used to develop an assessment framework of the proposed five strategies developed in the Cambodian Logistics Master Plan. These five logistics strategies have been developed to achieve Cambodia's SMART Logistics Vision 2025. By doing this, both quantitative and qualitative measures can be used to monitor the national logistics system performance.

The proposed improvement targets for Cambodia are based on requirements that by 2020 the country would need to achieve at least the mean score for each indicator that is under the mean. For those indicators that are over the mean, it is important that their score increases by at least one unit. The 2025 targets are based on at least another unit increase for each of the indicators. For the trading across border indicators, it is necessary to reduce the time and cost by at least 10% for the year 2020 and a further 10% by the year 2025. These targets were validated at a national level workshop in Cambodia on October 30, 2018.

Table 5 – Cambodia's M&E Framework With Targets

Strategy	Description	Indicator	2017	2020	2025
Strategy 1 Development of Economic Corridors & International Gateways					
Programs	Road Transport Capacity Enhancement	WEF :Quality of roads	3.2	3.5	4
		WHO/MPWT: Road fatality rate (%) (2013)	17.4	16.50	16.00
		WDI: CO2 emissions from transport (% of total fuel combustion) (2014)	63.61	62.00	61.00
	Promotion of Railways as an emerging mode	WEF :Quality of railroad infrastructure	1.6	3.5	4
	Inland Water Transport improvement	WEF :Quality of port infrastructure	3.7	4	5
	Sihanoukville & Phnom Penh Port Development	WDI: Container port traffic (TEU: 20-foot equivalent units: thousands)	482	500	620
Strategy 2 Development of Logistics Hubs for Multimodal transport					
Programs	Bavet Border Area improvement	LPI :Quality of trade & transport infrastructure	2.36	2.5	3
	Poi Pet Border Area improvement	LPI :Quality of trade & transport infrastructure	2.36	2.5	3

	Logistics complex development	LPI :Quality of trade & transport infrastructure	2.36	2.5	3
	Air cargo development	WEF :Quality of Air Transport Infrastructure	3.7	4	5
	Urban transport facilitation	LPI :Quality of trade & transport infrastructure	2.36	2.5	3
	Regional development support	WEF :Quality of Overall Infrastructure	3.4	3.5	4
Strategy 3 Realization of Seamless Border Management					
Programs	Port Management Enhancement	WEF :Irregular payments and bribes:	3	3.5	4
	Introduction of Cambodia NSW	WEF :Burden of government regulation	3.4	3.5	4
	Trade Support	WEF :Efficiency of legal framework in settling disputes	2.9	3.5	4
	Trade compliance improvement	WEF :Efficiency of legal framework in challenging regulations	2.8	3.5	4
	Optimization of CamControl and Procedures	WEF :Transparency of government policymaking	3.2	3.5	4
		LPI :Efficiency of customs and border clearance	2.62	3	4
Strategy 4 Capacity Enhancement of Logistics Service Providers					
Programs	Establishment of Logistics Technical Training Centre	LPI: Competence and quality of logistics services	2.6	3	4
		LSP: Average Order Cycle Time (days)	6.48	6	6
		LSP: Transportation Lead Time (days)	4.16	4	4
		LSP: Cash Conversion Cycle (days)	6.03	6	6
		LSP: Delivery in Full On Time (%)	85.84	90	95
		LSP: Damage rate (%)	2.86	2	2
	Public private Dialogue	WEF :Efficiency of legal framework in challenging regulations	2.8	3.5	4
		WEF :Transparency of government policymaking	3.2	3.5	4
	Logistics Business Modernization	User: Outsourcing ratio (%)	68	75	80
		User: Service level agreements (%)	26	50	80
		User: Delivery in Full & On Time (%)	82.32	85	90
		User: Damage rate (%)	3.46	2	2
		User: Customer complain rate (%)	5.8	2	2
		User: Ratio of returns (%)	3.68	2	2
		User: Forecast accuracy (%)	81.25	85	90
		User: Cash conversion cycle (days)	9.49	10	10
	Introduction of modern logistics technology	LPI :Ability to track and trace consignments	2.7	3.5	4
	Market Mechanism Enhancement	WEF :Local supplier quality	3.6	4	5
		WEF :State of cluster development	4	5	6
		WEF :Nature of Competitive Advantage	3.2	3.5	4
		WEF :Value chain breadth	3.6	4	5
		WEF :Control of international distribution	3	3.5	5
		WEF :Production process sophistication	3.1	3.5	5
Strategy 5 Strengthening of Legal and Institutional Framework					
Programs	Facilitation of Trade Agreements	TAB: Time to Export (Border Compliance) (Hours)	48	43	38
		TAB: Cost to Export (Border Compliance) (USD)	375	338	304

		TAB: Time to Export (Documentary Compliance) (Hours)	132	118	106
		TAB: Cost to Export (Documentary Compliance) (USD)	100	90	81
		TAB: Time to Import (Border Compliance) (Hours)	8	7	6
		TAB: Cost to Import (Border Compliance) (USD)	240	216	194
		TAB: Time to Import (Documentary Compliance) (Hours)	132	118	106
		TAB: Cost to Import (Documentary Compliance) (USD)	120	108	97
		WEF: Prevalence of trade barriers	4.1	5	6
		WEF: Trade tariffs (% duty)	9.3	8	7
		WEF: Prevalence of foreign ownership	4.5	5	6
		WEF: Business impact of rules on FDI	4.4	5	6
		WEF: Burden of customs procedures	3.2	3.5	4
	Enhancement of Borderless Transportation	LPI: The ease of arranging competitively priced shipments	3.11	3.5	4
	Optimization of Logistics Costs	User: Logistics cost/sales (%)	20.52	16	11
		User: Warehousing and inventory costs (%)	9.69	7.00	5.00

Discussions and conclusions

This paper proposed a refined M&E framework to assess logistics performance of a country by using Cambodia logistics master plan as a validating case study. The contribution of this paper is twofold. Firstly, Banomyong et al. (2008)'s framework was updated and refined. A list of KPIs that can be used to reflect national logistics performance at the national level was provided. These indicators were employed to present the baseline score for Cambodia. However, making use of existing macro-level indicators to measure a country's logistics performance may not be enough. Any country will need to have empirical data obtained from actual performance of its national logistics users to illustrate logistics capability on the ground. At the firm level, logistics baseline score reported by Governments can be used for benchmarking purpose in self-assessment exercises that are developed for competitiveness purposes.

Secondly, the paper provides policy-makers with a useful approach for national-level logistics policy development. It suggests how to holistically assess their national logistics systems and how to use proposed KPIs to investigate whether the developed policies satisfy the needs of its national logistics users.

As illustrated by the case of Cambodia, the refined framework and KPIs were used as an integral part of Cambodia's Logistics Master Plan development. Identified indicators were put in place to monitor weaknesses, poor designs in implementation strategies and improper actions. This basically helped track and assess implementation of the five logistics strategies to make sure that the developed strategies are aligned to the goals and objectives of Cambodia's Logistics Master Plan. Based on continuous monitoring, these weaknesses against targets set can then be revised to continually improve national logistics performance.

Evaluation, like monitoring, is a continuous process. The evaluation of output quality can be undertaken in such a way that shortcomings can be identified and corrected. Evaluation will feed into the planning process continuously so that the planned method of intervention can be modified to take into account realities and conditions on the ground.

Evaluation provides a tool for policy makers to ensure that focus is maintained. Therefore, performance management must align the performance metrics to the objectives and strategies of a country's logistics master plan. The M&E framework provides the basis for national logistics performance management. Aligning performance metrics ensures that the M&E is targeted and does not disrupt the overall master plan. Without alignment, it is difficult to know what to monitor or how to evaluate it.

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A framework for developing logistics policies by using logistics performance index: an implementation to Turkey

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Abstract

Researchers seek relations between LPI scores and other statistics for developing country logistics policies. The aim of this study is to develop a framework for recommending logistics policies to improve LPI scores of competing countries, specifically the emerging economies, by examining and benchmarking the strategies of countries with high or progressive LPI scores. The study implements both qualitative and quantitative methods for developing strategic recommendations in an uncertain business environment. The developed framework is implemented to provide strategic recommendations for Turkey. This framework can be used as a strategic tool for countries to sustain and improve their worldwide trade performances.

Keywords: Logistic Performance Index, Logistics, Logistics Strategy Development

Introduction

Logistics is one of the key elements of trade (Martí et al., 2014), and logistics performance significantly affects the volume of bilateral trade. It increases the competitiveness of not only the companies but also the countries, and countries recently recognized the importance of logistics in worldwide trade (Hausman et al., 2013). This emerged the need to develop a measurement system for the logistics performance, and develop strategies to advance country performance.

LPI is a survey-based index prepared by World Bank since 2007, which is extensively accepted worldwide (160 countries involved in 2018 version). LPI is a powerful tool for

countries to benchmark and assess their logistics performance in global platform and to understand the logistics challenges as well as the areas for improvement (Gogoneata, 2008). This helps countries to understand their current position and develop country strategies and policies to improve their performance in the worldwide trade.

Political decisions and implemented policies have both direct and indirect effects on the attractiveness of a region or a country in terms of business location decisions and foreign direct investments (Ojala and Çelebi, 2015). LPI is becoming an increasingly respected tool by countries, and, political authorities are increasingly using this tool to develop strategies (das Chagas et al., 2018). For example, in Indonesia, LPI is formally used to measure the performance of the Ministry of Commerce. The organization of Asia-Pacific Economic Cooperation (APEC) also uses LPI to measure the impact of an initiative to improve connectivity in the supply chain. The European Commission has used LPI in its Transport Evaluation Panel and its performance evaluation of the Customs Union (das Chagas et al., 2018).

However, knowledge is still limited to understand how LPI scores can be used to develop logistics policies to improve country trade. Literature focuses mostly to LPI or other indexes, their comparison or complementary use (e.g. Gogoneata, 2008; Hausman et al., 2013; Martí et al., 2014). To the best of our knowledge, there are not any studies in the literature examining the practices and policies of countries to improve their logistics performance and their LPI scores to provide a strategic benchmark for competing countries.

The aim of this study is to develop a framework that (i) understands the actions, policies, strategies, and investments behind LPI scores of the countries that either have risen in the ranking or have been consistently in top for the last ten years, and (ii) helps other countries, particularly, the emerging economies, to benchmark their performance and build strategies or policies to improve their worldwide logistics performance under given budget constraints.

The three research questions addressed in the study are as follows;

- RQ1: What are the strategies that determine and improve the countries' LPI scores?
- RQ2: What strategies should Turkey implement to improve LPI ranking?
- RQ3: How a best combination of strategies can contribute to formalize Turkish policies for improving its LPI ranking under budget constraints?

This study employs a multi-method approach. First, content analysis is applied to secondary data collected from various online sources, reports and news to code the logistics strategies implemented by the best-scored or progressive countries. Then, regression analysis is applied to calculate the effect of each coded action on each LPI criteria. This is followed by a survey implementation to estimate the costs of these actions, and a mathematical model is developed that maximizes the LPI score by picking a subset of actions for a given budget. This methodological framework is implemented to Turkey, to develop effective logistics policies for improving its competitiveness in the world trade.

This study makes a significant contribution on the logistics development of the countries and the development of the literature on the area. The methodological approach

followed in this study may lead the way for not only Turkey, but also other countries, to improve trade, and can be used to develop policy recommendations.

The outline of the study is as follows; after a literature review in Section 2, Section 3 presents the methodological framework. Section 4 discusses the implementation of the developed framework to Turkey and the last section concludes the study.

Literature review

The modern generation of global change is formed by complex interactions between people, firms, and organizations. Supply chains encompass nations and regions, and trade has turned out to be a 24/7 commercial enterprise. The performance in trade requires connectivity along not only roads, rail and sea, but also in telecommunications, monetary markets and information-processing (Ojala et al., 2014). A country having competitive advantage in terms of logistics performance increases its international trade, expands towards new markets and encourages businesses (Ekici et al., 2016).

Above mentioned evolution introduces LPI as a critical tool for countries to observe their performance over time, assess their relative position with respect to other countries, and outline the logistics areas to improve for achieving higher levels of performance in worldwide trade. Logistics performance needs to be understood, first, at national level to better evaluate the existing position and target exact trade and transport policy to be implemented across countries.

Studies show that, there is strong relationship between logistics and economic growth. Chu (2012) and Navickas et al. (2011) show investing in logistics is important for fostering economic growth, especially for undeveloped and developing country. As the backbone of international trade, logistics encompasses several activities such as freight transportation, warehousing, customs clearance, payment systems, which are mostly performed by private service providers for traders and owners of goods; however, it is also critical for public policies of national governments and regional and international organizations (Arvis et al., 2012). Ekici et al, (2016) mentioned that, due to the complexity of global supply chains, the efficiency of logistics depends on the efficiency of government services, investment and policies as well as other factors which influence the competitiveness of the nation as a whole.

Building infrastructure, developing regulatory regime for transport services, and designing and implementing efficient customs clearance procedures are just a few areas where government play an important role. (Ekici et al., 2016). LPI rankings serve as a benchmark for policy-makers and other interested parties for judging the relative competitive performance of their country within a global context. The logistics strategy is a set of guiding principles, driving forces and ingrained attitudes that help to coordinate goals, plans and policies, reinforced by conscious and subconscious behavior within and between partners throughout the network (Hayes and Wheelwright, 1984).

There are various studies about LPI in the literature. Hausman et al. (2013) and Martí et al. (2014) show that LPI influenced inter-country trade. Çemberci et al. (2015) and Ekici et al. (2016) discuss the relationship between global competition index and LPI. Van Gogoneata (2008) uses standard econometric techniques and LPI calculated by The

World Bank for evaluating the impact of several key macroeconomic variables on the quality of the logistics sector, whereas das Chagas et al. (2018) try to identify the most critical barriers that hinder Brazilian competitiveness with using LPI. Besides, literature focuses particularly to LPI or other indexes, their comparison or complementary use (e.g. Gogoneata, 2008; Hausman et al., 2013; Martí et al., 2014). Remedial work done in this area, showing that Global Competition Index (GCI) may increase the LPI ranking, or any increase in LPI criteria may increase competitive power (Çemberci et al., 2015; Ekici et al., 2016). However, knowledge is still limited to understand how LPI scores can be used as a benchmark to develop logistics strategies and country policies to improve trade.

A methodological framework

This study employs a multi-method approach. The steps include (i) identifying logistics policies via content analysis, (ii) determination of action impacts on LPI scores, (iii) detecting the costs and generating scenarios, (iv) detecting the optimal policies. We present each step in detail.

Identifying Logistics Policies

Content analysis is utilized in this study to analyze and interpret the textual data (Krippendorff, 2004) gathered from various online sources including logistics magazines, articles, newspapers, investments reports of the World Bank, Ministry of Transport publications and news to outline the strategies and policies implemented by countries to improve their logistics performances. Since LPI is published by 2007, data is collected for years between 2007 and 2018. The main categories and sub-coding are explored by making inferences from detailed reading of data inductively (Krippendorff, 2004).

The sample of the content analysis is identified through purposeful sampling (Flick, 2014). The countries with highest and progressive LPI scores within the last ten years are chosen. The high or increasing LPI scores are considered as an indicator of successful assessment and implementation of logistics policies. Generally, countries with steadily higher scores are among the high income countries according to the OECD report. Therefore, their actions would potentially provide important recommendations for the countries with lower or non-progressive LPI scores.

In content analysis, the logistics strategies of the sample countries are analyzed and coded by an iterative process and grouped under distinct categories. Categories with emerging data is constantly compared as the new secondary data sources are emerged and the analysis is progressed (Miles and Huberman, 1994; Krippendorff, 2004).

The reliability of the coding process was investigated by two independent researchers. In case of disagreement, the assessment of a third researcher was asked to resolve the dispute (Weber, 1990).

Determination of action impact on LPI

After the coding process is completed, we utilize regression analysis to determine the relation between the coded actions and their impact on LPI area scores. Regression analysis of data is a very powerful statistical tool (Mendenhall et al., 1996). It provides a

technique for building a statistical predictor of a response. Regression analysis is a branch of statistical methodology concerned with relating a response to a set of independent, or predictor, variables. The goal is to build a good model, a prediction equation relating response to the independent variables that will enable us to predict the response value for given independent values, with a small error of prediction.

In our notation, T is set of years at which LPI scores are announced, $t \in T$, J is the set of LPI areas, $j \in J$, C is the set of countries analyzed, $c \in C$ and A is set of actions determined by content analysis, $a \in A$. Parameters The number of type a actions taken by country c at year t is N_{cat} and the score of country c on LPI area j at year t is LPI_{cjt}. We estimate the impact of action a on LPI area j, α_{aj} via regression analysis.

Note that, actions in A set and the number of actions taken by a country in a year (N_{cat} values) are the outputs of the content analysis. An action taken by a country may improve the score on one LPI area but the same action may deteriorate the score of another area. To capture such effects of the actions, we conduct the regression analysis on each LPI area separately.

As one may expect, not all actions have significant impacts on each area. In order to find the most suitable regression model for each area, we employ backward elimination method with the threshold value of α=0.1 and obtain the α_{aj} values.

Cost detection and scenario analysis

After determining the set of actions and their impacts on each LPI area, we need to estimate the relative costs of these actions. For this purpose, we prepare a questionnaire to be answered by a target group of logistics experts.

We deploy an online questionnaire to increase the interactivity and provide flexibility to participants. Each participant could respond the questionnaire only once. We ask participants to estimate the relative costs of actions by assigning a score between 1 and 100 for each action. Recall that α_{aj} value represents the contribution of action a on the score of LPI area j. In the survey, we include all actions that has at least one LPI area j with a positive α_{aj} value.

Let E be the set of experts, $e \in E$, and r_{ea} be the response of expert e for action a. We normalize the response of each expert so that the total budget of all actions add-up to 100. We consider each action separately and treat the normalized survey results as samples from random distributions of action costs. For each action, we fit a random distribution to the normalized expert responses using Arena Input Analyzer.

Let $D(a)$ be the suggested distribution for the cost of action a. Using these random distributions, we generate the action costs of an instance k. Let c_{ka} be the cost of action a in instance k. We use K as the set of all instances.

Optimal policy determination

In the final stage of the framework, we develop a mathematical programming model that aims to maximize the LPI score by selecting a subset of actions under a given budget constraint. We define the actions based on content analysis, estimate the impacts of these

actions on each LPI criteria by regression analysis and generate the costs of taking these actions based on survey results.

We define additional parameters. Let w_j be the weight of LPI area j, LPI_{0j} be the current LPI area j score of country under consideration, b be the available budget and B_k be total cost of actions in instance k, $B_k = \sum_{a \in A} c_{ka}$.

The decision variables are x_a, LPI_{0j}^* *and* LPI_0^*. The decision variable x_a gets the value of 1 if action a is selected and 0 otherwise, LPI_{0j}^* and LPI_0^* are the modified LPI area j score and LPI score of country under consideration, respectively.

$$Maximize\ LPI_0^* = \sum_{j \in J} w_j\ LPI_{0j}^* \qquad (1)$$

s.t.

$$LPI_{0j}^* \leq LPI_{0j} + \sum_{a \in A} \alpha_{aj}\ x_a \qquad j \in J \qquad (2)$$

$$LPI_{0j}^* \leq 5 \qquad j \in J \qquad (3)$$

$$\sum_{a \in A} c_{ka}\ x_a \leq b \qquad (4)$$

$$LPI_{0j}^* \geq 0 \qquad j \in J \qquad (5)$$

$$x_a \in \{0,1\} \qquad a \in A \qquad (6)$$

The objective function (1) aims to maximize the final LPI score, defined as the weighted sum of the modified LPI scores of each LPI area. Constraint sets (2) and (3) define upper bounds on the modified area scores. Constraint set (2) imposes that for each LPI area, the modified area score cannot exceed the sum of current LPI score and the total impact of taken actions. Constraint set (3) defines the upper bound for each LPI area. Constraint (4) ensures that the total cost of taken actions do not exceed the budget. Constraint sets (5) and (6) define the decision variables.

We analyze the trade-offs between the available budget and the final LPI score. For a given instance k, we solve the above mathematical model for different budget values such that b=5%, 10%, 15%, …, 95%, 100% of B_k value. For each budget value b, we analyze the final LPI score and the selected actions for the given budget.

Implementation of the methodological framework: A Case of Turkey

The methodological approach explained in the previous section is implemented in Turkey, an emerging country, ranked 18th in the world economic size with $718B Gross Domestic Product (GDP), and has $198.6B imports, $157.9B exports, over 10 million Twenty-foot Equivalent Unit (TEU) logistics capacity and connects east and west.

As a result of the content analyses, the logistics actions of high-scored and progressive countries are identified under 234 codes, which are then grouped under 158 sub-groups and categorized to 16 distinct actions.

In order to outline the actions having significant impact on six LPI areas, separate regression analysis is conducted to these 16 actions, one for each LPI area. Each analysis is implemented via backward elimination method, and the actions with *p* values less than 0.005 are considered as having significant effects. Actions having positive effect on at least one LPI area are discussed in detail. Other actions are omitted in the rest of the study, since there is no motivation to spend budget on an action that has either zero or negative effect on all LPI areas.

According to the results of the regression analysis, there are six actions (out of 16) that have positive affect in at least one of the LPI areas. Table 1 presents the two actions affecting multiple LPI areas. The remaining action impacts are as follows: Efficiency studies on infrastructure 0.823; Marketing on ease of arranging shipments 0.504; use different modes of port on customs 0.384; and use different modes of transportation on infrastructure 0.42.

Table 1 - Impact of actions on LPI areas

Actions	Customs	Ease of arranging shipments	Quality of logistics services	Timeliness	Tracking and tracing
Cooperation	0.1104	0.0836	0.1368	0.1231	0.116
Environmentalist Mindset	0.509	0.389	0.513	0.454	0.495

Based on regression analysis, there are actions with negative effects on LPI. We believe that, these actions are implemented successfully by the developed countries. However, the negative impact of these actions on LPI scores would be caused by the emerging or less developed countries, which could not adopt these implementations effectively to their existing system.

We discuss the six actions with at least one positive affect in detail:

Cooperation: This action addresses the cooperation between two or more countries, or, between policy makers and private sector on customs operations, economic or logistics activities. Since the first introduction of LPI scores, more countries' public agencies and private stakeholders are implementing well-grounded programs to address the weakest links and stimulate cooperation along the macro supply chain (Ojala et al., 2010), rather than taking separate or individual actions. For example, countries including Kenya, Uganda and Burundi perform well in regional integration (establishing a trade corridor). A closer look on LPI scores of these countries shows the impact of the action (Arvis et al., 2016).

Environmentalist Mindset: Sustainable environmental thinking is an emerging field as a market driver (Rao and Holt, 2005; Ojala et al., 2010). This action addresses the countries, which are involved in environmental business activities; such as waste management, emission reduction, environmental protection. Reduction and control of the CO2 emission rates in the world comes first in terms of environmental activities. Encouraging the use of environmentally friendly vehicles and equipments by the government, and the development and strict supervision of waste disposal facilities are some actions that can be implemented as an indicator of environmental thinking. Policies can be implemented to provide incentives to motivate stakeholders towards environmental activities.

Marketing: This action is associated with strategies such as customer-orientation, advertising, and promotion of private sector. Marketing is also one of the most important elements in trade (Brooks et al., 2017). If the country wants to increase the volume of their ports, they should attract the interest of foreign shippers by implementing marketing strategies. For example, improving the customer orientation in the port management would increase the competitiveness of the port in worldwide trade (De Langen and van der Lugt, 2006).

Use Different Modes of Port: Actions developed to improve the port business models are found to be important to improve the LPI scores of the countries, such as forming a transfer center (a combination and distribution point in a transport network) or the use of the host model (e.g. Landlord: Port land owned by the state, but all operations carried out by private companies). This action can facilitate operational management and eliminate unnecessary complexities in ports.

Use Different Modes of Transportation: The actions of combining different types of transport (multi-modal transportation) and establishing a corridor model are evaluated under this action. Countries that take this action usually transport by connecting transport networks. One of the objectives of this strategy is to reduce the traffic in the preferred transportation mode, and to shorten the delivery time. Also establishment a regional corridor would support this action, due to the landlocked countries.

Efficiency Studies: The countries activities on efficiency studies, such as removing unnecessary administrative barriers, investing to remove bottlenecks, maximizing container efficiency, are evaluated under this category. The most remarkable action is making investments to remove bottlenecks. For example, Canada uses performance indicators to measure efficiency in ports and supply chains (Ojala et al., 2010), as measurements can help to detect opportunities to remove inefficient activities.

We next conduct the survey to a group of 27 logistics experts, with an average of 12 years of industrial experience, to estimate the costs of the selected six actions. We normalize the expert responses as described in Section 3 and fit random distributions for the cost of each action using Arena Input Analyzer. The fitted distributions are as follows: Cooperation, Normal (14.8, 5.35); Efficiency Studies, Normal (15.7, 4.68); Environmentalist Mindset, Normal (18.1, 4.49); Use Different Modes of Transportation, Normal (14.1, 5.06); Marketing, Triangular (10, 15.2, 30); and Use Different Modes of Port, Triangular (12, 16.8, 28).

Using the suggested random distributions, we generate 100 different instances. Note that, in each instance, the set of actions and impacts of these actions on each LPI are common. However, the costs of the actions are randomly generated. For each instance we compute the budget required to implement all actions (the total cost of all actions), and then solve the developed mathematical model for 20 different budgets levels, from 5% to 100% of the total budget. We develop the mathematical model and conduct the experiment on GAMS. Totally, we solve 2000 mathematical models and the total run time of all models is less than 5 minutes.

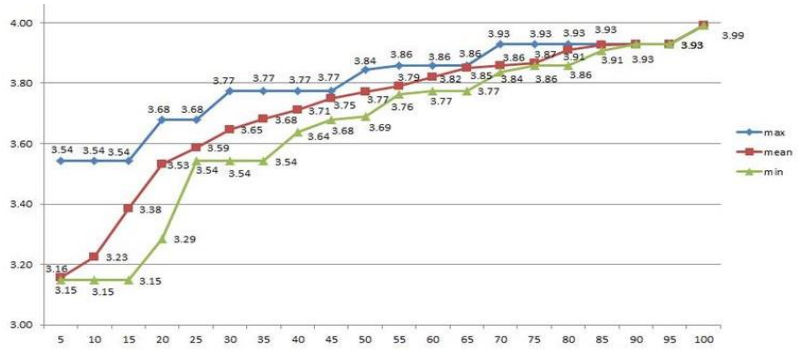

Figure 1 - LPI scores versus budget levels

Figure 1 reports the mean, minimum and maximum LPI scores for different budget levels. The LPI score starts at 3.15, current LPI score of Turkey, and increases to 3.99, best possible LPI score when all actions are taken. By using 20% of the budget required, the mean LPI score reaches to 3.53, roughly half of the possible range.

We also count the number of instances each action is selected for different budget levels. Even for small budget levels, environmentalist mindset has the highest selection rate. This is due to the combination of its high impact on several LPI areas and reasonable cost requirements. The mathematical model prefers to take the environmental mindset action even if the budget is 15% of the total action costs. Moreover, efficiency studies and cooperation actions are frequently selected actions even at lower budgets. Use of different modes of port action also contributes the LPI score, but mathematical model avoids taking this action nearly in all instances unless the budget level is 100%. Based on the experiments, the order of actions to be taken are as follows: (1) Environmentalist Mindset, (2) Efficiency Studies, (3) Cooperation, (4) Marketing, (5) Use Different Modes of Port (6) Use Different Modes of Transportation.

Conclusion

In this study, we propose a framework for developing logistics policies based on the LPI scores. We implement the proposed framework to Turkey and suggest strategies for improving Turkey's LPI score.

The frameworks start with analyzing the actions taken by selected countries and groups these actions via content analysis. Next step is to determine the impacts of the actions on the LPI are scores of the selected countries using the regression analysis. Afterwards, the costs of the actions are determined via surveys and several instances are generated based on survey responses. The penultimate step is to determine the best actions for different budget levels via a mathematical programming model. Finally, the results are analyzed to suggest strategies. We implement the proposed approach to Turkey, the suggested actions are ranked as environmentalist mindset, efficiency studies, cooperation, marketing, use different modes of port and use different modes of transportation. Especially the first three actions are highly recommended in case of limited budget.

We develop a framework that utilizes quantitative and qualitative methods. A further research direction is to improve the framework by suggesting methods for making better decision within the framework such as, country selection, impact and cost estimation.

Also it is possible to conduct a retrospective analysis to assess the power of the framework and calibrate the necessary components.

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Performance Measurement for Construction Projects

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Abstract

As construction projects advance more complicated, practitioners and researchers always deliberate on performance improvement. However, it is even ambiguous about what is performance and how to measure it. Through critically reviewing literature from 1987 to 2019, the need for an integrated measurement system is a considerable gap because contemporary frameworks just research one of the multi-facets of performance from a particular angle. For comprehensively measuring performance from the contractor perspective at the project level, a hierarchical performance measurement model (HPMMCP) will be developed using the quantitative method through Structural Equation Modeling with Amos.

Keywords: Structural Equation Modeling with Amos; Construction Projects; Performance Measurement;

Introduction

Research Background

Over the past few decades, the gradually complicated global business environment and rising competitiveness have emphasised the significance of performance measurement and further improvement (Neely, 2005). However, before structuring model to promote performance, it is even vague about what is the performance and how to measure it. According to Micheli and Mari (2014), if you can not measure the performance, you just can not improve it. Similarly, Kaplan (2009) indicates measurement is as fundamental to managers as it was to scientists. Therefore, performance measurement with high research and practical value is the imperative foundation of all the research and management of performance improvement.

Specific to the construction industry, which usually acts as an impetus to trigger the economic growth, plenty of government documentation mention that construction performance is difficult to accurately measure and meet the requirements of environmental change and progressing alteration. (Harris and McCaffer, 2013). Comparing with companies, to some extent, the project usually could be seen as a contemporary organization. However, the construction project is a little bit different than other projects owing to the typical feature of the construction sector. The average length of UK construction projects is more than 6 years, which may exist longer than some companies. If taking continuous maintenance into consideration, the extended project duration will be far more lengthened. Considering the specificity and significance, it is necessary to develop a performance measurement model for construction projects.

Owing to the lack of comprehensive performance measurement model of construction projects from the contractor perspective, firstly, it is a quite sincere obstacle for how to choose the qualified contractor by the client and how to certify they are qualified by the contractor (Aboelmagd, 2018). Secondly, misutilization of measurement models from one dimension of technical field (accounting, marketing, operation, or supply chain management) does impede performance comparison among different construction projects. Thirdly, project managers are burdensome and problematic to make development strategies，implement decision making, design performance-related pay for the employees, and even gain more investment because of unclear priority weights of different performance aspects. Therefore, a generalized construction project performance measurement model has great research value and practical value to develop.

Purpose

As construction projects advance more complicated, practitioners and researchers always deliberate on performance improvement. However, it is even ambiguous about what is performance and how to measure it (Bourne et al., 2003). Integrated performance measurement system and unified project performance index need to be developed and expanded (Nassar and AbouRizk, 2014). The purpose of this research is to develop a hierarchical performance measurement model (HPMMCP) for construction projects from the contractor perspective.

Literature Review

Concept of Performance Measurement

On the basis of different priorities, some researchers more focus on the association between project objectives and performance measurement. Sinclair and Zairi (1995) define that performance measurement as a process for assessing how successful organisation or individuals have been realised their objectives. Differently, some authors define project performance measurement from the perspective of application value. Performance measurement could be defined as a systematic method as a tool to evaluate the inputs and outputs in the process of project execution for constant enhancement (Chan, 2001).

As for construction projects, performance measurement has been defined as the formal and typical collecting and assessing of inputs, efficiency and effectiveness of construction projects (Chan et al., 2001).

Significance of Performance Measurement

Beatham et al. (2004) mention performance measurement is being included as a portion of strategic process control planning owing to four justifications including position checking, position communicating, priorities confirmation, and progress compulsion. Firstly, performance measurement could constantly keep track of the procedure in every phase and evaluate the ongoing situation as position checking. Secondly, position communicating as another reason could notify clients and working staff the specific working performance evaluation results with an aim to improve the transparency and promote employee involvement. Thirdly, priorities confirmation means that performance measurement is beneficial to confirm the unified priorities and sequence of every activity and during the project life-cycle. Fourthly, progress compulsion demonstrates that explicit performance measurement contributes to identify potential enhancement spaces and further promote performance advancement.

Performance measurement is recognized as a vital method of identifying the in promoting sustainable and feasible competitiveness for the UK construction projects and sector (Ahmad-Latiffi, 2012). The significance and necessity for an integrated and well-structured model to flexibly, effectively and accurately measure construction project performance are highlighted through analysing the importance of performance measurement.

Similarities and Distinctiveness between Construction Project and Company

The project is defined as a consociation with a temporary institution for delivering the particular service or production, which is regards as a lower-expense and speedy solution for a complicated consequence (Canonico et al., 2013). Comparing with other interim projects, the duration of the construction project is quite long. According to APM body of knowledge, the project life cycle covers the whole project duration until successful project delivery (Management, 2012). However, the extended life cycle may never be terminated owing to constant use of construction output (buildings, civil engineering, and specialized construction production) and continuous maintenance. In practice, considering the construction company insolvencies, to some extent, construction projects even have longer existence time than corporations. Therefore, the performance measurement of construction projects needs to holistically balance temporary and permanent objectives.

Performance Measurement Framework

Balanced Scorecard

Balanced Scorecard as one of contemporary performance measurement is structured by Kaplan and Norton (1992) to prevent researcher or practitioners for unduly focusing on the financial measures rather than operational measures. Scorecard (BCS) is the model to widely measure the performance in organisation level from four perspectives including financial, internal processes, customers, and learning and innovation (Kaplan and Norton, 1995).

Bassioni et al. (2004) note that BSC as one of the most vital performance management tool was utilised and cited during the last 75 years. The four BSC perspectives associate long-term enterprises' strategic objectives with explicit short-term activities (Pienaar and Penzhorn, 2000). The strategies for unit, division, department or even whole organisation should be learned by overall companies to guide their working activities, assess individual behaviours, adapt to the environmental changes. (Morris et al., 2006)

Although Balanced Scorecard is the most prominent model in research and practice, it still exists some disadvantages (Neely et al., 2000). BSC only generally identify the four dimensions without measurable and fixed sub-indicators. In application, the firms using BSC still spend a high proportion to go into liquidation (Bourne et al., 2000). Furthermore, actual perspectives related to construction suppliers and contractors are supposed to cover. Hence, there is a gap for exploring and developing a more comprehensive model for measuring project performance.

The European Foundation for Quality Management

EFQM is a non-profit institution build up in 1988 originally with an aim to motivate business excellence in European. Based on concise practical experiences of private or public companies across the whole Europe, the EFQM assessment format as the huge breakthrough in performance and quality management has been applied effectively(Van Marrewijk et al., 2004). According to Hellsten and Klefsjö (2000), EFQM excellence model as the management way is concentrated on quality, which is in allusion to long-term organisation success by way of customer satisfaction, acquired advantages of all members, and business improvement (Lee and Quazi, 2001).

The limitation of the shortcoming of EFQM cannot be ignored. There is no evidence to support the assumption for the same weights (50%) between enablers (formative factors) and results (reflective factors) in EFQM. The coefficients of every factor need to be calculated using a holistic model. Furthermore, the measurement model ought to identify reflective factors for accurately, efficiently assessing performance rather than classify formative factors for how to influence performance.

The Performance Prime

Neely et al. (2001) proposed a performance measurement model, which is focused on stakeholders and integrates the demand of stakeholders based on five related facets (strategies, processes, capacity, stakeholder satisfaction, and stakeholder contribution). This model gives performance measurement research a brand-new perspective to explicitly separate stakeholders satisfaction and their contribution (Powell, 2004). On the other side, The Performance Prism also receives some critique. Medori and Steeple (2000) mention that the lack of measures selection causes low feasibility and application of the framework without guidance. It is time-consuming and cost-

consuming to utilize the model in practice because companies need to identify all measures by themselves.

Discussion
Through critically reviewing the contemporary frameworks including Balanced Scorecard (BSC), European Foundation Quality Management (EFQM), and Performance Prime, these frameworks could coexist simultaneously on the grounds that every framework merely research one of the multi-facets of performance from a peculiar perspective and utilize obscure classification principle (Jin et al., 2013). According to Neely et al. (2002) and Bassioni et al. (2004), the need for a comprehensive model to cover all aspects of performance measurement and realize performance benchmarking generalization is a considerable gap.

Model Establishment

Factor Identification
An appropriate performance measurement framework provides a 'balanced' picture of the concrete business. That is the reason why different types of projects and business may need a diverse framework to more accurately align well with the specific project. After critically reviewing and discussing the project performance methods, frameworks, systems, measurement indicators adopted in the literature from 1987 to 2019, HPMMCP as a formal and unified construction performance evaluation system is structured for accurately and comprehensively measure performance covering financial and non-financial, internal and external, current and developmental potential aspects.

In HPMMCP, the first level is the integrated project performance, which should be further quantified and calculated to realise comparison among projects using project performance index (PI). Matching with the hierarchical structure and top-down method, for developing a more comprehensive and dynamic model, six unobservable factors (Financial performance, operational performance, client satisfaction performance, developmental potential performance, quality performance, and safety performance as can be seen in table 1) are used at the project level as a second layer.

Table1 – Performance Measurement Factors

Performance Measurement Factors
Financial Performance
Operational Performance
Client Satisfaction Performance
Developmental Potential Performance
Quality Performance
Safety Performance

Furthermore, every unobservable factor in the second level needs to be measured using some observable factors in the third layer in accordance with structural equation modelling.

Financial, Operational, and Client Satisfaction Performance
Financial Performance could be evaluated by three factors including profitability, cost variation, and billing. The operational performance will be assessed by six indicators, such as schedule variation, team satisfaction, equipment resource utilization, material

resource utilization, workforce capacity utilization, and sufficient communication. Furthermore, client satisfaction performance is measured through client demand fulfilment degree, client service, intention to the subsequent project.

Developmental Potential (New Factor)
In psychology, Dabrowski (1966) developed the Theory of Postive Disintegration (TPD), which research personality development. Developmental Potential as the cornerstone of the TPD is the in the first time proposed to describe the constitutional endorsement which measures the possibility of character and mental growth of a given person. Dabrowski (1966) indicates that there are many features contained in the concept of developmental potential.

Based on sociology and psychology, where there is a person, there is a character. One person has own personality so social collectives could equivalently exist. Through analogy with personality, a team of individuals has its own 'Teamnality'. In organizations, it should be could 'Organizationality'. As for the construction project, it could be named 'Projectnality'. Personality as one of the concepts in sociology, psychology, and healthcare research area already is transferred to utilize at the organization level. According to Blagoev et al. (2019), orgnalizationality could be seen as a more gradual differentiation to measure either organizations or non-organizations.

In this research, DP as a reflective indicator is switched from TPD to measure the growth possibility of project performance. If it shows not promising for the performance development that means current performance is not good enough, even if the situation of current financial statements, client satisfaction, and operation are qualified. The hypnosis is if there is a strong developmental potential which means the current project performance is actually good. Present status of projects does cause the result in the future. If the DP is weak, it not only just indicates that the financial performance has a high possibility to fall in the future but also do shows the current comprehensive performance is not good.

Developmental Potential represents a constellation of performance reflective factors. To more specifically, DP could be divided into Contract DP and Construction Project DP. It is nearly impossible to only measure construction project DP and ignore contractor DP. Thesis two DPs could integrate diverse measurement perspectives to more accurately reflect performance. Project DP could be further measured by innovation behaviour, organizational level satisfaction, consistency with corporate strategies, environment sustainability, and life-cycle maintenance as seen in Table 2.

Table 2— Project Developmental Potential Performance

Project Developmental Potential Performance
Innovation Behaviors (Product and Process)
Organizational Level Satisfaction
Consistency with corporate strategies
Environmental Sustainability
Life-cycle Maintainance

In Table 3, Contractor Team DP will be measured by five indicators including Dependability, Competitiveness, Risk Resistance Capacity, Innovation Motivation and Ability, and Flexibility.

Table 3— Contractor Team Developmental Potential Performance

Contractor Team Developmental Potential Performance
Dependability
Competitiveness
Risk Resistance Capacity
Innovation Motivation and Ability (Product, Process, Marketing)
Flexibility (meet unplanned challenges; problem-solving ability)

There is no developmental potential in the future is because the present project is no doing well. Therefore, DPP is a crucial indicator to measure immediate mode performance model.

Quality and Safety

Quality and safety as two prerequisites screen out the qualified construction project, which meets the initial standards by laws and regulations, industry requirements, and contract agreements. If one of quality and safety is not qualified, there is no need to keep calculating PI number.

In Table 4, Quality contains three fundamental requirement indicators including Technical Specification of Deliverables required by Laws and Regulations, by the UK Construction Industry, by Project Contract. Furthermore, the higher requirement of quality also is covered including Functionality, Construction Field Rework, Compliance degree with flexible requirements, Life-cycle Maintenance.

Table 4-- Project Quality Performance

Project Quality Performance
Technical Specification of Deliverables required by Laws and Regulations
Technical Specification of Deliverables required by the UK Construction Industry
Technical Specification of Deliverables required by Project Contract
Functionality (Fitness to Purpose)
Construction Field Rework
Compliance degree with flexible requirements;
Life-cycle Maintenance

As for Table 5, safety consists of three basic factors, such as Health and Safety Requirement by Laws and Regulations, by the UK Construction Industry, by Project Contract and four higher demand factors including Accident Rate, Dismissed Working Hours, Lack of Safety Assessment, and Extra Cost from Lost.

Table 5-- Project Safety Performance

Project Safety Performance
Health and Safety Requirement by Laws and Regulations
Health and Safety Requirement by the UK Construction Industry
Health and Safety Requirement by Project Contract
Accident Rate
Dismissed Working Hours
Lack of Safety Assessment
Extra Cost from Lost

Hierarchical Model for Construction Project Performance Measurement

After critically reviewing papers related to performance measurement factors, models, structures, and theories, the HPMMCP is built as can be seen in Figure 1.

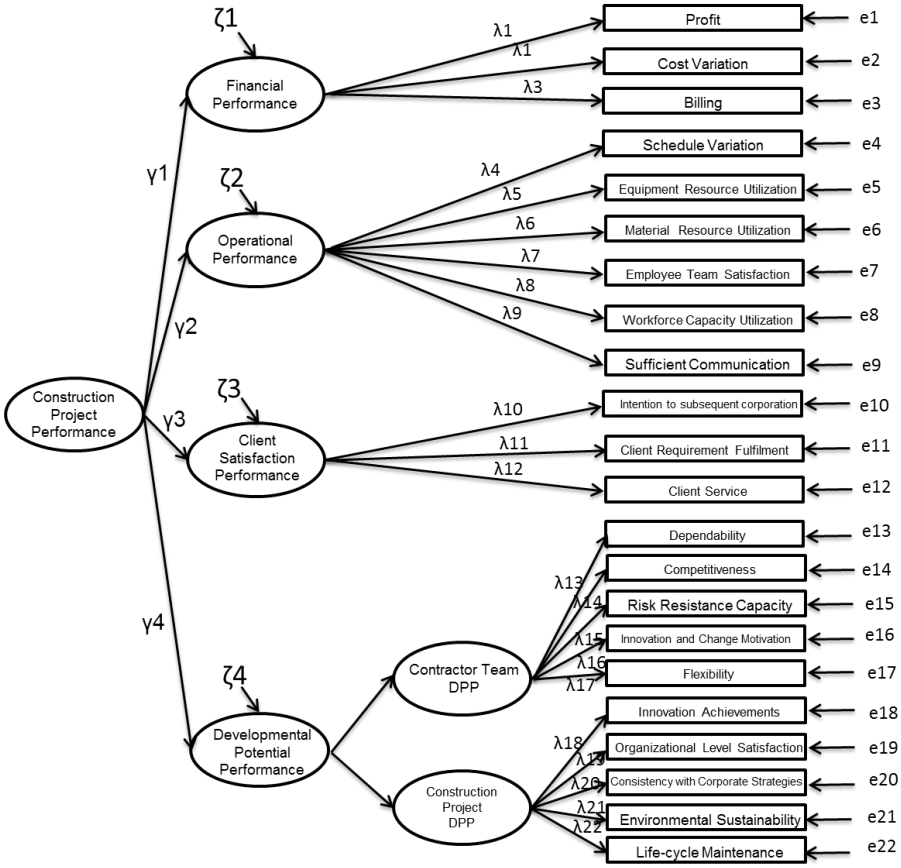

Figure 1: Hierarchical Performance Measurement Model for Construction Projects (HPMMCP)

This HPMMCP model earns high research and practical value. Firstly, it rationalizes the linkages between reflective performance indicators and project objectives. Secondly, HPMMCP comprehensively measures construction performance covering different aspects and maintain the generalization utilizing a large sample size, which effectively realizes the performance comparison among diverse construction projects. Managers could assess their project with other competitors to improve management and show stronger successful performance evidence in bidding conference. Thirdly, it is approached in setting up two prerequisites (quality and safety) that model not only assesses the project process but also guarantees project product. On the basis of implementing project delivery and providing qualified final outputs, project performance status and developmental potential will be measured by a hierarchical composition of reflective measurement indicators. Fourthly, HPMMCP thoroughly measures financial and non-financial performance, internal and external performance, prompt reflective performance and developmental potential performance in the subsequent project duration. Fifthly, HPMMCP propose a brand-new factor (DP) switched from sociology, which evaluates whether consequent circumstance is promising to reflect current performance. If the developmental potential of the project is weak, the present performance cannot be described as successful performance even

current financial numbers all show well. HPPMMCP provides an ingenious and comprehensive that directs management attention to what is vital for not only current performance status but also long-term performance. It assists for contractor teams to design, operate, validate their current performance measurement system.

Research Design and Methodology

Research method is required in conjunction with purpose, therefore, a quantitative method is used to test a theory and assign the weights in HPMMCP. After cross-sectional data collection from questionnaires, Structural Equation Modeling (SEM) as statistical analysis tool will be further relied on calculating weights, maintaining highly data adaptability, reliability, and validity, and reducing measurement error (Kline, 2015).

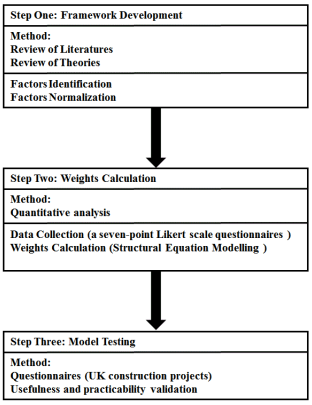

Figure 2: Steps of Research Design

In Figure 2, the research is designed in three steps: (1) structuring a performance measurement framework at project level from contractor perspective, (2) utilizing SEM to calculate weights among different factors and completing model establishment, (3) testing model by the questionnaires data from UK construction projects.

Conclusion

This paper has succinctly argued that construction project performance measurement has a huge significance and value. However, there is a lack of an integrated performance measurement model from the contractor perspective at the project level. The HPMMCP will be established to fill the gap and optimize construction project performance evaluation. First-hand data collected for UK contractors would be collected by questionnaires and analysed by Structural Equation Modeling with Amos to calculate all the weights and errors. After model modification, HPMMCP could effectively improve UK construction project performance measurement.

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Performance management systems and practices in an industrialised housebuilding on-site context: identifying improvement potential through a qualitative study

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Abstract

High wastage rates and unsatisfactory performance gains affect on-site working for industrialised housebuilding (IHB) production. Rarely used performance management systems (PMS) are often quoted as one obstacle to support systematic productivity and efficiency improvements. To prepare the field for the development of an informative PMS a multiple case study is carried out, in order to show the potential on applied performance management systems. The three cases show diversified application of performance management (PM), ranging from various performance indicators used for management decisions to almost ignoring generated measures. Different approaches in developing PMS for the identified corporate strategies are analysed.

Keywords: performance management, industrialised housebuilding, on-site assembly

Introduction

The construction industry, including industrialised housebuilding (IHB), suffers under high wastage rates, poor use of resources (Josephson et al., 2002; Josephson and Saukkoriipi, 2007), and limited productivity increases (Bornett et al., 2016) compared to other industrial sectors. Even though not clearly specified in literature, the improvement potential for IHB is considered to be immense and IHB companies should be able to better quantify and assess this potential.

The production processes of IHB companies have a unique position within construction industry, as story-high wall, ceiling and roof elements or modules are prefabricated within a factory and assembled on-site. The prefabrication of elements or modules is in the advantageous position of being able to implement clear structured processes, similarly to manufacturing industries. Increasing the productivity and

efficiency of these off-site processes is far easier as for on-site activities, as clear responsibilities can be defined and a measure and control of performance criteria is simple. It is obvious that off-site activities contributed the most to performance improvement in the IHB sector (Lessing et al., 2015).

In contrast, the performance improvement of on-site activities lags far behind. This may be explained in part by the inability to satisfactorily assess the performance of on-site production. The current methods do not provide accurate assessments of the effects of interventions, they are not reliable enough, are too cost- or time consuming for regular management of performance (Raffoni et al., 2018). Very many factors impact on the accurate measurement of performance falsifying or distorting the resulting data. Additionally the complexity of an IHB order-fulfilment process must be considered (Sardén, 2005). Further difficulties occur due to the on-site operations and to the segmented order fulfilment processes, as well as the variety of in-house and suppliers' employees involved (Knauseder et al., 2007).

IHB companies commonly implement performance management system (PMS) only for the assessment of core processes within the prefabrication processes or for analysing simple indicators such as on-site assembly duration in past-project evaluation (Lessing et al., 2015). This problem was noticed by Barker and Naim (2008) as they revealed that more than 60% of housebuilding companies do not collate data for performance management (PM) of on-site assembly. Neither do they use it for PI.

To ensure a sustainable improvement based on a companies' strategies, suitable PMS and performance indicators are an indispensable tool for control and the achievement of management objectives (Raffoni et al., 2018). To better cover the performance measurement and management of the IHB order fulfilment process, there is a need to improve PM of on-site construction processes.

Studies analysing the current PM within the IHB sector are rare, which makes defining the current situation and identification of improvements difficult. This paper aims to overcome this and reveal the state of art in on-site performance measuring, thereby identify the potential areas for improvement and prepare the field for the further development of significant PM systems. The multiple case study investigates the following research questions: (1) What is the state-of-the-art of performance measurement and assessment within an IHB on-site context? (2) What are the needs for improving performance management for various IHB production strategies?

Literature Review

The production processes of IHB companies divide in off-site and on-site activities. Off-site activities have a clearly structured process similar to those of manufacturing industries. The activities reoccurring and repeated many several times a day (Lessing et al., 2015). This contrasts with on-site production which is most commonly project-based, the predominant organisational form in construction industry. Activities performed during order fulfilment often recur in follow-up projects, although they may take place once as a specific feature within a construction project. The organisational form of the order fulfilment process may be classified as an intermediate position between process and project orientation (Höök, 2008). Beyond the effects on operational management this type of organisational form influences the whole PMS, from representing a companies' strategy, in performance criteria for on-site assembly, to data collection and analysis and finally, to the output of suitable performance indicators (PI).

Compared to other building sectors, prefab construction clearly benefits from its building systems as well as its design and production processes, when implementing PMS. The building system ensures that frequently used components, elements and their

intersections are standardised (Gibb, 2001; Lessing et al., 2015). This higher degree of standardisation within the building system became necessary due to the introduction of production machinery within prefab facilities, logistical issues and a rapid on-site assembly to name just a few. Compared to other construction systems, processes frequently reoccur and therefore lend themselves to better controlling, so the systematic improvement of processes and building system is possible (Höök and Stehn, 2008).

Production strategies in IHB

IHB companies' unique production strategies' differentiates themselves in the construction sector by:

- specialisation by building type, such as detached single-houses or residential buildings,
- the positioning of a company as cost leader or differentiator (Schreyögg and Koch, 2015) and
- the flexibility and productivity of the applied building system (Gibb, 2001).

Based on the work built of the flexibility and productivity of a building system, Barlow et al. (2003) highlighted various ways in which customers influence the design of buildings as well as the effects of this on the supply chain, the building system itself and the processes of housebuilding companies. The alignment of the customer order decoupling point (CODP) within a companies' order fulfilment process defines, as a consequence, its abilities to customise a product to the customers' satisfaction. This interconnection between the abilities of a production system and its ability to customise a building for a clients' needs was investigated by Jonsson and Rudberg (2015). The production classification matrix in figure 1 shows an ideal range between the degree of prefabrication and the degree product standardisation.

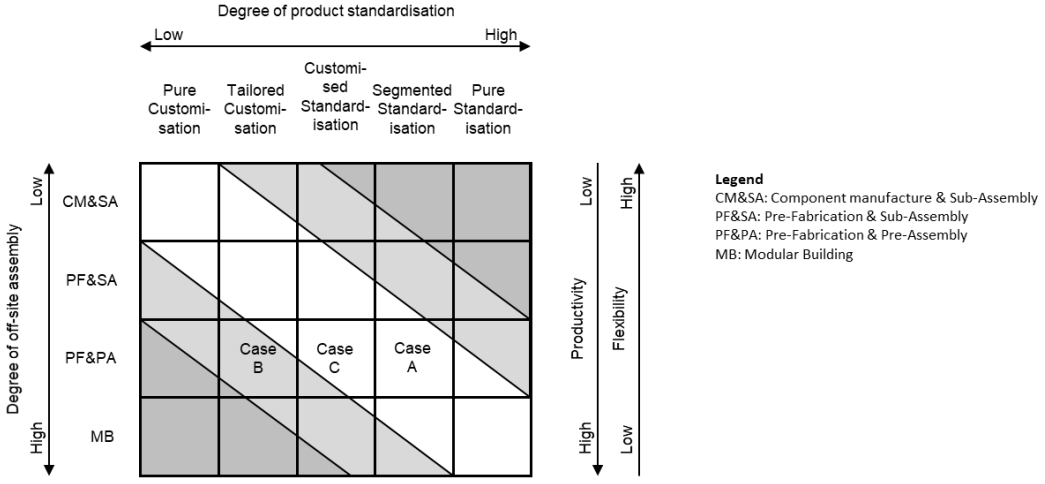

Figure 1 – Production system classification matrix according to Jonsson and Rudberg (2015) with classified cases

Performance measurement and management

PM facilitates better control the development of IHB organisations' economic performance and its ability systematically learn from experiences (Abu El-Ella et al., 2013; Bessant and Caffyn, 1997) The tools of PM should be embedded within an organisations system of regularly performance reviews. The output should promote decisions making revising the way of business operations (Kaplan and Norton, 1996; Womack and Jones, 2010). In this context a PMS should contain a balanced set of PI, developed for the specifics of a companies' strategy (Davenport and Harris, 2007).

Obviously, there are differences between the applicability of various PI, which may serve to report on past performance, help to control ongoing processes or both (Beatham et al., 2004). Measurements for helping to control ongoing processes are indispensable for identifying latent problems, assess the effect of intended actions and to provide feedback on target setting for further managerial decisions (Raffoni et al., 2018).

Previous work on PMS within construction industry focused on developing PI. Beginning in the 1990's various authors suggested PI enabling a control of performance criteria as safety, quality, rework, time or cost predictability, and environmental issues to name just a few. Most of them aimed to permit benchmarking between different organisations and construction supply chains. Less attention was paid to the relevant measures required for decision making processes to better attain the companies' management objectives. A further shortcoming was the neglect of data acquisition issues for these indicators (Raffoni et al., 2018). Furthermore, these studies did not focus on the specifics of IHB production, hence, they are not well suitable to this industry.

A few publications focused on the specifics of performance measurement in IHB and provide a very limited insight into the measurement of on-site production performance. A case study by Lessing (2006) found that performance measurement and re-use of experience is implemented in IHB companies variously from no use measurement up to total measurement of tasks within some parts of the order fulfilment processes. This includes at a maximum, the measurement of few key activities within prefabrication, the debriefing of design and an observation of the complete on-site assembly duration.

Most developed key performance indicators (KPI) as proposed in Jonsson and Rudberg (2017) aim to measure performance of production systems on a strategic level. They are useful when assessing the abilities of production systems to meet market demands, but are not intended for applications where the focus is on continually improving an existing production system at an operational level. Raffoni et al. (2018) revealed the necessity to break down a companies' strategic objectives into performance criteria and onto the creation of PI to impose a control and management function at the operational level which follow the corporate strategy.

Höök (2008) argued that in the few cases where IHB companies analyse on-site performance, they build their analysis is based on inappropriate PI such as construction lead time. It is also claimed that using financial metrics from cost unit accounting have limited benefits as they do not provide a suitable assessment of operational management objectives. Despite this it is a common measure in IHB companies. Current financial metrics do not reveal for the effects of interventions (Halman and Voordijk, 2012).

Newer approaches to assess the performance of improvement inventions are based on feedback from site visits or rely on a comparison between an estimated and a measured lead time for a specific process. These are mostly more resource intensive and not widespread. Many of them also have underlying biases or are not able to handle the complexity of the building process (Söderholm, 2010). Moreover, most known performance measurement approaches lead to difficulties caused by information overload, missing analysis of causes and effects and a failure to provide a comprehensive view on the building process (Raffoni et al., 2018). Consequently, construction site assembly is currently considered to be poor from an indicator perspective (Lessing et al., 2015).

Research design

A multiple case study approach is developed and involving IHB companies from Germany, Austria and Switzerland producing and assembling detached and multi-story houses. In order to collect insights from various corporate strategies specific cases are

selected, based on a systematic qualitative analysis of published company data on production principles. The sample includes 76 companies from the selected countries. From these, three cases are selected in order to covering various characteristics of product standardisation and alignment of the building systems. A description of the cases is given in the end of this section. How these cases are classified within the production system classification matrix from Jonsson and Rudberg (2015) is shown in figure 1.

Based on Yin (2018) various sources of evidence were considered in order to gain data. Documents and archival records were excluded for the reason due to unavailability and factual redundancy. Direct and participant observations were unsuitable for this scientific problem as they may have exceeded the time and cost budget for the study. Companies might also be cautious about directly involve researchers in such a high sensitive area. The finally best option seemed to collect data from the cases through interviews, whilst being aware of the weakness of this data collection method.

The face-to-face interviews were conducted by two researchers with representatives from the selected companies. The interviewees were mainly general managers or production managers, which in some cases involved experts from other departments. To focus the interview guidelines were developed grounded in theory of performance measurement and business performance analytics in construction industry. It was structured in five thematic fields and included 11 main questions. The interviews involved questions on a companies' corporate strategy and how it was broken down into performance criteria and PI, how decisions are built on these measures, how data are collected in an on-site context, the needs for improving weaknesses of current PM and a check for cases classification. To avoid biases within the interview guide, it was developed iterative by two authors following the procedure from Helfferich (2011) and was pretested by other researchers.

The interviews took between one and a half and three hours. As the interview partners were not allowed to audio record the interviews the scientists separately documented proceedings, which were subsequently combined. Interviews are analysed with a thematic coding and content analysis approach according to Hopf and Schmidt (1993). In a first step each interview is analysed separately, followed by a cross-case analysis to detect similarities and differences.

Case A

Case A is a larger industrialised housebuilder, which successfully has built detached and multi-story buildings for centuries. Their customers are private as well as commercial and institutional clients from Central Europe. To serve various customer segments they have established different brands through the customization opportunities. The IHB company has an established production system with the prefabrication of elements, including preassembly of components off-site and on-site assembly of these elements. The prefabrication degree is higher for the main brand with a more standardised product. Previously, the strategic focus was on cost leadership for the main brand. Currently they are shifting their strategic focus to deliver an affordable quality product.

Case B

The prefabricated housebuilder in Case B is a mid-size company providing mainly detached houses to private clients. The prefabrication degree of case B is at the level of prefabrication and preassembly of elements, which means that components as windows or similar installations are assembled off-site. The company provide a high degree of individualisation frequently working with a clients' architect, to provide a unique

structure. Their output is the least constrained by the building system. They are further differentiated by the scope of services they provide to clients, the guarantee for high quality standards as well as specific material and components featured. They calculate the features and services to build a home for each single project for sales and cost unit accounting.

Case C

The company representing Case C is a larger construction company, with a prefab housebuilding division. The housebuilding division serves detached and multi-story buildings to mainly private clients in Central Europe. The off-site prefabrication level of this case is very similar to those of Case B. The restrictions defined from their building system is located between Case A and B. To meet the requirements, this housebuilder is working together with contracted architects, which enables to serve architectural planned homes adapted to the requirements of their building system. This company differentiates from competitors through a high material and product quality as well as a short realisation period compared to other companies with prefabrication and preassembly of elements.

Case study findings

The findings of the analysed cases are presented in tables 1 and 2. The three cases show a diverse application of PM, ranging from a variety of PI used for management decisions as in case A & B to almost ignoring all the generated measures from case C. Despite the importance of PM for case A and B, they follow different approach to the generation of their data. For case A, indicators analysing the productivity are their preferred basis for controlling processes, whereas the indicators used from case B are predominantly financial metrics. The preference to these types of indicators was selected due to the individuality of the built projects, which only enable useful assessment on target/actual comparison.

The analysis of PI reveals that almost all company have their own perceptions of parameters such as productivity or quality of on-site work. Companies are interested in models they can adapt for their specific needs, as each of them pursues its own strategic goals. In addition, qualitative feedback was highlighted of major significance for the topic of quality control and management, as it documents the causes of problems or defects.

As presented in table 2 simple digital technologies to collect data now exist for on-site data collection. A app was implemented in case A which supported mobile time recording and site documentation. Additionally, it supports quality management by reporting rework time with photos and descriptions of the points of failure. Case B implemented a consistent ERP system which facilitates the direct work time reporting. Rework is recorded by time and task description. This case really highlighted the importance of reporting on-site data quickly, which ensures accurate analysis and processing of deviations in on-site production. This was also emphasised by the guideline to immediately analyse target attainment after completing a construction service. Additionally, this case also uses paper based checklists for quality and process control issues. Case C works exclusively with paper based documents for data collection.

The reliability of self-generated data was high in case A & B. Case C argued that they need to verify outcomes of indicators, due to the lack of an option to split up measures outcomes and interconnect them with reported data on failure.

The application of performance measures in management tasks is various widely. Case A showed an incorporation of indicators in various planning, management and

controlling tasks. One interesting feature was, for example, the use of measures on failure data to specify the training needs of on-site teams. Case A seems to be the highest level of PMS of all three examples. Analytics used for these management activities are descriptive, diagnostic and predictive. Case B uses performances measures for controlling activities, which are at least as important for their process improvement. Case C focuses also on using performance measures for controlling activities, though the measures generated by case A & B have a predominantly descriptive function.

The companies highlighted the need to improve their PM in the area of quality management and capacity planning. Automatic data generation as one option to gain data from on-site assembly was excluded from case B based on the argument that it maybe not applicable due to the individuality of their products.

Table 1 – Findings – Strategic focus, performance criteria & PI

	Case A (main brand)	***Case B***	***Case C***
Strategic focus *Focus on cost leader-ship or diversifi-cation*	Shift from cost leader-ship to diversification -Mass customisation concept -Trendsetter -Customer satisfaction -Material, product & service quality	Diversification -Tailor made planning -Innov. product solutions -Service oriented -Customer satisfaction -Material, product & service quality -Quality control	Diversification -Customer satisfaction -Realisation period -Material, product & service quality
Performance criteria	-Build projects / a -Satisfied customers -Project handover without remaining work -Backlog of orders -Material costs -Wage costs -Work safety	-Quality costs (rework & defect remedy) -Material costs -Construction service costs -Wage costs	-Build projects / a -Project duration -Material costs -Wage costs
Performance indicators	-Build project / a -Satisfied customers/total customers -% Project handover without remaining work / total project handover -Ø lead time of design & prefab processes to start of assembly (target/actual comparison) -Duration of structural work (target/actual comparison) -Effective production hours /project (target/actual comparison) -% Effective production hours / total hours -Revenue/effective production hour -Missing hours/team -workplace accident/team	-Duration for each construction service (target/actual comparison) -% Effective production hours / total hours -Costs for each construction service (target/actual comparison) -Costs for purchased components (target/actual comparison) -Costs for material (target/actual comparison) -Costs for reworking defects (on-site assembly) -Costs for reworking defects (customer service) -Defective components / supplier	-% roofing completed on 2nd construction day / total projects -construction lead time (target/actual comparison) -Duration of structural work (target/actual comparison) -Costs for each construction service (target/actual comparison)
Qualitative feedback	-Fotos & descriptions from reworking defects -Fotos & descriptions from customer services activities	-time observations for the assessment of changes in the production process -Checklists from QS -Feedback from foreman to reworking defects	-Inspection forms from site managers

Table 2 –Findings – data collection & analysis; PI application; needs to improve PM

	Case A (main brand)	Case B	Case C
Tools for data collection	-Smart phone app for reporting working time, time effort for rework and documentation (incl. photo documentation) of rework causes	-Consistent ERP system for reporting working time, time effort for rework and description of rework causes -Checklists to report on quality & process parameter	-Time sheets for reporting working time & time effort for rework -Inspection forms
Reliability on generated data	High trustworthiness in own data and analysis. If managers identify deviations in the data, they analyse possible causes. Reduced reliability in third person data & analysis	High trustworthiness in own data and analysis.	Managers try to verify outcomes of own measures through own observations and discussions with responsible interviews.
Context of analysing deviations from target setting	-Periodical controlling of target attainment (frequency dependent from the indicator (once a week/month))	-Immediate analysis of target attainment after completing a construction service -Debriefing meeting with responsible employees to analyse major deviations	-Periodical controlling of target attainment (once a month)
Application areas for PI & decisions based on PI	-Capacity planning -Quality control -Quality management -Productivity control -Profitability control -Customer satisfaction control -Control of work safety	-Quality control -Productivity control -Profitability control -Process improvement	-Productivity control -Profitability control
Kind of analytics used	-Descriptive analytics -Diagnostic analytics -Predictive analytics	-Descriptive analytics	-Descriptive analytics
Needs to improve the performance management	-Quality management: There is a high number of unrecorded defects and the reaction time to get feedback to problems is high. To generate data to possible defects through connected smart homes reduce the reaction time and contribute to improve quality management	-Improvement of current capacity planning by data integration within the ERP -Benefit from integrating customer service protocols within CRM and analysis of generated data -Caused by the individuality of offered buildings automatic data acquisition is no option to generate better data	

Discussion

The case study shows that PMS concerning on-site assembly have become state of the art. All three cases collect and analyse indicators of on-site production. Especially, case A and B have implemented a sophisticated set of PI's which are used as the basis of management decisions. This finding contradicts the arguments found in the literatures, that only few companies apply performance measures for this part of the production process. In addition, the argument that inappropriate measures are applied to assess the on-site performance can be rejected. Two cases incorporate their measures in various management decisions and trust in their data and analysed measures. The

argument, that on-site production is currently considered poor from an indicator perspective can clearly be rejected.

To adapt a company's own PMS to its corporate strategy as suggested by the literature is definitely necessary. Case B, which has a very flexible building system, is forced to do target/actual comparisons based on its cost unit accounting. The customisation of the buildings offered require this kind of comparison for financial metrics. Deviations from the target trigger management activities. On the contrary, case A is able to use PI on a more general basis. Their building system has a higher degree of product standardisation. They do not have the need to control each building individually to generate information on the on-site production activities. However, they also use actual/current comparisons for parts of the production process, where the individuality of the buildings produced requires it.

Case B indicate that finance metrics from cost unit accounting are an appropriate measure for IHB companies with a higher degree of product customisation. For the application for this type of metrics it seems important to ensure a rapid assessment after completion of a construction service. Additionally, data to rework or other process deviations should be processed in a way which enables an assessment of failure causes and effects. Again this contradicts the literature which argues, that metrics out of cost unit accounting do not provide a suitable assessment of management objectives. When looking at case C it is easy to understand this argument, since their collection of data did not provide them with the ability to connect data of failure causes with the effects visible at the time of reporting. To overcome the current approach of using financial metrics for performance assessment in IHB there is a needs to be a rethink about the way data is collected on-site and analysed.

A pivotal role is also given to digitalisation concepts which enable faster feedback on on-site processes, by the use of digital tools for reporting of working time as shown in cases A & B. These tools provide the opportunity to identify and react much more accurate on weaknesses in current processes.

The requirement to improve the current state of on-site PM was emphasised in areas of quality management and capacity planning. When comparing the cases, it is clear that IHB industry is very inhomogeneous in its application of PMS and the use of information generated for management decisions. The need to improve use of PMS within the industry is clear. It seems important that companies with a lower developed PMS are able to learn from the management practices of those companies which take a lead within PM and find and deploy suitable data collection and analysis tools themselves.

Conclusion

The assessment of various performance variables from construction site processes is essential for a systematic identification of performance weaknesses and to ensure their elimination. In this manner, PM provides a targeted improvement of building systems and on-site processes, to raise IHB companies' competitiveness.

The systematic selection of companies from Germany, Austria and Switzerland guarantees a good overview of the IHB segment with the research illustrating the development of PMS in assessing on-site performance by these companies. It further shows the assessment outcomes which are used in controlling activities and for management decision making. Despite an increase of applying PMS the findings indicate, that the implementation of PMS and the management practices applied are very diverse within the industry.

There are companies with a more and some with a less sophisticated PMS, which provides potential for improvement. Identified improvement potential is a starting point

for further research, to develop concepts which allow a better inclusion of indicators of construction site processes within PMS. Additionally, there is a need to include more cases to gain data from companies with different characteristic values, concerning their specialisation by building type, the positioning of a company as cost leader or differentiator and the flexibility and productivity of the applied building system. A limitation of the current paper is that it is founded on three cases. Due to the limited number of cases, a careful use of the current studies' findings is suggested.

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The relationship between innovation and productivity in services - An analysis perspective using data envelopment analysis (DEA) and structural equation modeling (SEM)

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Abstract

This research proposes a dual analysis pattern oriented to the operational aspects of the company, which, on the one hand, investigates efficiency in the use of resources and in obtaining results, and on the other hand, analyzes the innovation routines. The results confirm empirical evidence that capabilities emerge from several interrelated routines and that there is a strong conceptual link between features, routines, and performance, expanding comprehension related to the specific ways in which capabilities can be built and developed.

Keywords: Innovation, Performance, Capabilities.

Introduction

Critics of the Resource Based View (RBV) consider analyzes of operational capabilities' performance, in general, very aggregated, which hinders the examination of composition and interaction of the operational resources used (Bromiley, Rau, 2015, 2016). Management research also recognizes the importance of capabilities to achieve competitive advantage, but rarely investigates capabilities at the operational level where they actually occur (Peng et al., 2008). These gaps guide the development of this research, which, from a more operational perspective, aims to understand **how companies organize their structures to induce innovations and create competitive advantages that become superior operational performance.**

This way, based on Economics, with support of the theoretical model related to the Production Possibilities Frontier, which establishes limits for productive capacity of a company, the efficiency of each one of the sample companies was measured, with the support of the DEA methodology (Data Envelopment Analysis). On the other hand, Evolutionary Economics and Dynamic Capabilities, both theories that position routines as the capabilities foundation, support the orientation of this research in studying capabilities through their underlying routines. Therefore, capabilities were modeled as a second-order latent construct, and each set of routines was measured, supported by CFA-SEM (Confirmatory Factor Analysis and Structural Equation Modeling), as a latent first-order construct from measurement items developed according to the theory. In addition,

this way of conceptualizing and measuring capabilities, from a set or bundle of routines, is supported by requirements such as inimitability, value and rarity that are characteristics of the capabilities, in correspondence with the RBV (Helfat; Peteraf, 2003, Peng, 2008).

Therefore, this research proposes a dual analysis standard oriented to the operational aspects of the company that, on the one hand, investigates, compares and thoroughly evaluates the efficiency in the use of resources and in obtaining results (DEA), and on the other hand, it maps, analyzes and measures operational procedures or routines (CFA-SEM). In order to make feasible the proposed analysis, we used primary data from 212 Brazilian hotels (response rate 43%), randomly selected, in 2016.

Methodology

The diffusion of innovation among hotel companies reflects a high degree of heterogeneity, mainly characterized by the low propensity to develop new products and processes, especially in independent establishments or in smaller companies. Therefore, the hotel sector, in particular, has become a fertile field for research that intends to investigate significant levels of structural heterogeneity and variance in the routines of operational processes. (Howell et al., 2004). Consequently, this research has found a convenient environment for the development of an investigation that seeks to unravel the phenomenon underlying organizational operational interactions that produce synergies - in creating, integrating and recombining resources - in order to obtain new forms of value and thus the production of new sources of competitive advantage (Helfat; Peteraf, 2003, Peng et al., 2008).

Considering (a), on the one hand, the need to understand the operational means or routines that create essential competitive advantage to achieve superior operational performance (Peng et al., 2008). (b) Taking into account, on the other hand, criticisms of the RBV for ignoring the performance variations that occur within most companies, from a more operational perspective (Bromiley, Rau, 2015, 2016). (c) Based on the Resource-Based View (RBV), according to which **internal organizational mechanisms** - as previous factors of absorptive capacity - can be considered as **sources of innovation** (Cohen; Levinthal, 1990) and **competitive advantage** (Zahra; George, 2002), capable of **providing superior performance**. Considering the above, this paper investigates **the superior operational performance of organizations** through **the internal organizational mechanisms** related to the development of integrated routines (Tidd et al., 2008) and structured according to the specificities of each company and the context in which they act (Birkinshaw et al., 2011).

A new dual analysis environment was proposed for the evaluation and analysis of the relationship between innovation and operational performance. Thus, based on two tools frequently used in the research – (a) Data Envelopment Analysis (DEA), which became a of the most applied analysis tools to measure efficiency in several service activities, especially in the hotel sector; and (b) Factorial Confirmatory Analysis and Structural Equations Modeling (CFA-SEM), the degree of relationship of this efficiency (DEA) with the capabilities of improvement and innovation was measured.

From the measurement of the efficiency of each company, using DEA, it becomes possible to analyze and evaluate the routines, of improvement and innovation, according to the model of Peng et al. (2008) of each one of these companies, and, in this way, observe and seek to understand the elements underlying the relationship between these routines and efficiency, from a more operational perspective. In this sense, **the unit of analysis of this work is the hotel**, where the routines are effectively implemented, and the processes are performed. Data envelopment analysis is a technique used to measure allocative efficiency that seeks to minimize inputs or maximize outputs in production

processes. It aims to measure the allocative efficiency of productive units that present multiple inputs or multiple outputs. DEA refers to a technique based on linear programming that allows a) to identify a possible efficiency frontier for a given sample of organizations that have similar or homogeneous operational characteristics and belong to the same segment of activity; and b) to make comparisons on the efficiency achieved between the use of resources and the respective results obtained by each of the organizations in their operational processes, and it is possible to identify best practices in the use of resources by efficient production units.

In relation to the innovation analysis, the research by Peng et al. (2008) operationalizes the concepts of improvement and innovation capabilities as packages of higher-level routines, proposed from a model with second order factors. The measurement items were also developed for each set of routines they identified. And, from a large sample, they used a rigorous empirical method to examine the structure of latent variables related to their capabilities. Thus, according to the conclusions obtained by the research published by these authors, the understanding that capabilities are represented by interrelated bundles of routines was empirically demonstrated from the theoretical foundations of the field of Operations Management and Management literature (Peng et al., 2008). Considering the identification of routines relevant to the improvement or innovation capabilities, as well as the measurement scales selected based on previous studies, the Confirmatory Factor Analysis was adequate for the analysis (Shah; Goldstein, 2006).

In order to facilitate the proposed analysis, we used primary data from 212 hotels that answered an electronic questionnaire made available via the web to 493 randomly selected hotels - 43% response rate - from a register of 2,173 hotel companies and potential suppliers of Petrobras, in the Brazilian territory, for the year 2016. To be accepted in this register, the hotel that intends to provide services to Petrobras must fulfill a set of pre-contractual operational requirements which, in the case of this research, guarantees the degree of homogeneity (similarity) necessary for the nature of the applied methodology. The operational data used for the empirical analysis were collected from the hotels in three successive waves, between 08/09/2016 and 03/22/2017. To evaluate the potential late response bias, the initial and final responses were compared with t-test (Armstrong; Overton, 1977), whose results did not present significant differences between the samples. As there was a single informant per hotel, the potential bias common method was not evaluated. The amount of sample elements was slightly below the rule that determines the ratio between subjects and variables, in the proportion of 10:1 (Hair Jr et al., 2012), for CFA-SEM. In relation to DEA, the literature recommends at least a number of DMUs (Decision Making Units) equivalent to twice the product between the number of input and output variables (Dyson et al., 2001), that is, 28 DMUs for the case of this research. For all respondents it was guaranteed confidentiality regarding the identifications of the respective companies. The profile of the respondents corresponds mainly to employees who occupy managerial positions or higher (79%) and with more than 4 years in the current position (83%), which indicates that most of the respondents are able to provide the information requested in the questionnaire.

For each hotel, data were obtained from 33 different variables, which are divided into two groups, according to the analyzes performed: a) seven input variables and two output variables, used in the DEA, to measure the efficiency of hotels; and b) twenty-four variables used to measure the impact of the underlying routines on improvement and innovation capabilities, according to the model developed by Peng et al. (2008). The variables for the DEA evaluated structural, qualitative, performance and adherence aspects to technological changes, while the variables for the modeling of innovation and improvement constructs used the same items of the questionnaire of Peng et al. (2008),

with the necessary adaptations for the hotel sector. The standardization adopted in the previous research was maintained through the application of the questionnaire with a seven-point Likert scale. The aforementioned adaptation was criticized and validated by a group of eight senior executives working in the hotel sector, while the results analysis was evaluated with the support of these senior executives and researchers from the University of Algarve.

Based on a large literature review, we selected the input variables used to measure efficiency (DEA) a) classification of the hotel by Petrobras; b) number of monthly hours worked by employees; c) number of rooms; d) percentage of employees using peripherals, such as tablets, smartphones, point of sale, order terminals, scanners, printers and others connected to the network or hotel systems in their activities; e) occurrence of the last event related to the introduction of new technologies or the development of processes or services; f) impact caused by the introduction of the latest technology or by the last development of processes or services; and g) occurrence of the last training regarding new technologies or the development of processes or services. And the output variables considered were: a) customer evaluation and b) annual percentage occupancy rate (Hu; Cai, 2004; Sigala 2004; Wagner, Shimshak, 2007; Hsieh; Lin, 2010). The variables to measure improvement and innovation (CFA-SEM), used as basis the theoretical construction of Peng et. al. (2008), adapted for 24 items used in the measurement questionnaire, divided in relation to the respective innovation and improvement capacities, and subdivided in relation to the respective sets of routines.

The correlation, asymmetry and kurtosis levels of the variables meet the needs of the analyzes performed. The bivariate analyzes reinforce the understanding observed in the analysis of correlations and clusters, whose variables that characterize certain groups present a higher degree of correlation with each other. In the case of the CFA-SEM variables, the data were collected using a proposed likert scale and analyzed in accordance with the three structural equation modeling (SEM) requirements: independent observations, random sampling and non-linearity (Hair Jr et al. , 2012). The analysis of the absent and discrepant data was performed and no impact was observed for the quality of the sample. Univariate analyzes showed a normality pattern. The combined distribution of the pairs of variables presented bivariate normality, with linear and homoscedastic bivariate graphs and the patterns of asymmetry and kurtosis were within acceptable limits (Hair Jr et al., 2012). The multicollinearity tests were performed with the SPSS and no dimension had two or more indicators with variance greater than 0.50. However, the degree of multicollinearity of the items included in the CFA-SEM suggest the need to treat the data, because the condition index was 32. This action was not performed so that the model did not lose adherence to the original model. In any case, the condition index was very close to the limit (30), which allowed the analysis to continue.

In order to meet the main objective of this research, five structural models were proposed, as follows: Model 1 - Apply the model of Peng et al. (2008) for a group of hotel companies considered to be efficient according to measurement by the DEA; Model 2 - Apply the model of Peng et al. (2008) for a group of hotel companies considered to be inefficient according to DEA measurement; Model 3 - Replicate the model of Peng et al. (2008) for all the hotel companies in the sample; Model 4 - Include in the model of Peng et al. (2008) a categorical efficiency variable according to DEA and factor composition according to CFA; and Model 5 - Replicate the model of Peng et al. (2008), with a second-order factor, in order to verify the hypothesis that, in the service area, especially in the hotel sector, there is a greater concern of managers with the improvement to the detriment of innovation (Aranda, 2002; Assink, 2006). In this case, the two second order factors of

the model of Peng et al. (2008) could be replaced by only one second factor, that is, improvement.

Results

To measure efficiency, the DEA technique was applied, considering variable returns of scale and orientation to outputs, through the software Frontier, and it was observed that 41 hotels operate with total efficiency (100%), 65 with high efficiency (91% to 99.99%) and the remaining 106 have different degrees of inefficiency (51% to 90%). Sensitivity tests were also performed for the results found (Ramanathan, 2003).

Innovation and improvement are two-dimensional constructs and, according to Peng et al. (2008), the indicators used to measure different aspects of these constructs "have already been submitted to factorial analysis by several authors who have found the aforementioned structure." For researchers who have developed this model, improvement and innovation capabilities are shaped as a second-order latent construct, consistent with the concept of a bundle of routines. In this sense, each set of measurement items is used to measure a latent construct of the first order, that is, a specific set of routines. This way of conceptualizing the capabilities is supported by the RBV (Barney, 1991).

Confirmatory factorial analysis (CFA) was used to evaluate the overall fit of the model, the reliability and validity of each first order factor. CFA involves the estimation of an a priori measurement model, in which the observed variables are mapped to the latent constructs according to the theory (Peng et al., 2008). Since it identified routines relevant to the capabilities of improvement or innovation and measurement scales selected from previous studies, CFA has become a suitable technique for this research (Shah; Goldstein, 2006). Since improvement and innovation capabilities, although different, are related (Cole, 2001), were also evaluated - global fit model, reliability and validity of the measuring instrument - through the CFA. Together, the structural equation modeling (SEM) was used to simultaneously evaluate the relationships between the different constructs of each proposed model:

In relation to the structure test, the models 1 and 2, although approaching a similar solution to previous research in the CFA, were not processed by AMOS because they did not meet the sample size requirements for structural equation models (Wolf et al., 2013). The models 3, 4 and 5 were processed in the SPSS (CFA) and AMOS (SEM) and, for each of the three proposals, therefore, a second order factor model was specified. Thus, in each of the three proposed models, each measurement item loaded its first-order routine and, simultaneously, each first-order routine loaded the second-order construct. With 3 models available, the tests were then started to evaluate the adjustments of each model.

Regarding the adjustment of the models, the chi-square was used to evaluate the theoretical model. The value of the chi-square can vary between zero, when considering the saturated model, and a maximum value, when no relation between the independent model variables is considered. A statistically non-significant result for the chi-square indicates that the sample covariance matrix and the covariance matrix estimated by the model are similar (Amorim, 2012). If the difference is significant, it cannot be said that the model fits the data, so that the chi-square test should not be statistically significant (Mueller, 1999). This test, however, is sensitive to sample size and number of variables in the model (Hair Jr et al, 2012) and may sometimes induce inappropriate rejection. The root mean square error (RMSEA) is a relevant overall adjustment index. It should be less than 0.08 and preferably less than 0.05 (Kline, 2005; Loehlin, 2016). The Tucker-Lewis index (TLI) evaluates the incremental adjustment, as well as the comparative adjustment index (CFI) and the incremental fit index (IFI). For these three indices, values above 0.90 indicate a good fit (Hair Jr et al., 2012).

Table 1: Global adjustment of proposed models

Indexes	Model 3	Model 4	Model 5	Recommended Values (*)
Chi-Square	**306,62**	1034,327	343,542	p>0.05 (not significant)
Degrees of freedom	268	295	275	-
RMSEA	**0,026**	0,109	0,340	< 0,08
CFI	**0,985**	0,769	0,974	> 0,90
TLI	**0,983**	0,745	0,971	> 0,90
IFI	**0,985**	0,771	0,974	> 0,90
Normed Chi-Squared	**1,144**	3,506	1,249	< 2

(*) Kline (2005)

Source: prepared by the author.

The model 3, whose objective was to replicate the model of Peng et al. (2008) for all the hotel companies of the sample, presented better adjustment than the other models, according to table 1: normalized chi-square was 1.144 (p <0.001), RMSEA was 0.026, below the limit, and CFI, TLI and IFI were, respectively, 0.985, 0.983 and 0.985.

Since the models can be considered nested, it is possible to compare them with the chi-squared difference test to indicate that the two constructs can be considered effectively different from each other (Carneiro, 2007). Thus, between models 3 and 4, the chi-square difference was 727.7 and the difference of degrees of freedom was 27, so the observed difference is greater than the statistical limit of significant 55.5 (p <0.001). In the case of models 3 and 5, the chi-squares difference was 36.9 and the degrees of freedom of 7, therefore, greater than the limit of 24.3 (p <0.001). And for models 4 and 5, the chi-squares difference was 691.8 and the degrees of freedom of 20, therefore, greater than the limit of 45.3 (p <0.001).

We also examined the standardized residues of the three models, because when the residuals are small, the model is considered a good representation of the data. Generally, it is recommended that no more than 10% is greater than 2.5 (Hu; Bentler, 1995). None of the standard residues has an absolute value greater than 2.5.

In relation to the validity and reliability, in the model 3 all the adjustment measures are above the recommended cut-off points and, therefore, suggestive that the specified model can capture the relations between the variables adequately. A priori, the specification of the factorial structure that presents a good overall fit through the CFA provides a more rigorous test of convergent and discriminant validity (Campbell; Fiske, 1959). Once the model 3 presented the best fit, analyzes of the validity and reliability of this model and its factors were performed.

Convergent validity aims to verify the similarity or convergence between individual items that measure the same underlying latent variable. In this research, the loads were verified in the aspects of signal, magnitude and importance in the context of the model. It was found that all loads of the first-order factors were above 0.50, with the exception of item 4 (we believe that the improvement of a process is never complete, there are always conditions for further improvements), which presented result close of limit, ie 0,48. The second-order factor presented loads greater than 0.60, all loads with positive and statistically significant signs (p <0.01) (Chin, 1998).

Discriminant validity refers to the degree to which the measures of different latent variables are unique and distinct from each other. It needs to be demonstrated both among first order factors and second order factors. In this study, the average variance extracted (AVE) method was used (Shook et al., 2004). In this method, the AVE of each pair of factors must be greater than the square of the correlation between this construct and any other construct (inter-construct correlation), which indicates the discriminant validity (Fornell; Larkin, 1981). The variance extracted from the four constructs was above 50%. This indicates that the measurement error was smaller than the explained variance and suggests convergent validity (Shook et al., 2004).

Regarding the composite reliability aggregate measure of the degree of intercorrelation or internal consistency between the measurement items of the same construct, a reliability value greater than 0.70 is recommended (Peng et al., 2008). All factors presented composite reliability above the cut-off point of 0.70, ie, all constructs presented adequate levels (Hair Jr et al., 2012).

The models 3, 4 and 5 were processed in SPSS-CFA and AMOS-SEM, with model 3 presenting results similar to the previous research for construct improvement (continuous improvement, process management and leadership involvement) while the innovation construct presented differences from the original model. Thus, instead of three first-order factors (the search for new technologies, the multifunctional development of products and the development of processes and equipment) and a second-order factor - innovation - there was only one factor of the first order, which was called "research and development management" with support in the literature (Coombs, Miles, 2000; Djellal et al., 2003; Krasnikov, Jayachandran, 2008).

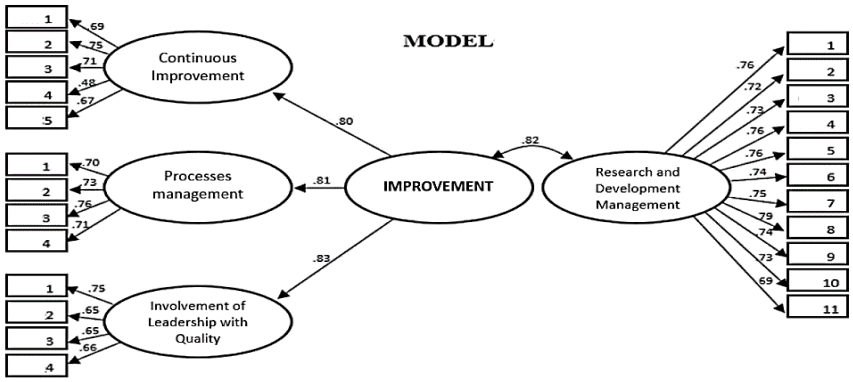

Figure 1: Model 3 presented the best overall adjustment in relation to the other proposed models. Source: prepared by the author.

As performed by Peng et al. (2008), we also tried to evaluate other forms of analysis of different models, i.e.: a) to evaluate a model in which each first-order factor is loaded into a single second order factor, as in this work, b) evaluate other possible models with two second order factors, as shown in the work of Peng et al. (2008). However, in this study, possible models with two second order factors did not manifest themselves with the sample data.

About the impact of performance improvement, the main objective of this research is to analyze how hotel companies guide their internal resources, according to the proposed conceptual framework, in order to induce innovations, create competitive advantage and achieve superior operational performance. In Figure 1, it was demonstrated the routines and how they are organized in order to contribute to the improvement capability, supported by confirmatory factorial analysis (CFA) and structural equation modeling (SEM). It was also possible to measure and evaluate the efficiency of each hotel unit, comparing which inputs, and in what volumes, are able to produce certain results, that is, to achieve relative efficiency levels within the sample, supported by the Data Envelopment Analysis (DEA). However, since the capability improvement is related to the productive activity, permeating its processes and manifesting itself in the different forms of organization of its elements - inputs, routines and products -, then this capability must be significantly related to operational performance of each hotelt (He; Wong, 2004).

To evaluate the relationship between improvement and performance, the effects of the improvement capability on performance were estimated by regressing their factor scores

on an index of three measures of operational performance (Chen et al., 2004): (a) Customer satisfaction (Kandampully; Suhartanto, 2000; Bowen; Chen, 2001); (b) Occupancy rate (Banker et al., 2000; Morey, Dittman, 2003; Abdullah, Haan, 2012); (c) Efficiency (Anderson et al., 2000; Hwang, Chang, 2003; Barros, 2005; Paço, 2014). The performance measures used in this work are objective, and the costumer evaluation was obtained from the TripAdvisor site (O'Connor, 2010; Li et al., 2013; Filieri et al., 2015), the occupation rate was informed through the questionnaire used and the efficiency rate of each hotel was measured with the DEA, based on data on inputs and products reported by the hotels in the questionnaire. A standardized regression equation was estimated for the three mentioned operational performance variables (Flynn et al., 1990). Before estimating the regression model, the assumptions for regression analysis were verified and no violation of regression assumptions was found.

Table 2: Impact of improvement in performance.

Improvement	Efficiency (DEA)	Occupancy rate	Customer Satisfaction
	0,272 (p<0,001)	0,298 (p<0,005)	0,414 (p<0,000)

Source: prepared by the author.

The improvement capability is significantly related to the three performance measures as can be observed in table 2. The observed regression result meets the objective of this research because it indicates that the improvement capability is significantly related to the operational performance and its impact varies according to the type of operational performance involved. This result, like that of Peng et al. (2008), contributes to establish the validity related to the capability measures criterion.

Conclusions

One of the main results achieved by this research is the understanding that the routines associated with the improvement capability form separate and internally consistent bundles of routines, i.e., the bundles of routines are significantly related to operational performance. Thus, this research was able to confirm the notion of capabilities as a bundle of routines, also for the service area, especially for the hotel sector, and to establish an "objective" conceptual link between routines, capability and operational performances for this sector of the economy. A second finding of this research refers to the fact that, for the hotel sector, instead of three first-order factors (search for new technologies, multifunctional product development and development of processes and equipment) - and a second order factor - innovation - only one first-order factor was found, which was called “research and development management”, with support in the literature (Coombs, Miles 2000, Djellal et al., 2003, Krasnikov; Jayachandran, 2008). Thus, another important aspect of the research results refers to the fact that the routines related to the innovation process are present in the model and significantly impact the improvement capability. The literature supports this hypothesis in several empirical researches (Aranda; Molina-Fernández, 2002; Assink, 2006; Hertog et al., 2011). **A third finding of this research refers to the identification of the improvement capability impact on indicators that reflect the performance of a hotel.** The results of the research bring important academic and managerial contributions. From the academic point of view, it advances in the understanding that the capabilities represent bundles of routines for the services area, confirming a more operational perspective for the Research in Operations Management, under a RBV conception. For managers, it contributes to the development of effective behavioral patterns, that is, the development of routines integrated to the broader skills, considering the specifics of each company, as well as the context in which they operate.

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Factors enhancing productivity in industrial environments

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Abstract
Although productivity has been explored for centuries as part of operations management, a comprehensive theory of the factors that lead to productivity improvement is still missing. The objective of the present study is to identify from literature these factors and their interrelationship. A structured literature review and a contingency theoretical perspective is applied. In relation to findings, nine factors categories and 57 factors are identified as having been portrayed in the extant literature as having effect on productivity. Moreover, a factor-productivity conceptual model is developed, highlighting the elements of productivity improvement as opportunities for productivity management within industrial organizations.

Keywords: Productivity, Contingency theory, Literature review

Introduction
Productivity is a key factor for sustainable survival and growth. The World Bank Group (WBG) and the International Monetary Fund (IMF) named productivity improvement as one of their three major objectives for nations and countries (Kim, 2018). The progressing globalization with trends such as offshoring of manufacturing or consolidation of industrial sectors increases the pressure to stay competitive in the market (e.g. Wacker et al., 2006; Walker et al., 2014; Naoum, 2016). That makes it important for firms to focus on improvement of the input-output ratio that might result in a competitive advantage in their industry (e.g. Bernolak, 1997; Tangen, 2005). In the past, innovations led to major productivity gains such as the moving assembly line or labour specialization (Schmenner, 2015). However, today's emerging technologies, such as digitalization or Industry 4.0, can only contribute partly to the enhancement of productivity. Instead and because resources within organizations are limited, productivity improvement initiatives requires prioritisation and an understanding of the entire bouquet of opportunities, their interrelationship and the context in which they operate. Therefore, a systematic and effective productivity management that takes into account the manifold productivity enhancement facets is essential for organizations existence and continued growth.

Productivity has been explored in operations management literature and related disciplines in the last four decades and different kinds of productivity have been in focus (Tangen, 2005). Multiple factors influencing productivity have been identified in their particular context and analysed in surveys (e.g. Noble, 1997; Mapes, 2000) and case studies (e.g. Gunasekaran et al., 2000; Krishnan and Srinivasan, 2007). Thus, research on productivity is comprehensive but also fragmented and an advanced theory of the factors leading to productivity improvement is still missing (e.g. MacHuca et al., 2011; Zhang et al., 2012). Hence, there is no study that summarizes factors effect on productivity across studies and unfolds consolidated findings into managerial practices.

Drawing on a contingency approach, this study aims to extend theory on the interrelationship between productivity enhancing factors and its implications to productivity management: *Based on the contingency theory, what are the antecedent factors to productivity and how do they relate to productivity management?*

The contingency theory provides a structure to the different variables that are involved in the productivity enhancing mechanisms: On the one hand, the environmental variables that are beyond manager's control, and on the other hand, the resource factors that are within manager's sphere to influence (Luthans and Stewart, 1977; Sousa and Voss, 2008). Based on prior research of 841 selected articles of the last 40 years within peer-reviewed operations management journals, nine factor categories and 57 factors are identified as having effect on productivity. In relation to findings, a factor-productivity framework is developed with theoretical substance of the identified productivity improvement factors and their interrelations.

Reviews on productivity

Although productivity is a major concern to operations management, the portion of articles having productivity as a central theme, is still very low (Walker et al., 2014). In order to exemplify this, we were only able to identify three previous comprehensive reviews of productivity related research within the field of OM.

Almost 40 years ago, Aggarwal (1980) identified 99 factors influencing productivity out of 27 case studies across industries in the US. He did some effort to classify these factors into ten factor groups. Aggarwal (1980) elaborated six "uncontrollable situations", nowadays called contingencies, that hurt productivity, such as old traditions or rigid organizational structures. His review can be understood as a comprehensive summary of productivity improvement strategies at that time.

Schmenner (2015) reviewed the innovations that took place to improve productivity between the year 1776 and 1950. This emergence of innovations resulted in a major efficiency or effectiveness step at the time, when the joint effects of multiple innovative factor came together. Examples of such innovations are the moving assembly line (years 1913/1914) or lean manufacturing (from 1940s on). According to Schmenner (2015), these innovations are underlying concepts that further improvements can ground on and which are successful across industries. He elaborated "the theory of swift even flow" which according to Walker et al. (2014) is one of the few unique OM theories.

With the objective to discover the major trends and issues of productivity, Jin et al. (2016) analysed 213 core studies in the period between the 1970s and the year 2013. They identified nine productivity issues and grouped them into four categories: fundamental (labour, technology, IT systems), additional (process, tool and method), environment (trade, regulations), and performance (business performance, operational performance). From the nine productivity issues, they derived from focus group interviews six megatrends. For the period from the 2000 on, they discovered "information" and "innovation" as the megatrends and cutting edge within productivity literature.

Towards a contingency approach to productivity management

The objective of this study is to apply contingency theory (CT) to productivity because of our ambition to identify the mechanism of productivity management. Thereby, we follow the recommendation of Sousa and Voss (2008) that see CT as a useful theoretical lens for OM issues, especially for areas where theory is not advanced. The CT assumes that when organizational structure fits to environmental forces organization efficiency and thus productivity increases (Burns and Stalker, 1961; Lawrence and Lorsch, 1967).

Sousa and Voss (2008) distinguish between three types of variables involved in the

interplay between the environmental forces and the organization structure aiming for a fit: The *contextual variables* that represent the environmental forces, the *response variables* characterizing all organizational and managerial action taken, and the *performance variables* measuring the results of the fit. Luthans and Stewart (1977) elaborates the response variables and distinguished between the *resources* and the *management* of an organization that characterize the response on environmental forces. Venkatraman (1989) identified six types of organizational fit and one of them, *mediation*, has been investigated in multiple applications of the CT (e.g. Shah and Ward, 2003; Demeter et al. 2011; Peng et al., 2011; Chavez et al., 2015). Hence, there are five kinds of variables that are elements in our initial framework of productivity management.

Contextual variables - Multiple factors and their antecedents characterizing the context of industrial organizations have been discovered in OM literature (e.g. Aggarwal, 1980; Schmenner and Cook, 1985). The ability to manage environmental variables is very limited and only, if at all, possible to change long term with substantial effort (e.g. Luthans and Stewart, 1977; Sousa and Voss, 2008). Scholars distinguish between the external and internal environmental variables (e.g. Siggelkow, 2001; Pedersen and Sudzina, 2012; Zhang et al., 2012). The external variables represent forces that are not in range of control of the organization (e.g. governmental laws, economical character, etc.) while internal factors are within the responsibility of the organization but are dependent on the managers' level in hierarchy (Luthans and Stewart, 1977).

In contrast, *resource variables* (e.g. Luthans and Stewart, 1977; Mohanty, 1988; Franco and Bourne, 2003), represent all tangible and intangible resources management has direct control of and on which they can operate to receive desired change (Luthans and Stewart, 1977; Dangayach and Deshmukh, 2001). Human, financial, informational, and technological resources, grouped in different categories, representing the wide spectrum of influence, for instance from the skills of an operator to the reputation of the organization within the industry or region (Dangayach and Deshmukh, 2001).

Management variables - The intervening variable, the management, includes all individuals in the organization with authority to make decisions. According to Luthans and Stewart (1977), managers need to consider environmental and resource variables as well as their relationship to initiate changes in strategy with the objective to establish fit resulting in productivity improvement. Recent studies emphasize goals as essential and important drivers for performance (Zhang et al., 2012). The most important targets concerning performance are termed competitive priorities, which are cost, quality, delivery, dependability, flexibility and innovations (Noble, 1997; Peng et al. 2011).

Mediator variables - According to Drazin and van den Ven (1985), mediation follows an interaction approach, where either the fit between a single contingency variable and a single response (resource or management) variable generates performance or a feasible set of those variables. Management introduces management practices as mediators, that help to channel certain resource variables (Youndt, 1996; Shah and Ward, 2003; Sousa and Voss, 2008; Baird et al. 2011; Garcia et al., 2014; Tortorella et al. 2018).

Productivity variables – Productivity can only be analysed in two ways, either by comparing a variation within the industry on a certain point of time or within the same organization over a period (Bernolak, 1997; Noble, 1997). The productivity variables are represented by financial and non-financial measures (e.g. Bourne et al, 2005; Pederson and Sudzina, 2012). Most organization measure labour productivity as a ratio between labour costs/hours and turnover (e.g. Noble 1997). Others include equipment or capital productivity. Total Factor Productivity represent a measurement system including all input resources and analytical methods are applied such as Malmquist or Tornqvist productivity index (Jin et al., 2016).

Research methodology

This structured literature review (e.g. Tranfield et al., 2013) grounds on the initial framework of productivity management derived from CT applications in OM. For clarity reasons, we explain some wording that results from the theoretical implications of the previous section: Factors have a relationship on productivity. The factors are characterized by antecedents that operationalize the factor. Factors are consolidated in factor categories. Our review is organized in the following way (Figure 1):

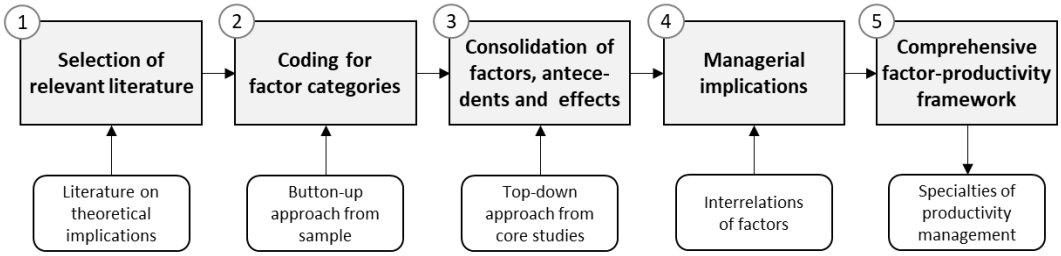

Figure 1 – Research methodology

Phase 1 - For data collection, the Scopus electronic search engine has been utilized to identify relevant articles (e.g. Walker et al., 2015; Jin et al., 2016). For the identification of the most relevant peer-reviewed journals we applied the quality assessments of OM journals of Petersen et al. (2011), Fry and Donohue (2013) and Harzing's Quality Journal List (63rd edition, 29 July 2018). As a result, 841 relevant English language articles were identified from the top nine OM peer-reviewed journals of the period from 1980 until 2018. In order to identify the most relevant information, the 841 articles were classified in three categories using pre-defined inclusion criteria (e.g. Tranfield et al., 2013)

Phase 2 - In our review, the purpose of the coding was to prepare the multiple identified antecedents, factors, and their effects for consolidation and comparison. The coding, was according to grounded analysis performed as a button-up approach and was applied to antecedents and factors categories (Easterby-Smith, 2015). The coding structure and the assignment of factors to the coding structure was discussed among the authors for validation reasons. For every factor identified having a relationship to productivity, a factor code was assigned. In addition, a factor category was assigned to every identified factor having influence on productivity found in the articles.

Phase 3 - Once codes were assigned, the effects of each factor-productivity-relation was summarized resulting in a consolidated finding about that particular factor. For quantitative research, mostly surveys, the significance level has been relevant, while for quantitative research, the recommendations or experiences have been evaluated concerning their effects (Gunasekaran et al., 2000; Krishnan and Srinivasan, 2007).

Phase 4 - After factors and their effects were analysed, managerial implications were formulated. We expected, that especially in situations of interaction of factors, important information for management could be deduced from the relationships between factors. Finally, the managerial implications identified in the article where summarized.

Phase 5 - The initial framework of productivity management has been updated and the identified factor categories were assigned to one of the four variable types.

Findings on managerial implications for productivity improvement

Based on the literature analysis, 327 single factor-productivity relationships and their effects on productivity where identified. The 327 single relationships, presented in Table 2, are related to 57 factors that were grouped into nine factors categories. Those nine categories represent the four variables type identified in the theoretical sections,

which are: Contingency variables; Resource variables; Management variables and Mediator variables. For each of those four types of variables, OM literature mirrors how they can affect productivity and contribute to productivity improvement.

Table 2 – Identified factors, categories and effects

			1 - no effect	2 - effect (no direction)	3 - negative	4 - positive	Total
Contingency variables	External environment	Character of foreign economy		5			5
		Competitive priorities & Hostility	4		1	2	7
		Country & Region of firm	1	1			2
		Economical character of environment	1	6		1	8
		Industry of firm	2	4		1	7
		Laws & Regulations		3	1	2	6
		Resource availability for firm		9			9
		Technological volatility			1		1
		Union & Works council	2				2
	External environment		**10**	**28**	**3**	**6**	**47**
	Organizational context	Age of firm and equipment		1	2	1	4
		Facility & Layout		1		3	4
		Firm size	4			1	5
		Hierarchy levels			1	1	2
		Launches & Changes	1		2		3
		Number of practices		2	1		3
		Ownership of firm		2			2
		Product breadth & Complexity	2		2		4
		Product lines character	1			2	3
		Product type	3		1		4
		Product volume and mix	2	1	3	2	8
		Resources for improvement			3	1	4
	Organizational context		**13**	**7**	**15**	**11**	**46**
Management variables	Leadership & Communications	Beliefs within firm		1		1	2
		Direction & Feedback		1		7	8
		Functional aligment within firm	1	3		6	10
		Improvement focus & reflection	1	1	2	8	12
		Leadership skills		1	2	5	8
		Motivators & Valuing	1	2		2	5
	Leadership & Communications		**3**	**9**	**4**	**29**	**45**
Mediator variables	Management practices	Data management		1		3	4
		Environmental programs				1	1
		JIT/Kanban		1		7	8
		Lean & 5S				8	8
		Performance & Productivity measurement			1	3	4
		SPC & Quality tools		1		2	3
		TPM		3		3	6
		TQM/A		3	1	5	9
	Management practices			**9**	**2**	**32**	**43**
Resource variables	Labour & Workplace	Ergonomics of workplace		2		2	4
		Knowledge & Skills auf workforce	1	6	6	11	24
		Payment & Allocation of workforce		1		4	5
		Work organization	3	4	1	4	12
		Working environment		2	2	4	8
	Labour & Workplace		**4**	**15**	**9**	**25**	**53**
	Material & Supply Chain	Customer structure	3				3
		Delivery & Shipping		1		2	3
		Inventory & Stock	2	1	1	4	8
		Suppliers & Purchase Management		1	1	3	5
	Material & Supply Chain		**5**	**3**	**2**	**9**	**19**
	Process	Capacity availability			1	1	2
		Changeover knowhow	1	1		2	4
		Dependability & Effiency	1		2	4	7
		Line balancing capabilities			1	1	2
		Manufacturing System & Reengineering		1		7	8
		Material flow character		2		15	17
		Planning, Scheduling and Control		5	1	2	8
	Process		**2**	**9**	**5**	**32**	**48**
	Product	Product design capabilities		1		2	3
	Product			**1**		**2**	**3**
	Technology	Alignment of technology				2	2
		Automation & Control level		2		2	4
		Equipment & Tools maturity		1		4	5
		IT tools integration	1	3		1	5
		Technological capability		3		4	7
	Technology		**1**	**9**		**13**	**23**
Total			**38**	**90**	**40**	**159**	**327**

The productivity enabling variables and their interrelations

The analysis found support for the existence of all the different types of variables defined in section 3 and provided insights into their interrelationship. For the contingency

variables, it can be concluded that the external environment (47 relationships) and organizational context (44 relationships) influences productivity quite evenly by the number of identified effects. Compared to the other variables, however, the contingency variables seems to have less positive effect (17 of 91 relationships) and therefore might not contribute as strongly as the others to productivity improvement.

The moderating effect of contingency variables on the relation between resource variables and productivity measures has been found to be relevant in two ways. Firstly, we identified a contingency factor "resource availability for the firm", that received unison strong support for affecting productivity (Mohanty, 1992; Mapes, 2000; Rantanen, 2001; Bhattacharya and Narayan, 2015). Secondly, we discovered from literature, that contingency variables having their "counterpart" among resource variables. Especially the contingencies connected to resource factors categories Labour and Workplace (e.g., Schmenner, 1991; Demeter 2011; Sartor et al., 2016; Spring et al. 2017; Orzes et al., 2017) and Product (Mukherjee et al., 2000; Eckstein et al., 2015; Abolhassani et al., 2018) need to be considered for productivity management in accordance to the analyzed literature.

Compared to the contingency variables, resource variables were found to affect productivity more intensive (75% vs 92% of single relationships). Among resource variables, the categories "Labour & Workplace" and "Process" were the most relevant (101 of 147 relationships) while the resource factor category "Product" according to the analysis plays for productivity improvement only a minor role in OM (3 of 147 relationships). From the literature, we identified two dominating factors among resource variables. The factor "Knowledge & Skills of workforce" is considered very relevant as a contributor to productivity improvement (Mohanty, 1992; Gunasekaran et al. 1994; Bernolak, 1994; Rantanen, 2001; Mapes, 2002; Demeter et al., 2011). That implies from the reviewed literature, that focusing on the training of people or hiring higher-skilled people as well as the involvement of human resource department could be understood as a key element for productivity management. Also strong agreement and support for the productivity improving effect of the factor "Material flow character" can be found in the literature (Schmenner and Cook, 1985; Schmenner and Swink, 1998; Mapes, 2000; Gunasekaran et al., 2000; Neumann et al., 2006; Demeter et al., 2011). Hence, this is a support for one of the few original OM theories, the "Theory of swift even flow" (Schmenner and Swink, 1998).

Also in relation to management practices, strong support was found on its positive impact on productivity improvement (32 of 45 relationships). Especially there were a general agreement around the enabling nature of two management practices: First, "Just-In-Time", is understood as a concept to reduce stock and inventory at all stages of the supply chain and to increase the material flow, and was found to have improving effects on productivity (Gunasekaran et al., 1994; Shah and Ward, 2003; Fisher, 2007 about Hayes 1981). Second, "Lean and 5S", was found to have a positive effect on productivity improvement across multiple publications (Bernolak, 1997; Gunasekaran et al., 2000; Shah and Ward, 2003; Chavez et al. 2013 and 2015).

Managerial implications

By evaluating the interrelations between the different variables, it is further possible to extract and summarize a set of managerial recommendations in relations to the five resource factor categories.

The resource *Labour & Workplace* is connected to responsibilities of the human resource (HR) manager. In order to enhance productivity in the organization, the literature indicates that the HR manager consider labour regulation as relevant for the case of site

location selection (Bhattacharya and Narayan 2015). In addition, organization should accept their social responsibility and aim for social certification standard SA8000 (Sartor et al., 2016). In addition, HR manager could improve the implementation of motivational and incentive systems, which should be aligned with layout/flow and the work organization (Neumann et al., 2006). Competitive salaries and promotion of physical and mental health of employees will further improve the productivity of the organization (Mohanty, 1992). Also, dedicated positions for productivity improvement, process engineering should be created for productivity reason (Mapes, 2000). Literature also indicates that the HR manager should promote a careful assignment of mandatory work to line and shift leaders to ensure spare time for productivity improvement, for example to support line operators (Krishnan and Srinivasan, 2007).

The resource *Material & Supply Chain* belongs to the responsibilities of the supply chain (SC) manager. The SC manager should implement a supplier strategy that is appointed by certified suppliers, daily deliveries and pull supply system (Garcia et al., 2014). Furthermore, only a few different suppliers should be in the portfolio and supplier management should be a combination of pressure and training. (Fisher, 2007; Garcia et al., 2014). The SC manager should initiate inventory reduction program and implement JIT and Kanban to avoid shortage of material (Gunasekaran et al., 2000). The new program implementation should be accompanied by enough training of operators and show strong management commitment (Gunasekaran et al., 2000). When the SC manager is to select a successor or a manager for supplier management, a manager with high-perceived management strength should be selected (Schmenner, 1991).

The production manager and manufacturing engineering manager take the responsibility for the resources of *Process* and *Technology*. In order to enhance productivity in their organization they should rely upon cooperation in many directions to save resources. Thus, they should promote cross-industry cooperation for fusion of technologies, which implies a strong corporation within the industry (Jin et al., 2016). In addition, production planning should be done at corporate level rather than only at single sites (Schmenner and Cook, 1985). Further, managers should urge for alignment of technology and management to avoid technical improvements that do not fit the strategy or the budget (Kao et al., 1995). Production and manufacturing engineering manager should careful prove the introduction of new technology. It should be only considered after re-assessment and optimization of old technology (Bernolak, 1997). A final managerial recommendation is to keep the age of equipment low and exchange old equipment as soon as possible (Schmenner, 1991).

Finally the research & development (R&D) manager is responsible for the *Product*, Since R&D is not that present in OM research, only few implications can be derived from our analysis. Nevertheless, in focus for OM stands the manufacturable designs for new products that the R&D manager needs to ensure (Fisher, 2007). In order to promote and facilitate such a manufacturable design, R&D manager are urged to install extensive cross-functional discussions involving manufacturing, design, and sales (Fisher, 2007).

The framework of productivity management

Based on the theoretical derivation and findings from our analysis the following framework describing the mechanism of productivity management can be derived (Figure 2).

The analysis identified four relationships that were all found to be relevant for productivity change: First, the existing resources of the organization can have effect on productivity directly or via a mediator. Second, the directions and intensity of these effects are influenced by contingency forces. Third, management can assign and change

existing resources of the organization. Fourth, management can implement mediators, which in turn alter the original effect of contingency variables. In addition, we identified two new relationships, which have not been considered in the theoretical section and are an additional contribution of the detailed analysis: Within the group of resource variables, there are relations of the factors among each other (1). Contingency variables affect management variables and with them managerial decisions (2).

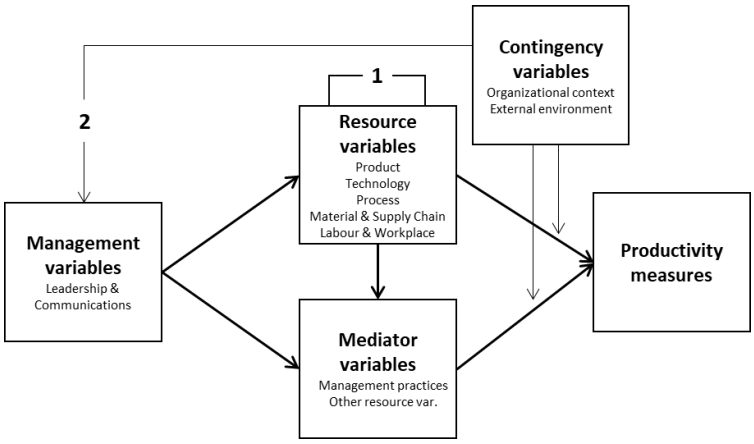

Figure 2 – Updated factor-productivity framework

Discussion and conclusion

The present review shows that the literature is rather diverse in relation to which factors affect productivity as well as to the size and direction of the identified effects. Only for a few of the factors, existing research do agree on their relevance for productivity.

By comparing the different types of variables concerning their ability to influence productivity, the analysis also showed some diversity. For the mediator variables, represented by management practices, current literature always report an effect on productivity. In contrast, for the contingency variables, multiple contributions report no effect on productivity.

As the result of our analysis of the managerial implications, we also identified diversity in the applied managerial mechanisms. Table 3 exemplifies three different mechanism of general management all used as productivity management mechanisms: Cooperation, delegation and reduction (Table 3).

Table 3 – Mechanism of managerial implications: cooperation, delegation, reduction

Factor cluster / topic	From	To	Mechanism
Leadership / Hierarchy	Many layers	Few layers	Reduction
Material & Supply Chain / Supplier strategy	Many suppliers	Few suppliers	Reduction
Process / Production planning	Site	Corporate level	Delegation
Technology / Technology in general	Own technology	Cross-industrial fusion of technology	Cooperation
Technology / Developing countries	Development of own technologies	Technology transfer	Cooperation

This paper contributes to research and practice in several ways. For researchers, it provides a current, comprehensive and structured overview of the variables and factors of productivity improvement. Nine factor groups and 57 factors enhancing productivity was identified from operations management literature. This factor structure could become a foundation for comparing and positioning future research concerning productivity-related factors. Secondly, this review provides a theoretical framework for productivity enhancing mechanisms by describing the different roles and relationships of contingency, response, mediator and management variables.

For practitioners it is a catalogue to identified contingency factors that need be considered in certain situations and for planned management actions. Furthermore, the derived managerial implications provide a bouquet to operationalize productivity improvement initiatives. Thus, this review presents a comprehensive overview of the opportunities to manage productivity for certain function within an organization (i.e., Labour & Workplace, Material & Supply Chain, Product, Process, and Technology).

However, like any other study this study has some limitations. One limitation is related to the fact that we mirrored in our review the operations management literature on contingency theory applications, however the identified relationships of the variables and factors where not empirically verified. The developed factor categories are only one way to cluster the multiple factors and their antecedents and other congregations could be possible. Another limitation is related to the fact that the consolidated effects of each factor considered each finding equally, regardless of the type of research (i.e. survey, case study, etc.), the sample size and significance level.

In relation to future research, the identified relationships in the developed productivity-enhancing framework should be verified empirically. Thus, developing a database to record the relationships of factors discovered contingency combinations would make findings more comparable and help educe new theory. Further, more research is needed on how productivity and performance more generally might hold a different set of implications for their management: What is unique in relation to productivity management compared to the management of other performance dimensions? Does productivity management lead to a more sustainable organization?

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A Qualitative Investigation into Subsidiary Level of Multinational Corporations Performance Management and Measurement - Learnings from South East Asia

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Abstract

Performance Management and Measurement (PMM) practices is a key consideration for management and companies. Presently, research on PMM is scarce and often carried out from a headquarter level. In addition, focus is often on Performance Management Systems (PMS) and their ability to achieve objectives, but misses out on the people function and how, and if, a PMM system is contextually and institutionally fitting. Hence this research focus on PMM practices and their fit in South-East Asia. The findings provide avenues for research and suggestions on working with PMM from a people function perspective.

Keywords: Performance Management, People and performance, South-East Asia

Introduction

As organisations continue to expand globally, the need to evaluate and redefine their strategies, structures and processes as to achieve and maintain competitive advantages (Busco et al., 2008; Biron et al., 2011). In this context, the introduction and adoption of PMM practices as a means to increasing employee performance across global MNEs have become a focus area for management within organisations (Biron et al, 2011; Dossi & Patelli, 2010; Azofra et al., 2002; Xi, 2011; Nankervis & Compton, 2006). The need for both scholars and practitioners to conceptualise a more refined PMM that will facilitate the process of performance measurement (PM) was highlighted by Eccles (1991), and since then, specific PM models have been developed and are currently widely used among organisations as means to track and measure performance. These include, but are not limited to, Performance Pyramids, Tableau de Board, Economic Value Added, Balanced Score Card and Business Navigator (Xi, 2011; Mahlendorf et al., 2012; Chen & Dodd, 1997; Chen & Dodd, 2011; Kaplan & Norton, 1992; Ax & Bjørnenak, 2005). Through these models, both financial and non-financial aspects of performance are considered,

defined, measured, managed and the outcomes are used to inform organisations' performance.

However, as MNEs globalise, the role of PMM faces new challenges as global organisations aspire for the entire MNE, both HQ level, regional HQs and subsidiaries to utilise a standardised PMM system (Buchelt, 2015; Xi, 2011; Shih et al., 2005; Mellahi et al., 2016). Standardisation is thought to allow the MNE to achieve desired outcomes across all of the organisation (Busco et al, 2008; Biron et al, 2011; Bourne et al, 2018). The scope of PMM in MNEs is broad, it encompasses dynamics of people and teams, interaction among sub-units, relationship between parent and subsidiary organisations, as well as PMM in the supply chain (Bourne et al, 2018). With global workforces, the need to adapt to the challenges of measuring, administering and controlling operations within diverse geographical and cultural contexts has become critical to MNEs success (Welch & Welch, 2006; Busco et al, 2008; Barrett et al., 2005; Vo & Stanton, 2011), There are suggestions that for today's MNEs, people are a competitive advantage and hence being able to measure their performance is of particular interest (Buchelt, 2015). Hence, the need to ensure standardised practices and processes between the subsidiaries and headquarter (HQ) to ensure there is congruence is seen as a key organisational challenge.

Current PMM research has seen a focus on the functions of PMM practices and processes in relations to organisations' performance, however there is paucity in literature surrounding the use of these practices and processes within MNEs operating in the international markets (Xi, 2011; Vo & Stanton, 2011; Mellahi et al., 2016, Claus, 2008; Claus & Hand, 2009). This paucity is surprising considering the significant role PMM practices and processes play in the organisation's strategic priorities in relation to subsidiaries, managers and employees, and the different types of behaviours that are expected and rewarded by MNEs (Biron et al., 2011; Fletcher & Williams, 1996). PMM practices and processes have also been shown to influence non-operational aspects of the organisation; the people function as it deals with the assessment and development of employee competence, enhancement of employee performance and distribution of rewards (Cascio, 2006; Fletcher, 2001; Schuler et al., 1991). This gap in literature have prompted this study to explore the perceptions of subsidiary professionals and provide their understanding of PMM practices and processes and their deployments. This is the first step of a study where first the perceptions are investigated, then both HQ and subsidiary are investigated and finally measured. The aim of this paper is two-fold. Firstly, it seeks to discover how does the PMM practices and processes facilitate the people function within subsidiaries of MNEs operating in SE Asia? Secondly, it seeks to discover the perceptions of subsidiary managers on the contextual and institutional fit of the PMM practices and processes. The paper is structured as follows. Firstly, a theoretical foundation providing an overview of PMM processes and practices within MNEs and subsidiaries. Secondly, an outline of the research methodology. Thirdly, findings from this study are described and discussed. Finally, conclusion and implications for future research and practice are briefly discussed.

Background and Theoretical Foundation

Principles and Definition of Performance Management

PMM practices and processes have been widely utilised by Human Resource (HR) practitioners within organisations to achieve and improve individual and organisational performance (Nankervis & Compton, 2006; Vo & Stanton, 2011; Aguinis & Pierce, 2008; DeNisi & Murphy, 2017). While a range of models and techniques which measure both

financial and non-financial measurements have been identified, and PMM practices and processes in organisations are not new, scholars have not agreed on an acceptable model of employee PM (Gibbs, 2008; Vo & Stanton, 2011; Buchelt, 2015). Despite the lack of consensus on employee PM model, a review of literature has shown that there is some consensus on three PM features: (1) Establishing employee objectives, (2) Monitoring and measuring employee performance, (3) Providing feedback and rewards systems, and planning to improve future individual and organisational performance (Milliman et al., 2002; Murphy et al., 2004; Mabey & Salama 1995). With the three agreed PM functions in mind, this study hence adopts DeNisi and Murphy (2017, p.421) definition of PM where PM is defined as "wide variety of activities, policies, procedures and interventions designed to help employees to improve their performance". We believe this definition provides a broader scope than other proposed competing definitions, and also encapsulates the basic principles of PM identified and adopted by this paper. We also believe that this definition fits within a dominant HR paradigm which investigates the relationship between HR Management (HRM) and organisational performance (Wright & McMahon, 1992). In this paradigm, the relationship between HRM and organisational performance is defined as the "planned HR deployments, with activities intended to enable an organisation to achieve its goals and objectives (Wright & McMahon, 1992, p.298). This definition moves away from traditional HRM, whereby it attempts to link HRM practices with the strategic management processes of an organisation, as well as it emphasizes on the co-ordination among different HRM practices through a pattern of planned action. By adopting this lens, it provides us with a clear delineation of the role of PM in facilitating the people function within organisations.

The use of Performance Management and Measurement within MNEs

With globalisation, there has been a trend to standardise processes so that Central HQ (CHQ) can compare and contrast performance across the entireness of the MNE (Chung et al, 2014; Luo & Tung, 2007; Ramamurti, 2012). One area where this have been of particular interest is in the area of PMM (Mellahi et al., 2016). While PMM practices and processes have been recognised to have profound impact on enhancing organisational effectiveness, as well as maintaining competitive advantage, there is significant paucity on existing body of literature on how MNEs utilise PMM practices and processes with their overseas subsidiaries (Mellahi et al., 2016; Thite et al., 2012). Previous studies have suggested that effective PMM policies and practices needs to consider culture and local practices within the contexts of the subsidiaries (Amba-Rao, 2000; Srinivasa Rao, 2007). However, such suggestions lead to a lack of ability to compare and contrast and significant between and within the MNEs depending on both host and home country specific factors (Coates et al., 1992; Rosenzweig, 2006). Early studies on PM in international settings saw two competing tensions, namely convergence theory and divergence theory, which sought to explain the degree to which PM practices and processes can be transferred from one country to another (Lindholm, 1999, Vo & Stanton, 2011). Convergence theorists argued that convergence, driven by the advancement of technology, has facilitated MNEs to employ identical practices across countries (Sparrow et al., 1994). That subsidiary is able to mimic similar practices and processes across the entire MNEs to ensure there is convergence. Alternatively, divergence theorists argued the importance of the uniqueness of each context made convergence impractical and suggested that practices and processes should be adapted to suit local contexts (Brewster & Larsen, 1992). This thought suggests that there is acceptable variation between host and parent country. Since then, PM practices have received attentions from scholars within the comparative HRM, and a number of studies suggested that cultural differences

can influence elements of PM practices and processes, and that the transferability of PM between host and national countries cannot be assumed (Vance et al., 1992; Paik et al., 1996; Snape et al., 1998; Milliman et al., 1995; McEvoy & Cascio, 1990; Bernthal, 1996; Pucik, 1988; Mendonca & Kanungo, 1997). However, there is a paucity of recent such studies that look at PMM practices within MNEs, this is an empirical weakness since given the expansion of MNEs in foreign markets there is a need to see more recent evidence discussing how subsidiaries work with PMM and this prompted this study to explore the perception of subsidiary professionals and provide their understanding of PMM processes.

Theoretical Framework

Our study uses Comparative Institutionalism (CI) as a starting point to investigate the phenomena of interest. Comparative Institutionalism theory (CIT) is a framework widely used to study the spread of organisations practices across countries (Vo & Stanton, 2011), as well as providing insights into the sources of organisational heterogeneity across societies (Edman, 2016). CI draws from several perspectives; organisation studies, sociology and political economy (Hotho & Saka-Helmhout, 2017). Since it is concerned with how the forms, outcomes and dynamics of economics organisations can be influenced and shaped by societal institutions, and their consequences (Morgan et al., 2010), we believe CI will provide an interesting insight into the current phenomena and add to current literature surrounding PMM practices and processes. In addition, CI is deemed to be more cognizant to the notion that institutional orders and their associated logics can be diverse across different societies, due to historically embedded institutional processes and arrangements that are dictated by its society (Hotho & Saka-Helmouth, 2017). CI sees three distinct features, firstly an institutional perspective that pays explicit attention to the institutional arrangements at the societal levels, which takes into account the political, financial and education systems, which have been shown to have an effect on the level of the organisational field (Hotho & Saka-Helmhout, 2017). Secondly, a configurational perspective that focus on the interdependence between societal institutions, which means, rather than analysing societal institutions in isolation, CI calls for the consideration of distinct societal institutional configurations when conceptualising the notion of institutions (Crouch, 2010). Thirdly, CI also pays explicit attention to the link between societal institutions and firm- and society- level outcomes (Hotho & Saka-Helmouth, 2017). At the firm level, CI shows that societal background institutions can impact on resources that are available to organisations, and the capabilities they develop (Estevez-Abe et al, 2001; Casper & Matraves, 2003; Hall & Soskice, 2001). With this understanding, we propose that the variations across societies in which the subsidiaries of MNEs operate in, can influence the state, the market, the profession as well as the organising principles required to operate the organisations.

Research Methodologies

A total of 28 participants were interviewed using semi-structured interviews. The sample was defined as: a person who is formally responsible for PM practices and processes within the Singaporean-subsidiary of a MNE. Our point of departure was that it was primarily important to research the participants' experiences and opinions. In the mapping of the perceptions of PM programmes, it was stressed in the beginning of the interview that we did not want the official corporate statements. Rather we would like to hear how things were in the local reality, favourable and unfavourable aspects, successes and failures, earlier experiences and future scenarios in respect of PM. Among the sampled participants, 36% were female and 64% male, and the firm tenure ranged from four to 30

years; hence the majority of participants were tenured and experienced practitioners. No local HR-practitioners or employees were interviewed (this is taking place in the follow-up study, carried out currently). All participating interviewees were expatriates and had a previous history with the company before relocating to Singapore. There was enough experience amongst the participants to be deemed topic experts. In addition, these participants were active within HR generally had a more strategic HR function; overseeing several countries and not working with daily compliance tasks. All interviewees were employed in the subsidiaries of Scandinavian MNEs. All CHQ were in Scandinavia, but a common trait among the MNEs was that a substantial part of their business was outside Scandinavia (currently all the MNEs have more than 50% of their turnover outside Scandinavia). The interviews took place in a broad variety of companies from major sectors (all Industry Standard Coding Identification main codes represented).

Even though the study is based on the perceptions of 28 interviews, our experience was that the attitudes and perceptions held by the interviewees tended to converge over time. It is a rather homogeneous group of actors we have interviewed, within a very limited geographical area. Many of the interviewees knew each other from different professional forums, and it cannot be ignored that this has influenced the responses. Saturation therefore emerged rather quickly, matching theoretical evaluations within the qualitative methodology literature. Francis et al. (2010) and Constantinou et al. (2017) have in their investigation found that saturation level in interview studies is achieved very fast, when carrying out thematic analysis. Francis et al. (2010, p. 1231) mention 15 interviews whereas Constantinou et al. (2017, p. 583) claim that the threshold can already happen at the seventh interview. This does however depend on the broadness of the selected themes and sub-themes, as well as the level of homogeneity within the population. Finally, it is the gatekeeper's reasoning we are investigating adhering to the understandings presented by Falconbridge et al. (2009). We hence assumed that the interviewees are the ones making the decisions and, in that respect, it is more a study of their "translations" of CHQ policies and programmes, and how and from which criteria they define and select. We have selected illustrative interview quotes from the 28 transcribed interviews. It is obviously based on our personal selection among hundreds of pages but in many respects, the quotes are very good proxies for the attitudes held in general by the participants. The research team read through the transcripts, adding notes, trying to seek out the "true meaning" of the participants' experiences. Reading and reflecting on the material allowed us to get a holistic view of the general themes and perceptions held by the interviewed participants (Cresswell, 2009). Our findings support the notion that institutional orders and their associated logics can be diverse across different societies, and in this case, due to financial embedded institutional processes and arrangements that are dictated by the employees.

Findings and Discussions

Participants have shared their experience on how the role of PMM practices and processes facilitate the people function within the organisation through the means of developing competence and talent among employees. This notion has been previously suggested by scholars (Biron et al, 2011; Dossi & Patelli, 2010; Xi, 2011; Nankervis & Compton, 2006). Participants have also agreed that the role of PMM practices and processes in today's business environment can transcend beyond the operational scope, and the process can be used to facilitate growth of employee in identifying their current performance and ways to enhance performance (Milliman et al., 2002; Murphy et al., 2004; Mabey & Salama 1995). Through the data gathered from our participants, it was

identified that, a small number of employees have in fact have accepted PM as an opportunity for individual career development and such notion has also been previously reported by Maley and Moeller (2014).

> "PM, we measure not just competences but also values and results. The employees are looking at what they get out of PM, what competences they can see developed."

> "Ah it's a matter of setting a goal, an aspirational goal, then the manager is expected to set a pathway for the employee."

What was also evident through this study is the notion that the contexts, in which the subsidiaries operate in, have influenced elements of PM practices and processes, and the transferability of PM between parent and host countries cannot be assumed (Paik et al., 1996; Snape et al., 1998; Milliman et al., 1995; Bernthal, 1996; Mendonca & Kanungo, 1997). For example, a large number of the participants have highlighted the employees' perception of the role of PMM as a tool in bargaining for a higher salary and additional financial rewards or benefits. These findings have provided further support to earlier findings that PM practices and processes is not only used for the assessment and development of competence, but it can also be used to facilitate the distribution of rewards Cascio, 2006; Fletcher, 2001).

> "PMS, I try to talk about values and they talk about money. Good luck talking values with people that are trying to make ends meet. That works in Scandinavia but not out here."

> "The issue with PMS is that since it's here linked solely to additional financial rewards or promotion……our system is bound not to work."

The challenge faced is that the institutional context of SE Asia is not receptive for PM as being a tool to develop a competitive strategic advantage, instead it is focused on rewards, and in this particular context, extra remuneration. In SE Asia, almost all companies offer a so called 13th month of remuneration, and this is what PM has been contextualised as by employees. In this context, the measurements are hence linked to monetary rewards, making any discussions about competence development rather moot. It might be suggested that PM needs to be de-coupled from the 13th month reward appraisal process that most of the participants believed hindered any focus on competence or value development.

> "PM, while we attempt to link them to overall goals, at firm, unit and individual level, down here such reasoning is to abstract. If a person has performed their way good, the idea that they aren't rewarded accordingly leads to frustration."

> "The locals see the appraisal as a time when the manager decides whether they get a full 13th month salary or not"

Despite this tension, responses from the participants have highlighted a somewhat positive perception regarding the contextual and institutional fit of PMM practices and processes within their respective subsidiaries. These perceptions align with the notion proposed by the CIT framework; in which there can be variability in organisation practices across parents and host countries due to the heterogeneity across the societies.

> "The local context is more regional to be honest, the region here sees similarities that we need to work with. There is a vast difference in what is expected by our employees versus what HQ assumes. For example, we expect the employees to suggest their own goals, that's not doable in SE Asia."

Furthermore, participants have reported a PM system that adheres to a top-down alignment. The PM model used, such as MBO, was perceived among employees to be a 'fair' method in obtaining robust feedback pertaining to the performance and used as an opportunity for further development of competence.

> "We use MBO, goals are initiated by the employee and agreed upon by the line manager…that is great on paper."

> "PM is hierarchal down here, we must accept that, the employees demand it. The manager sets the path and if they point out a path then the employee feel taken care of and feel that this employer will look after them."

The findings derived from this study have provided support for our proposal earlier, in which, the variations across societies in which the subsidiaries of MNEs operate in, can influence the state, the market, the profession as well as the organising principles required to operate the organisations. Whilst there is the recognition for the need of standardised practices and processes with the subsidiaries and HQs to ensure competitive advantage is maintained and achieved, the importance of contextual and institutional fit cannot be overlooked to ensure there is acceptance from employees. By drawing on CIT framework, we propose that the view, forms, outcomes and dynamics of PMM practices and processes in this case have been influenced and shaped by societal institutions due to the heterogeneity of MNEs and their subsidiaries.

Within this context, the institutional arrangement at the societal level, namely the role of the financial system appears to be a driving force among employees who have perceived PMM practices and processes as a means to bargain for more reward. As relayed by participants in our study, this tension has an effect on the organisation when it comes to managers attempting to instil values and align these values to achieve competitive advantage as required by HQ. From a configurational perspective, the responses from our participants have prompted us to analyse all aspects of the societal context when trying to make sense of the experience and perception of our participants. It was unreasonable to analyse these responses without considering the contexts in which the subsidiaries operate in, which have been influence by a range of systems (financial, political and economy). Finally, the societal context in which the subsidiaries operate in have impacted on the view of PMM practices and processes, and in turn, impact also on the resources associated with the role of PMM. Instead of using PMM as an opportunity to develop competence and values, employees are seeking extra remuneration and detracting away from the role of PMM as perceived by HQ.

Limitations and Future Research

While this study has provided some recent and empirical findings and insights into PMM practices and processes among subsidiaries in SE Asia, it is imperative to keep in mind that these findings and insights are only applicable to the participants that were involved in this study, as well as the subsidiaries in which they were employed within. Despite these limitations, the findings and insights have provided empirical support for the field

of PMM, and also add on to the current paucity in literature. In the interest of progressing understanding of PMM practices and processes within subsidiaries, we offer the following considerations for future research. Firstly, that a larger sample is used to add breadth to the findings we have presented and secondly, to measure the impact that these findings may have on the effect and results that are expected from a globalised PM program.

Conclusion

Through this study, there is evidence to suggest that PMM practices and processes within subsidiaries can facilitate the people function by identifying areas for improvement. Interestingly, there is also the perception that PMM practices and processes are used as a tool in bargaining for pay increase, promotion and additional rewards, which is contrary to the perception of MNEs. Despite this tension between the view of PMM between MNEs and their subsidiaries, participants in this study have expressed a somewhat positive view of PMM practices and processes. In addition, there is also evidence to suggest that the transferability of PMM practices and processes from MNEs to subsidiaries cannot be assumed, as participants have indicated having to adapt some of these practices and processes to ensure there is a better alignment to the requirements of the context in which the subsidiaries operate within. The CIT framework adopted by this study delineated how the processes and practices within organisations can be influenced and shaped by its own societal context.

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An integrated framework of company performance trend analysis for motor vehicle manufacturers

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Abstract

The motor vehicle manufacturing sector is regarded as the engine of Europe. There is more to a healthy motor vehicle manufacturer than the financial statistics. However, current efforts in the field of performance measurement and management haven't provided sufficient quantitative trend analysis with environmental concerns for motor vehicle manufacturers. This research aims to design an integrated framework which can serve as an approach to the missing trend analysis. This framework exclusively involves quantitative analysis based on secondary data. This framework can form the basis for a statistic which can assist users to better understand their decisions with environmental concerns.

Keywords: Trend analysis, Autoregressive models, Motor vehicle manufacturer

Introduction

The motor vehicle manufacturing sector is regarded as the engine of Europe. On the other hand, this sector has a negative impact on the environment directly and indirectly. Its manufacturing activities involve consuming a large volume of resources and generating products as well as various pollutants. For example, the volumes of carbon dioxide emitted in the year 2017 contributed around 72% to global greenhouse gas (source: PBL Netherlands Environmental Assessment Agency). Therefore, there is more to a healthy motor vehicle manufacturer than the financial statistics.

So far, much concentration is on the historical performance and on the things that have already happened (Unahabhokha et al., 2007). Manufacturers forecast their performance mainly relying on experts' judgment and some financial data for decision making. In other words, current efforts in the field of performance measurement and management haven't provided sufficient quantitative trend analysis with environmental concerns for motor vehicle manufacturers. To narrow this gap, this research aims to

design an integrated framework which can serve as an approach to the missing trend analysis.

To measure multi-dimensional company performance, performance analysts use composite indicators (CIs). A CI may be defined as a single index "which is formed when individual indicators are compiled on the basis of an underlying model of the multidimensional concept" (Glossary of Statistical Terms from the Organisation for Economic Co-operation and Development). Historical data of a variable collected at regular intervals in time sequence is called a time series. Time series analysis can assist decision makers to better understand variables' trend and more accurately forecast its future value. There are several conventional methods for trend analysis such as the deductive method, the joint opinion method and regression models. Besides, there are several advanced tools that have been applied to quantitative trend analysis such as adaptive neuro-fuzzy inference system (ANFIS).

The rest of the paper is organized as follows. Section 2 presents a literature review on company performance measurement indices for manufacturers and on trend analysis methods. Section 3 presents the method in this paper, namely, an integrated framework which can serve as an approach to the missing trend analysis. Section 4 provides concluding remarks, limitations in this research and two recommendations for further research.

Literature

Company performance indices of manufacturers

Constructing CIs involves five phases, including selecting variables, weighting variables, aggregating variables into a single index and post analysis of the index. This research does a literature review on CIs at the company level for manufacturers.

To discriminate stable car companies from unstable ones, the average value leverage factor was proposed. Its value is based upon the average R-value by a linear least squares correlation analysis between three variables, namely, turnover per employee, profit per employee and research and development expenditure per employee. Companies can be ranked according to the scores from this stability factor (Beelaerts van Blokland et al., 2018).

A global performance measurement model for decision making was developed based on the performance measurement questionnaire and analytic hierarchy process (AHP) (Chahid et al., 2014). With a case study in an automotive supplier, the authors said their work presented a complete view of performance measurement in the Moroccan automotive manufacturing sector.

To develop a composite sustainable supply chain performance index for measuring organizations' contribution towards supply chain sustainability, an integrated method of literature review for selecting 42 indicators, Liberatore score and fuzzy AHP for weighting qualitative indicators and the signal to noise ratio approach for weighting quantitative indicators (Gopal and Thakkar, 2015).

Evaluation of organizations' sustainability performance was performed by a sustainability index with the technique of AHP for indicators' weights, min-max for the normalization, and simple additive weighting (SAW) for aggregating. A case study in a Portuguese automotive company was presented, but due to the sufficient data and responses to the questionnaire, only a partial conclusion was drawn (Salvado et al., 2015). Afterwards, a similar research was done by assessing the level of sustainability performance of the UK automotive supply chain from 1999 to 2014. The main difference between the two researches is that this one used the Delphi technique for

weighting and with ambiguity associated to indicators selection (Azevedo and Barros, 2017).

A quantitative measurement model was proposed with a new conceptual framework. Methods involved techniques of fuzzy logic and analytic network process. A case study in nine truck manufacturers was presented with data during the fiscal year 2004 to 2015. The result out of the Technique for Order of Preference by Similarity to Ideal Solution was used as a validation which indicated the higher accuracy of the model (Zeng and Beelaerts Van Blokland, 2018).

Trend analysis methods

ANFIS (Jang, 1993) was developed which is endowed with neural learning capabilities of ANNs (Mavi et al., 2017). ANFIS is able to solve tough realistic problem due to it: 1) presents a better learning ability; 2) achieves highly nonlinear mapping; 3) requires smaller size of training data set (Mavi et al., 2017).

For testing the model performance, root mean square error (RMSE) and mean absolute error (MAE) are commonly used. RMSE is a frequently used performance criterion which measures the difference between values predicted by a model or forecaster and the target or desired values. It is suggested that the RMSE is not a good indicator of average model performance and might be a misleading indicator of average error and therefore the MAE would be a better metric for that purpose (Willmott and Matsuura, 2005). However, the RMSE appears to be more appropriate to represent model performance than the MAE 1) when the error distribution is expected to be Gaussian, and 2) considering the RMSE satisfies the triangle inequality requirement for a distance metric (Chai and Draxler, 2014).

In terms of the application of trend analysis at the company level, some studies focus on forecasting financial trends, such as the sales of the printed circuit board with a weighted fuzzy neural network (Chang et al., 2007), the sales of medical products with a comparison study on feed forward neural networks, radial basis networks and ANFIS for their accuracy and convergence (Koulouriotis and Mantas, 2012), the supplier evaluation and selection with ANFIS, using mean square error and linear regression analysis for evaluation (Özkan and İnal, 2014), the online market research with a warning system based on neuro networks and fuzzy logic (Kaiser et al., 2011) and a customer satisfaction model based on neuro-fuzzy technique (Chan et al., 2012).

Method

This research designs an integrated framework of quantitative trend analysis for motor vehicles manufacturers. This approach consists of six phases. In phase I, a conceptual framework of company performance for motor vehicle manufacturers is developed. To identify the variables, a literature review is conducted. Besides, this research refers to released documents 1) from motor vehicle manufacturers, 2) from the International Organization of Motor Vehicle Manufacturers and 3) from the Global Reporting Initiative.

Construct a composite indicator of company performance

During phase II to phase IV, a company performance index for motor vehicle manufacturers (I_{MVM}) is constructed. The adoption of methods should be suitable in specific applications. Otherwise, the methods as well as the results derived might be controversial. For instance, there is one crucial assumption in real cases that there is

some degree of non-compensability between variables. Therefore it is improper for researchers directly adopt several techniques such as the SAW method.

The method in Phase II is the Shannon entropy equation for weighting variables. Phase III is a normalization method based on the min-max method. In Equation (1), $x^*_{ij}{}^t$ is the normalized value of variable j on manufacturers i at the fiscal year t. "+" denotes the variable which satisfies "the larger its value is, the better the result gets" and "-" denotes the variable which satisfies "the smaller its value is, the better the result gets".

$$x^{*t}_{ij} = \begin{cases} \dfrac{x^t_{ij}}{\max\limits_i x^t_{ij}} + 1, for(+) \\ \dfrac{\min\limits_i x^t_{ij}}{x^t_{ij}} + 1, for(-) \end{cases} \tag{1}$$

The method in Phase VI is a geometric mean for aggregating individual variables into the single index I_{MVM}. Construct an multiplicative function in Equation (2), where I_i^t is the overall performance index for manufacturer i at fiscal year t, w_j stands for the final weights of indicator j.

$$I^t_i = f\left[x^{*t}_{ij}, w_j\right] = \prod_{j=1}^{n} x^{*t}_{ij}{}^{w_j} \tag{2}$$

Trend analysis of company performance

There are several conventional methods for trend analysis such as the deductive method, the joint opinion method and regression models. Besides, there are several advanced tools such as ANFIS that have been successfully applied to quantitative trend analysis. Based on a literature review, this research adopts two commonly used methods, namely autoregressive models and ANFIS for trend analysis. In phase V i), the I_{MVM} trend is analyzed based on autoregressive models. Different autoregressive models can be developed for different manufacturers. Calculate the mean square error (MSE) between the real value and the estimated value during the fiscal year (FY) 2008 to FY 2017. In phase V ii), the I_{MVM} trend is analyzed based on ANFIS. The implementation of ANFIS in this research can follow five steps.

1) Build a dataset of input variable and the output variable, split it into two sets, and input the data sets. Around 70%-90% of all data (Azadeh et al., 2011) works as the training data set for finding the optimal ANFIS structure, while the rest data works as the testing dataset for validating the model.
2) Decide the membership function (MF) type and the number of the MFs for each variable. The Trimf and the Tramf are often used MFs due to their computational simplicity for decision makers. In order to choose the appropriate MF(s), a comparison study on some error criteria from different MFs can be conducted in this step. The lower value of the error, the suitable the MF is.
3) Give other parameters for learning, and apply a hybrid learning algorithm to the model. Important parameters include the number of iterations (epochs) and the value of Error tolerance. Error tolerance is best left set to 0 considering the trend of the training error remains unclear.
4) Start learning process using command anfis. The training will stop after the training data error remains within the Error Tolerance.

5) Test forecasting capability of the developed model. Conduct the comparison of independent values and the corresponding output values by training and testing data respectively. RMSE is widely used as the termination error criterion considering it is the most commonly used measure to reflect the goodness of model fit (GüNeri et al., 2011). The lesser the RMSE value is expected.

In phase VI, the results from the two methods are compared. The method with less errors can be identified. Use the identified method to calculate the I_{MVM} value from the FY2018 to FY2020. All the phases within the integrated framework of company performance trend analysis for motor vehicle manufacturers are shown in figure 1.

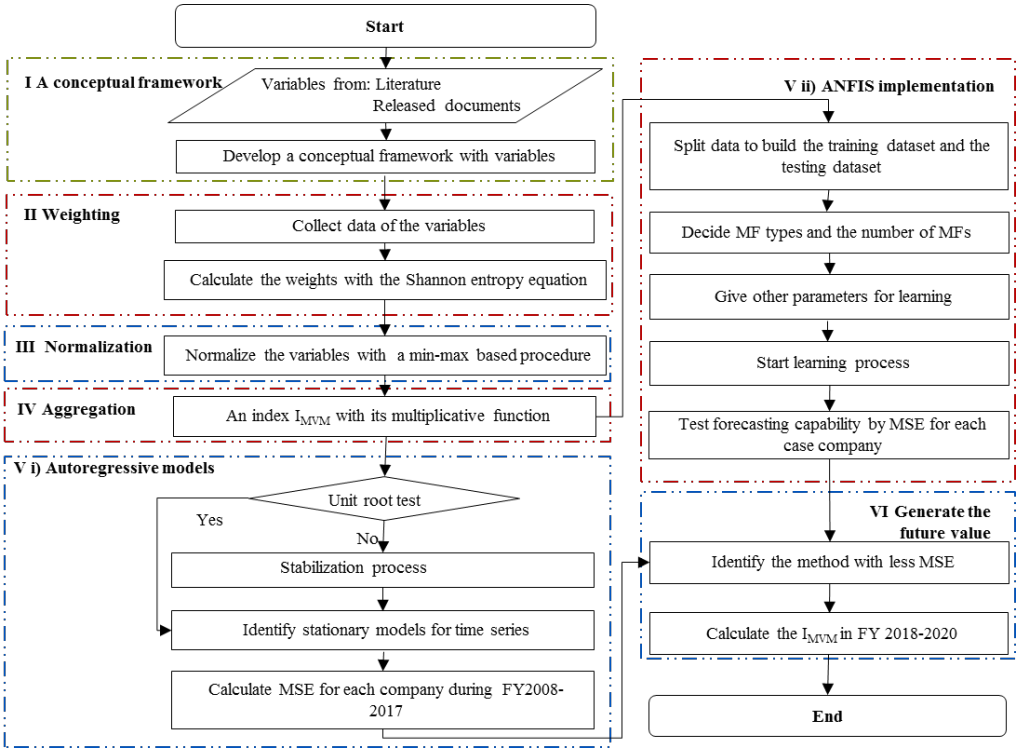

Figure 1 – An integrated framework of company performance trend analysis for motor vehicle manufacturers

Conclusion

This paper contributes to current literature in the field of performance measurement and management with an integrated framework to analyze company performance trend for motor vehicle companies. Two trend analysis methods are involved, namely autoregressive analysis and ANFIS. is new. Environmental variables can be identified and included into the conceptual framework of company performance measurement for motor vehicle companies. Besides, the index I_{MVM} is transparent about the methods which are used. This quantitative trend analysis as well as the I_{MVM} is based on secondary data. By the comparison study on the errors from autoregressive models and from ANFIS, the better trend analysis method can be identified. This trend analysis can serve as a statistical tool. This tool can assist users to better understand the consequence of their decisions in the complex business management.

There are two limitations and accordingly two recommendations for further research as follows. 1) The construction of the composite indicator missed the post analysis phase. This indicates that the effectiveness of the index hasn't been validated. Therefore,

a post analysis phase is suggested. 2) A computational demonstration of the method is was missing. Therefore, data analysis with a case study in motor vehicle manufacturers is suggested.

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When deviating from standard processes leads to higher performance - How companies can improve complexity management by understanding deviations of process standards

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Abstract

Deviations from predefined process standards often occur in order to reach higher performance levels. Based on a structured literature review and a data analysis of over 1,000,000 data lines, we developed a theoretical framework to understand the characteristics of desired and undesired process complexity. To validate the positive performance impacts of process deviations we present a case study of two production companies and demonstrate the findings of their analyzed end-to-end processes of actual process paths, as opposed to their predefined processes. We conclude with actionable alternatives on how management can use complexity to enhance logistic performance.

Keywords: Process complexity management, business process reengineering, process mining

Introduction

With expanding interlinking activities between business partners and the increasing demand of customers for individual products, complexity management became an integral part of the management agenda. Fulfilling this new market need and simultaneously enhancing logistic and financial performance has become one of the major challenges for top management (Bode, Wagner, 2015).

Complexity can influence performance in both positive and negative ways. For example a larger product variety can help the company to open up new markets and increase revenue (Aitken et al., 2016).

(Marley et al., 2014), (Bode, Wagner, 2015), (Fisher, Ittner, 1999) investigated the negative impacts of complexity on increasing supply chain disruptions, a higher failure rate and increasing need for supervision and control. Aitken et al. (2016) raised the position that there is a difference between necessary and unnecessary complexity: Necessary complexity can be helpful to reach strategic company goals, for instance by accepting a lager product variety to offer customers a wider product range. Unnecessary

complexity can hinder reaching the strategic company goals and thus, must be avoided. However, complexity can also have positive performance impacts when deviating from predefined process standards.

Latest technology developments gave rise to software programs called process mining tools, which help to analyze large data volumes and identify actual taken process paths within a company's business wherever electronic data is available.

In this research we aim to understand the positive aspects of additional process complexity through deviation from standard processes by using the term "desired" and "undesired" complexity. We aim to investigate the characteristics and emergence of desired and undesired complexity and to develop a heuristic framework to illustrate the cause-and-effect-relationships between impact factors and performance effects of desired and undesired process complexity. Further, we show how latest process mining tools can be used to identify process deviations in order to apply this approach to multiple processes by introducing a case study of two companies.

The remainder of the article is structured as follows: First, we illustrate a review of the current state of literature. Second, we present the theoretical background. Third, we expose our heuristic framework and highlight the research gap. Fourth, we present and discuss the main findings of our case study. The paper concludes with some theoretical and managerial implications and gives advice for further research.

Structured Literature Review

In order to investigate the current state of literature and highlight the research gap we did a structured literature review on articles between 1998 and 2017. For the literature review we identified 18 keywords, which were supplemented during the search process, documented in Table 1.

Table 1: Keywords for literature research

Keywords	Added keywords during search
process complexity	process mining
process (complexity) management	measurement of complexity
complexity (management)	complex systems
complexity theory	process variances
complex (adaptive) systems	business process reengineering
complex networks	process deviations
process deviations	transaction cost theory
complexity drivers	cognitive bias
	network indicators

These keywords were combined to research strings resulting in 248 papers. For the subsequently followed forward and backward search relevant criteria were defined. This search resulted in 314 papers. To reduce the number of papers we choose criteria such as focus on process complexity, measurement techniques of complexity and business process improvement methods, resulting in 38 papers. All remaining papers were investigated by using a structured analysis approach. The focus of the article analysis was investigating (1) the used theory, (2) characteristic of complexity, (3) complexity drivers and (4) the impact of complexity on performance to develop a general understanding of complexity and to develop a framework to explain the cause-effect relationship between the different complexity types.

Theoretical Background

We give a brief definition of process complexity. In order to show how process complexity can be analyzed we present several graph theoretical measurements and

highlight the influence of process complexity on performance. Then, we present reasons for deviating from process standards and show how business process reengineering can be solved with the help of process mining tools. Based on this analysis we highlight the research gap.

Process Complexity

A high task variety, a variety of different inputs and uncertainty are characteristics of complex processes (Mani et al., 2010). (Karimi et al., 2014) added to that definition the uncertainty and interdependence between the individual activities of a business process. (Größler et al., 2006) state process complexity also named internal complexity is an answer to the complexity resulting from the outside business environment. (Schäfermeyer et al., 2012) indicates that business processes even need a certain level of complexity to be able to respond to the environment.

Process complexity therefore can be defined as a process characteristic describing the effort which is needed to fulfill the process goal. Task variety, involved parties and subject areas determine the level of process complexity.

As business processes are the core element of a company's operations, it is absolutely important to understand the characteristics and influences on process complexity to be able to respond with the correct management action.

Measurement of complexity

In order to define the level of complexity and therefore respond with the correct action alternative it is necessary to measure the degree of complexity.

In the field of network research there exist several indicators to measure complexity (Boccaletti et al., 2006). For this paper we used the relevant indicators which are necessary to define the level of process complexity. The shortest path length is one of the basic indicators which defines the shortest connection between two nodes within a network. Another quite commonly used indicator is the so called betweenness centrality. This measurement is based on the shortest path length and characterizes a node as important if it belongs to a high value of shortest path lengths. (Boccaletti et al., 2006).

Performance vs. Complexity

The majority of business literature focuses on the negative impacts of complexity.

According to (Bode, Wagner, 2015), (Marley et al., 2014) (Allesina et al., 2009) complexity should be reduced or avoided wherever possible. They argue with the negative impact of complexity on logistical performance, a more complicated decision-making process and increasing supply chain disruptions.

Following the argumentation of the normal accident theory, the likeliness of failures increases with an increasing complexity and tight coupling of processes (Perrow, 1999). This theory was applied in several research field of supply chain management, manufacturing and transportation to explain why failure and process disruptions occur. According to this theory due to the high number of interactions errors will occur in unexpected ways. In combination with the tight coupling, therefore failures can spread easily within the network and it´s "normal" that failures and therefore disruptions will occur (Marley et al., 2014).

(Aitken et al., 2016) questioned whether the only possible impact of complexity is negative and therefore distinguish in their paper between "strategic or necessary" and "dysfunctional or unnecessary" complexity.

According to the authors (Aitken et al., 2016), (Bozarth et al., 2009) strategic

complexity empowers the company to reach their strategic goals like a higher product variety increases the complexity but also enables the company to gain market share. In contrast, dysfunctional complexity in a process impedes its performance. Thus, a healthy level of complexity can have positive performance impacts and even deviations from standard processes can lead to an increase in performance.

Deviation from Process Standards

People often take alternatives to reach their goals despite of predefined standard process steps. They do so actively but sometimes also unconscious.

Deviating from standard processes could mean on the one hand, doing process steps in a different sequence than the standard process pretends. On the other hand deviation could also result in a completely new set of process activities which are not intended in the standard process.

Especially the external factors time pressure and multitude of information encourage the phenomenon of cognitive bias and lead people to deviate from predefined standard processes (Arnott, 2006). The employee has to react fast and there is not enough time to comply with all necessary process steps, therefore the employee seeks possibilities for reaching the process goal as fast as possible in spite of known, standard process requirements (Bendul, 2016).

Additionally, missing knowledge and lack of transparency are reasons influencing why people deviate from process standards. They are just not aware of how the process should be exactly executed and therefore decide on their own what they think is the best way to reach the process goal. Lastly, another reason might also be that employees sometimes get the instruction from their supervisors to do a task in an unique way, which is not in line with companywide defined process standards.

While these are more of an unconscious action, some people also actively deviate from standard process. They are convinced that their process path is better than then defined one to reach the process goal. Moreover, after a process change this is a quite common phenomenon. Accordingly, people also tend to do their task the same way they have carried out in the past, even if new process standards have been implemented by the company´s management. (Marjanovic, 2000).

Business Process Reengineering and Process Mining

As presented in the previous section on normal accident theory, depending on their complexity level, systems contain an inevitable failure potential and the only way to abandon this is to redesign the system. This is also true for the system of business processes. Beside other business process improvement techniques such as Six Sigma, continual business process improvement and core process redesign, Business Process Reengineering (BPR) is one approach to improve business processes (Grant 2016).

BPR is a method used for achieving higher performance through a radical change of current business processes (Hammer, Champy, 1993). Therefore, BPR entails a total rethinking of how processes are currently carried out and how process goals can be achieved. (Murray, et al., 2000).

When selecting which processes should be reengineered, a company should focus on strategic processes. Strategic processes are defined as core processes which are directly related to the company’s business purpose and contribute to reach the strategic goals (Hanafizadeh, Osouli, 2011).

Other than the need to select the right processes to re-engineer, choosing the right

method for their alteration is a key factor for successful BPR. Cheung (1998) suggest two types of appropriate approaches for BPR projects, one is non-digital and the other is software-supported or software enabled.

Process Mining is a young software technology which could be used as a support tool for BPR. Based on the analysis of event-logs within the system of a company this technology enables analyzing really taken process steps. It supports process analysis, process policy conformance and the understanding of process models and is therefore a useful tool to support business process improvements (Polpinij et al., 2015).

Theoretical Framework of Process Complexity and Research Gap

Process Complexity Framework

Based on our structured literature review, we developed a heuristic framework for explaining the emergence of process complexity, taking into account its characteristics and interdependency to other complexity types within a production company.

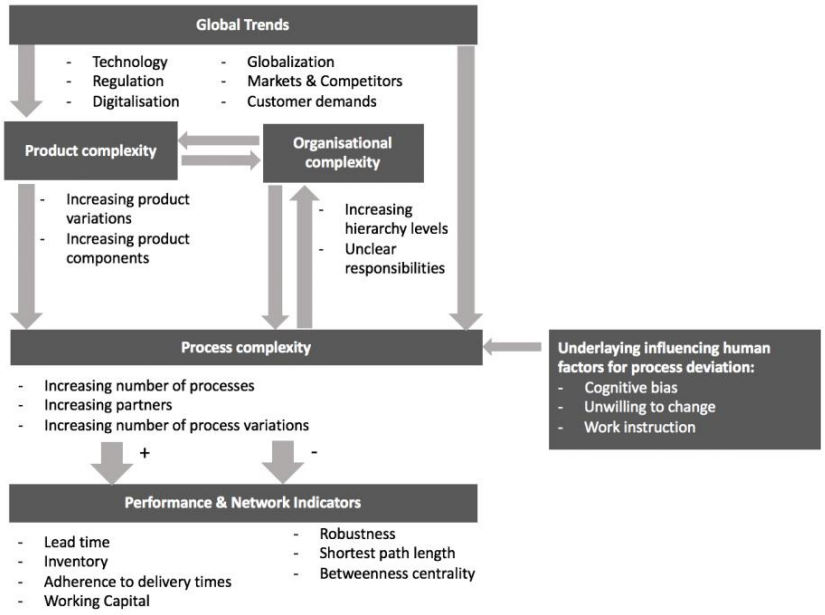

Fig. 1 Process Complexity Framework

In general, there are three categories of complexity within a production company; which are product, process and organizational complexity (Größler et al., 2006).

Different developments such as technical development, market and customer demands Are global trends which have either directly or indirectly influenced product or process complexity (Bode, Wagner, 2015). The different product variations and relevant number of components determine the product complexity.

Process complexity in general is determined by the number of possible process path alternatives and process steps actually taken (Mani et al., 2010). Organizational complexity can be characterized as the structure of hierarchy and delegation levels in an organization. Product complexity as itself also influences process complexity and organizational complexity (Größler et al., 2006). Organizational complexity can be characterized as the structure of hierarchy and delegation levels in an organization (Größler et al., 2006).

Their interdependencies can be exemplified through the following sample; a larger number of product variants and components require a lager number of suppliers which in turn often require different souring processes. Thus, an increase in product variants and therefore complexity, often directly leads to correspondingly higher process complexity. Increasing the number of product components also leads to the need for more employees (for example for product design, construction etc.) and therefore, also to an increasing organizational complexity (Bode, Wagner 2015).

These interdependencies go both ways, product complexity impacts organizational complexity, but organizational complexity can also effect products. Organizational complexity is often characterized by many levels of hierarchy and unclear responsibilities, which can lead on the one hand to higher product complexity due to unclear construction standards for example and on the other hand to a higher process complexity (Aitken et al., 2016).

Human factors are also reasons for deviating from predefined standard processes which influence process complexity (Arnott 2006), (Marjanovic, 2000). It is undisputable that process complexity impacts the performance of processes in terms of their lead times, inventory, delivery reliability and working capital (Bode, Wagner, 2015), (Aitken et al., 2016) as well as on network indictors like robustness, shortest path length and betweenness centrality (Boccaletti et al., 2006), (Meyer et al., 2015).

Research Gap

Aitken et al. (2016) argue that the desirability of different complexity levels should be distinguished, such that an acceptable level is identified depending on the strategic relevance. As only negative impact of complexity on corporate performance has been addressed in literature, there is a need for further research of the positive impact of process complexity on specific key performance indicators like process throughput times.

Furthermore, the reasons for deviation from predefined process standards must be further investigated. To further discussion on this gap, this paper aims to contribute to the research goal; how process deviation increase corporate performance in terms of process throughput times and how people behavior affect deviation from process standards.

Case Study

In order to explore above-mentioned question we present a case study of two German production companies (see table 2) and demonstrate the findings of two analyzed end-to-end processes, with a combined total of 1.794.000 data records of process paths truly taken, as inputted by employees in each respective companies SAP system. The characteristics of the two chosen companies are presented in the table below:

Table 2: Key facts of the companies

	company I	**company II**
branch	metalworking plant engineering	aviation
annual turnover	> 900 Mio. €	> 400 Mio.€
employee	2.000	1.500

The two chosen production companies dispose about all relevant key business processes with a relevant spectrum of attributes and complexity aspects like number of suppliers and customers, invoices in different currencies and delivery routes. The two chosen companies are large corporations. Therefore, also the company size, involved

departments and employees as well as the data and process volume represent the situation of a multitude companies. As both companies are production companies they often deal with all three presented complexity types; of product, process and organizational complexity. Moreover, there are many involved parties which contribute to the complexity, such as various departments, and employee hierarchies within a single process, which allows for an assessment of the underlying human factors on process complexity can be investigated.

For the analysis we used extracted data of one accounting period from the company´s Enterprise Resource Planning (ERP) system of the purchase-to-pay and the order-to-cash process. In total 1.794.000 single data records were analyzed by using a process mining tool, named Celonis.

Table 3: Analyzed data records

process	data record
purchase to pay	1.593.000
order to cash	201.000

Based on event logs within the ERP system and the time stamps of the several process step activities the process mining tool is able to mirror the actually taken process paths. Based on the analysis of the time stamps Celonis is also able to determine the used throughput time. It is possible to define a target process and doing a conformity check if the process path and the specific steps are the same as they were defined in the target process or if there occurred some process violations.

The central measured values from the tool are the throughput time based on the analysis of the time stamps and the cases per step, based on the analysis of the IT-documents per process activity. In the following section we show the process deviations taken, as well as their identified influence on performance indicators.

Findings

Comparison of Planned vs. Actual Process Paths

The standard process predefined by management are first shown for purchase-to-pay (Figure 2) and order-to-cash (Figure 3).

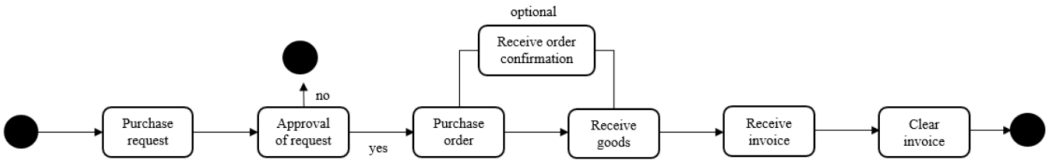

Fig. 2 Standard purchase-to-pay process

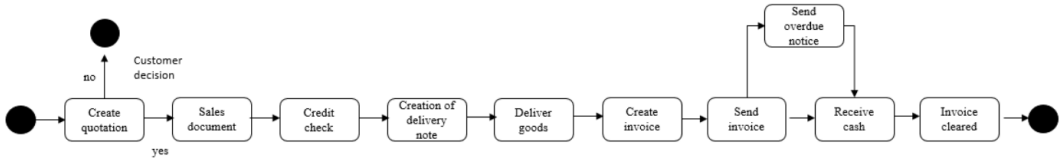

Fig. 3 Standard order-to-cash process

To validate our framework about desired and undesired complexity we present the following example from our analysis of the invoicing part of the order to cash process. We investigated in the order to cash process a normal throughput time of 23 days.
For this sub process part a normal throughput time of 8 days is defined as a standard.
The activity "send overdue notice" for sent invoices where there is no cash income yet, is defined by the company as a desired activity. Even the throughput time of the whole process increased by 17 days and also the process complexity increased due to the extra loops, it is a necessary complexity increase and certainly also by management a desired process step, from a company strategic point of view.

Figure 4 shows the comparison to Figure 2 of the network topology between the purchase-to-pay standard process with its accepted path alternatives and the process path actually within the company.

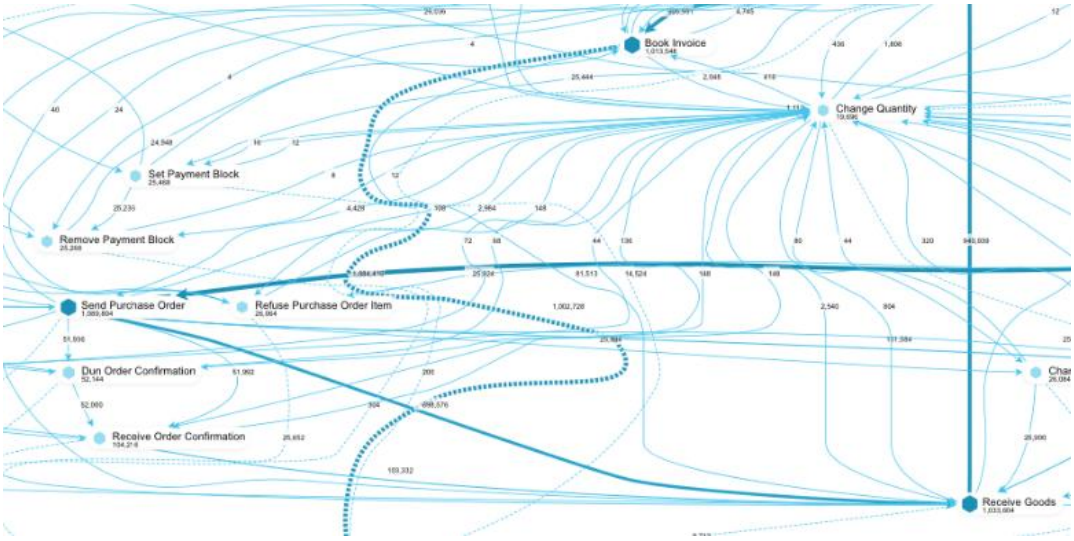

Fig.4 Real-taken process paths within purchase-to-pay process

As also the figure illustrates, we investigated a higher static complexity due to the increase of possible path alternatives. Also, a higher dynamic complexity occurred due to the taken process paths and the deviation from the standard process.

We investigated the shortest path length of the taken process path. *Dij* defines the length between one node i to another node j.

$$L = \frac{1}{N(N-1)} \sum_{i,j \in \mathcal{N}, i \neq j} d_{ij}$$

The shortest path length increased by 7-9%. This means there is a higher effort necessary to reach the process goal and confirms the increase in complexity.

By using a process mining tool process throughput times can be easily investigated. We analyzed the throughput times of the two end-to-end processes in the several taken process path variants. Apart from the standard process there were 655 alternative actions in the purchase-to-pay process of Company I and 11.421 variants in Company II, taken by the employees involved in the process. In the order-to-cash process 636 variants exist in Company I and 76 variants in Company II.

Regularly the throughput times increased when deviating from predefined standard processes. But we also identified between 10% and 20% process variants where the deviation from the standard process has led to a decrease of throughput time by 10-12%.

Further, we found that even when people deviate from predefined standard process within the process activity sequence, the start point and the process end for each taken variant was always identical. This indicates that the employees which are involved in the respective processes, actively or unconscious, take alternatives but always to reach the identical process purpose. For example in the purchase to pay process we investigated cases where the process starts directly with the order and afterwards the purchase request was placed in and approved in the system. This indicates that the employee was under time pressure to quickly receive the goods and there was no time to wait for the approval of the request.

Performance increase due to process deviation

Further, we investigated, deviations from standard processes resulting in a shorter throughput time for example due to different starting activities as predefined in the standard process or due to different process activities within the process or due to a different sequence of process steps. These were undesired process steps, but contributed to a better corporate performance.

Therefore, this is already a first indication for a necessary Business process reengineering. This implies that the really taken process path leads to a better performance result than the defined standard process. Are there undesired process alternatives which lead also to a performance decrease management should choose action alternatives to abolish this situation. In case there is a performance increase and also the process steps are desired management should proceed and maintain the current situation. Whereas a performance decrease in combination with desired process steps also indicates a necessary business process reengineering. This implies also that the predefined standard processes lead to a lower performance than the really taken process paths.

Conclusion

This paper investigated the characteristics and emergence of desired and undesired process complexity.

The presented heuristic framework illustrates the cause-and-effect-relationships between impact factors and performance effects of desired and undesired process complexity. It has been shown that an increase of process complexity and the deviation from standard process can increase performance.

First approaches have been developed to explain reasons and influencing factors of process deviations.

From a practical perspective the used data analytics methodology of the process mining tool shows how current data analytics tool can be used in practice and help to analyze big volumes of process data and identify really taken process paths within a

company's business. Further we gave advice for management to choose the correct action alternative based on the level of desired complexity and the performance impact.

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A pull approach to performance measurement systems design

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Abstract

The literature covering the design of performance measurement systems (PMS) is extensive. Empirically based cases showing how to identify and present the information to support decision-making in the best way is however not as commonly described. The purpose of this article is therefore to close this gap and to propose a novel methodology, the Pull approach, for designing performance measurements. It will provide a description of the Pull approach, position it into context in the literature and exemplify how the methodology could be used by presenting industrial case studies.

Keywords: Operations strategy, performance management, KPI

Introduction

The upbringing of this paper was an industrial need to design more effective performance measures. Measures that really measure the right things, resulting in information that is needed for decision making on all organizational levels. The literature covering the design of performance measurement systems is extensive. However, how to identify and present the information to support decision-making in the best way is not as commonly described. The purpose of this article is therefore to close this gap and to propose a novel methodology for designing performance measurement or indicators.

This article will provide a description of the Pull approach, compare it to similar or alternative approaches in the literature, and illustrate how the methodology is used through a number of industrial cases. Finally, reflections and conclusions will be done as well as a description of planned future research.

Methodology

There are several performance measurement system (PMS) design methods presented in the literature. A literature review of methods for PMS design was carried out, with the purpose to position the Pull approach in comparison to alternative methods.

Further was case study methodology used to structure and carry out the industrial case studies. Three different cases from the same industrial company are presented in this article. The cases illustrate and evaluate the use of the same methodology for different kind of performance measures and at different hierarchical levels. Case A was the first case, conducted during a welding line installation. In Case B the methodology was used in a project implementing an equipment scanning weld quality. In Case C the methodology was instead used to identify cost of poor quality measures.

The Pull approach workshop has elements of action research. However, the social context is limited to one company and the democratic aspects that, while being important to create a good work environment, are limited by the organization of the company.

Literature review

The literature covering performance measurement systems and their design are extensive. Yadar and Sagar (2013) describe the historical development of performance measurement and management (PMM) frameworks, focusing on the years 1991-2011. In the first half integrated and balanced PMM systems were developed, such as balanced score card (Kaplan and Norton, 1992). In the second half more dynamic multi-stakeholders perspective have been more in focus e.g. the Performance Prism (Neely et al, 2001). Yadar and Sagar (2013) emphasize the need of validating frameworks empirically and to apply it in a practical context. They further state that there is a limited mechanism available to help transform information into value-adding activities. Ravelomanantsoa et al (2018) present a state of the art of different approaches for performance measurement systems design. The approaches are compared based on their characteristics of being recommendations, structural architectures, procedural architectures, generic performance indicators, methodological support tools or reference models. They state that a complete methodology cannot stop at the PMS design but must be implemented in the company information system. They identify a gap in this area since only a few approaches take this step into account.

Ravelomanantsoa et al (2018) also point out that none of the approaches take the form of the performance indicator into account. They thereby identify another gap regarding data visualization and the influence the cognitive impact might have on the decision-making.

When it comes to the design of a PMS it is important to not start by asking “What should we measure?” (Neely and Bourne, 2000). Before the PMS can be designed, the levers that different stakeholders can pull in order to achieve the organizational goals must be identified as well as the cause and effect relations between these lavers. Then the right performance measures (PMs) can be designed based on the understanding of the priorities of the organization and the actions needed to achieve the goals. For the design of individual PMs several authors recommend using the performance measurement record sheet developed by Neely et al. (1997) which consists of 10 elements that needs to be addressed for each PM. However, the gap regarding data visualization identified by Ravelomanantsoa et al (2018) can also be found in this framework since none of the elements are addressing the presentation of data.

Boyer and McDermott (1999) define strategic consensus as the level of agreement within an organization regarding the relative importance of cost, quality, delivery and flexibility to the organization’s operational goals, as well as the relationships between

these competitive priorities and operational policies. Their case studies revealed that operators and managers in the same firms exhibited significant inconsistencies in their manufacturing priorities, indicating a lack of strategic consensus. That is also in line with Marinho and Cagnin (2014) who show that in practice the notion of stakeholder involvement, mutual experimentation and learning, and of a common vision is still neglected. Further Goh (2012) identifies stakeholder involvement and engagement in the process of an effective public sector performance measurement system as one of the key factors. A Pull approach can be one way to facilitate the discussions necessary to enable this stakeholder involvement and strategic consensus.

Pull approach description

Given the theoretical arguments previously described, regarding the need of empirical studies as well as strategic consensus, visualization and stakeholder involvement, the remainder of this paper will be devoted to the Pull approach. The background of the methodology is an industrial need to design more effective PMs. The Pull approach is summarized in Figure 1. The Pull approach emphasizes a collaborative attitude and is preferable done as a workshop. When deciding on participants in the workshop, the aim should be cross functionality since it will bring knowledge both from push and pull perspectives.

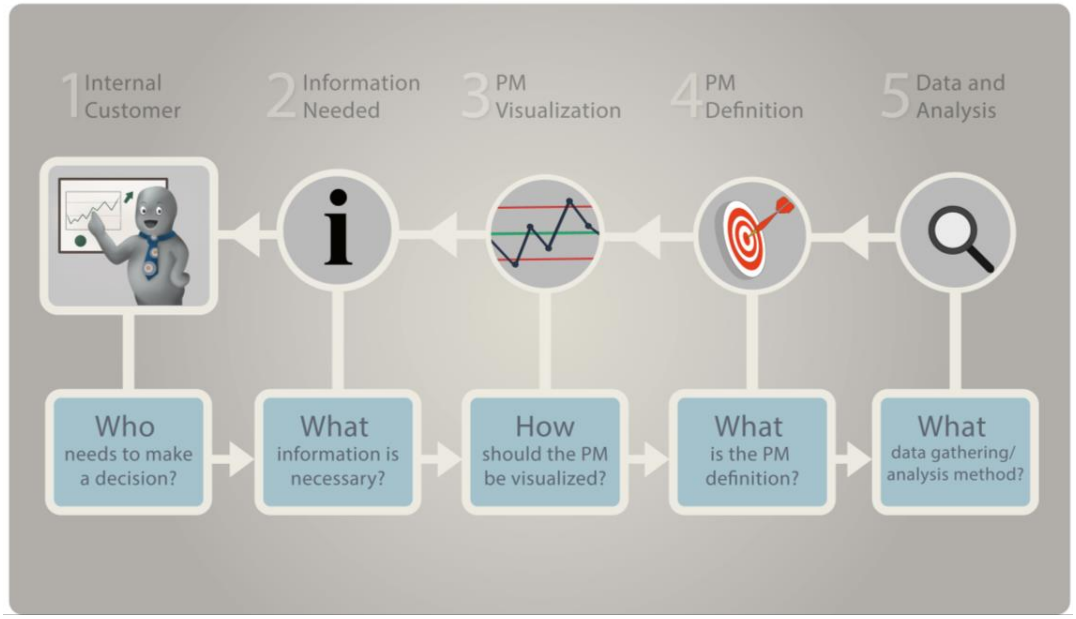

Figure 1- Illustration of the Pull approach used in the case studies.

The Pull approach was originally designed as an alternative to the technology push that the industrial researcher saw in her organization. The performance measures were designed based on the available measurement technology, not based on an actual need for certain information to make important decisions. The Pull approach turned around that logic and instead promoted the organization to start with identification of the stakeholders, the internal customer of information (Ericson Öberg, 2016). That can be compared with the explanation by Martin (1994) where technology push is mainly driven by internal research and development activities and market pull is driven by external market forces (that in this case would represent the stakeholders).

The first step is to identify who needs to make a decision, since the performance indicators or information should assist in the decision-making. The next step is to decide what information is necessary for that decision-maker and how it should be presented to convey the information in the best way. When this is clear it is time to define in detail what properties to measure and their definition. Finally, the requirements on data gathering and analysis method can be defined, e.g. level of automation. When those steps have been conducted for all internal customers it is easy to see what is in place and where there are any gaps. The gaps can be compiled into an action list with responsible persons and dates.

The first applications concerned measures for assessing welding quality in a heavy machinery industry. The industry-employed researcher that developed the methodology realized that the same way of working can be applied for different kind of performance indicators and at different organizational levels. This idea was developed as part of the researcher's PhD thesis (Ericson Öberg, 2016) and it was included in a handbook for designing, implementing, using and revising performance measurement systems (Almström et al, 2017). However, the methodology, the "Pull approach" was not detailed nor put in a perspective of similar approaches to design performance measures, in the handbook or in the PhD thesis. That omission became apparent when the same constellation of researchers that wrote the handbook, wanted to use the methodology in a new research project "SMART PM". There was no comprehensive method description that any of the researchers could use to help the participating industrial companies to focus on the right performance indicators.

Initially the Pull approach was inspired by SIPOC, which is a tool commonly used in Total Quality Management (TQM) and Six Sigma projects to create a high level process map. The elements are suppliers, inputs, process, outputs and customers (Brook, 2010 and Parkash and Kaushik, 2011). The mapping is often done following the material or information flow starting with supplier, but it can also be more lean influenced with a pull approach with the reversed order (Guerorguiev, 2018) or starting with the output (Silverstein et al, 2017). In the Pull approach, the reverse order is used, starting with the information customer, the stakeholder.

Empirical findings

Case A – welding line installation

Case A was the first time the methodology was used. During the workshop conducted by four people, 10 internal customers were identified with more than 60 information need items, see Figure 2 below. The four people attending were industrial the Phd student, the welding specialist, and two manufacturing project managers. Several improvements of the methodology were identified e.g. to limit the scope and include more participants in the workshop.

Figure 2 - Post-its were used in the workshop to capture input from the participants.

Case B – scanning of welds

In this case, scanning of welds showed in Figure 3, six internal customers of information were identified. It resulted in several defined information needs, ranging from preferred parameter settings to improvement project comparisons. One learning was to involve the managers with the budget responsibility for the area, in order to enable the implementation of identified gaps.

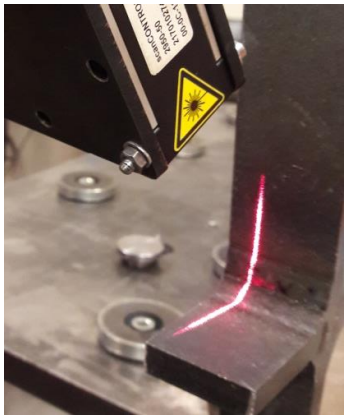

Figure 3 - Scanning of welds to assess quality.

Case C – cost of poor quality

This workshop regarding cost of poor quality, see Figure 4, was not done face to face but online with participants in different countries. It required more preparations in terms of describing the inputs as well as compiling the results. Six internal customers where identified. A conclusion from the workshop was that the same definition and data gathering could be used for several different information needs.

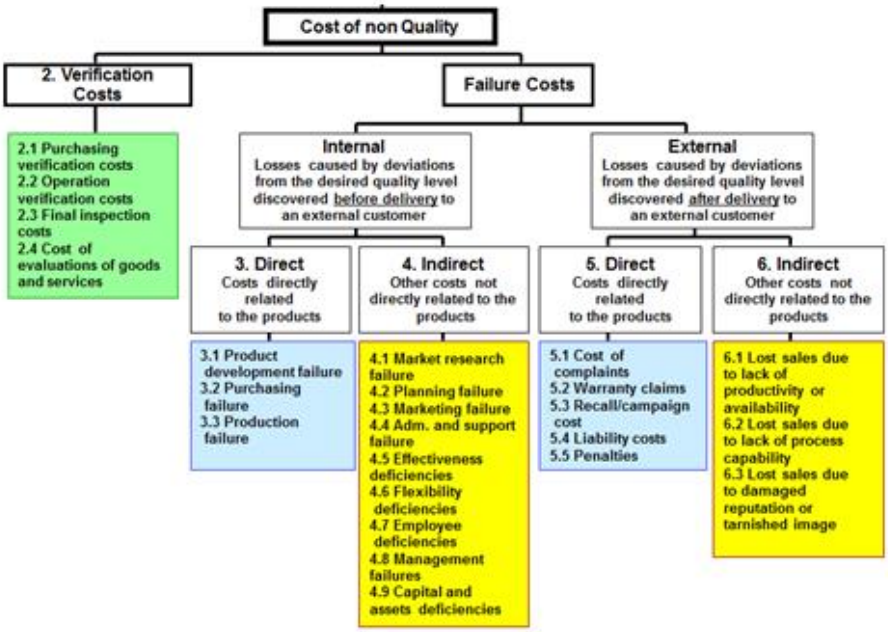

Figure 4 – Cost of Poor Quality items.

How to carry out a Pull workshop

Based on the experiences from the cases a standard procedure has been formulated to be used primarily for our need in the research project SMART PM that involves manufacturing companies of different sizes. However, the workshop is designed to be of use in different contexts and the procedure and the following instructions can easily be adapted as needed.

Preparation for the workshop

Before the actual workshop is carried out, the company needs to identify an area or section in the workshop that will be focused. Next step is to, for the chosen area, define which problem that needs to be solved. Which strategic or operational decision-making needs improvement? What are the current and desired modes? The next preparation step is to decide which stakeholders that should participate. The recommendation is that at least one person from the following functions is to be included:

- Supervisor
- Operator
- Production engineer
- Maintenance

Depending on the problem that needs to be solved or which improvement needs to be implemented, for example representatives from planning, logistics, finance, quality and environment could also participate.

In the SMART PM project, the workshop is led by one or more of the participating researchers and is conducted for at least two hours. If the company wants to use the methodology, the workshop can be led by the problem owner. The time spent depends on how many stakeholders' information need are discussed.

Implementation of the workshop

During the actual workshop, the following steps are carried out:

1. Start by briefly discussing the topic, so that all stakeholders have a common picture of what the problem is or what should be achieved. (about 5 min)
2. Identify who needs to make a decision related to the identified topic, because the information that is needed is developed to support the decision. This step provides a list of internal stakeholders. (about 5 min)
3. Identify the information needed to make the decision. Review all stakeholders' information needs to provide a complete picture of the needs. (about 5 min per stakeholder)
4. Decide on how, how often and when the information should be presented to different stakeholders. Do this for each identified information. (about 5 min per information)
5. When this is clear, it is time to define in detail which parameters / PMs are to be measured and how to define them. (about 5 min per information)
6. Finally, the measurement and analysis method can be defined. How should the information be collected? What equipment is needed to collect the information? Can the information collection be automatic? Make an analysis for each measurement. (about 5 min per information)
7. Compile which actions need to be performed, by whom and at what time, to accomplish the identified change to move from current to desired mode. (about 1 hour)

The time required to complete the workshop depends on how many stakeholders participate and how complex the problem or improvement is (how much information needs to be collected and visualized). A guiding estimation is that it takes 3 hours to complete the workshop.

Expected results

After the workshop we expect to have:

- A clear picture of what is to be achieved
- A case study description with a relatively detailed plan for implementation
- A method that can be used for structured work with information management for decision-making.

Discussion

A lot of the performance measurement system design models described in theory are conceptual and on a high level. As pointed out in literature there is a need for methods supporting the implementation of getting the measurement a part of the company's information system. The Pull approach is a hands-on method that is ready to be used by people involved in performance measurement design in industry. It suits best as a methodological support tool, where also e.g. Six Sigma belongs according to Ravelomanantsoa (2018).

This article contributes to the operations management theory by providing examples and illustrations of established performance measurement theory through the industrial case studies. It further contributes to the industry through the success stories that these cases illustrate. That is also in line with the desire for strategic consensus through collaborative design which cannot be achieved if functions address issues separately. The result in itself is not always the important part but the process to achieve it. The involvement of the stakeholders in the process not only make them reflect upon their own information need, but also give an increased understanding of other stakeholders´ situations.

The initial case studies demonstrated that the Pull approach has the potential to be

suitable for different types of problems and PMs. That flexibility is necessary since organizations will face increased speed of change in information needs for different stakeholders. Further studies and analyses of cases from different companies and contexts are however necessary, which is already planned in the SMART PM project.

Conclusion

Even though the area of performance measurement systems design is well covered in the literature, some important gaps still exist to explore. This paper proposes a novel methodology, the Pull approach, for designing performance measurements to identify and present the information to support decision-making in the best way.

The Pull approach will be further used in the research project SMART PM where the focus is on digitalization of the use phase (measure, analyze, report, and make decisions). Several companies of varying sizes and industry areas will participate to make it possible to analyze the Pull approach's suitability in different contexts.

Acknowledgement

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The role of performance management practices in gaining preferred customer status

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Abstract

Prior research has not adequately examined performance measurement and management practices driving supplier satisfaction and performance. By using survey data (482 supplier responses), this study finds that supplier evaluations do not directly improve supplier satisfaction nor performance but their effect is mediated by collaborative performance management. This study contributes to the literature by examining the outcomes of performance measurement in an inter-organizational setting; highlighting the perspective of a supplier and non-financial performance information; and by presenting performance measurement and management practices in a supplier-buyer relationship as new antecedents for supplier satisfaction. Future research avenues are proposed.

Keywords: Performance management, Purchasing and supply management, Supplier satisfaction

Introduction

Buyer-supplier relationships have been a widespread theme for both researchers and practitioners in the past decades. Information sharing in supply chains and business relationships has likewise gained a lot of attention and its benefits are widely acknowledged (Cheng et al., 2011). However, the outcomes of information sharing depend on "what information is shared, how and with whom" (Li and Lin, 2006). Existing studies on buyer-supplier relationships often highlight the benefits of close supplier collaboration (Lambert et al., 2004) but more focused studies are needed providing an understanding of the actual practices applied in these relationships. *The aim of this study is to analyze the role of performance measurement and management practices of a buyer-supplier relationship in improving supplier performance and supplier satisfaction.*

Until very recently, most studies on performance measurement and its outcomes have concentrated on intra-organizational performance instead of inter-organizational relationships. Earlier studies indicate that inter-organizational setting affects performance measurement and its outcomes (e.g., Cousins et al., 2008; Jääskeläinen, 2018) but there are only limited empirical evidence until now. Moreover, there has been a call for studies that address the phenomenon of collaborative performance measurement from the

viewpoint of actual performance outcomes of interfirm relationships (Dekker et al., 2016). In this study, the interest is in collaborative performance management, which is studied as a mediator for the benefits supplier evaluation and performance information sharing.

Trust is typically seen as an enabler of communication and interaction between actors (e.g., Ireland and Webb, 2007). In any case, the role of trust cannot be ignored when close relationships between companies are studied. While there are not many studies explicitly studying trust and performance management, several studies have been carried out on the relationship between trust and management control mechanisms (Caglio and Ditillo, 2008; Velez et al, 2008). The results are unclear and conflicting (Velez et al., 2008). Some studies find trust as complementary to formal control mechanisms (such as performance measurement) while others indicate substitutive relationship between formal controls and trust (e.g., Caglio and Ditillo, 2008).

Supplier satisfaction is important for buyers since satisfied customers more probably invest in their customer relationships. More studies on the antecedents of supplier satisfaction in cross-industrial settings have been called for (Pulles et al., 2016). Altogether, *there seems to be a gap of studies investigating trust, and performance measurement and management practices driving supplier satisfaction*. This study intends to fill this gap.

Hypotheses formulation

With the performance of a wider supply chain rather than a single firm in mind (Maestrini et al., 2017), *trust* plays a significant role in open information sharing (e.g., Ireland and Webb, 2007; Narasimhan and Nair, 2005). Mutual trust has been identified as crucial in inter-organizational use of accounting information (e.g., Kajüter and Kulmala, 2005) and performance information sharing (Mouritsen et al., 2001). Trust reduces the fear of exposing confidential information and loss of power when sharing information (e.g., Li and Lin, 2006). Indeed, in this study, a supplier's trust is linked to the supplier's willingness to share performance information with a buyer. The following hypotheses is formulated:

> *H1 The presence of a supplier's trust in a buyer-supplier relationship is positively related to the sharing of performance information in the relationship.*

Trust supports long-term collaborative relationships between supply chain partners (Spekman et al., 1998). Collaboration in performance management benefits from trust (Velez et al., 2008). Trust is supportive to mutual goal setting (e.g., Spekman et al., 1998) and a predictor of collaborative behavior between business partners (Ring and Van de Ven, 1994). Based on the indications of earlier studies, this study suggests that supplier's trust is supportive to collaborative performance management in business relationships. Consequently, the following hypothesis is posed:

> *H2 The presence of a supplier's trust in a buyer-supplier relationship is positively related to the existence of collaborative performance management.*

Supplier performance measurement can align goals and priorities in the supplier-buyer relationship (e.g., Danese and Romano, 2012). A link between the use of supplier performance measurement and collaboration (e.g. joint problem solving) between buyer and supplier has been identified (Mahama, 2006). Collaborative relationships can specifically benefit from effective supplier evaluation (Cousins et al., 2008). In turn, the deficiencies in the performance measures and accounting practices may inhibit their use in inter-organizational collaboration (e.g., Busi and Bititci, 2006; Caglio and Ditillo, 2008). Transparency of supplier evaluation criteria and results reflecting mature practices

is an antecedent of the benefits, since these support the supplier in understanding customer expectations (Prahinski and Fan, 2007).The following hypothesis is presented:

H3a Mature supplier evaluation practices are positively related to collaborative performance management.

Supplier evaluation may improve the performance of suppliers (Hald and Ellegaard, 2011; Prahinski and Benton, 2004). Lack of supplier evaluation may lead to opportunistic behavior and deviation from collaboration (Danese and Romano, 2011). The benefits are dependent on the communication of supplier evaluation results (Sundtoft and Ellegaard, 2011). Consequently we hypothesize:

H3b Mature supplier evaluation practices are positively related to supplier performance.

Supplier evaluations can have a positive impact on the quality of the supplier-buyer relationship (e.g., Cousins et al., 2008; Mahama, 2006). Supplier evaluations can be seen as an example of mature supplier relationship management practices of a buyer. Earlier research suggests that the maturity of a buyer's supplier relationship management practices can have a positive impact on how a supplier perceives the status of its customer (Bemelmans et al., 2015). We hypothesize:

H3c Mature supplier evaluation practices are positively related to supplier satisfaction.

Collaborative performance management requires that supply chain members have common and agreed targets for performance (Marchand and Raymond 2008) and share performance information (Busi and Bititci, 2006). Prior research posits that with firms engaged in collaborative performance management, collaborative goals between these firms cause a demand for information sharing between them (Dekker et al., 2016). Disclosing cost information between organizations may relieve the tension in negotiations and increase trust and commitment to a long-term relationship (e.g., Bastl et al., 2010). We hypothesize:

H4a Performance information sharing in a business relationship is positively related to collaborative performance management.

As supplier development aims to increase supplier performance, firms successful in supplier development share information with their suppliers (Carr and Kaynak, 2007). In addition to sharing information from a customer to a supplier, also information sharing from a supplier to a customer may be important in influencing supplier performance (Zhou and Benton, 2007) and eventually supplier performance as well (e.g., Prajogo and Olhager, 2012). Inter-organizational accounting information can reduce the costs of inter-organizational processes (Bastl et al., 2010). In turn, isolation of demand and supply processes may result in mismatches (Esper et al., 2010). Hence, we hypothesize:

H4b Performance information sharing in a business relationship is positively related to supplier performance.

Even though prior research seems a bit inconclusive about whether information sharing between supply chain members leads to higher supplier performance (Pooe et al., 2015), some studies conclude more widely that information sharing leads to higher satisfaction in the supply relationships (e.g., Nyaga et al., 2010; Kembro and Näslund, 2014). Supplier satisfaction is driven by the operative practices of a business relationship, such as a communication (Hüttinger et al., 2014). We hypothesize:

H4c Performance information sharing in a business relationship is positively related to supplier satisfaction.

Collaboration (e.g. joint problem solving) between companies has a positive impact on performance in supply chains (e.g., Mahama, 2006). Earlier literature shows that supplier's commitment is needed for supplier development to increase supplier

performance (Prahinski and Benton, 2004). Mutual commitment is a key embodiment of collaborative performance management (cf., Ferreira et al., 2012). Therefore, we hypothesize:

H5a Collaborative performance management is positively related to supplier performance.

While earlier research has indicated that collaborative relationships and activities increase buyer's satisfaction (Nyaga et al., 2010; Whipple et al., 2010), research has also found that collaborative relationships (Forker and Stannack, 2000), relational behavior (Hüttinger et al., 2014) and intensity of collaboration (Essig and Amann, 2009) positively affect supplier satisfaction (Hüttinger et al., 2014). Thus, we hypothesize:

H5b Collaborative performance management is positively related to supplier satisfaction

Figure 1 presents the research framework and hypotheses. The main antecedents of the model are buyers' supplier evaluation practices, performance information sharing in the relationship and supplier's trust. Collaborative performance management (joint approach for setting targets and reviewing performance in a business relationship) is used as a mediator in the model explaining both supplier performance and supplier satisfaction. This study also utilizes control variables: key supplier status (defined by buyer), company size, service-orientation of a supplier and relationship length.

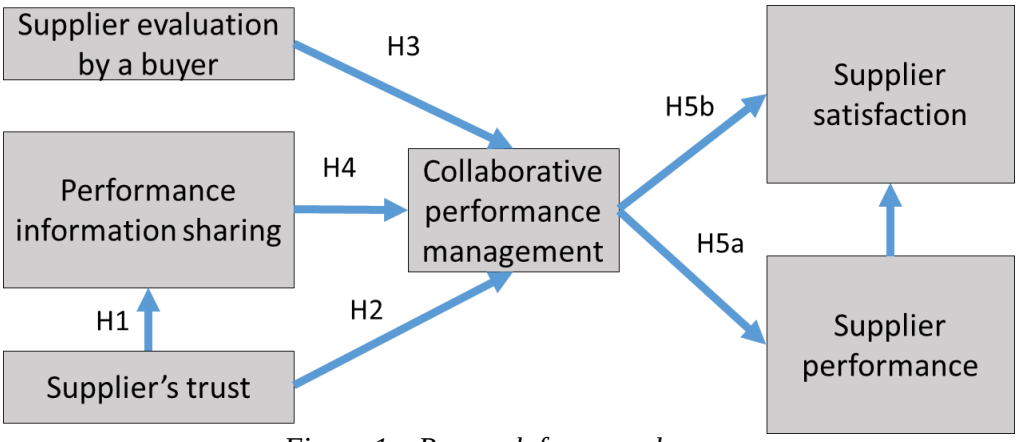

Figure 1 – Research framework

Methodology

Empirical data

The survey was sent to the suppliers of four buyer companies. The unit of analysis is the supplier-buyer relationship between the respondent's company and one of the buyer companies. The buyer companies are large Finnish companies operating in business-to-business markets. Two companies are manufacturing (machinery industry and equipment) and the two others are service industries (information and communications technology, ICT). The industries were selected to achieve variation in several contextual settings, including both service and manufacturing companies.

The questionnaire comprised 30 items measured with a 7-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. The measurement scales of studied variables were designed based on existing literature. The survey was tested with the intended population and fellow researchers, which led to minor changes in the phrasing of the questions to avoid confusions and to assure that the intended respondent understand the statements correctly. Some changes were also made to the order of the questions used in the survey. The items of the survey can be requested from the authors.

The respondents had access to the web-based questionnaire for three weeks, and two reminder messages were emailed to the respondents. Non-response bias was tested by dividing the responses into the following three groups: initial invitation, first reminder, and second reminder. T-test between the groups for the main constructs of this study revealed no statistically significant differences, indicating that non-response bias is not a problem in the study.

The survey was sent to a total of 1,840 suppliers in the autumn 2018. A total of 482 usable responses were received, meaning a response rate of 26.5%. The respondents were the suppliers' contact persons (key account managers, CEOs and senior managers) for their relationship with the specific customer and thereby well-informed regarding the particular customer relationships.

The size of the supplier companies was rather evenly distributed varying from companies with annual revenue of around 2M€ to companies with more than 500M€ revenue, and the companies had typically long relationships with their customers (more than 10 years). Slightly less than one third of the suppliers had obtained key supplier status according to their customer. Majority of the suppliers (70%) were direct suppliers.

Analysis methods

The survey data was analyzed by using IBM SPSS Statistics 24 and SmartPLS 3.0. PLS-SEM is a component-based estimation method that maximizes the amount of variance explained and does not assume data distributions. PLS-SEM is particularly useful when the research focuses on prediction and explaining the variance of key target constructs (Reinartz et al., 2009). We applied PLS-SEM for the following reasons. First, it is useful for testing predictive models with latent variables when the theory is less developed, and the purpose is in theory development instead of theory testing, such as in the case of our study (Hair et al., 2014). Second, PLS-SEM is a suitable choice when the investigated model is complex. Third, PLS-SEM can be used when the variables are non-normally distributed. A bootstrapping procedure with 5,000 rounds was used in the analysis.

The number of missing values varied between 0-5%. Casewise (listwise) deletion was applied by reducing the sample size to 359. Harman's single factor test revealed that no single factor was accountable for the majority of variance in the data indicating that common method bias is not likely a problem in our study.

This study utilized reflective constructs whose internal consistency and reliability were examined by using composite reliability (CR) (Fornell and Larcker, 1981), average variance extracted (AVE) and factor loadings (e.g., Hair et al., 2014). The Composite Reliability (CR) varied between 0.885 and 0.954, exceeding Nunnally's (1978) threshold of 0.7. The values for AVE varied between 0.53 and 0.919, exceeding the 0.50 cut-off (Fornell and Larcker, 1981). All the Cronbach alphas were higher than 0.7, as suggested by Hair et al. (2014). Most of the survey items had outer loadings higher than the 0.7 threshold (Henseler et al., 2009). Two items with a loading higher than 0.6 was utilized in the study. When using the threshold of 0.2 was used for investigating cross-loadings between the items, no cross-loadings were found. The squared correlations between the pairs of constructs is always lower than the AVE for each individual construct indicating satisfactory discriminant validity (Fornell and Larcker, 1981).

Multicollinearity was tested by using the variance inflation factor (VIF). The outer VIF values varied between 1.6 and 6.8, which is well below the cut-off level of 10, often considered as an indicator of serious multicollinearity (Duzann and Shariff, 2015). The effect size (F^2) of the relative impact of a specific exogenous latent variable on an endogenous latent variable was examined with Cohen's test. The test for the predictive

relevance of the model was carried out by applying Q^2 statistics through the cross-validated redundancy approach (Hair et al., 2014).

Results

Tables 1-4 present the results for the hypotheses of this study. Table 1 shows that supplier's trust has a strong positive effect (β=0.475, $p < 0.001$) on the supplier's perception of performance information sharing in the relationship. F^2 for the effect size is medium. None of the control variables seems to have an effect on performance information sharing in the relationship.

Table 1 Antecedents of performance information sharing

Antecedent	**PLS SEM analysis results**				
	β	**VIF**	**t-value**	**Significance (p-value)**	**F^2**
Supplier's trust	0.475	1.031	11.643	p <0.001	0.285
Key supplier status	0.071	1.043	1.505	0.132 (n.s.)	0.006
Relationship length	-0.065	1.045	1.231	0.218 (n.s.)	0.005
Large company size	0.032	1.058	0.764	0.446 (n.s.)	0.001
Service-orientation of a supplier	-0.016	1.055	0.356	0.722 (n.s.)	0.000
R^2	0.233				
R^2adj	0.223				
Q^2	0.136				

As hypothesized, supplier's trust has a positive relationship with collaborative performance management (β=0.259, $p < 0.001$) (Table 2). The effect size for this path is small. Also supplier evaluation practices are positively related to the collaborative performance management (β=0.350, $p < 0.001$) with medium effect size. In addition, performance information sharing is positively associated with collaborative performance management (β=0.243, $p < 0.001$). Effect size for this path is small. None of the control variables has a significant effect on collaborative performance management.

Table 2 Antecedents of collaborative performance management

Antecedent	**PLS SEM analysis results**				
	β	**VIF**	**t-value**	**Significance (p-value)**	**F^2**
Supplier's trust	0.259	1.465	4.983	p < 0.001	0.092
Supplier evaluation	0.350	1.682	5.873	p < 0.001	0.146
Performance information sharing	0.243	1.649	4.291	p < 0.001	0.072
Key supplier status	0.066	1.050	1.723	0.085 (n.s.)	0.008
Relationship length	0.030	1.054	0.908	0.364 (n.s.)	0.002
Large company size	0.060	1.060	1.667	0.096 (n.s.)	0.007
Service-orientation of a supplier	0.075	1.055	1.944	0.052 (n.s.)	0.011
R^2	0.501				
R^2adj	0.491				
Q^2	0.350				

Table 3 presents the results on the drivers of supplier performance. It can be seen that the levels of performance information sharing (β=0.246, $p < 0.001$) and collaborative performance management (β=0.274, $p < 0.001$) are positively related to a supplier's performance. The effect sizes for both of these paths are small. The hypothesis suggesting

direct link between supplier evaluation practices and supplier performance is not supported. Large company size seems to be slightly associated with higher supplier performance (β=0.078, p < 0.05) but the other control variables have no statistically significant effect on the results.

Table 3 Antecedents of supplier performance

Antecedent	**PLS SEM analysis results**				
	β	**VIF**	**t-value**	**Significance (p-value)**	**F^2**
Supplier evaluation	-0.008	1.871	1.458	0.145 (n.s.)	0.005
Performance information sharing	0.246	1.720	3.925	p < 0.001	0.044
Collaborative performance management	0.274	1.835	3.719	p < 0.001	0.050
Key supplier status	0.009	1.050	0.168	0.866 (n.s.)	0.000
Relationship length	-0.056	1.051	1.181	0.237 (n.s.)	0.004
Large company size	0.078	1.048	2.262	p < 0.05	0.007
Service-orientation of a supplier	0.089	1.060	1.806	0.071 (n.s.)	0.009
R^2	0.190				
R^2adj	0.174				
Q^2	0.079				

Table 4 presents that hypotheses regarding the links between mature supplier evaluation practices and supplier satisfaction, and performance information sharing and supplier satisfaction are not supported. In turn, collaborative performance management has a strong positive relationship (β=0.456, p < 0.001) with supplier satisfaction. The effect size for this path is medium. Large companies seem to be slightly less satisfied (β=-0.086, p < 0.05) with their customers. Other control variables do not have a significant effect.

Table 4 Antecedents of supplier satisfaction

Antecedent	**PLS SEM analysis results**				
	β	**VIF**	**t-value**	**Significance (p-value)**	**F^2**
Supplier evaluation	0.086	1.880	1.439	0.150 (n.s.)	0.007
Performance information sharing	0.094	1.795	1.738	0.082 (n.s.)	0.008
Collaborative performance management	0.456	1.928	6,416	p < 0.001	0.182
Supplier performance	0.086	1.235	1.439	0.150 (n.s.)	0.023
Key supplier status	-0.018	1.050	0.459	0.646 (n.s.)	0.001
Relationship length	0.028	1.055	0.705	0.481 (n.s.)	0.001
Large company size	-0.086	1.056	2.180	p < 0.05	0.012
Service-orientation of a supplier	-0.035	1.070	0.848	0.397 (n.s.)	0.002
R^2	0.407				
R^2adj	0.393				
Q^2	0.248				

Overall, it can be seen that the structural model explains 23% of the variation in performance information sharing, 50% of the variation in collaborative performance management, 19% of the variation in supplier performance and 41% of the variation in supplier satisfaction. Although all these numbers can be seen as satisfactory, it can be perceived that there are clearly also other explanatory factors for performance

information sharing and supplier performance, which were not included in our structural model. The tests for predictive variances suggests that the model has predictive variance varying from large (collaborative performance management) to medium (supplier satisfaction) and small (performance information sharing and supplier performance).

Discussion and conclusions

Despite the increasing amount of research on performance measurement in supply chains, empirical studies demonstrating the outcomes of performance measurement in supply chains or collaborative dyads are rare (e.g., Maestrini et al. 2017). This study presented how supplier evaluation practices and performance information sharing link to supplier satisfaction and supplier performance and how collaborative performance management mediates these outcomes. It contributes to the literature by demonstrating the importance of trust in facilitating performance management in a buyer-supplier relationship. It is known that trust affects positively the sharing of information in business relationships (e.g., Ireland and Webb, 2007; Sahay, 2003) and this study extends the same observation to the supplier's sharing of performance information. It is also known that trust supports mutual goal setting (Sahay, 2003) and collaborative behavior between business partners (Ring and Van de Ven, 1994). This study extends these findings to collaborative performance management in buyer-supplier relationships.

This study adds to the studies on the outcomes of information sharing in supply chains (e.g., Kembro and Näslund, 2014) by specifying the information shared as performance information (Kehoe and Boughton, 2001). While earlier studies has investigated the benefits inter-organizational accounting (e.g., Caglio and Ditillo, 2008), this study extends these studies by highlighting the perspective of a supplier and non-financial performance information. This study also explains some of the mixed results regarding the benefits of information sharing in supply chains (Pooe et al., 2015). It is suggested that performance information sharing may directly improve supplier performance but its effect on supplier satisfaction is mediated by collaborative performance management.

Supplier evaluations are an embodiment of mature purchasing and supply management practices and they have evidently several positive effects on buyer-supplier relationships, e.g. in the form of goal alignment (Danese and Romano, 2012) and improved communication (Sundtoft and Ellegaard, 2011). While earlier studies have identified a link between supplier evaluations and supplier performance (Hald and Ellegaard, 2011; Prahinski and Benton, 2004), this study finds that this link is indirect. Collaborative performance management practices are required in order to obtain the benefits in the form of supplier satisfaction and supplier performance. Hence, against some earlier observations, it is not yet enough to have transparent criteria for supplier evaluation (Prahinski and Fan, 2007) nor good communication practices for the results (Sundtoft and Ellegaard, 2011).

More studies on the factors affecting supplier satisfaction status have been encouraged (Hüttinger et al., 2014). This study contributes to the literature of supplier satisfaction by providing empirical evidence with a large data set in a cross-industrial setting (Pulles et al., 2016) and by presenting performance measurement and management practices in a supplier-buyer relationship as new antecedents for supplier satisfaction.

This study utilizes the responses of suppliers; a future study could increase the understanding of the impacts of performance information sharing and collaborative performance management on the buyer performance. Further studies could differentiate supplier groups, e.g. service/manufacturing suppliers, suppliers with customized/standard solutions, direct/indirect suppliers or key/non-key suppliers. Further studies could also use objective measures for supplier performance.

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Big Data Analytics in Supply Chain Performance Measurement Systems

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Abstract

Big data analytics discloses new opportunities for supply chain performance measurement systems (SCPMS). However, the potential of big data analytics in SCPMS is dispersed in the literature, and it has not been thoroughly investigated yet. This paper addresses this issue via a literature review that provides a clear understanding of the big data analytics applications in SCPMS. The obtained findings are categorized according to the dimensions of big data analytics capabilities, which affords a structured perspective of the area and provides insights for future research directions. In this sense, the achieved results are promising for both practitioners and researchers.

Keywords: Performance Measurement Systems, Supply Chain, Big Data Analytics

Introduction

Supply chains are generating a vast amount of data, used for planning and controlling purposes. The growth in the data generation is known as big data, which can be defined as "a holistic approach to manage, process and analyze 5 V's (i.e., volume, velocity, variety, veracity, and value) in order to create actionable insights for sustained value delivery, measuring performance and establishing competitive advantages" (Wamba et al., 2015). Despite its vagueness, this definition describes important characteristics, processes and potential impacts of data-driven scenarios. The use of analytics techniques in big data is called big data analytics.

Performance measurement is a process of quantifying the efficiency and effectiveness of a past or an ongoing activity (Neely et al., 1995). Performance measurement systems consist of a set of multidimensional performance measures (Bourne et al., 2003) which can support the decision-making of business activities such as planning and controlling.

With the help of big data analytics, managers can collect and analyze a large amount of heterogeneous data; consequently, they can measure and gain more insights into their businesses, which can bring improved decision-making and performance (McAfee and Brynjolfsson, 2012). Accordingly, big data analytics has the capability of improving decision-making processes by allowing better performance measurement mechanisms (Nudurupati et al., 2016).

Big data analytics enables more robust data analysis and performance calculation (Maestrini et al., 2017) which can affect the supply chain performance measurement systems (SCPMS). Data collected in real-time enables to measure performance quickly (Dweekat et al., 2017), enhancing the speed and flexibility of the data-driven decision-making (Addo-Tenkorang and Helo, 2016). As an example, Waller and Fawcett (2013) state that big data analytics enables to gather weather, traffic congestion, and driver characteristics data, allowing to calculate optimal routing which brings benefits to transportation management.

Therefore, big data analytics can give new opportunities for SCPMS. However, to the best of our knowledge, the potential of big data analytics application in SCPMS is dispersed in the literature and has not been thoroughly investigated yet. To address this gap, this paper aims to identify big data analytics applications in SCPMS. Within this context, the following research question is put forward: What are the big data analytics applications in SCPMS?

A literature review was conducted to gather scientific works dealing with big data analytics application in SCPMS. Then, the papers selected in the literature review are investigated according to the dimensions of big data analytics capabilities identified by Arunachalam et al. (2018).

This paper is organized as follows. First, the section "Research Method" presents the literature review process, including the searched database, inclusion and exclusion criteria; and the dimensions of big data analytics capabilities. Next, a theoretical background on SCPMS and big data analytics is provided. Then, the big data analytics applications in SCPMS are presented and categorized according to the dimensions of big data analytics capabilities. Finally, the paper ends presenting research limitations, outcomes of this work, and possibilities for future research.

Research Method

The authors conducted a structured literature review on the application of big data analytics in SCPMS. The adopted approach was based on the guidelines presented by vom Brocke et al. (2009). The literature review aims to support the mapping of the current understanding of big data analytics applications in the field of SCPMS and to develop the existing knowledge of the studied topics further.

The search in the database Scopus, realized in October 2018, selected papers which have the combination of search terms big data, supply chain, measure and its derivations such as measurement and measuring in the field of title, abstract and keywords. We selected the Scopus database because it is "the largest abstract and citation database of over 20,000 peer-reviewed journals", covering other databases such as Elsevier, Emerald, Taylor and Francis, and Springer (Mishra et al., 2016). Only journals, conference papers, and book chapters written in English were selected. Since big data analytics is a recent topic, no time boundary was stated for the publications. In total, the initial search resulted in 38 papers.

The authors analyzed all titles and abstracts and included papers which potentially describe the application of big data analytics in SCPMS, or the relationship between these two topics. The papers, which do not mention applications of big data analytics, or do not mention measures or measurement systems in the supply chain domain were excluded according to the exclusion criteria. Beyond the selected papers, a reference tracking called snowball (i.e., checking the references of the selected papers in a backward and forward search) resulted in the inclusion of additional papers. In the end, the total amount was 20 papers.

The findings obtained by the conducted literature review were categorized according

to the dimensions of big data analytics capabilities identified by Arunachalam et al. (2018). As a result of their study, a comprehensive systematic literature review of peer-reviewed journal papers published between 2008 and 2016, Arunachalam et al. (2018) identified five key dimensions of big data analytics capabilities, i.e., Data Generation, Data Integration and Management, Advanced Analytics, Data Visualization, and Data-Driven Culture.

Among these dimensions, Data-Driven Culture was not considered in our work. Although data-driven culture is of seminal relevance to the topic of big data analytics, particularly in the context of SCPMS, the work of Arunachalam et al. (2018) directs the focus of this dimension towards more elements such as organizational culture, political issues, people skills, and culture capability. Such a focus is, however, outside the scope of our work.

Theoretical Background

This section is divided into two parts. In the first part, we give an overview of SCPMS. In the second part, we discuss the definition of big data and big data analytics.

Supply Chain Performance Measurement Systems

A supply chain is defined as a network of organizations connected by the flow of materials, information and financial resources that are involved in the different processes and activities that produce value in the form of products and services delivered to the final customer (Christopher, 1992; Stadtler and Kilger, 2015). The relationship between companies in a supply chain contributes to the improvement of the operational performance in areas such as quality, cost, and flexibility. Supply chain management targets onto the integration of business processes ranging from the acquisition of raw material to delivery of the final product to the customer (Mentzer et al., 2001).

Performance measurement systems (PMS) consist of a set of multidimensional performance measures which can be created and used to identify whether customer needs are met where problems exist; assist companies to understand its processes; ensure decisions are based on facts, not on supposition; and show if improvements planned actually happened (Bourne et al., 2003; Gunasekaran and Kobu, 2007; Parker, 2000).

Measuring the performance of the supply chain has a broader scope of a traditional PMS, whereas SCPMS can control and monitor the performance of multiple supply chain members and not only a single company's boundaries. Thus, SCPMS becomes more challenging, since it involves the collection of data from many sources (Maestrini et al., 2017).

Therefore, the definition for SCPMS is mostly equal to the PMS definition, while adding the aspect of the supply chain environment. SCPMS can be defined as a set of carefully chosen measures related to the supply chain goals, which can be used for a stable quantification of the efficiency and effectiveness of supply chain processes and relationships that adequately reflect the current performance while revealing improvement potential towards the defined goals (Maestrini et al., 2017).

The SCPMS lifecycle usually consists of 4 phases: design, implementation, use, and review. The goal of dismantling the SCPMS into different phases is to ensure the successful adoption of such a system (Maestrini et al., 2018). According to these authors, the design phase defines the unit of analysis (e.g., supply chain processes), the extent of involvement of external members (i.e., active, passive or no involvement), and the performance measures. In the implementation phase, data collection, performance measures calculation, and reporting management occur. The use phase involves

communication and feedbacks upon performance. Finally, updating existing targets, and developing new measures are included in the review phase.

Big Data Analytics

In today's digital era, big data has become a significant topic across several organizations (Addo-Tenkorang and Helo, 2016). Many authors have defined big data in different ways, but most of them agree on similar aspects. Big data comprises characteristics like high dimensionality, numerous possible data sources, significant amounts of data that require new forms of processing which can enhance decision-making, insight discovery and process optimization (Chen and Zhang, 2014).

Five main V dimensions are mentioned in the literature, i.e., volume, variety, velocity, veracity, and value. Volume refers to the enormous amount of generated data. Variety is described as the different types of data (i.e., structured, semi-unstructured or unstructured) that could be collected from heterogeneous sources. Velocity relates to the speed with which data should be collected and analyzed in order to make accurate decisions. Veracity means which extend data can be trusted. Finally, value should be the outcome of the data analysis and which should also lead to achieve business advantages (Demchenko et al., 2013; Hu et al., 2014).

The combination of big data and analytics - big data analytics - allows to get meaningful insights, turn data into valuable information, and make the decision-making process more efficient (Demirkan and Delen, 2013; Sanders, 2016). Big data analytics is a research area which can provide numerous opportunities for academic and management practitioners (Wamba et al., 2018).

Three types of analytics can be distinguished: descriptive, predictive and prescriptive. Descriptive analytics involves the description of current and past situations, aiming to identify problems or opportunities and verify what happened in the business. Predictive analytics uses data to predict what will happen in the future or to advance future hypotheses. Prescriptive analytics informs what to do, and uses models to specify optimal behaviors and actions. It can also propose strategic solutions based on analyses (Davenport, 2013; Gravili et al., 2018; Wang et al., 2016).

In the supply chain context, big data analytics can provide valuable insights for decision makers, leading to a multitude of benefits that can bring competitive advantage (Wamba et al., 2015). Some benefits are related to enhancing the speed and flexibility of making decisions, which can be more data-oriented. The real-time data streams can improve the decision response time (Addo-Tenkorang and Helo, 2016; Brinch, 2016; Tiwari et al., 2018). Additionally, big data analytics can be used to optimize transportation, identify optimal distribution center locations and delivery routes, therefore, minimize costs, improve productivity and inventory management, and optimize of stock levels (Sanders, 2016).

Findings: Big data analytics in SCPMS

This section presents a detailed summary of the finding obtained by the conducted literature review. As described in the section Research Method, the dimensions of big data analytics capabilities identified by Arunachalam et al. (2018) were employed here to categorize the findings.

Data Generation

In the implementation phase of SCPMS, performance-relevant data need to be effectively collected (Dweekat et al., 2017). Big data analytics advances opportunities for external data collection which can be collected across different supply chain members

and at different levels stemming from heterogeneous sources and different types of data (i.e., structured, semi-unstructured or unstructured) (Ramakrishnan and Ma, 2018; Vassakis et al., 2018). Mobile devices are an example of a data source, which can enable companies to measure more accurately (Vassakis et al., 2018).

Nudurupati et al. (2016) conducted a case study and found that big data analytics can make it possible to have new measures. As an example of new measures determined using a big data source, Bertolini et al. (2017) presented and validated several Radio Frequency Identification (RFID)-based measures, which can only be calculated via RFID, i.e., it was not possible to have these measures without RFID.

As another example of the big data analytics benefit to SCPMS, it can help track and analyze employee performance measures allowing the identification of top performers and unsatisfied workers. With the use of big data analytics for this measure, companies can see real-time data rather than annual reviews which are sometimes based on human memory (Tiwari et al., 2018). Additionally, the use of real-time data to measure the managerial activities performance can bring benefits to companies by permitting them to respond quickly to competitors (Vera-Baquero et al., 2015).

It is worth nothing, in the SCPMS design phase, before collecting the data used for the performance measures, it is necessary to define the objective of the measurement process, and what should be measured (Bourne et al., 2000). Companies need to concentrate on measuring what brings benefits to competitive priorities, customer service, and firm profitability (Sanders, 2014). Besides that, measuring supply chain performance should be context specific; thus, performance measures differ in different circumstances (Mishra et al., 2018).

Data Integration and Management

The Data Integration and Management dimension includes elements such as data governance; data integration; and data quality, characterizing the ability of companies to use techniques to integrate, transform, and store data from heterogeneous data sources (Arunachalam et al., 2018).

As already mentioned, data can come from various supply chain members containing different types of data with different structures; for this reason, the integration of all gathered data is very relevant to the performance measurement. However, data integration from multiple companies is a challenge in SCPMS (Maestrini et al., 2017). Besides the difficulty of integrating data from different sources, the challenge arises as a result of companies which abstain from sharing data among the members of the chain since data usually represents a valuable asset that could give a competitive advantage (Arunachalam et al., 2018).

One critical element big data analytics application in SCPMS is data quality. Poor data quality can negatively affect the decision-making in the supply chain and its performance (Arunachalam et al., 2018; Hazen et al., 2014). Therefore, it is suggested to use methods like statistical process control to monitor, control, and improve the data quality (Hazen et al., 2014).

Before the introduction of the next dimension, it is relevant to understand that big data analytics is performed through two kinds of processing approaches, real-time processing and batch processing (Arunachalam et al., 2018; Hu et al., 2014). The main difference between them is that in the batch model the data is first stored and then analyzed, whereas, in the real-time approach, the data is analyzed as soon it arrives. As it could be inferred, these two approaches also lead to architectural differences. For instance, batch processing architectures require large and complex storage systems, and stream processing architectures demand high-performance processing systems (Hu et al., 2014).

Advanced Analytics

Advanced Analytics dimension encompasses elements to process data and extract value. Analytics include applications that support decision-making allowing managers to make better decisions (Gravili et al., 2018).

In order to conduct different types of analytics (i.e., descriptive, predictive, and prescriptive), companies need advanced analytic techniques which can turn the large volume of heterogeneous data into significant insights (Gravili et al., 2018).

Analytic techniques comprise several techniques like time series analysis and forecasting used to extract meaningful patterns and predicts the future based on historical data (Wang et al., 2016), cluster analysis, Bayesian classification, decision tree, artificial neural networks, support vector machine (Kitchin, 2014), logistic regression, and random forests (Rozados and Tjahjono, 2014). Those techniques can be used to calculate the supply chain performance measures.

Data Visualization

Data Visualization dimension is related to the visualization of performance measures utilizing dashboards and reports. Chen and Zhang (2014) explain that this category entails a huge significance for big data analytics since it should represent the results clearly enough to extract the hidden knowledge of the data. In this dimension, organizations use different tools to set and visualize the results easily and deliver them adequately and timely to make decisions (Arunachalam et al., 2018). In the context of SCPMS, the results are the performance measures, which can be related to different supply chain activities (e.g., strategic, tactical, operational) and processes (e.g., plan, source, make, and deliver) (Gunasekaran et al., 2004).

The reports and dashboards should be produced according to the needs of each company or each area in terms of content, frequency, and transparency (Maestrini et al., 2018). Therefore, big data analytics can provide support regarding data reliability, timeliness, and task automation. Arunachalam et al. (2018) mention some benefits included in the Data Visualization dimension such as monitoring future demand, visualizing delivery routes, and tracking material. This dimension, as well as Data Integration and Management, and Advanced Analytics are part of the SCPMS implementation phase.

As part of the SCPMS phases use and review, there are benefits which can be obtained using SCPMS. The SCPMS support continuous improvement, decision-making, and behavior change, control supply chain strategy, facilitate a transparent communication between people, and improve organizational performance (Gunasekaran et al., 2004; Maestrini et al., 2017; Sanders, 2016).

Franco-Santos et al. (2007) identify different roles for performance measurement systems like strategy management and learning. Just like any other performance measurement systems, these roles are the same in the supply chain context. The big data analytics application likely enhances those outcomes. However, the benefits of SCPMS can only be obtained if the performance measures are correctly interpreted and analyzed and if the necessary actions take place in the companies. Additionally, review the performance measures is an important process for companies which want to keep their measures aligned with the strategy (Bourne et al., 2000).

Final Remarks

This paper addresses the gap in the SCPMS literature by moving a step forward towards identifying big data analytics applications in SCPMS, and categorizing them according

to the four dimensions of big data analytics capabilities introduced by Arunachalam et al. (2018) (i.e., Data Generation, Data Integration and Management, Advanced Analytics, and Data Visualization). The identified big data analytics applications in SCPMS include, for example, the use of different data sources to create new measures or bring more information to the existing ones; the importance of integrating external and internal data; chances of real-time measurement; different analytic techniques which can be used; and the dashboards and reports created with the support of big data analytics.

The findings presented in this paper are limited to the literature review conducted in one database. A new literature review could be conducted considering more databases and white papers. In this way, the results could be broader. As the second limitation, this work does not focus on challenges and restrictions that the use of big data analytics in SCPMS can bring, for example, high volume accumulates data noise and creates high computational costs (Wang et al., 2016). In this manner, further research could usefully explore these challenges and present possible countermeasures to them.

The results of this study are promising for both practitioners and researchers. Practitioners could use the results of this research to understand which big data analytics applications in SCPMS could fit in their supply chain. Researchers, on the other hand, might use the findings of this research to have a structured understanding of big data analytics applications in SCPMS. Besides, this work can be used as a theoretical foundation for future studies. Thus, this work serves as a preliminary study leading its way to other researchers to improve it. The next step will be to analyze the outcomes of this research empirically in order to check how practitioners react to the use of big data analytics in SCPMS.

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Doing shop floor management: a Pragmatist Take on working practice at shop floor level

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Abstract
With the aim of improving the understanding of the influencing roles of social- and technical matters in Shop Floor Management (SFM) this paper addresses how companies can facilitate a digital transition of SFM visualisation boards. By combining a pragmatic understanding with Science-Technology-Society studies that social- and technical matters form sociotechnical practices, this paper studies SFM in three companies. Findings are; the social- and technical matters are interrelated and influence SFM. In all three companies the main challenges are technical matters – inappropriate information architecture and data collection. In one company, the challenge is a habitual approach for doing SFM meetings.

Keywords: Shop Floor Management, Pragmatic, Sociotechnical practice

Introduction
Doing SFM is, by its nature, a social activity, in which visualisation boards (Parry and Turner, 2006) are the glue for the social interplay among the practitioners (Galsworth, 2017). Yet, in the era of industry 4.0 the practitioners witness new digital features embedded in the technical equipment (Rajan and Safiotti, 2017; Tao and Zhang, 2017; Zhuang et al., 2018). These new technologies influence both the performance management and continues improvement actions as well as the working practice at the SFM level (Kagermann et al., 2013; Tezel, 2016; Winby and Mohrman, 2018).

Despite new technologies pave the way for using digitised visualisation boards to accomplish performance management and continues improvement actions, the application of this kind of digitised equipment at SFM level is still incipient (Meissner et al., 2018). Rather than using the digitised visualisation board, the practitioners are applying analogue visualisation boards originating from the principles of conducting short and effective SFM meetings (Iuga, 2017) and the power by hand mindset (Galsworth, 2017). As a result, this paper argues, that the prevailing managerial approach at SFM level is characterised by the industry 2.0 era (like Eaidgah et al., 2016), which paralyses our understanding of how to digitise the SFM level.

With the aim of improving our understanding of how to digitise SFM visualisation boards, we focus our study on the actions and the consequences of actions. To do so, this

study draws on pragmatism (Dewey, 1938) and combines this understanding with the idea from Science-Technology-Society studies (Henderson, 1999), that social and technical matters form a sociotechnical practice (STP). Thus, actions are influenced by the composition of the STP and, simultaneously, actions influence the composition of the STP. An empirical study of performance management and continues improvement actions in three different companies form the basis of exploring two research questions: 1) W*hat are the characteristics of the STP*?, and 2) H*ow can a company facilitate a gradual transition towards a digitised era*?

The paper's contributions are an illustration of applying a pragmatic approach to study performance management and continues improvement activities at the SFM level with the aim of revealing different characteristics of STPs when doing SFM meetings. The proposed framework consists of two dimensions: a social dimension and a technical dimension. By combining these dimensions, the model suggests four characteristics of STPs.

Theory

The section starts with elaborating the notion of actions within a STP from the viewpoint of pragmatism after which a framework to study the unfolding STP is presented.

Theoretical positioning

Joan Woodward's empirical study of 100 manufacturing organisations in the 1950s (Woodward, 1958) sow the seeds of lengthy academic discussions of whether the *social*- or *technical* matters determines actions. At the threshold of the current industrial revolution, the huge focus on the benefits of embedding digitised technologies in the manufacturing equipment seems to favour the *technical* matters at the expense of the *social* matters (Winby and Mohrman, 2018). As an example, Yin et al. (2018) account for how Industry 4.0 has reshaped the SFM level and thus brought smart manufacturing on the forefront. A group of researchers (e.g. Kagermann et al., 2013) argues that the exponential development of digitised technologies, big data and artificial intelligence pave the way for the application of digitised manufacturing equipment that are autonomous, capable of controlling themselves in response to different situations and that the equipment is self-configuring. It indicates that the ongoing development of artificial intelligence (Zhuang et al., 2018) and machine learning algorithms (Rajan and Safiotti 2017) combined with interoperability and interconnection among technical equipment (Tao, et al., 2017) will result in a situation where the majority of actions at SFM level is performed by *technical* matters.

However, the *technical* enabled actions have some limitations compared to the *social* enabled actions. In all likelihood artificial intelligence and machine learning algorithms embedded in the technical equipment will not exceed practitioners' reflective capabilities in the near future. In contrast to computer-controlled equipment, practitioners are capable of drawing on their common sense, reflective experience, and creative- and social intelligence as well as perception and manipulation capabilities to accomplish actions in unstructured and changing contexts (Frey and Osborne, 2013). Thus, actions are in some situations enabled by *social*- or *technical* matters or by a mixture of *social*- and *technical* matters.

Subscribing to pragmatism (e.g. Dewey, 1933; 1938) the enabling *social*- and *technical* matters for actions depend on the problematic situation being handled (Dewey, 1938). With his concept of imbrication Leonardi (2013) demonstrates these unfolding roles of matters and also that both *social*- and material matters (here *technical*) have the capacity to act; these *socio-technical* actions result in the two distinct group of influencing

matters become interlocked in a particular sequence. However, given that humans have intentionality (Leonardi, 2013), they decide how the *socio-technical* matters become imbricated and forms a STP (Leonardi, 2013). The STP influences and is simultaneously influenced by actions in a trajectory manner (Mathiasen, 2015). Despite appreciating the notion of imbrication, the following section spells out the understanding of actions within a STP; i.e., action and thinking, action and meaning-making, and habitual and reflective actions.

Action and thinking is inseparable and situation-dependent. Pragmatism (e.g. Dewey, 1938) rejects any kind of dualism including the viewpoint, that human behaviour can be divided into a triggering stimulus, subsequent a thinking process, and finally, an action.

Action and meaning-making go hand in hand. In other words, when a practitioner acts, his/her observations of and reflection about influencing *socio-technical* matters enter into a process of inquiring (Dewey, 1933; 1938). In this process of inquiring, the *socio-technical* matters acquire meaning when each of the involved practitioners strives to understand what is going on and gradually handles the problematic situation. This understanding implies that each practitioner uses *socio-technical* matters to create their individual understanding, but the creation of both individual and common understanding also involves other practitioners' understanding.

Habitual and reflective action should be understood as two extremes on a continuum. Dewey (1933) advocates for this dual nature of thinking-in-action and highlights that a human conducts both habitual- and reflective actions. While the latter is a prerequisite for accomplishing the meaning-making process and thus gain new experience, the former habitual attitude of mind has two different roles, which are being a stabilising factor for living in present-day society and being a standard way of drawing inferences (Dewey, 1938, p. 21). In the following the framework to study the influencing roles of sociotechnical matters are presented.

Conceptualisation the framework for studying the sociotechnical practice

This section starts with explaining four stages of STPs within a framework studying the STPs, next the social- and technical matters in the framework are described, and finally figure 1 summaries the framework. Zhuang et al. (2018) propose the following four stages of working practices (here STP).

The Single Point STP is characterised by a low influence of social- and technical matters presented in the framework. In this STP, the organization and management do not meet the optimal requirements to accomplish successful SFM. The STP is stuck in old habitual procedures without any support from technologies to aid in decision-making. Most data are gathered manually, and as a result, the data gathering and analytical processes is not fully reliable. This practice release passive (reactive) management and control methods (Zhuang et al., 2018).

The *Integrated* STP is characterised by a low-medium influence of the social- and technical matters presented in the framework. In this STP, most data are gathered automatically and is real-time, but the organisation show a passive strategy of processing and analysing the data. The decision-making at the SFM level at this stage is believed to increase as the real-time data provide a more reliable data foundation. This practice release real-time management and control methods (Zhuang et al., 2018).

The Collaborative STP is characterised by a medium influence of the social- and technical matters presented in the framework. In this STP, the appliance of wide applications as machine learning and big-data related technologies makes it possible to enhance the decision-making and thereby the performance level as these technologies support a stronger analytical foundation for assessing the data. As these new features

seems has a huge impact on the practice, the human behaviour at shop floor have not been adjusted to this transition stage, and therefore this might course several organisational and management challenges. This practice release predictive management and control methods (Zhuang et al., 2018).

The Smart/Intelligent STP is characterised by a high influence of the social- and technical matters presented in the framework. In this STP, the manufacturing system can predict behaviour of the equipment status, human resources and make decisions autonomously based on a solid and reliable data foundation. This practice demands a proactive management strategy, where the technical equipment and human are in balance to assess and analyse the data. (Zhuang et al., 2018).

The Social Matters

Clear objectives - The origin of SFM management is not consistently defined and nor are the objectives but most companies associate the pursued objectives by the use of lean principles (Hertle et al., 2015). Therefore, SFM objectives are typically structured from quantitative figures such as operational figures as KPIs (Hertle et al., 2015, Steenkamp et al., 2017). The SFM objectives are necessary for the accomplishment of the SFM activities, as they base the foundation to secure a common goal for the practitioners to work towards (Eaidgah et al., 2016). Without clear common objectives, it is impossible to accomplish SFM as a social activity (Ahrens and Mollona, 2007).

Structure and procedures - At present there is identified an increasing practical and theoretical interest in how organisations can organise and integrate knowledge to support their management activities (Beckhy, 2003, Zhuang et al., 2018). Academia suggest that organizations should use structures and processes, such as clear guidelines and routines to codify and transfer knowledge in their social-collaborative environment e.g. SFM board meetings, so the knowledge is transferred to have the same meaning for everyone involved in the activity (Bechky, 2003; Kumari and Kulkarni; 2016, Holm, 2018). Holm (2018) among others state that it is important to acknowledge the social interaction at the SFM level to ensure commitment from the practitioners, meaning, the practitioners should be involved more actively in the procedures.

Managerial Approach - Manufacturing enterprises are currently facing extensive challenges with regard to adapt new technological features referred to the concept of smart manufacturing (Schumacher et al., 2016). Subsequently, the increasing complexity on all organisational levels create uncertain environments for the companies to act within, as their organizational and technological capabilities not has adjusted in synergy along with the new technological features (Hertle et al., 2015; Schumacher et al., 2016; Holm, 2018). Academia state that the competency development of the practitioners are the most important aspect within this transition, because the current competency levels are low and do not possess a high degree of flexibility, adaptability and initiative (Hertle et al., 2015; Syberfeldt et al., 2016; Buer et al., 2018). Holm (2018) and Zhuang et al. (2018) agrees upon that the development of the capabilities at the SFM level is a prerequisite for changing the current management controlled by old reactive habitual procedures.

The Technical Matters

Visualisation boards - The prevalent academia suggest that enhanced transparency by obtaining real-time data to enhance better decision-making at the SFM level offers the advantage of being more agile e.g. respond quickly to volatile demands (Friedemann et al., 2016; Steenkamp et al., 2017; Buer et al., 2018). However, the problem at the SFM level is that the practitioners constantly receives torrents of data from their environments, which not are easy or relevant to understand (Eaidgah et al., 2016). Academia and

practitioners at the SFM level using visual management boards have addressed this problem. No common and clear definition defines visual management boards, but drawing on academia this paper define these as dashboards, which have digital representation capacities that support the practitioners' understanding of accomplishing SFM activities (Eaidgah et al., 2016; Steenkamp et al., 2017; Galsworth, 2017).

Information architecture - The information architecture at the SFM level is a blueprint and navigational aid to the content of information-sharing (Toms, 2002) at the board meetings. How the interaction among the practitioners is conducted, is strongly influenced by the environments information architecture. As the manufacturing currently is a battlefield of competition, companies have started to adapt advanced technologies to aid in decision-making to achieve better planning and control (Zhang et al., 2011). Hence, the management and control facilities at the SFM level are required to adopt technologies that enhance real-time data and interoperability to secure enhanced performance if the companies wants to stay competitive (Zhang et al., 2011).

Data foundation – A valid data foundation is a prerequisite for harvesting the beneficial outcomes of applying digital technologies to support decision-making at the SFM level (Meissner et al. 2018). Many processes discussed at the SFM level today is managed through manual "pen-and-paper" processes, where the data is not stored digitally (Buer et al., 2018) and as a result, this hinder the company to reapply information, hence, data is often lost if it is not stored digitally in an easy assessable way. By automating the data gathering, the data will more likely be gathered under the right conditions and the data foundation will be strengthen and the probability of errors are reduced (Buer et el. 2018).

Figure 1 summarises the framework for studying the STP.

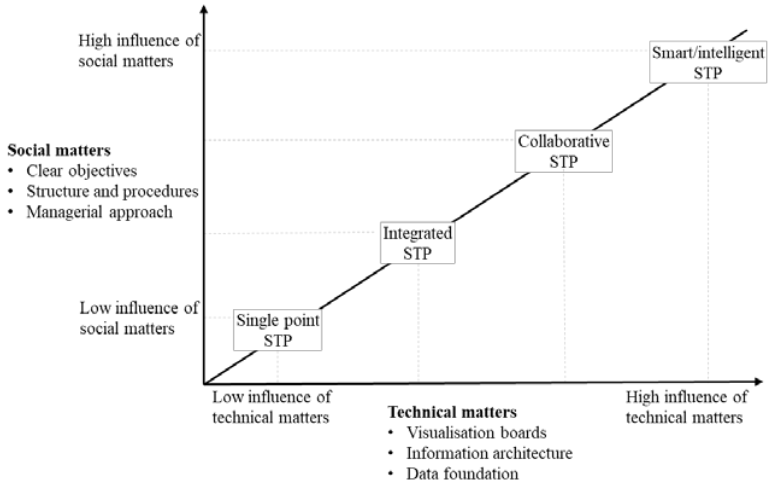

Figure 1. Conceptualisation of a framework to study actions to study STP.

The conceptualised framework consists of two dimensions: a social- and a technical dimension. By combining these two dimensions, the frame suggests a scale evaluating the social- and technical matters from a low to a high degree, wherefrom four characteristics of STPs are identified. The four STPs, which are; Single Point STP, Integrated STP, Collaborative STP and Smart/intelligent STP are inspired by Zhuang et al. (2018) and these reveal different approaches in term of using analogue and digitised boards when accomplishing SFM activities.

Methodological considerations

The research draws on pragmatism (Dewey, 1938) and combines this understanding with Science-Technology-Society studies (Henderson, 1999), that social and technical matters fuse into a STP. The empirical data is collected by one of the authors and it consists of observations of SFM board meetings followed by semi-structured interviews in three large international companies. One of the authors took the role as a complete observer and did all interviews. To structure the interviews, we draw on the observations of the SFM board meetings and the conceptualisation of the framework presented in the theoretical section. The observations was discussed during the semi-structured interviews with practitioners to enhance the trustworthiness of the observational findings. Each observation lasted in average two hours, while the interviews in average lasted 30 minutes. Notes were taken simultaneously during the observations and interviews. Drawing on Stake's (2000) case study, the three companies are considered as particular cases, which provide us insight into the STPs in which performance management and continues improvement actions are conducted. The three companies are designated; Company 1, Company 2 and Company 3, se table 1 for further information.

Table 1- Overview of the three case companies regarding company size, industry as well as the number of SFM board meeting observations and interviews conducted in each company

Company	Number of employees	Industry	Number of SFM meetings observed	Number of interviews
Company 1	23,000	Renewable energy	Four	Three
Company 2	40,000	Brewery	Two	Two
Company 3	26,000	Meat processing	Two	Two

The three cases – empirical findings

Table 2 summarise the empirical findings from the three case companies. The socio- and technical matters from the conceptualised STP framework structure the findings.

Table 2 -The three case companies structured by social- and technical matters

Company 1: Social matters	
Clear objectives	Clear objectives, mainly quantitative figures. The objectives are discussed thoroughly at each SFM board meeting
Structure & procedures	Collaborative culture, clear guidelines to follow during the SFM board meeting and clear roles among practitioners. The SFM board meeting agenda is followed very strictly
Managerial approach	Focus on involving practitioners even more in the processes and give them more responsibility. There is a desire to enhance the competency level at shop floor
Company 1: Technical matters	
Visualisation boards	Increasing use of digitised SFM boards. The digitised boards are only used for enhancing the visualisation of the figures. The role of the digitised visualisation boards is to be a support tool in decision-making related to improve efficiency in the production
Information architecture	The information structure is a bit unclear, mainly due to a very complex production set-up and the use of semi-automatized production equipment. Very difficult to gain access to ERP data
Data foundation	Huge amounts of data are gathered automatically but in an unstructured way. The manually collected data is not fully reliable; the company works determined to gain a more reliable data foundation
Company 2: Social matters	
Clear objectives	Clear objectives, mainly quantitative figures. The objectives are not discussed very thoroughly; it appears as being "a standardised approach" at SFM meetings
Structure & procedures	Very limited collaboration. Board meetings are considered as must to comply with standard procedures; practitioners appear as silent participants. Meetings are considered as being none value adding
Managerial approach	At present, no focus on enhancing the performance level during SFM board meetings, but the management has realised an urgent need for improving the meetings. Low commitment due to a lack of using real-time data and too unstructured data, practitioners are reactive
Company 2: Technical matters	

Visualisation boards	Analogue SFM boards are used; functions mainly as bulletin boards. Very limited use of digitised SFM boards; mainly due to strict legalisation requirements. Work determined on capturing SFM board meeting notes digitally
Information architecture	Lack of real-time data and too unstructured data for analytical decision-making. The information structure is not clear, lack of data transparency
Data foundation	The data foundation is too unstructured. Data are gathered and stored, but not in an accessible way
Company 3: Social matters	
Clear objectives	Clear objectives, mainly quantitative figures. Objectives are not discussed very thoroughly; it appears as being "a standardised approach" at SFM meetings
Structure & procedures	Collaborative culture. Practitioners involved are proactive. Structure & procedures facilitate that all practitioners contribute during SFM meetings
Managerial approach	The company is currently in a process of implementing a more "advanced version of LEAN"; accordingly, huge focus on developing practitioners' competences and implementing more efficient standardised processes at SFM level
Company 3: Technical matters	
Visualisation boards	No use of digitised SFM boards. The applied analogue boards do mainly function as bulletin boards, on which notes are written down and sketches are made to explain ideas/suggestions to solutions. The company has started an investigation of implementing digitised visualisation boards including digitised data treatments and analytical tools.
Information architecture	The information is unstructured resulting in a lack of information transparency across the factory
Data foundation	Unstructured data collection as well as inappropriate data foundation

Analysing and discussion

With the aim of improving our understanding of how to digitise SFM visualisation boards, this section commences with an analysis of "what are current characteristics of the STP in the three case companies". Next, this understanding is used to elaborate how can a company facilitates a gradual transition towards a digitised era.

The empirical study of performance management and continues improvement actions in the three different companies shows rather different characteristics of the STP across the three case companies.

Company 1 had clear objectives for issues being discussed during the SFM meetings. This combined with well-structured SFM meetings and huge focus on complying with the overall procedures for accomplishing the meeting resulted in proactive actions. The practitioners reflected on both the information depicted on the visualisation boards and comments from the manager and colleagues. This collaborative approach formed a practice in which the practitioners achieve a common understanding of the problematic issues being discussed. In order words, actions at the SFM meetings were aligned. As for the technical matters, the company had not yet implemented digitised visualisation board all around the factory. Likewise, the information architecture and in particular the data foundation in company 1 is insufficient for generating reliable data and real-time data to utilise the real-time nature and predictive power of data. Based on the interviews with the company, the top management is aware of the information architecture and thus data foundation is the bottleneck for developing the SFM level into a STP enabling smart and intelligent application of data and information.

Company 2 had likewise clear objectives for issues being discussed during the SFM meetings. The SFM meetings followed standardised procedures, which combined with rigid structures resulted in a habitual mindset and thus reactive actions. The practitioners did not reflect on the information depicted at the visualisation boards and appeared as silent participants. As for the technical matters, the company had only implemented digitised visualisation board in a very limited part of the factory. Likewise, the information architecture and in particular the data foundation in company 2 is insufficient for generating reliable- and real-time data to utilise the real-time nature and predictive

power of data. Based on the interviews with the company, the top management has realised an urgent need for improving the meetings and they think that the low commitment among the practitioners is caused by using too unstructured data having a debatable reliability. Top management thinks that a reliable data foundation and real-time data will enhance the SFM performance level into a STP enabling strong analytical data assessment and data transparency, thus using real-time data to predictive decision-making.

Company 3 had likewise clear objectives for doing the SFM meetings. The SFM meetings are well-structured and the procedures ensured close collaboration among the practitioners. The managerial approach drew on appropriate procedures, but these were too rigid. Due to the rigid procedures, the practitioners actions were routinized, despite they apparently reflected on both the information depicted on the visualisation boards and comments from the manager and colleagues. Indeed the discussions were one-dimensional and it was difficult to see a problem from different angles. As for the technical matters, the company did not use digitised visualisation boards. Likewise, the information architecture and in particular the data foundation in company 3 is insufficient for generating reliable data and real-time data to utilise the real-time nature and predictive power of data. Based on the interviews with the company, the top management has realised an urgent need for improving the managerial approach to achieve a common culture and improve the competency level at shop floor. The company desires to enhance the data foundation and the data assessment in an attempt to transform the STP enabling real-time data analyses.

Based on the above analyses including a ranking of the social- and technical matters into low, medium and high, the influencing roles each of the companies' current STP and intended STP is placed in figure 2.

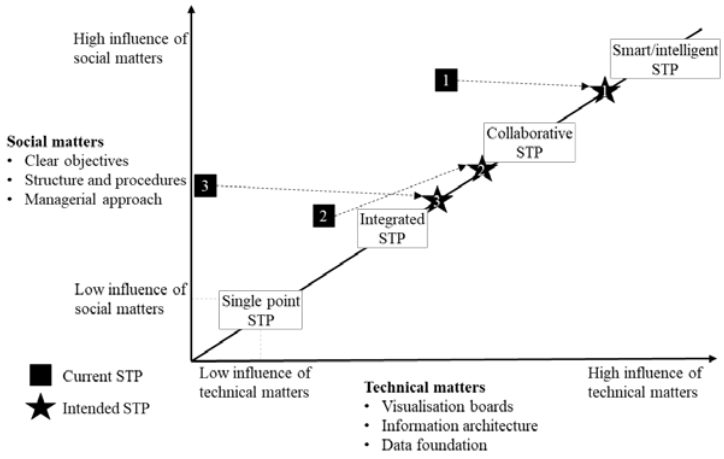

Figure 2. The current and intended STP of the three companies.

To achieve sufficient benefits it is important to balancing the social- and technical matters (e.g. Kagermann et al., 2013) for which reason the intended STP of the three companies are placed on the diagonal line suggested by Zhuang et al. (2018). The proposed transition route for each of the three companies are illustrated as the dotted arrow from current to intended STP to show how the companies must develop their strategy to reach the intended STP. Academia suggests that the transition must happen gradually and that the companies need to achieve a sufficient balance between the influencing roles of social- and technical matters respectively, before moving forward to a more digitised STP (Tao et al., 2017; Zhuang et al., 2018). As it appears from figure 2, the current STP for all three

companies are not in balance. In general, for the three companies, the technical matters constrain the transition to the intended STP. The analysis indicates that it is mainly an insufficient data foundation and problematic information architectures, which hinder the companies in transforming the SFM into the digitised era. The prerequisites for entering the digital era at SFM meetings in company 1 and 3 are that the management should facilitate a technical development of the information architecture. The current information architecture in both companies do not facilitate proper data collection, data coding and data storage. In other words, the interoperability among the technical equipment, from sensors to application levels (e.g. Tao et al., 2017), is too weak. As for company 1 the main problem in terms of insufficient data foundation is actually that none of the practitioners in the manufacturing are allowed to gain access to data stored in the SAP systems (Enterprice Planning systems). Retrieving core data and information from SAP is restricted to few key employees working in the IT-department. In company 3, the management should digitise the current manual coding of the automatically collected data; as it is not, the automatically collected data are useless due to the underlying causes are not stored in the SAP systems. The challenges in company 2 are dual. The technical issues are identical with company 1 and 3; i.e., the focal point for the management should be to enhance the information architecture and data foundation. Despite the company has clear objectives to be discussed during the SFM meetings, the social dimension needs to be improved. Currently, the SFM meetings seem to be a "coffee meeting" in which the practitioners wail about unusual data to make proper decisions. The manager should challenge the habitual attitude of mind, which permeates both the practitioners and management. This could be facilitated if the standard procedures are rephrased in way that forms a more open, flexible and reflective collaboration during the SFM meetings.

Conclusion

The purpose of the paper is to improve the understanding of how to digitise SFM visualisation boards. Based on the analyses of three high automated companies, the paper shows that the unfolding STP during the SFM meetings are characterised by a huge focus on the social matters at the expense of the technical matters.

The STP at SFM level when practitioners are operating with highly digitised manufacturing equipment is completely different compared with the STP when applying non-digitised SFM visualisation management board. By digitising the SFM visualisation board, companies benefits from access to real-time- and reliable data to enhance data transparency, which will pave the way for more effective decision-making at the SFM level. Likewise, the "socio" part will not be catch in two rather different "technical systems". As the application of digitised visualisation boards will reduce the gap between the two different "technical systems" to a level, in which practitioners will be more capable in developing new capabilities and thereby gain maximal benefits from both the digitised manufacturing equipment and digitised visualisation management boards.

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Unpacking the productivity narrative in manufacturing organisations

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Abstract

This paper explores the narratives around productivity in UK manufacturing firms. Whilst we hear a lot about the UK's poor productivity from politicians and economists, this paper explores the conversations within manufacturing firms. Initial evidence from a project funded by the ESRC through the Productivity Insights Network is presented. It appears that there are many different narratives around productivity and often the conversations in the manufacturing firms bear little resemblance to the productivity statistics being presented by politicians and economists. The work is innovative in that it moves the conversation from the economists, politicians and statisticians to the manufacturing workplace.

Keywords: manufacturing, productivity

Introduction

Productivity growth, or the lack of it, has become a global concern (OECD, 2015; WEF, 2017). As Krugman (1994) suggests: "productivity isn't everything, but, in the long run, it is almost everything". The most recent data from the Office for National Statistics

(ONS) suggests that many of the biggest EU nations are also facing negative labour productivity growth (Romei, 2019). Governments all over the world are concerned about productivity growth (OECD, 2015; WEF 2017). The most recent data from the Office for National Statistics (ONS) suggests that many of the biggest EU nations are facing negative labour productivity growth (Financial Times, 13 Jan 2019).

The UK based authors have been hearing regular reports in the media about the UK's poor performance in terms of productivity growth, which since the global financial crisis of 2008 has been falling behind its European neighbours and G8 member nations. But as operations researchers, who spend significant time out in industry, the authors started to question whether the media headlines aligned with what they were seeing and hearing in manufacturing firms. So the authors wanted to explore productivity from the perspective of manufacturing firms.

There has been very little academic work that looks at the narratives around productivity within firms. Recently there have been a few studies by professional bodies who have started to look at productivity from the perspective of the firm. The CBI (2017) report "Unlocking Regional Growth" is one of the few studies that has taken the conversation down to the level of the firm, although the analysis was still very much at a macro level. Similarly, the EEF 2016 and 2018 reports also pull out key factors that are influencing productivity in the manufacturing sector. But none of these studies actually take the conversation to the workers on the shop-floor.

Fast forward 10 months and the work reported in this paper is an early stage output of an exploratory study funded by the UK's Economic and Social Research Council (ESRC) through the Productivity Insights Network. The project discussed in this paper takes the productivity discussion down to the operational level of the workers in manufacturing organisations. It seeks to investigate the narratives around productivity in manufacturing firms. It seeks to understand how productivity is understood at different levels of the firm and asks the question whether productivity is being discussed and measured at different levels. The project engages in conversations with employees at different levels within manufacturing firms and is innovative in that it moves forward the conversation around productivity in a meaningful way, engaging the employees.

This conference paper is an early output from the project and is structured as follows. Firstly the authors investigate the dialogues taking place around productivity in the literature (and particularly considering this in the context of manufacturing). This involves interrogating the literature from a number of academic domains, as well as looking at industry reports. The research approach of the project is then discussed before the authors present findings from initial interviews with people working in manufacturing firms. The paper concludes with a discussion on these preliminary findings and explores future avenues for research.

What does the literature tell us about productivity?

In the UK, our poor productivity performance, particularly compared to other economies, has become a popular subject for politicians, economists and commentators. The lack of improved productivity growth is perceived as problematic (CBI, 2017; EEF, 2016; IoD, 2018; McCann, 2018). So what is the big concern? And what are these productivity statistics actually telling us? To answer these questions we have to first look at how productivity is being defined and measured by these commentators. And herein lies one of the first problems – there are multiple definitions of productivity (eg. this is highlighted by CMA July 2015). According to the ONS Productivity Handbook (2017) "productivity represents the relationships between inputs and outputs in the production process". The European Association for National Productivity Centres (EANPC 2005:12) defined

productivity as "an expression of how efficiently and effectively goods and services are being produced". These definitions highlight how productivity essentially measures the efficiency in production by relating the output obtained from some given inputs. Productivity measurements typically adopt physical or economic units and relate them as an output–input ratio. So it follows that to improve productivity the key levers are increasing output (addressing the numerator) or decreasing the input (addressing the denominator) or ideally working on both simultaneously.

When we hear productivity figures discussed in the media, we need to look closer at what is actually being discussed. Economists look at both the levels and at the growth rates of productivity. When we hear about comparisons between countries it is important to understand what is being compared. It could be a snapshot of productivity at a point in time or productivity growth over time.

Then we have the main measures of productivity – labour productivity and total factor productivity. This is another thing to check when examining reports about productivity. Labour productivity as the name suggests focuses on output per unit of labour input. And within this approach some studies look at output per worker or output per hour worked. This could be important in looking at national figures as it is known that in some countries people work longer hours than others. Italy and France are said to work significantly less hours a year than say the USA largely due to different holidays, while workers countries such as the Netherlands typically work a 4 day week, with many companies experimenting with it in different locations. The Mexican's, Korean's and Costa Rican's are currently averaging the longest working hours annually. However these are average contracted hours – and some might argue bear little resemblance to the actual hours worked by people (the Independent, 19 July 2018). The other approach, total factor productivity (TFP) takes into consideration other input resources (not just the labour), including expenditure on capital and resources. It could be argued that it is more difficult to get a real handle on TFP, especially at a macro, aggregated level. TFP growth looks at the difference between output growth and the growth of inputs (labour and capital).

CMA (2015:p42) observe that the measurement of productivity presents a series of challenges, "for example for measurement purposes the value of output rather than the volume is sometimes used. With this measure, high levels of prices, for example due to market power, can erroneously give the impression of high productivity". One of the problems is often when productivity is discussed in the media reporters are not clear on what type of productivity is being discussed or the units being measured. Next time you hear a report on productivity the authors challenge you to stop and see if it is clear what is being discussed. Productivity measurements can also focus on different levels of analysis for example the overall economy, a sector of the economy, the enterprise, the plants, the machineries or the individuals. In terms of academic discourse on productivity, until recently much of the work has been within the economics and policy domains. But more recently we are seeing a wider discourse on productivity. Researchers from a range of social science disciplines are now talking about productivity, linking productivity levels to technological, organizational, demand, and market related factors. Examples include organisational structures (e.g. Syverson, 2011; Garicano and Heaton, 2007), human capital (Fox and Smeets, 2011), incentives and rewards (Lazear, 2000), human resources practices (Ichniowski and Shaw, 2003) and managerial talent and practices (Bloom and Van Reenen, 2007).

Given the current interest in productivity in the UK, the Productivity Insights Network (https://productivityinsightsnetwork.co.uk/) was established in January 2018. Funded by the Economic and Social Research Council (ESRC) they are a network of multi-disciplinary social science researchers, whose aim is to change the tone of the productivity

debate. To date the network has undertaken a number of reviews. Possibly the most comprehensive cross-disciplinary look at productivity to date is Philip McCann's (2018) "Productivity Perspectives Synthesis". In this McCann explains how the way we think about productivity has changed over the years.

What do we know about the productivity narrative in manufacturing organisations?
The authors are specifically interested in the narratives around productivity in manufacturing firms. There have been very few academic papers looking at productivity in manufacturing in the academic literature. Whilst they did not set out to look at productivity in manufacturing, Smart et al (2017) identified "productivity and innovation" as a theme in the industrial sustainability literature. Smart et al (2017) conducted a systematic review, reviewing 574 articles on industrial sustainability and suggest that industrial sustainability is yet to achieve a paradigmatic consensus. Instead three distinct and unifying dialogues emerge from their review: "productivity and innovation", "corporate citizenship" and "economic resilience" were identified. The authors note a "preoccupation with efficiency strategies" (p1427). They note that much of the productivity and innovation literature (relating to industrial sustainability) comes from the operations/production management literature with significant focus on material and resource use and efficiency. Within the operations management literature, we do see much more focus both in the literature and in firms around efficiency rather than productivity. Mankins (2017) suggests that narratives within firms often focus on efficiency and are often conflated with productivity. CMA (2015) also observe the confusion over efficiency and productivity in everyday language.

Whilst there is little work on manufacturing productivity in the academic literature, in the past few years there have been a number of reports from professional bodies such as the CBI, IoD and EEF (now renamed Make UK). The CBI (2017) explored influences on the UK's productivity success in their report "Unlocking Regional Growth" and the EEF (2016, 2018a, 2018b) has produced a number of reports highlighting key issues for UK manufacturing including the factors influencing productivity success. EEF contributed one of the most relevant studies for this project, "Productivity: the state of the manufacturing nation" (EEF, Spring 2016). They noted that the productivity growth of manufacturing outperformed that of services and the whole economy in the two decades to 2014, suggesting that manufacturing may not be the source of the UK's weak performance" (p3). Whilst being positive about the actions of manufacturers the EEF suggest that manufacturers need to focus more on improving productivity of the company as a whole rather than just the factory, and on adopting major advances in technology (p3). Relevant to this paper, EEF (2016:p3) put forward the view that "manufacturing has the potential to be a major driving force behind improving the productivity performance of the UK economy" and go further to suggest "the sector will get further if government and businesses are talking the same language about productivity". The EEF report concludes that by focusing too much on a macro-economic view of productivity we "could be missing a trick", suggesting it is important to "dig deeper" and look at different sectors and indeed the businesses themselves. Echoing this view, one of the most recent calls comes from CIPD in their Labour Market Outlook (winter 2018-19:p15). CIPD point out that often these headline media productivity figures are derived from "official statistics" that aggregate data "from the whole economy, representing outputs as disparate as cars, haircuts, and public services. And observe that "it is no wonder that this abstract macroeconomic concept may feel distant from the everyday practice of employers".

CIPD asked their members if productivity is a term often used when discussing performance. And half agreed they do – but there were big differences by sector. The

CIPD survey suggests that 71% of manufacturing firms are using the term – but the term is used by only 18% of education employers and just 16% in the voluntary sector. CIPD (2019:p16) suggest that this discrepancy might come from the fact that "measurement is much easier in some industries than others. It is much easier to measure the value of a car that is openly traded in the market than a teacher's lesson."

In a similar investigation the Institute of Directors, IoD (2018: p9) report that "60% of IoD SME members do not formally monitor productivity in their organisation". IoD suggest that many small business leaders prefer to frame productivity as "working smarter" but opt to focus their measurement on other measures such as profit and revenue. IoD call for "supporting businesses to understand and monitor their productivity". The IoD calls for a better understanding of what productivity is, what it means for performance, and how it can be monitored, in order to promote a "productivity mindset" in SMEs." (p9). A similar call for better understanding and common language comes from Be the Business (May 2018). So there is a clear gap in understanding around the narratives of productivity at the level of the firm. And there is a call to arms that says only by speaking common language can we really drive real improvements in productivity that the UK wants to see.

Research design of the "Manufacturing Productivity Narratives" project

The authors of this paper wanted to address this gap, at least in the context of manufacturing firms, and to engage with people in manufacturing firms to really understand the narrative around productivity. The researchers also seek to engage in conversation about the drivers and constraints – from the perspectives of people working in manufacturing firms. Indeed the project will also go on to analyse whether there are different views at different levels of the firms and in different sectors. But this will be reported in later papers.

The project is a short, 9 month, pioneer project funded by the UK's Economic and Social Research Council (ESRC) through the Productivity Insights Programme (Reference ES/R007810/1). Further information on this and related projects can be found at https://productivityinsightsnetwork.co.uk/). It is an empirical study incorporating an exploratory, inductive systems thinking approach with a multiple case study design. The project focuses on firms within four key sectors in the UK: food & drink, automotive, aerospace, pharmaceuticals, as well as looking at high value manufacturing (HVM) organisations across the sectors. The aim is to move the productivity conversation forward, away from the economists, politicians and statisticians to the workplace by engaging with employees in manufacturing firms. Qualitative data are collected from 20 purposefully selected firms via 60 semi-structured interviews with three levels of personnel (Director, Manager and Supervisor), observations during site visits, firm-related archival data, and a review of secondary information about the firm and sectors. Engaging directly with employees working in manufacturing companies, provides a much-needed perspective from inside the firm and across the firm hierarchy, a perspective highlighted as crucial by Boys (2019) who advocates the need to "continue research into firms' attitudes and awareness of the issue." Interim findings will be shared via two workshops in regional locations with key manufacturing stakeholders from industry and Government, before final reporting in July 2019.

Initial findings

Whilst presenting early stage findings (a fuller analysis will be presented at the conference in June) this section of the paper delivers initial insights into how productivity is understood and measured at different levels in manufacturing firms. The data presented

in this paper is based on 20 interviews transcribed to date. By June our analysis will include a significantly higher number of interviews and will be stratified by sector and by level in the firm.

Usage of the term "productivity" is common but not universal

So far in our investigations more interviewees have confirmed that productivity is discussed in their organisation than those saying it is not a term used. The following quotes demonstrate this,

"You've got a target and productivity is something that at the very start of the shift I tell my team the target at the end of the shift is that we should reach a certain point." (C2)

"Yes, we look at this on a rolling basis" (E1)

"We use the word productivity" (F2)

But it is certainly not used by all firms interviewed to date,

"Not as such. We use various terms for how effective we are at… how efficient we are. I guess… not really productivity." (B1)

"We don't refer to productivity by its name" (D2)

The terminology is variable

A significant number of interviewees recognise that the language is confusing and the terminology used differently by different people. This is evidenced in the following quotes from interviews:

"Yes but variations across sites. Not a standard." (F2)

"It is nothing to do with the way government looks at productivity in GDP terms" (E1)

"Externally one of the real bugbears that I have is that everybody means something different by it [productivity], so it is a completely meaningless word to use externally. Internally we're absolutely specific. Externally, the first question we ask is what are you actually measuring. What is the basis of comparison between what you're telling me and what you're asking me and my company"? (E1)

"Productivity is quite an old-fashioned terminology […] productivity can often be constrained into only the manufacturing side. (D1)

Productivity is linked to other narratives

Throughout our interviews to date we are finding that productivity definitions can sometimes get entwined with narratives about efficiency, effectiveness, measurement and company and site specific terminology. Conversation often turns to measures to try to show what they mean by productivity. When talking about measuring productivity interviewees have talked about many things including: machine utilisation, OEE, on-time delivery, standard work, and output per unit of time. The following quotes show a range of things people conflate with productivity.

"Efficiency well that sort of overlaps with productivity" (E1)

"We don't refer to productivity by its name. […] We're trying to drive efficiency through effectively greater output with a similar size headcount over the period. That's

how we would I suppose at the broadest sense measure productivity. Are we winning the orders that we generate in the sales, are we increasing the margins? As a business are we getting more efficient in terms of the outcome financially of the business?" (D2)

"How efficient you are, not effective but efficient… this is my interpretation. How efficient you are at turning the raw material into the finished good… well, as a business how efficient you are at satisfying the customer. Fulfilling that customer desire, the whole way through, so selling… you know, the cost of sale, that's important, I didn't even mention that. I don't think we ever measure any cost of sale type efficiency of productivity. Cost of sale, cost of design, the whole value chain piece, the cost of making it, delivering it, supporting it. That whole efficiency piece." (B1)

"The measure of productivity is quite simply we break down all of our task into an hour's content through industrialisation studies and work studies. We do that as part of the NPI, the product introduction process, and then we use that to set a standard for all the jobs in the facility. We then do a working out of how many people we need to run the facility. In doing that and taking into account all our costs as well, we work out effectively what's called our cost rate. That is a cost per hour that we run the business by. So, that's important. (A2)

"We use the word productivity. We record… we look at efficiency in utilisation but more utilisation." (F2)

"Productivity can often be constrained into only the manufacturing side. So, we tend to follow more business-oriented KPIs that give you a measure of growth. […] I think we talk more about growth, improving our competitiveness than we do, than being fixated on something like productivity. […] So, when I hear productivity, my first go-to metric would be our five-year plan." (D1)

This is consistent with what some of the reports from the professional bodies were saying, as well as evidence from the academic literature (eg. Smart et al 2017 and Mankins 2017)

Internal communication

In our interviews we are picking up on different language at different levels of the firm (this will be further analysed and presented in June). But the quotes below give some suggestions of the issues:

"*It's sort of translated … as it goes through the organisation it's translated into an appropriate language for the audience, if that makes sense, rather than having a standard headline" (F2)*

"they might not know the productivity off the cuff, the charge hand would, by the way, but […] they'd be able to show you where it's measured there, and also how it's tracked day by day at that level. (E1)

"Inside the company whilst as employees we're using productivity all the time to talk about in our measure and standard hours" (E1)

If politicians and policy makers want to be utilising the correct levers to improve productivity then they need to be able to speak the same language as those within firms, including manufacturing. So it is important that we understand the language used.

Conclusions and further work

Consistent with our expectations from the limited literature, our initial primary research is suggesting that productivity means different things to different people within manufacturing and is measured in many different ways. Some manufactures will track aggregated measures at a high level, such as turnover per employee but often the conversation is more about the manufacturing shop floor and will be measured using multiple metrics eg. OEE, output per line, downtime etc. There is no single measure being used in the firms we have spoken to but rather multiple measures are used. This is in line with what we found by interrogating the existing but limited existing literature (eg EEF 2016, CIPD 2019). Often productivity is measured against some kind of target, standard or benchmark. For some this might be standard units of work and for others it might be against a target.

Speaking to people within manufacturing organisations is exposing a greater richness of the challenges and complexities. Some economic and policy studies have talked about certain sectors as being more productive than others in the UK. ONS for example suggests that chemicals and pharmaceuticals alongside automotive being the most productive sectors in terms of output per hour (£). EEF also talks about manufacturing productivity being higher than services and higher than the overall national picture. But statistics only tell you so much. Engaging in conversation with people within the manufacturing firms themselves reveals a much more complex picture. If we take a sector such a pharmaceuticals then we see some firms with big manufacturing sites with almost continuous manufacturing. Unsurprisingly such operations will look highly productive – with high volumes, low variety, high levels of automation, low staffing levels etc. But the other side of the pharmaceutical sector we can also see companies who are engaged in a lot more of the development work – needing significant investment, with high levels of regulation that see little or no return in the short term. So it's not as simple as talking about sectors being productive.

Obviously manufacturers who have low variety, high volume and who are highly automated products will have economies of scale and might look productive (eg. pharma and automotive come out well in ONS figures) – particularly if you are talking about labour productivity and if you are measuring units of output. But at the same time companies operating in high vale areas where there is significant design and customisation – may also be productive as long as they are charging premium prices for their products and the market can bear it. And if you are measuring output in value, rather than units. Which brings us to whether firms who are operating as high value manufacturers - in terms of competing on things other than price (design, innovation, quality etc.) will be more productive. Well that depends on how you are measuring it. As we saw from our review of the literature there are many different ways of measuring productivity. You could argue that a firm who is HVM has more opportunity to manipulate the numerator (the output in terms of value £). Whereas a firm who is operating more at the commodity side of things has less scope to manipulate the output in £ through innovation – and will naturally focus more on the efficiency angle and reducing the inputs. If we are using value (revenue) as our output measure then we can see how much such a company's productivity is at the mercy of market forces – no matter how hard they work at reducing inputs. If the demand and hence the price of the good was to shoot up then obviously the company's productivity would shoot up, without the company actually doing anything different. But the slip side if the price goes down then productivity, if measured using value will go down.

Conversations in our study so far are dominated by talk about reducing inputs and efficiency, with very little about increasing business outputs. Whilst EEF in 2016 did hear some talk of step change investment and investment in R&D, as yet we are not

hearing this. More commonly the focus is on waste reduction, utilisation, lean, supply chain etc. If this continues to be the case then this perhaps opens up interesting avenues for further research and potential targets for improving productivity.

Relevance/Contribution

By engaging with workers at all levels and exploring the current pressures and metrics at different levels of the firm this paper starts to identify some of the opportunities for improving productivity, moving the conversation forward and addressing some of the challenges of measurement. This really moves the focus from a macro level to a micro level. Whilst presenting only early stage findings (a fuller analysis will be presented at the conference in June) this paper delivers insights into how productivity is understood and measured at different levels in manufacturing firms. The research uncovers different clusters of definitions used within manufacturing organisations and contrasts these with the economic definitions used by economists and politicians. The research also uncovers the use of productivity definitions that show a real disconnect between the levers of government and the levers of the firm as well as show where they can align. The paper contributes to the operations management literature relating to productivity measurement, and providing empirical evidence from the manufacturers themselves rather than just data from their manufacturing sectors. The paper may also be of interest to managers in industry and to policymakers by improving the evidence base.

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Plant Location, Design and Layout

Method for the continuous migration planning of the design of global production networks

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Abstract

The presented paper describes a method for the continuous migration planning for the design of global production networks. Based on the input of the strategic- and tactical planning the paper focuses on setting up a migration plan by defining certain migration projects, which describe structural changes in the form of different migration steps. Moreover, restrictions concerning the financial budget and time frame as well as potential dependencies during the implementation are considered. In order to guarantee a continuous tracking of the implementation and to provide an efficient overview of the migration status the idea of a migration cockpit is presented.

Keywords: Production network; Continuous network design; Migration planning

Introduction

The environment of global production networks becomes increasingly fast changing, due to globalization, technology changes accompanied by digitalization and demographic changes (BCG and Fraunhofer IPA, 2015; strategy&, 2017).

Access to new sales markets does not only offer advantages to companies, but also demands a high degree of adaptability. In a volatile environment, producing companies must be able to react as quickly to changes in order to save costs. Consequently, the network design becomes more challenging because of increased dynamics and complexity.

Most production networks are historically grown and motivated from evolutionary and opportunistic decisions (Christodoulou et al., 2007; Friedli et al., 2014), each individually decided for itself by corresponding argumentations and detailed cost analysis (Ferdows, 2009). Consequently, an integration of network decisions into exisiting organizational structures is only considered in rare cases.

There is no generic solution for the design of global production networks. Many approaches deal with the strategic design of global production networks by using mathematical optimization models (Cheng et al., 2015). Thereby, a detailed view on the implementation and the migration planning is not considered (Neuner, 2009).

That this procedure is not sufficient for today's dynamic environment is reinforced by the fact that many network decisions are reversed (Sayem et al., 2018). In order to avoid mistakes and to enable a fast respond to changes, a process for the continuous design of production networks is required (Reuter et al., 2016).

Migration planning in research

Many existing approaches only slightly touch on aspects of a continuous migration planning. Some use detailed mathematical optimization models to find the best network configuration. However, they see the migration as a deterministic procedure without continuous evaluation (Jacob, 2005; Stoffel, 2016).

Many approaches focus only on the economic efficiency. The technological feasibility and possible dependencies are not considered. Therefore a continuous evaluation of the migration progress is not ensured (Moser, 2018; Schuh et al., 2014).

Some approaches determine a migration plan to achieve the optimal production network. Though, it is only on a high aggregation level. A detailed view on migration projects and dependencies is not discussed. As a result it is not easily possible to identify interactions in the network and to initiate measures (Lanza and Ude, 2009).

Summarizing, many approaches focus on time and costs, however, technological feasibility still plays a subordinate role. Despite detailed modelling, the creation of a detailed migration plan is usually disregarded. Migration planning often serves to select and evaluate appropriate network alternatives. Further, the implementation of the migration is mostly seen as a deterministic approach. A continuous evaluation by monitoring the migration progress as well as making adjustments during the migration are not provided. Moreover, a suitable visualisation of the migration status is not intended.

Approach for setting up a migration plan

This paper aims to define a method for the continuous migration planning for the design of global production networks in accordance to the reference process for the continuous design of production networks (Schuh et al., 2017). The migration planning focuses on the implementation of the target network. Therefore, all relevant decisions regarding the network strategy, -design and product allocation were already made on the strategic and

tactical planning level and can be regarded as predefined (Schuhe et al., 2018). This information represents the input for the migration planning (cf. figure 1).

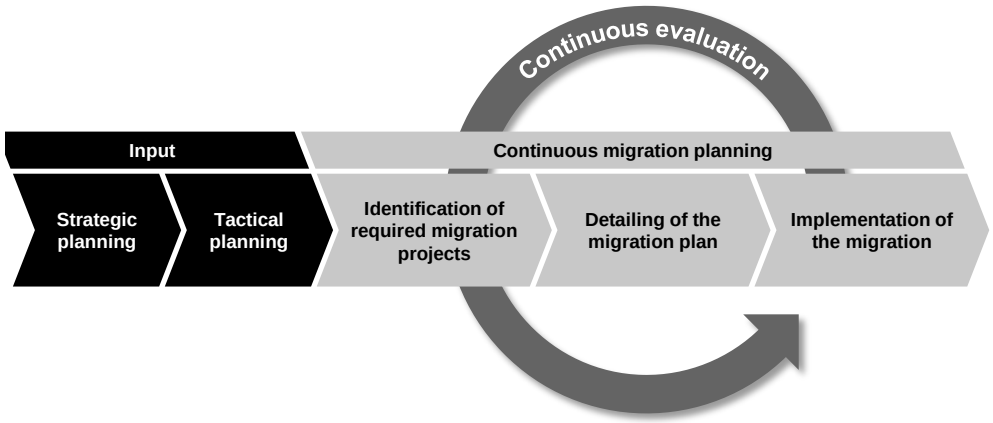

Figure 1: Methodical approach for the continuous migration planning

Based on the input, the gap to achieve the target network configuration can be derived. The gap describes the differences between the current- and target network configuration regarding the design of the sites and the product allocation in the network. The migration planning has the task to close this gap through the conduction of different structural changes. Structural changes are divided in the categories construction, deconstruction, technology shift and changes in product allocation (Sälzer, 1985). Thus, the migration presents an amount of different structural changes.

To conduct the closing certain migration steps have to be defined, which describe the transition in detail. Due to the individuality of each company and the associated production network, it is not possible to provide a general instruction for defining the necessary migration steps. Rather, the determination of respective migration steps must be examined separately for each individual case, situation- and purpose-specifically. Still, an attempt is made to describe generically a procedure for determining relevant migration steps for the respective structural changes. Approximately three migration phases have to be formed, into which the steps can be divided:

- *Planning and preparation:* This phase includes all organizational tasks which have to performed in the beginning of the actual structural change.
- *Technical implementation:* In this phase, the actual network change takes place, thus the technical implementation of the structural changes.
- *Integration into existing organizational structure:* Once the structural changes have been completed the changes must be integrated into the existing organizational structure. Corresponding tasks of the respective sites or processes are to be carried out to the desired extent. Thus, it includes the start-up phase towards a stable production.

Thus, different migration steps can be categorized concerning their migration phase and their structural change. Besides the logical relationship between individual migration phases, strong dependencies can occur between individual migration steps. The dependency exist primary in the form of a sequential relationship. A dependence on several migration steps is therefore also conceivable.

A coordination of all necessary migration steps under consideration of existing dependencies would make the creation of a suitable migration plan extremely complicated. As a result, individual migration steps are be summed up into separate migration projects, between which dependencies can exist. The migration projects form the planning basis for the subsequent creation of the migration plan.

In general, it must be ensured that migration projects only contain migration steps that are in a factual context to each other. Accordingly, migration steps can be combined into vertical migration projects overlapping different migration phases of a concrete structural change.

The scope of summarized steps varies from project to project. While the migration steps of a project are already dependent on each other due to the factual context, different migration projects or different migration steps can be dependent on each other beyond project boundaries. The dependencies do not have to refer to a structural change, but can lie in the form of horizontal dependencies between different structural changes. For example, it can simultaneously involve the dismantling of an existing site and the expansion of other sites.

The context of vertical migration projects and horizontal dependencies is shown in figure 2.

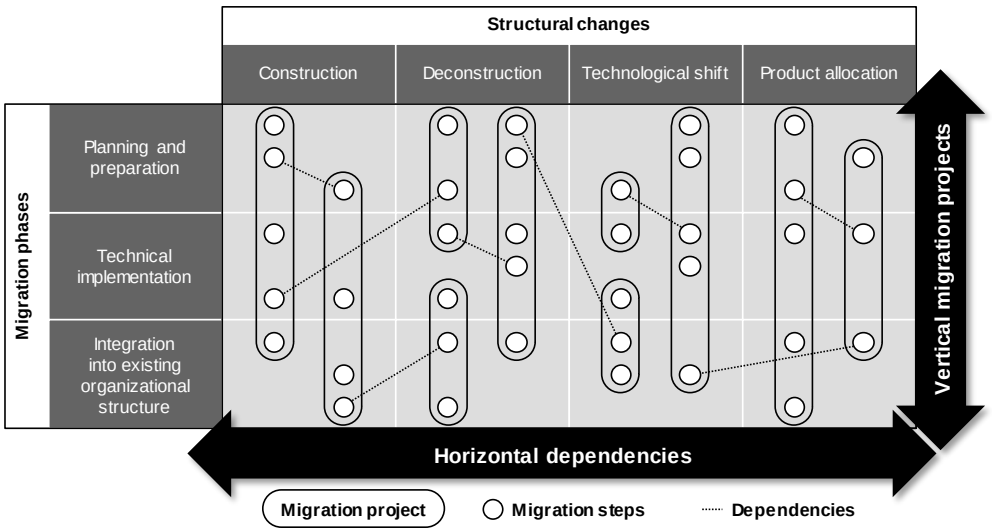

Figure 2: Vertical migration projects and horizontal dependencies

In addition to the characteristics of the design of the sites, products and processes, restrictions must be defined in which have to be taken into account for the migration. On the one hand, a time horizon has to be set for the implementation of the migration. On the other hand, a migration budget limits the available financial resources. In order to increase the flexibility for planning, an acceptable overrun should be defined for the budget and time horizon. Further, the overrun supports the continuous tracking of the current migration status during the implementation.

Beyond the restrictions, possible dependencies should be identified, which can occur during the migration because of certain structural changes. Structural changes do not affect only the directly involved sites but can also have an extensive impact on the whole production network. The resulting influence can have either a positive or a negative effect on the overall network. Negative interactions along the migration can have a negative impact on the success of the migration project and thus on the targeted outcome. In order to prevent this and make appropriate adjustments, it is important to identify interactions

at an early stage. In the context of the design of global production networks, the relevant interactions that occur mainly consist of the violation of existing capacity conditions and requirements, e.g. process capacity and resource availability.

After defining the migration restriction and relevant dependencies, the migration plan can be set up. To find the best migration plan a net present value approach is chosen. The associated objective function is shown in equation (1).

$$MAX \sum_{t=0}^{T} \left(E_t - \sum_{i=1}^{I} I_{ij} \cdot x_{ijt} \right) \cdot p^{-t} \quad (1)$$

E_t Describes the incoming payments received during period t. Since migration can have a far-reaching impact on the entire production network, it is important to ensure that the proceeds from the direct and indirect involvement of sites are taken into account. For example, it could be that an important process has to be restarted by a technology shift. Other locations that are dependent on this process are therefore also not able to call up their full performance potential during the ramp-up phase, which also indirectly influences their revenues from the migration. In order to find out which locations are indirectly influenced by the migration, a detailed analysis of the network process structure is required.

I_{ij} A migration project can involve several time-independent investments. In this case, the variable describes the amount of investment associated with the migration step *j* of the migration project i. It is important to note that in this case, the investments are only cash-effective investments. Consequently, only external investments should be taken into account with regard to migration costs. While the repayment phase of any debt financing was not taken into account when estimating the duration of the respective migration projects, repayment and interest payments to be made must be considered over the entire period, as they have a significant influence on the net present value. The amount of the investments to be made is based on the cost estimation of the migration projects.

p^{-t} Presents the discount factor for period t with $p = discount\ rate + 1$

x_{ijt} As a decision variable it can only take the values *{0;1}*. It specifies the period in which a concrete migration step is performed, taking into account existing dependencies. If the migration step is conducted in the period t, its value is *1*, otherwise *0*.

After the migration plan with all relevant information about the individual migration projects has been created, the actual implementation can take place. Due to the high dynamics and complexity in which the company and thus also the production network are, a deterministic implementation of the migration plan is not recommended. A continuous evaluation of the migration must be consulted.

Each individual migration project is evaluated with regard to its implementation and compliance with the restrictions. The evaluation of the migration results from the evaluations of the respective migration projects. The cost and time frame can be

reviewed by a performance value analysis, it provides information on the current cost and time situation with additional consideration of the degree of completion.

Further, existing dependencies should be analyzed to identify prematurely any issues. Occurring changes concerning the restriction or dependencies can lead to delays or require an adaptation of the migration plan. Therefore, a continuous evaluation of the migration has to be carried out.

Depending on the scope of the migration project, a large number of migration projects is required to achieve the desired target network configuration. As a result, it is difficult to track the current migration status. For the upper decision-making level it is important to know to which extent their specifications are integrated into the reality in order to plan further network strategies. Consequently, in a simple visualization, the migration status of the entire migration project should be displayed (figure 3).

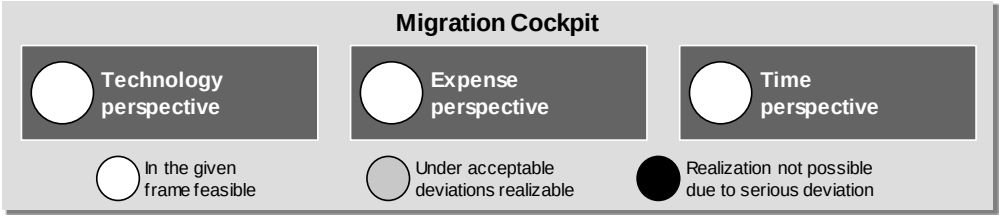

Figure 3: Migration cockpit to track the current migration status

The migration cockpit provides visualized information concerning the current migration status for the technology-, finance- and time perspective. A three stage scaling evaluates each perspective. If the perspective is in the given frame feasible, the migration occurs as planed without any issues. Under acceptable deviations realizable means, that certain restriction are not met, but the migration can still be realized in the aspired way (e.g. the expenses have exceeded the budget, but the overrun compensates the deficit). While the first two stages lead to successful implementation of the migration plan, the third stage underlines serious deviations, which require the need for action.

Thus, a suitable visualization in form of a migration cockpit gives a brief overview of the current migration status and points out directly, in which perspective adjustments or a closer look are required.

Conclusion

In order to conduct a successful production network design, this paper presents a method for continuous migration planning. By setting up detailed migration projects and pointing out existing dependencies, a continuous tracking of the migration progress and interactions in the network is possible.

Furthermore, the paper provides an outlook, how the migration status can be displayed in a migration cockpit. As part of a global control center, it supports decision makers by giving an overview of the current migration progress at any time.

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A multi-scenario analysis to improve layout efficiency

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Abstract

Logistics costs represent a large portion of overall costs. This research is focussed on a plant belonging to an aerospace component supplier, and its purpose is to reduce the layout costs in one of its warehouses. Both qualitative and quantitative approaches are used. 44 scenarios based on layout decisions, storage assignment policies and alternative picking routes fitting the company were compared. Findings showed that travelling distance could be reduced when the allocation of items in shelves follow their picking frequency and when class-based storage with return routing policies is used;using these guidelines does not impact process time and picking quality.

Keywords: Case study; Layout efficiency; Warehousing

Introduction

The ability to compete is paramount and efficiency, regardless of the organisations' overall approach, is an issue companies continuously strive for. Companies in peripheral geographies face additional challenges to compete in primary markets, as they have to overcome additional costs derived from their location. Geography cannot be overcome without relocation costs, but costs can be explored to compensate for this factor.

Although storage of products by itself does not add value to the customer (Tompkins and Smith, 1998; Carvalho, 2018), it has an immediate impact on the warehouse operation costs (Tompkins and Smith, 1998; Rushton et al., 2017).

Warehousing costs are an essential key in the overall costs a company has to support and can be streamed to compensate for the geography ones. Excluding inventory costs, the picking activity alone represents about 55% of the warehousing costs (Drury, 1998). Additionally, travelling during the picking activity is estimated to require about 50% of the time of the resources (Tompkins et al., 2010). Even small savings in this travelling time can have a generous impact on the operation costs.

This research focuses on a plant, Lauak Portugal, located in a peripheral European country. This plant is a partner factory of an aerospace metallurgic company, Groupe Lauak, that has plants in many different countries. These plants compete among themselves for company contracts. Service quality and fulfilment of due dates to customers are relevant in this industry. Although most products are developed jointly with the customers, the cost issue is a pertinent aspect for maintaining the competitiveness of the plant within the group. It is thus essential to continuously monitor costs while looking for strategies that allow reducing them, with warehousing costs, and particularly picking-related costs, playing a vital role in this search. The purpose of this research is thus to improve the warehousing costs in one problematic warehouse for the plant, contributing to its competitiveness inside the company.

This research is grounded on a systematic literature review on warehousing procedures and layout alternatives (Tompkins and Smith, 1998; Tompkins et al., 2010; Stock and Lambert, 2001; Rushton *et al.*, 2017), which support the development of theoretical scenarios. The analysis of these scenarios is based on data collected from interviews, observation, documentation and archival records. A case study approach is conducted following literature recommendations (Yin, 2018; Voss et al., 2002).

Literature background

Logistics management aims to offer the highest possible level of customer service while decreasing response time and logistics costs. To achieve the most suitable solution for each company case, a trade-off between these dimensions (service quality, time and cost) must be reached. It is based on how the several logistics activities are conducted.

Warehousing is one of the many logistics activities identified in the literature (see for instance Stock and Lambert (2001), Rushton *et al.* (2017), Carvalho *et al.* (2018)). Despite being essential to the whole chain, in most cases, this logistic activity by itself does not add any value to the final customer (Tompkins and Smith, 1998; Christopher, 2016; Carvalho et al., 2018). As Ballou mentions (2004: 470), "storage become an economic convenience rather than a necessity". Warehousing activities help companies managing their gap between supply and demand, decreasing supply chain vulnerability and decoupling demand from production capabilities (Ballou, 2004; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018).

When holding materials at a warehouse, the layout decision has a strategic impact as it will impact the trade-offs within the logistics attributes. Minimising travel distance and facilitating internal flows are the aims of the layout decisions (Carvalho et al., 2018). Its typology is usually classified based on how products are moved inside the facility and the location of the doors. Typically they are: Directional or Flow-through; Broken flow or U-shaped flow (Carvalho, 1996; Tompkins et al., 2010); L-shaped flow when the receiving and shipping areas are neither located side by side nor in opposite sides of the facility; a mixture between the three main typologies (Rushton et al., 2017).

In many situations, facility constraints lead the layout configuration; nonetheless, if it is possible to decide, there are guidelines to be considered. Flow-through layouts reduces travelling time inside the warehouse and decreases the traffic and internal congestion because the receiving and shipping areas are on opposite sides (Carvalho et al., 2018), but this typology is more suited for factory warehouses, cross-docking platforms, or facilities that deal with materials with more or less similar rotation (Rushton et al., 2017). U-shaped layouts lead to reduced average travel distance, as the start and end points of its flows are close, and reduced space allocated to the reception and shipping areas; it is more suited for the storage of products with different rotations and/or shapes and weights, which

might difficult their movement (Carvalho et al., 2018; Rushton et al., 2017). Regardless of flow typology, all warehouses have the same main internal movements.

Each warehouse has its internal activities. However, all of them have the same 4 main functions (Tompkins and Smith, 1998; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018): Reception of products; Storage until they are needed; Picking to satisfy an order; and Shipping to the user that requested them.

When assigning locations to storage of products, three main ways can be identified: 1) define a fixed/dedicated location to each product; 2) randomly store products in whatever empty places are available during the reception period (which leads to a higher average travel time (Glock and Grosse, 2012)); 3) define areas for each product, but not a specific location (each product has a single associated area, yet is randomly stored inside it – class-based storage) (Hausman *et al.*, 1976).

The fixed location alternative, although simple in terms of locating products in the facility, requires that the company keeps space available for the maximum level of inventory for every stock keeping unit (de Koster et al., 2007). Random storage, although simple to conduct and leading to better space utilization (Stock and Lambert, 2001; Carvalho et al., 2018), requires computerized central registration as product location is continuously changing (Carvalho et al., 2018) and leads to greater travel distance to complete the same picking list (Stock and Lambert, 2001; Carvalho et al., 2018) if products do not have similar rotation. Class-based location tries to combine the advantages of the two previous methods (Chan and Chan, 2011; Carvalho et al., 2018). It increases the warehouse performance up to 40% when compared to the random storage (Rao and Adil, 2013) and reduces travel distances as products are located in the facility based on their rotation (Chan and Chan, 2011).

Hall (1993: 76) defined picking as "the process by which items are retrieved from stocking locations in a warehouse". The picking activity has a direct impact on the trade-off of the logistics attributes as it has to balance the efficiency of the use of resources (which impact time and cost) and effectiveness (measured usually in terms of the number of errors) produced (Carvalho et al., 2018). Depending on the defined goal, there are four main ways to pick products (Van den Berg and Zijm, 1999; Tompkins and Smith, 1998; Ballou, 2004; Rushton et al., 2017; Carvalho et al., 2018): 1): Pick by Order (the picker has the responsibility to collect every item from one order and only one at a time); 2) Pick by Line (the picker collects the quantity required to satisfy at once several different orders from each location); 3) Zone Picking (requires dividing the warehouse into areas, and the picker collects all the items stored per zone, changing to another after collecting all the products from that zone); 4) Batch Picking (a few numbers of orders are assigned to a single picker, who is responsible for collecting all the products from those orders at the same time).

Choosing between the different picking techniques should be aligned with the warehouse policy. A company should pick by order when orders have many lines to pick (Carvalho et al., 2018). Although it is simpler when the picking is paper-based, the productivity level is the lowest due to the time the picker needs to complete an order (Tompkins and Smith, 1998; Carvalho et al., 2018; Rushton et al., 2017).

Using picking by line leads to a higher number of errors but also to a faster conclusion of activities (Carvalho et al., 2018). Due to the number of errors it can lead to, it is more suited for companies with a few lines to pick per order (Carvalho et al., 2018).

Resembling picking by order is zone picking. It is most suited for companies operating different systems and equipment inside the same warehouse (Tompkins and Smith, 1998; Carvalho et al., 2018), when orders are usually too big for a single picker, or if there is any justification for physical storage segregation (Rushton et al., 2017). It leads to more

errors but at the same time shows higher productivity (Carvalho et al., 2018). The same way zone picking is for picking by order, batch picking is more suited for picking by line (Carvalho et al., 2018).

Selecting the best picking method depends, among other issues, on product range, order size, and the equipment used to collect the products (Rushton et al., 2017).

Companies can foster their efficiency using picking routes policies (de Koster et al., 2007; Roodbergen et al., 2008; Çelk and Süral, 2014). Several routing strategies are possible inside a warehouse, among which: i) Transversal Strategy, in which the picker enters at one side of the aisle, crosses it, and exits on the opposite side (Goetschalckx and Ratliff, 1988; Hall, 1993); ii) Return Strategy, in which the picker enters on an aisle and picks all the products from one side and then returns collecting products from the other side of the aisle, exiting on the entry point (Goetschalckx and Ratliff, 1988) (also called Largest Gap Return Strategy, according to Hall (1993)); iii) Mid-Point strategy, which is the same as the return strategy, but the return point is the middle point of the aisle (Hall, 1993); iv) S-shape curves, which is basically a traversal strategy where the picker does not need to cross an aisle if there is no picking to do (De Koster and Van Der Poort, 1998; Roodbergen & De Koster, 2001a).

Manzini et al. (2007) studied the impact of several variables on picking cycle time and concluded that return is the best strategy when it comes to a quadratic warehouse, and transversal when a company operates a rectangular one. Due to its simplicity, the S-shaped strategy can be used by some companies, but the real savings arise when companies select an optimal algorithm as a picking method. Particularly, Ratliff and Rosenthal (1983) propose an algorithm that allows determining the optimal picking route that minimises the travelling distances inside the warehouse. According to these authors, the procedure starts by selecting the closest shelf to the entry point. After picking that product, the shelf closer to the initially selected product should be the next chosen one. The picker should follow this procedure until the order list is completed.

Whatever warehouse policy a company adopts, it must consider the type of products, their size, shape, weight and rotation, the location of the products in the facility, the picking policies and the service policies. It is only from the aggregation of these different aspects that time and cost can be reduced while maintaining service quality.

The company: Lauak Portugal

Lauak Portugal is a partner factory of Groupe Lauak, a French group that owns a set of industrial companies supplying the aeronautical market. This research is focused on one specific plant based in Setúbal, Portugal, that transforms metal sheet into a wide range of aircraft components.

This plant has four warehouses: two for raw material (thin and thick material), one for work-in-process, and one for the final product. The company considers that the picking process in the final product's warehouse is consuming an excessive amount of time and, for this reason, this research is focused in this specific warehouse.

The warehouse for final products has three horizontal aisles (hereafter referred to as A1 [bottom aisle], A2 [middle aisle] and A3 [top aisle]), organised with 44 shelves. It follows a U-flow configuration. Shelves are organised according to 3 product families:

- FAI: prototypes waiting for quality approval to be shipped to the customer;
- ESKU: products of a partner factory of the group;
- PFBE: final products owned by Lauak Portugal; it is considered the most relevant family inside this warehouse.

Independently on the product family, products are randomly stored on the shelves that are dedicated to its particular family. There are different boxes on the shelves to

accommodate small and medium size products. Large items are freely placed on the shelves. Regarding the picking process, it follows a picking list organised according to the delivery date, with products that have the closest delivery date being the ones that should be picked first. This organisation clearly shows that the picking process is far from being optimal. This research thus explores alternative picking routes along with alternative allocations of products on the shelves, and the impact of these alternatives in the total travelling distance in the picking process. The savings achieved in terms of travelling distance will have an impact on the warehousing costs, thus resulting in savings in the total cost supported by the company.

Methodology

This research is based on case study approach (Voss et al., 2002; Yin, 2018), and involves several consecutive research steps:

- Step I: Characterizing the current operation in the warehouse, with emphasis on the organisation of the warehouse, on the allocation of products and on the picking activity;
- Step II: Defining a set of alternative theoretical scenarios for storage assignment of products and picking routes;
- Step III: Assessing and comparing alternative theoretical scenarios;
- Step IV: Presenting recommendations for the company.

Different tools are used in each of these steps, either to collect or to treat data.

Step I: Characterizing the current operation in the warehouse

The detailed and accurate characterisation of the current operation in the warehouse requires the collection of a wide variety of data. Following both qualitative and quantitative approaches, several information sources are used, following Yin (2018): documentation, archival records, informal interviews, and direct and participant observations.

A qualitative approach is based on unstructured informal interviews with employees with different hierarchical roles to understand in detail the warehouse organisation and internal operations. Particularly, the head of logistics, the picker and the warehouse manager are interviewed. Direct observation and official documents are also used, allowing to assure data triangulation (Eisenhardt, 1989; Voss et al., 2002; Yin, 2018).

Quantitative data is also measured using direct and participant observations, namely: i) distances travelled between and across aisles and shelves inside the warehouse; ii) data related with the picking activity in one specific period; iii) the volume of each product and shelf location in the warehouse. Additionally, the daily stock is extracted from the company's ERP (archival records), and the average stock is calculated based on this information.

Step II: Defining a set of alternative theoretical scenarios

A set of alternative theoretical scenarios for the storage assignment of products and picking routes are defined based on literature recommendations. Particularly, 66 scenarios are considered based on 22 picking routes and 3 storage assignment strategies.

- Picking routes: the Traversal, Return, and Mid-Point strategies are used (Goetschalckx and Ratliff, 1988; Hall, 1993; de Koster and Van Der Port, 1998; Roodbergen and de Koster, 2001a). The S-Shape Curves strategy is not specified because it is equivalent to the Transversal strategy in this specific warehouse. Also, the algorithm proposed by Ratliff and Rosenthal's (1983) is also considered as an

alternative picking route. By examining these four different strategies, 22 picking routes are obtained, according to Table 1;

- Storage assignment: Random (SA-1), Class-Based (SA-2) and Fixed/Dedicated (SA-3) strategies are considered, following the recommendations of Hausman et al. (1976), De Koster et al. (2007), Chan and Chan (2011), Glock and Grosse (2012) and Carvalho et al. (2018). ABC analysis is used to classify products for Fixed/Dedicated and Class-Based strategies, using the picking frequency as criterion (Chan and Chan, 2011).

Table 1. Picking Routes

Picking routes	Number of routes	Strategy
PR-1 to PR-18	18	Return Strategy in one aisle and Transversal in the other two aisles, changing the aisle in which the route is started (6 scenarios starting in A_1, 6 scenarios starting in A_2 and 6 scenarios starting in A_3)
PR-19	1	Return strategy in every aisle
PR-20 & PR-21	2	Middle-Point strategy in one aisle (A_2 or A_3) and transversal in the other two.
PR-22	1	The algorithm proposed by Ratliff and Rosenthal (1983)

These 66 scenarios should be compared with the current situation in the warehouse, i.e., with a reference scenario (hereafter called *Current Scenario*) representing the picker's real movements inside the warehouse in one specific period.

Step III: Assessing and comparing alternative theoretical scenarios
The efficiency of the theoretical scenarios defined under Step II is assessed in terms of the total distance travelled inside the warehouse, according to Equation (1):

$$\sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij} * T_{ij} \quad (1)$$

in which i and j represents a location point inside the warehouse (it can be the entrance or a shelf), n represents the number of shelves plus one (to include the entrance), D_{ij} represents the distance between a location point i and j (with $i \neq j$), and T_{ij} represents the frequency in which the distance between location point i and j is travelled.

These scenarios are then compared with the current scenario in the warehouse (hereafter called Scenario 0), in which a specific warehouse layout, storage assignment and picking route are used in the daily operation (as described in the following section). To allow this comparison, all scenarios should be simulated with the same data used to characterise Scenario 0 (i.e., data related to the number of products received and delivered during a specific period).

Step IV: Presenting recommendations for the company
Based on the results obtained by comparing all the scenarios, managerial recommendations are presented to the company.

Case study
This section first presents the scenarios selected for analysis and then follows for the key results obtained based on the simulation of these scenarios.

Selected theoretical scenarios

Within the set of 66 scenarios defined above, only 44 are further anaysed in this research – the Fixed/Dedicated storage is not used in the analysis as it is not considered a doable policy by the company. Within this setting, only Random Storage (SA-1) and Class-based Storage (SA-2) are considered, together with the 22 picking routes (PR1 to PR22) – Table 2 presents a summary on the scenarios considered for analysis.

Table 2. Theoretical scenarios under study

		Storage assignment strategies	
		SA-1	**SA-2**
Picking routes	**PR-1 to PR-18**	PR-1/SA-1 to PR-18/SA-1	PR-1/SA-2 to PR-18/SA-2
	PR-19	PR-19/SA-1	PR-19/SA-2
	PR-20 & PR-21	PR-20/SA-1 & PR-21/SA-1	PR-20/SA-2 & PR-21/SA-2
	PR-22	PR-22/SA-1	PR-22/SA-2
Total number of theoretical scenarios		22	22
		44	

Class-based Storage requires classifying the different products. The following steps were conducted:

- First: Products are first classified according to the families already in use to organise the warehouse: FAI, ESKU and PFBE (classification imposed by the company). There are specific areas in the warehouse for each family, and it is not possible to mix families;
- Second: Within each family, ABC analysis is used to classify products in A, B and C items, according to the picking frequency;
- Third: Within each family and class, items are further divided into small, medium and large items. This classification is also required because the size of the products will also affect the selection of the shelf where it should be stored.

Based on such classification, 9 classes are defined. PFBE products should be first allocated to the shelves closer to the warehouse entrance, followed by ESKU products, and then by FAI products (according to company recommendations). Within each of these product families, items with a higher turnover (A items) should be stored closer to the warehouse entrance. Afterwards, within each family and class (A, B and C), products should be allocated randomly, although respecting the organisation in terms of volumes (it is not possible to mix small, medium and large items in the same shelf).

Key results

The 44 scenarios are simulated using data related to the picking activity recorded for one specific period of activity, and the current scenario was also analysed for this period. Table 3 summarises the key results of this simulation.

The results obtained for the first 22 scenarios – scenarios related to the 22 picking routes and random storage (PR-1/SA-1 to PR-22/SA-1) – are summarised in the left half of Table 3. According to these results, the proposed scenarios allowed reducing the travelling distance between 38,45% and 46,25%, when compared to the currently travelled one per month in the picking activity. Within these 22 scenarios, the ones that allow obtaining the highest saving in terms of travelling distance are the ones identified in bold in the table and that are characterised by picking routes mixing transversal and return strategies (PR-2/SA-1, PR-3/SA-1 and PR-15/SA-1).

Table 3. Total travelling distance in the period in the picking activity per scenario

		Storage assignment strategies			
		SA-1: Random Storage		SA-2: Class-based Storage	
		Total travelling distance (units of distance)	Reduction compared to the current scenario (%)	Total travelling distance (units of distance)	Reduction compared to the current scenario (%)
Picking routes	**PR-1**	340 584	43,65		
	PR-2	**324 916**	**46,25**	**215 612**	**64,33**
	PR-3	**325 936**	**46,08**	**215 224**	**64,39**
	PR-4	338 622	43,98		
	PR-5	348 352	42,37		
	PR-6	341 710	43,47		
	PR-7	338 494	44,00		
	PR-8	345 782	42,79		
	PR-9	336 020	44,41		
	PR-10	348 905	42,28		
	PR-11	366 277	39,40		
	PR-12	349 659	42,15		
	PR-13	341 630	43,48		
	PR-14	340 550	43,66		
	PR-15	**324 884**	**46,25**	**215 209**	**64,40**
	PR-16	366 492	39,37		
	PR-17	372 054	38,45		
	PR-18	348 692	42,31		
	PR-19	347 546	42,50		
	PR-20	355 193	41,24		
	PR-21	367 260	39,24		
	PR-22	326 894	44,92		
Current scenario		604 443 (units of distance)			

The right half of Table 3 summarises the results obtained for the four scenarios that resulted in the shortest travelling distance when random storage is considered, but now with class-based storage being imposed. These three scenarios were simulated with the same data used for the other 22 scenarios, but while imposing the new allocation of products in the warehouse according to the products' classification proposed above. Implementing these scenarios would allow reducing the travelling distance in the picking process at an even larger extent, when compared to the current scenario, with reductions of around 64%.

Discussion

Random storage theoretical scenarios showed to be able to reduce the distance travelled (and consequently warehousing costs) in every picking policy considered when compared to the current company policy. Nonetheless, it has to be taken into account that random storage may lead to a more time-consuming picking process if investments in information systems are not conducted as additional time might be required to find the items. This way, the reduction of at least 38,45% in distance travelled may not represent a similar reduction in the required picking time.

As the company has 3 different product families, each with items showing different picking frequencies, Class-based Storage was also analysed as a more organised random storage alternative. Findings showed that this storage assignment policy leads to even

more reduced travelled distance. Although items are also randomly stored in a specific area and within that area they are organised on the shelves based on their size, they are nonetheless easier/quicker to find than in the Random storage alternative – this is because there is a quite limited number of alternative locations where they can be found. This alternative showed a reduction in the distance above 64%, which is likely to accommodate an eventual increase of time in finding the specific item in the shelves.

Picking quality should not be affected by any of the storage assignment policies or by any of the picking routes considered as no changes in terms of a more picking by line or picking by order orientation were considered.

It is possible to state that the company is currently using a suboptimal solution and that, without any investment, can reduce warehousing costs.

Conclusions

This research aimed at assessing picking policies to reduce warehousing costs, therefore contributing to Lauak Portugal competitive position within Groupe Lauak. Diverse different storage assignment (SA) policies and various picking routes (PR) were considered. From 66 possible initial scenarios (3 SA; 22 PR), 44 were considered (2 SA; 22 PR) as the remaining did not suit the specific case.

The 3 different product families were considered in defining zones in the warehouse. Families were divided into classes based on picking frequency; each class was further classified based on the size of the product as they require different shelving conditions.

Results show that significant savings in terms of the travelling distance in the picking activity can be achieved when alternative picking routes are considered, with even higher savings being obtained when the allocation of products in the shelves follow the picking frequency of products. Nevertheless, when comparing the results obtained when different picking routes are simulated (with the same storage assignment of products), no significant differences arise. Additionally, Class-based Storage showed to be a more organised solution than Random storage when product families exist.

This research contributes to practice, specifically to the analysed company. Additionally, this approach, with necessary adjustments, can be adopted by other companies to assess their policies and to find more efficient warehousing solutions.

A period of less than a year was considered, which might limit the usability of these findings. Analysing a full year would allow including seasonal uses of items, which might influence the frequency of use of the different locations. Nevertheless, the period considered was considered by the company as representative of its overall operation.

As further research, several topics may worth pursuing. Particularly, although not considered as feasible by the company, alternative layouts could be evaluated since it may result in further improvements in the picking activity. Also, a more in-depth analysis in the nature of products may lead to the organisation of products into different families, with an expected impact in the classification and allocation of products. Finally, exploring optimisation methods to identify the optimal scenario could also be pursued.

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A multi-scenario analysis to improve layout efficiency

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Abstract

Logistics costs represent a large portion of overall costs. This research is focussed on a plant belonging to an aerospace component supplier, and its purpose is to reduce the layout costs in one of its warehouses. Both qualitative and quantitative approaches are used. 44 scenarios based on layout decisions, storage assignment policies and alternative picking routes fitting the company were compared. Findings showed that travelling distance could be reduced when the allocation of items in shelves follow their picking frequency and when class-based storage with return routing policies is used;using these guidelines does not impact process time and picking quality.

Keywords: Case study; Layout efficiency; Warehousing

Introduction

The ability to compete is paramount and efficiency, regardless of the organisations' overall approach, is an issue companies continuously strive for. Companies in peripheral geographies face additional challenges to compete in primary markets, as they have to overcome additional costs derived from their location. Geography cannot be overcome without relocation costs, but costs can be explored to compensate for this factor.

Although storage of products by itself does not add value to the customer (Tompkins and Smith, 1998; Carvalho, 2018), it has an immediate impact on the warehouse operation costs (Tompkins and Smith, 1998; Rushton et al., 2017).

Warehousing costs are an essential key in the overall costs a company has to support and can be streamed to compensate for the geography ones. Excluding inventory costs, the picking activity alone represents about 55% of the warehousing costs (Drury, 1998). Additionally, travelling during the picking activity is estimated to require about 50% of the time of the resources (Tompkins et al., 2010). Even small savings in this travelling time can have a generous impact on the operation costs.

This research focuses on a plant, Lauak Portugal, located in a peripheral European country. This plant is a partner factory of an aerospace metallurgic company, Groupe Lauak, that has plants in many different countries. These plants compete among themselves for company contracts. Service quality and fulfilment of due dates to customers are relevant in this industry. Although most products are developed jointly with the customers, the cost issue is a pertinent aspect for maintaining the competitiveness of the plant within the group. It is thus essential to continuously monitor costs while looking for strategies that allow reducing them, with warehousing costs, and particularly picking-related costs, playing a vital role in this search. The purpose of this research is thus to improve the warehousing costs in one problematic warehouse for the plant, contributing to its competitiveness inside the company.

This research is grounded on a systematic literature review on warehousing procedures and layout alternatives (Tompkins and Smith, 1998; Tompkins et al., 2010; Stock and Lambert, 2001; Rushton *et al.*, 2017), which support the development of theoretical scenarios. The analysis of these scenarios is based on data collected from interviews, observation, documentation and archival records. A case study approach is conducted following literature recommendations (Yin, 2018; Voss et al., 2002).

Literature background

Logistics management aims to offer the highest possible level of customer service while decreasing response time and logistics costs. To achieve the most suitable solution for each company case, a trade-off between these dimensions (service quality, time and cost) must be reached. It is based on how the several logistics activities are conducted.

Warehousing is one of the many logistics activities identified in the literature (see for instance Stock and Lambert (2001), Rushton *et al.* (2017), Carvalho *et al.* (2018)). Despite being essential to the whole chain, in most cases, this logistic activity by itself does not add any value to the final customer (Tompkins and Smith, 1998; Christopher, 2016; Carvalho et al., 2018). As Ballou mentions (2004: 470), "storage become an economic convenience rather than a necessity". Warehousing activities help companies managing their gap between supply and demand, decreasing supply chain vulnerability and decoupling demand from production capabilities (Ballou, 2004; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018).

When holding materials at a warehouse, the layout decision has a strategic impact as it will impact the trade-offs within the logistics attributes. Minimising travel distance and facilitating internal flows are the aims of the layout decisions (Carvalho et al., 2018). Its typology is usually classified based on how products are moved inside the facility and the location of the doors. Typically they are: Directional or Flow-through; Broken flow or U-shaped flow (Carvalho, 1996; Tompkins et al., 2010); L-shaped flow when the receiving and shipping areas are neither located side by side nor in opposite sides of the facility; a mixture between the three main typologies (Rushton et al., 2017).

In many situations, facility constraints lead the layout configuration; nonetheless, if it is possible to decide, there are guidelines to be considered. Flow-through layouts reduces travelling time inside the warehouse and decreases the traffic and internal congestion because the receiving and shipping areas are on opposite sides (Carvalho et al., 2018), but this typology is more suited for factory warehouses, cross-docking platforms, or facilities that deal with materials with more or less similar rotation (Rushton et al., 2017). U-shaped layouts lead to reduced average travel distance, as the start and end points of its flows are close, and reduced space allocated to the reception and shipping areas; it is more suited for the storage of products with different rotations and/or shapes and weights, which

might difficult their movement (Carvalho et al., 2018; Rushton et al., 2017). Regardless of flow typology, all warehouses have the same main internal movements.

Each warehouse has its internal activities. However, all of them have the same 4 main functions (Tompkins and Smith, 1998; Rushton et al., 2017; Bartholdi and Hackman, 2017; Carvalho et al., 2018): Reception of products; Storage until they are needed; Picking to satisfy an order; and Shipping to the user that requested them.

When assigning locations to storage of products, three main ways can be identified: 1) define a fixed/dedicated location to each product; 2) randomly store products in whatever empty places are available during the reception period (which leads to a higher average travel time (Glock and Grosse, 2012)); 3) define areas for each product, but not a specific location (each product has a single associated area, yet is randomly stored inside it – class-based storage) (Hausman *et al.*, 1976).

The fixed location alternative, although simple in terms of locating products in the facility, requires that the company keeps space available for the maximum level of inventory for every stock keeping unit (de Koster et al., 2007). Random storage, although simple to conduct and leading to better space utilization (Stock and Lambert, 2001; Carvalho et al., 2018), requires computerized central registration as product location is continuously changing (Carvalho et al., 2018) and leads to greater travel distance to complete the same picking list (Stock and Lambert, 2001; Carvalho et al., 2018) if products do not have similar rotation. Class-based location tries to combine the advantages of the two previous methods (Chan and Chan, 2011; Carvalho et al., 2018). It increases the warehouse performance up to 40% when compared to the random storage (Rao and Adil, 2013) and reduces travel distances as products are located in the facility based on their rotation (Chan and Chan, 2011).

Hall (1993: 76) defined picking as "the process by which items are retrieved from stocking locations in a warehouse". The picking activity has a direct impact on the trade-off of the logistics attributes as it has to balance the efficiency of the use of resources (which impact time and cost) and effectiveness (measured usually in terms of the number of errors) produced (Carvalho et al., 2018). Depending on the defined goal, there are four main ways to pick products (Van den Berg and Zijm, 1999; Tompkins and Smith, 1998; Ballou, 2004; Rushton et al., 2017; Carvalho et al., 2018): 1): Pick by Order (the picker has the responsibility to collect every item from one order and only one at a time); 2) Pick by Line (the picker collects the quantity required to satisfy at once several different orders from each location); 3) Zone Picking (requires dividing the warehouse into areas, and the picker collects all the items stored per zone, changing to another after collecting all the products from that zone); 4) Batch Picking (a few numbers of orders are assigned to a single picker, who is responsible for collecting all the products from those orders at the same time).

Choosing between the different picking techniques should be aligned with the warehouse policy. A company should pick by order when orders have many lines to pick (Carvalho et al., 2018). Although it is simpler when the picking is paper-based, the productivity level is the lowest due to the time the picker needs to complete an order (Tompkins and Smith, 1998; Carvalho et al., 2018; Rushton et al., 2017).

Using picking by line leads to a higher number of errors but also to a faster conclusion of activities (Carvalho et al., 2018). Due to the number of errors it can lead to, it is more suited for companies with a few lines to pick per order (Carvalho et al., 2018).

Resembling picking by order is zone picking. It is most suited for companies operating different systems and equipment inside the same warehouse (Tompkins and Smith, 1998; Carvalho et al., 2018), when orders are usually too big for a single picker, or if there is any justification for physical storage segregation (Rushton et al., 2017). It leads to more

errors but at the same time shows higher productivity (Carvalho et al., 2018). The same way zone picking is for picking by order, batch picking is more suited for picking by line (Carvalho et al., 2018).

Selecting the best picking method depends, among other issues, on product range, order size, and the equipment used to collect the products (Rushton et al., 2017).

Companies can foster their efficiency using picking routes policies (de Koster et al., 2007; Roodbergen et al., 2008; Çelk and Süral, 2014). Several routing strategies are possible inside a warehouse, among which: i) Transversal Strategy, in which the picker enters at one side of the aisle, crosses it, and exits on the opposite side (Goetschalckx and Ratliff, 1988; Hall, 1993); ii) Return Strategy, in which the picker enters on an aisle and picks all the products from one side and then returns collecting products from the other side of the aisle, exiting on the entry point (Goetschalckx and Ratliff, 1988) (also called Largest Gap Return Strategy, according to Hall (1993)); iii) Mid-Point strategy, which is the same as the return strategy, but the return point is the middle point of the aisle (Hall, 1993); iv) S-shape curves, which is basically a traversal strategy where the picker does not need to cross an aisle if there is no picking to do (De Koster and Van Der Poort, 1998; Roodbergen & De Koster, 2001a).

Manzini et al. (2007) studied the impact of several variables on picking cycle time and concluded that return is the best strategy when it comes to a quadratic warehouse, and transversal when a company operates a rectangular one. Due to its simplicity, the S-shaped strategy can be used by some companies, but the real savings arise when companies select an optimal algorithm as a picking method. Particularly, Ratliff and Rosenthal (1983) propose an algorithm that allows determining the optimal picking route that minimises the travelling distances inside the warehouse. According to these authors, the procedure starts by selecting the closest shelf to the entry point. After picking that product, the shelf closer to the initially selected product should be the next chosen one. The picker should follow this procedure until the order list is completed.

Whatever warehouse policy a company adopts, it must consider the type of products, their size, shape, weight and rotation, the location of the products in the facility, the picking policies and the service policies. It is only from the aggregation of these different aspects that time and cost can be reduced while maintaining service quality.

The company: Lauak Portugal

Lauak Portugal is a partner factory of Groupe Lauak, a French group that owns a set of industrial companies supplying the aeronautical market. This research is focused on one specific plant based in Setúbal, Portugal, that transforms metal sheet into a wide range of aircraft components.

This plant has four warehouses: two for raw material (thin and thick material), one for work-in-process, and one for the final product. The company considers that the picking process in the final product's warehouse is consuming an excessive amount of time and, for this reason, this research is focused in this specific warehouse.

The warehouse for final products has three horizontal aisles (hereafter referred to as A1 [bottom aisle], A2 [middle aisle] and A3 [top aisle]), organised with 44 shelves. It follows a U-flow configuration. Shelves are organised according to 3 product families:

- FAI: prototypes waiting for quality approval to be shipped to the customer;
- ESKU: products of a partner factory of the group;
- PFBE: final products owned by Lauak Portugal; it is considered the most relevant family inside this warehouse.

Independently on the product family, products are randomly stored on the shelves that are dedicated to its particular family. There are different boxes on the shelves to

accommodate small and medium size products. Large items are freely placed on the shelves. Regarding the picking process, it follows a picking list organised according to the delivery date, with products that have the closest delivery date being the ones that should be picked first. This organisation clearly shows that the picking process is far from being optimal. This research thus explores alternative picking routes along with alternative allocations of products on the shelves, and the impact of these alternatives in the total travelling distance in the picking process. The savings achieved in terms of travelling distance will have an impact on the warehousing costs, thus resulting in savings in the total cost supported by the company.

Methodology

This research is based on case study approach (Voss et al., 2002; Yin, 2018), and involves several consecutive research steps:

- Step I: Characterizing the current operation in the warehouse, with emphasis on the organisation of the warehouse, on the allocation of products and on the picking activity;
- Step II: Defining a set of alternative theoretical scenarios for storage assignment of products and picking routes;
- Step III: Assessing and comparing alternative theoretical scenarios;
- Step IV: Presenting recommendations for the company.

Different tools are used in each of these steps, either to collect or to treat data.

Step I: Characterizing the current operation in the warehouse

The detailed and accurate characterisation of the current operation in the warehouse requires the collection of a wide variety of data. Following both qualitative and quantitative approaches, several information sources are used, following Yin (2018): documentation, archival records, informal interviews, and direct and participant observations.

A qualitative approach is based on unstructured informal interviews with employees with different hierarchical roles to understand in detail the warehouse organisation and internal operations. Particularly, the head of logistics, the picker and the warehouse manager are interviewed. Direct observation and official documents are also used, allowing to assure data triangulation (Eisenhardt, 1989; Voss et al., 2002; Yin, 2018).

Quantitative data is also measured using direct and participant observations, namely: i) distances travelled between and across aisles and shelves inside the warehouse; ii) data related with the picking activity in one specific period; iii) the volume of each product and shelf location in the warehouse. Additionally, the daily stock is extracted from the company's ERP (archival records), and the average stock is calculated based on this information.

Step II: Defining a set of alternative theoretical scenarios

A set of alternative theoretical scenarios for the storage assignment of products and picking routes are defined based on literature recommendations. Particularly, 66 scenarios are considered based on 22 picking routes and 3 storage assignment strategies.

- Picking routes: the Traversal, Return, and Mid-Point strategies are used (Goetschalckx and Ratliff, 1988; Hall, 1993; de Koster and Van Der Port, 1998; Roodbergen and de Koster, 2001a). The S-Shape Curves strategy is not specified because it is equivalent to the Transversal strategy in this specific warehouse. Also, the algorithm proposed by Ratliff and Rosenthal's (1983) is also considered as an

alternative picking route. By examining these four different strategies, 22 picking routes are obtained, according to Table 1;

- Storage assignment: Random (SA-1), Class-Based (SA-2) and Fixed/Dedicated (SA-3) strategies are considered, following the recommendations of Hausman et al. (1976), De Koster et al. (2007), Chan and Chan (2011), Glock and Grosse (2012) and Carvalho et al. (2018). ABC analysis is used to classify products for Fixed/Dedicated and Class-Based strategies, using the picking frequency as criterion (Chan and Chan, 2011).

Table 1. Picking Routes

Picking routes	Number of routes	Strategy
PR-1 to PR-18	18	Return Strategy in one aisle and Transversal in the other two aisles, changing the aisle in which the route is started (6 scenarios starting in A_1, 6 scenarios starting in A_2 and 6 scenarios starting in A_3)
PR-19	1	Return strategy in every aisle
PR-20 & PR-21	2	Middle-Point strategy in one aisle (A_2 or A_3) and transversal in the other two.
PR-22	1	The algorithm proposed by Ratliff and Rosenthal (1983)

These 66 scenarios should be compared with the current situation in the warehouse, i.e., with a reference scenario (hereafter called *Current Scenario*) representing the picker's real movements inside the warehouse in one specific period.

Step III: Assessing and comparing alternative theoretical scenarios
The efficiency of the theoretical scenarios defined under Step II is assessed in terms of the total distance travelled inside the warehouse, according to Equation (1):

$$\sum_{i=1}^{n} \sum_{j=1}^{n} D_{ij} * T_{ij} \quad (1)$$

in which i and j represents a location point inside the warehouse (it can be the entrance or a shelf), n represents the number of shelves plus one (to include the entrance), D_{ij} represents the distance between a location point i and j (with $i \neq j$), and T_{ij} represents the frequency in which the distance between location point i and j is travelled.

These scenarios are then compared with the current scenario in the warehouse (hereafter called Scenario 0), in which a specific warehouse layout, storage assignment and picking route are used in the daily operation (as described in the following section). To allow this comparison, all scenarios should be simulated with the same data used to characterise Scenario 0 (i.e., data related to the number of products received and delivered during a specific period).

Step IV: Presenting recommendations for the company
Based on the results obtained by comparing all the scenarios, managerial recommendations are presented to the company.

Case study
This section first presents the scenarios selected for analysis and then follows for the key results obtained based on the simulation of these scenarios.

Selected theoretical scenarios

Within the set of 66 scenarios defined above, only 44 are further anaysed in this research – the Fixed/Dedicated storage is not used in the analysis as it is not considered a doable policy by the company. Within this setting, only Random Storage (SA-1) and Class-based Storage (SA-2) are considered, together with the 22 picking routes (PR1 to PR22) – Table 2 presents a summary on the scenarios considered for analysis.

Table 2. Theoretical scenarios under study

		Storage assignment strategies	
		SA-1	**SA-2**
Picking routes	**PR-1 to PR-18**	PR-1/SA-1 to PR-18/SA-1	PR-1/SA-2 to PR-18/SA-2
	PR-19	PR-19/SA-1	PR-19/SA-2
	PR-20 & PR-21	PR-20/SA-1 & PR-21/SA-1	PR-20/SA-2 & PR-21/SA-2
	PR-22	PR-22/SA-1	PR-22/SA-2
Total number of theoretical scenarios		22	22
		44	

Class-based Storage requires classifying the different products. The following steps were conducted:

- First: Products are first classified according to the families already in use to organise the warehouse: FAI, ESKU and PFBE (classification imposed by the company). There are specific areas in the warehouse for each family, and it is not possible to mix families;
- Second: Within each family, ABC analysis is used to classify products in A, B and C items, according to the picking frequency;
- Third: Within each family and class, items are further divided into small, medium and large items. This classification is also required because the size of the products will also affect the selection of the shelf where it should be stored.

Based on such classification, 9 classes are defined. PFBE products should be first allocated to the shelves closer to the warehouse entrance, followed by ESKU products, and then by FAI products (according to company recommendations). Within each of these product families, items with a higher turnover (A items) should be stored closer to the warehouse entrance. Afterwards, within each family and class (A, B and C), products should be allocated randomly, although respecting the organisation in terms of volumes (it is not possible to mix small, medium and large items in the same shelf).

Key results

The 44 scenarios are simulated using data related to the picking activity recorded for one specific period of activity, and the current scenario was also analysed for this period. Table 3 summarises the key results of this simulation.

The results obtained for the first 22 scenarios – scenarios related to the 22 picking routes and random storage (PR-1/SA-1 to PR-22/SA-1) – are summarised in the left half of Table 3. According to these results, the proposed scenarios allowed reducing the travelling distance between 38,45% and 46,25%, when compared to the currently travelled one per month in the picking activity. Within these 22 scenarios, the ones that allow obtaining the highest saving in terms of travelling distance are the ones identified in bold in the table and that are characterised by picking routes mixing transversal and return strategies (PR-2/SA-1, PR-3/SA-1 and PR-15/SA-1).

Table 3. Total travelling distance in the period in the picking activity per scenario

		Storage assignment strategies			
		SA-1: Random Storage		SA-2: Class-based Storage	
		Total travelling distance (units of distance)	Reduction compared to the current scenario (%)	Total travelling distance (units of distance)	Reduction compared to the current scenario (%)
Picking routes	**PR-1**	340 584	43,65		
	PR-2	**324 916**	**46,25**	**215 612**	**64,33**
	PR-3	**325 936**	**46,08**	**215 224**	**64,39**
	PR-4	338 622	43,98		
	PR-5	348 352	42,37		
	PR-6	341 710	43,47		
	PR-7	338 494	44,00		
	PR-8	345 782	42,79		
	PR-9	336 020	44,41		
	PR-10	348 905	42,28		
	PR-11	366 277	39,40		
	PR-12	349 659	42,15		
	PR-13	341 630	43,48		
	PR-14	340 550	43,66		
	PR-15	**324 884**	**46,25**	**215 209**	**64,40**
	PR-16	366 492	39,37		
	PR-17	372 054	38,45		
	PR-18	348 692	42,31		
	PR-19	347 546	42,50		
	PR-20	355 193	41,24		
	PR-21	367 260	39,24		
	PR-22	332 866	44,92		
Current scenario		604 443 (units of distance)			

The right half of Table 3 summarises the results obtained for the four scenarios that resulted in the shortest travelling distance when random storage is considered, but now with class-based storage being imposed. These three scenarios were simulated with the same data used for the other 22 scenarios, but while imposing the new allocation of products in the warehouse according to the products' classification proposed above. Implementing these scenarios would allow reducing the travelling distance in the picking process at an even larger extent, when compared to the current scenario, with reductions of around 64%.

Discussion

Random storage theoretical scenarios showed to be able to reduce the distance travelled (and consequently warehousing costs) in every picking policy considered when compared to the current company policy. Nonetheless, it has to be taken into account that random storage may lead to a more time-consuming picking process if investments in information systems are not conducted as additional time might be required to find the items. This way, the reduction of at least 38,45% in distance travelled may not represent a similar reduction in the required picking time.

As the company has 3 different product families, each with items showing different picking frequencies, Class-based Storage was also analysed as a more organised random storage alternative. Findings showed that this storage assignment policy leads to even

more reduced travelled distance. Although items are also randomly stored in a specific area and within that area they are organised on the shelves based on their size, they are nonetheless easier/quicker to find than in the Random storage alternative – this is because there is a quite limited number of alternative locations where they can be found. This alternative showed a reduction in the distance above 64%, which is likely to accommodate an eventual increase of time in finding the specific item in the shelves.

Picking quality should not be affected by any of the storage assignment policies or by any of the picking routes considered as no changes in terms of a more picking by line or picking by order orientation were considered.

It is possible to state that the company is currently using a suboptimal solution and that, without any investment, can reduce warehousing costs.

Conclusions

This research aimed at assessing picking policies to reduce warehousing costs, therefore contributing to Lauak Portugal competitive position within Groupe Lauak. Diverse different storage assignment (SA) policies and various picking routes (PR) were considered. From 66 possible initial scenarios (3 SA; 22 PR), 44 were considered (2 SA; 22 PR) as the remaining did not suit the specific case.

The 3 different product families were considered in defining zones in the warehouse. Families were divided into classes based on picking frequency; each class was further classified based on the size of the product as they require different shelving conditions.

Results show that significant savings in terms of the travelling distance in the picking activity can be achieved when alternative picking routes are considered, with even higher savings being obtained when the allocation of products in the shelves follow the picking frequency of products. Nevertheless, when comparing the results obtained when different picking routes are simulated (with the same storage assignment of products), no significant differences arise. Additionally, Class-based Storage showed to be a more organised solution than Random storage when product families exist.

This research contributes to practice, specifically to the analysed company. Additionally, this approach, with necessary adjustments, can be adopted by other companies to assess their policies and to find more efficient warehousing solutions.

A period of less than a year was considered, which might limit the usability of these findings. Analysing a full year would allow including seasonal uses of items, which might influence the frequency of use of the different locations. Nevertheless, the period considered was considered by the company as representative of its overall operation.

As further research, several topics may worth pursuing. Particularly, although not considered as feasible by the company, alternative layouts could be evaluated since it may result in further improvements in the picking activity. Also, a more in-depth analysis in the nature of products may lead to the organisation of products into different families, with an expected impact in the classification and allocation of products. Finally, exploring optimisation methods to identify the optimal scenario could also be pursued.

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From China to the West: why manufacturing locates in high-cost countries

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Abstract

This paper examines differences and similarities between motivations of manufacturing offshoring and backshoring. By analysing two unique databases of manufacturing offshoring (113 cases) and backshoring (468 cases) from China, we find that flows from China to high-cost countries (whether offshoring or backshoring) share some common drivers, such as allowing proximity to customers, exploiting the "made in" effect, and seeking specialised resources. Our findings highlight reasons why manufacturing may expand its presence in Western countries as a result of both repatriations and of foreign direct investments from large economies such as China, and therefore point to potential areas of policy intervention.

Keywords: Reshoring, Offshoring, Location

Introduction

Ever since the nineties, the rise of manufacturing offshoring from high-cost to low-cost locations has received considerable attention from both business and academia (Schoenherr et al., 2008; Fredriksson and Jonsson, 2009). However, more recently some of the former low cost countries have seen a drastic increase in various costs (Kumar, 2009), including labour. Weakened location advantages have led many Western firms to relocate some manufacturing activities back to their home countries. In academia, this notion of manufacturing backshoring – namely a company decision to bring production or sourcing back to the home country, has attracted great interest (Foerstl et al., 2016; Fratocchi et al., 2016; Kinkel and Maloca, 2009; Gray et al., 2017; Ketokivi et al., 2017). Research though, has not paid equal attention to the

"raisons d'etre" of offshoring of manufacturing to high-cost countries by companies headquartered in China (Deng, 2012), other than market expansion and critical assets acquisition (Li et al., 2016).

Additionally, previous research suggests that there is a disconnection between motivations for backshoring and offshoring. Backshoring typically concerns flows from low-cost to high cost countries and its motivation is predominantly value-driven (Johansson et al., 2018; Fratocchi et al., 2016), while offshoring involves flows from high-cost to low-cost countries, and is predominantly cost-driven (Da Silveira, 2014; Fratocchi et al., 2016). What remains unknown is whether this difference still holds when the geographical directions of reshoring and offshoring are aligned.

This paper aims to offer a new perspective on the differences and similarities between the motivations of manufacturing offshoring and backshoring, by comparing manufacturing location moves by Chinese companies to North America and Europe (offshoring) and relocations of North American and European companies from China to the headquarter countries (backshoring). Findings may be of special interest for understanding the distinctive advantages of locating manufacturing in the West and for the design of policies aimed at attracting manufacturing and FDI to high-cost countries.

Literature background

Theory

The eclectic paradigm of international production (Dunning, 1980, 2000) proposes a unifying frame whereby location advantages are just one of three broad factors affecting international production. In particular, the attractiveness of the Location-specific endowments of alternative countries interacts with the firm's Ownership of a set of income- generating assets (Barney, 1991), and the firm's interest to Internalize activities (Buckley and Casson, 1976; Williamson, 1985) for the generation and/or exploitation of competences (OLI model). Further, Dunning (2000) subsumes the location drivers into four categories of contextual factors that affect the international configuration of production: (1) "the economic and political features of the country or region of the investing firms, and of the country or region in which they are seeking to invest"; (2) "the industry and the nature of the value added activity in which the firms are engaged"; (3) "the characteristics of the individual investing firms"; (4) "the raison d'être for the FDI," i.e., whether the direct investment or alliance is market-seeking, resource-seeking, efficiency-seeking (motivated by rationalization), or strategic assets seeking (i.e., intended to protect or improve ownership advantages of the firm). Dunning's paradigm has been applied to explain several types of location decisions, and reshoring (Ellram et al., 2013). As our study focuses on manufacturing location decisions at the country level and we do not consider the make-or-buy aspect, the eclectic paradigm's *location advantages* is a suitable tool for our analysis.

Offshoring and backshoring: Empirical evidence

Since academia started to focus on the concept of offshoring in the early 2000s, numerous empirical studies have investigated the factors motivating companies to offshore manufacturing. Among these motivations, cost reduction, has emerged as one of the most important motivations for offshoring (Aron and Singh, 2005; Canham and Hamilton, 2013; Da Silveira, 2014). Firms have offshored production activities to low-wage countries to seek lower costs of labour and other productive inputs (Doh, 2005; Jensen and Pedersen, 2011). Other

motivations include opening up new markets, access to foreign distribution channels, access to materials and goods, producing in the proximity of the customer, securing knowledge, and following the investor (cf. Dunning, 1980, 1988; Hollenstein, 2005; Kinkel et al., 2007; Kinkel and Maloca, 2009; MacCarthy and Atthirawong, 2003). Of all low-cost offshoring destinations, China, in particular, has attracted significant scholarly interest due to its position as the world factory (Zhang, 2006). Economic factors such as cost reduction, cost saving, and capital investment reduction have been the major drivers for companies to offshore manufacturing to China (Fang et al., 2004; Salmi, 2006). More recent studies note that motivational factors such as improved product quality, increased efficiency, and availability of major logistic platforms, (Nassimbeni and Sartor, 2007; Towers and Song, 2010; Sinha et al., 2011) have also played key roles in foreign firms' decisions to offshore manufacturing to China.

On the other hand, since the notion of reshoring emerged as a hot topic in recent years, many studies have also examined the motivations for reshoring (cf. Ellram et al., 2013; Fratocchi et al., 2014; Gray et al., 2013). For instance, Kinkel and Maloca (2009) found that factors such as lack of flexibility, delivery ability, and quality problems at the foreign locations were the root cause of reshoring. In the case of the UK automotive sector UK, Bailey and De Propris (2014) found that rising costs overseas, high quality production in the UK, simpler transport and logistics, the availability of a skilled workforce, a strong supply chain, and better quality R&D and innovation were the most prominent motivations for reshoring. Fratocchi et al. (2016) identify as many as 31 prominent motivations for reshoring by reviewing both scholarly and practitioner studies. Two motivations, namely the reduction of labour costs between the host and home countries and poor quality of production abroad were found to be the most frequently acknowledged motivations for reshoring. However, based on the literature review and evidence collected from secondary sources, the authors conclude that value-driven motivations tend to characterise reshoring more frequently than offshoring.

Chinese outward FDI to developed economies

The recent phenomenon of Chinese outward foreign direct investment (OFDI) to advanced economies is reshaping the global business landscape in many ways (Deng et al., 2017). However, the motivations behind such operations remain unclear. While mainstream theory tends to assume that firms internationalise to exploit competitive advantages, it has been found that Chinese firms, on the contrary, generally internationalise in order to address competitive disadvantages (Child and Rodrigues, 2005). Extant literature suggests that Chinese OFDI to developed economies is mainly driven by the search for strategic resources, such as superior skills, marketing expertise, and proprietary technologies (Deng, 2007; 2012). In particular, when investing in developed economies, Chinese firms tend to seek sophisticated technology or advanced manufacturing know-how by acquiring foreign companies or their subunits that possess such proprietary technology (Luo et al., 2010). Additionally, Buckley et al. (2008) point out that while knowledge acquisition has become increasingly important to Chinese MNEs, much of Chinese investment in some developed economies is also resource seeking, in addition to the appeal of developed countries' markets (Child and Rodrigues, 2005). In terms of firm characteristics, it is revealed that Chinese firms with high state ownership are likely to focus on developing markets, whereas firms affiliated to a higher government level increase OFDI in developed countries (Wang et al., 2012). Specifically, large State-owned Asset Supervision and Administration Commission (SASAC) controlled firms are especially attracted to richer developed markets (Ramasamy et al., 2012).

Methodology

Two independent databases were used, while adopting homogeneous procedures for gathering and classifying data. Regarding manufacturing backshoring from China to North America and Europe, the database built from secondary sources of Ancarani and Di Mauro (2018) was used, and backshoring cases originating from China and directed to Europe and North America were extracted (468). Regarding manufacturing offshoring from China to North America and Europe, an analogous database was built using secondary data extracted from Chinese press sources (113 cases). The use of secondary data is granted by the fact that the phenomena of Western companies' reshoring from low-cost countries and Chinese offshoring to high-cost environment is unfolding and ongoing. Therefore, newspaper articles, as a type of secondary data, can provide timely and pertinent research source (Yeung et al., 2016) to assist in capturing the essence of these contemporary events in a longitudinal context.

For the backshoring database, a data set on backshoring from 2011 to the end of 2017 was developed by gathering information from several sources. First, the historical archives of relevant international business newspapers, national-level newspapers and business magazines were considered. Then, articles adopting selected keywords (reshoring, back-shoring, backshoring, nearshoring, back-reshoring, insourcing, on-shoring, in-shoring, reverse globalization, relocation, repatriation in combination with manufacturing) were searched for. Additionally, white papers by major consulting companies (e.g. Boston Consulting Group, McKinsey, Accenture and Grand Thornton) were also reviewed. Finally, internet search engines with the above-mentioned keywords were used to further check that no relevant news concerning reshoring was missing. With respect to US companies, data collected by the Reshoring Initiative (www.reshorenow.org) was also gathered.

For the offshoring database, the following steps were taken in collecting the data. First, we searched for newspaper articles that used offshoring-related keywords (namely, moving production to, start production in, and establishing a factory in) together with the names of developed economies as listed in the UN's most recent country classification (https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/WESP2019_BOOK-web.pdf) in the CNKI (China National Knowledge Infrastructure) database. The CNKI is China's largest and most comprehensive academic online library, covering more than 600 core full-text Chinese newspapers (CNKI, 2019).

Two of the authors are native Chinese speakers and the working language of the research team is English. The authors held meticulous discussions and reached a consensus on the translation of each keyword and motivational factor extracted. A keyword table in both the Chinese and English languages was created to ensure transparency and traceability. The researchers then used internet search engines, namely Google and Baidu, to search for magazine articles and company news releases, using the above-mentioned keywords to further check that no relevant information concerning the moving of manufacturing from China to high-cost environments was missing. The entire data mining process was conducted manually by the researchers.

For both of the databases, we carried out pre-testing with twenty sources, to ensure that the researchers used aligned inclusion and exclusion criteria for all cases. For the backshoring database, the unit of analysis was the single decision/project to move back offshore activities. For the offshoring database, the unit of analysis was the single decision/project to move manufacturing from China to high-cost environments. We counted two cases if a company has reshored production from two different host countries/moved production from China to two

different high-cost host countries. Chinese firms' overseas production activities involving joint ventures with local firms, mergers and acquisitions of local firms, and natural resource exploitations were excluded. The agreed criteria were then applied to the entire sample.

For data analysis, we applied a content-analysis method inspired by Krippendorff (2004). The purpose was to identify the various motivational factors influencing firms' manufacturing backshoring/offshoring decisions. The motivational factors were inferred from company interviews reported in the articles, or from reporters' descriptions of each case. As the process of extracting motivational factors from large blocks of text and categorising them is interpretative, to avoid misinterpretation, the researchers reviewed each case and categorised their observed motivations independently. Then the results were cross-validated. In the case of different results, the researchers reviewed the source article together, discussed meticulously, and reached an agreed decision.

Next, a principal components exploratory factor analysis (EFA) was performed to discover the structure of the identified motivational factors and build aggregated motivations. Varimax rotation was employed to generate interpretable scores and factor loadings. The results from the two independent databases are presented and compared in the below section.

Results

The backshoring sample is entirely made up of private firms, 60% of which are SMEs. In terms of reshoring country, 58% of firms return to the US and the remaining proportion to EU countries. Most prominent industries are textile and clothing (19%), electronics (18%) and machinery (16%).

In the Chinese sample, the EU countries and North America are the two most significant areas represented. Developed Asia and the Pacific is the other area featured. The sample includes cases of offshoring by Chinese firms from a variety of manufacturing industries. A few industries – clean energy, food processing, automotive and household appliances – stand out due to the higher number of cases. In terms of firm ownership, the vast majority of firms that have engaged in offshore manufacturing are private firms, with only a minority of firms being state-owned. In addition, almost all of the firms are large firms, with only a small handful being SMEs. A breakdown by host country region, firm size, and firm ownership type reveals that Chinese SMEs only offshore manufacturing to the EU countries, while large Chinese firms mainly offshore manufacturing to North America. The vast majority of private Chinese firms offshore manufacturing to North America and the EU countries, whereas North America is the destination for half of the SOEs.

The EFA procedure allowed identifying ten higher-ordered factors with eigenvalues higher than one that drive Western firms' backshoring behaviour (see Table 1). These factors account for 64.03 percent of variance. Western firms' backshoring activities are motivated by responsiveness, quality, direct costs, total cost of sourcing, hidden costs, innovation, brand recognition, lack of skills, and loyalty. For the Chinese sample, two highly frequent motivations (market expansion and changes in tariffs and taxation) were excluded from EFA because of their very low correlation with remaining motivations. EFA led to identify four higher order factors that drive Chinese firms' offshoring activities (see Table 2), explaining 72.72 percent of the total variance. Chinese firms' offshoring factors include responsiveness, quality, cost, and customer proximity.

***Table 1**. Motivations of Western manufacturing reshoring: Exploratory Factor Analysis*

Factor		**Factor loadings**
Responsiveness	customer proximity	0.7395
	production flexibility	0.7021
Quality	high quality	0.7699
Costs	logistics costs	0.754
	labour costs	0.6953
Cost of sourcing	change in total cost of sourcing	0.6827
Hidden costs	rework	0.7002
	delay/delivery time	0.5844
Innovation	product innovation	0.775
	process innovation	0.7025
Brand recognition	Walmart effect	0.8259
	made in effect	0.7109
Lack of skills	absence of local suppliers	0.7673
	energy costs	0.6786
	know-how	0.6117
Loyalty	loyalty to home country	0.8906

***Table 2**. Motivations of Chinese manufacturing offshoring to high-cost countries: Exploratory Factor Analysis*

Factor		**Factor loadings**
Responsiveness	delay/delivery time	0.8984
	production flexibility	0.8764
Quality	made in effect	0.8489
	availability of raw materials	0.7733
Costs	labour costs	0.9104
	changes in total cost of sourcing	0.8170
Customer proximity	customer proximity	0.7112

Discussion

We start by comparing offshoring factors identified for Chinese firms with offshoring motivations in previous literature. As already discussed, cost has been widely considered as a factor for manufacturing offshoring towards low-cost countries (Roza et al., 2011; Ellram et al., 2013; Linares-Navarro et al., 2014; Tate et al., 2014; Di Mauro et al., 2018), while market expansion and strategic asset seeking have been used to explain Chinese firms' outward FDI toward advanced economies (Deng et al., 2017; Li et al., 2016). However, same for the case of

Chinese firms' offshore manufacturing to high-cost countries, and thus deserve further research attention.

By comparing the EFA results of the two samples, our study shows that there is overlap as well as differences in motivational factors between the phenomena of Chinese manufacturing offshoring and Western manufacturing reshoring. Although previous studies suggest there are disconnections between the motivational factors for reshoring and offshoring, as offshoring is driven by cost-related considerations whereas reshoring is motivated by value-related factors (Fratocchi et al., 2016), our research finds that offshoring can also be motivated by value-related considerations (Fratocchi et al., 2016) and by strategic seeking motivations other than innovation.

Overall, our results suggest that Chinese offshoring to advanced economies and Western backshoring are both motivated by the need to lower total manufacturing costs, increase responsiveness, and achieve higher perceived quality. The motivation to lower total manufacturing costs is especially apparent in the case of Chinese textile firms' offshoring to the USA, where the labour costs are higher, but other costs such as international logistics, utilities and raw materials are lower. Quality-related factors such as the "made in" effect, commonly known as the country-of-origin (COO) effect, also represent an important motivation for Chinese firms' offshoring activities. In terms of differences between the two samples, market expansion and changes in taxation are the two most prominent and unique factors for Chinese offshoring, while innovation, lack of skills, brand recognition, and loyalty to home country are motivational factors unique to Western' firms' backshoring activities.

Conclusion

In this research, we set out to understand the similarities and differences between manufacturing backshoring and offshoring from China to high-cost countries. By analysing two unique databases, we compare backshoring and offshoring motivations. Since manufacturing location/relocation from low-cost to high-cost countries is a novel research topic and empirical evidence is rather limited, we thus provide a better understanding of these current phenomena and enrich the extant body of knowledge. Interesting findings have emerged from the preliminary comparative analysis of motivations. First, our research finds that flows from China to high cost countries (whether offshoring or backshoring) share some common drivers such as allowing proximity to customers, exploiting the "made in" effect, and seeking specialised resources. These results highlight reasons why manufacturing may expand its presence in Western countries as a result of both repatriations and of foreign direct investments from large economies such as China, and therefore point to potential areas of policy intervention.

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Project Management

The activities of Project Management Offices and the satisfaction of project personnel in high technology new product development

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Abstract

The adoption of best practices in project management depends on the existence of an infrastructure for supporting project managers and teams. Companies have created Project Management Offices (PMO) for this purpose. This research presents an investigation carried out in final phases of an action research for implementing a PMO to support new product development (NPD) process in a high-tech company. Results suggest that in NPD projects, activities of "logistic support" as prototype-parts planning and control can help PMOs to reduce tensions in the project´s work climate, because they bring PMO personnel to the value-added chain of the project.

Keywords: High-technology industries, Product development, Project Management Office.

Introduction

The adoption of best practices in project management (PM) depends on the existence of a minimum of infrastructure supporting project managers and teams. Companies have created Project Management Offices (PMO) for this purpose. According Crawford (2002), a PMO is an organizational structure established to facilitate PM activities and bring improvements to the organization's management by managing the portfolio and aligning projects with corporate strategy.

The implementation of PMO is an issue that deserves attention, due to: the difficulty in properly dimensioning it in terms of size, standards, procedures and training of qualified people (Aubry and Brunet, 2016); the cultural barriers involved (Crawford, 2002); and even external issues such as the decision structure, strategy and project portfolio management of the company (Bredillet et al., 2018). In spite of researches carried-out in the last ten years, the literature often reject predictive manners of PMO implementation, because of its intrinsic strategy-structuring process.

High-tech companies have complex projects running and often coexist with several of them in parallel. Therefore, the obstacles to the adoption of PMOs are especially important. In these companies, support resources are often seen as a waste and PM techniques as "bureaucratic" methods that decrease creativity and speed (Jugend, 2015).

This research presents an investigation carried out in final phases of an action research in which a research group helps a high technology company to implement a PMO for support their new product development process. In the research, the group implemented a set of activities, and at the end, they submit a questionnaire to the company people for gathering data from satisfaction with PMO functions. This paper discusses the results of this questionnaire.

Theoretical background

Authors as Kerzner (2006) and Heldman (2003) named PMOs differently: strategic Project offices; Project support office; program support office; Project management office; project management´s support office; and program office. According the authors, the first PMOs happened in military, aerospace and civil construction projects in the middle sixties.

At the end of seventies to the middle eighties, as Project management software started to be common, these offices were expanded to other areas. Technical people started to be located on PMO for supporting Project activities. At the end of eighties and middle of nineties, those PM software increased their capacity for monitoring and controlling Project efforts enabling PMOs for working in multi-project contexts, and alignment among projects and business strategies.

According Crawford (2002), a Project office can be as simple as few people working in scheduling, or many people working on planning, monitoring and reporting. PMO models must be in accordance to company demands. Some authors classify them in function of their report functions in the company hierarchy (Crawford, 2002) or according to its main functions (Hobbs and Aubry, 2008), or even according to its control over project machine (Project Management Institute, 2017).

Dai and Wells (2004) compare PM practices and performance in companies with and without PMO. These authors identify more effective PM practices in PMO-supported companies, especially in terms of better PM methodology implementation and high-level of lesson learning processes. Mullaly (2006) analyses PM practices in Canadian and North-American companies. He observes that more maturity levels imply on better Project performance, and relates these results with the presence of a Champion for implementing PM practices. On the other hand, Crawford (2006) suggests that a PMO dedicated to support or to direct projects drives more maturity in PM practices.

Hobbs and Aubry (2007) studied functions and typologies of PMOS. They identified groups of functions that generally comes together in PMO operations. Some functions relates to monitoring and control Project performance, others focus in PM competencies and methodologies. A third group base their activities on multi-project management. A fourth group is oriented to strategy management, and the last one is directed to organizational learning. From the 27 researched functions, three could not be statistically grouped: perform specialized tasks, manage client interfaces, and recruit, select and define salaries for Project managers.

Aubry, Hobbs e Thuiller (2007) point a tendency in research PMOs under a positivist background resulting in difficulties to understand and manage them. Hobbs and Aubry

(2007) identify in a large variety of forms and functions, the difficulty for define PMOs in general. These authors found that monitoring and controlling functions are more common in PMOs, and conclude that PMOs reinforce PM maturity and vice-versa in a virtuous cycle.

Julian (2008) studied the role of PMO leaders on knowledge transfer among projects. He identifies an approach focused on poor performer projects, which generates a defensive posture from Project personnel. Hobbs, Aubry and Thuillier (2008) thought PMOs as organizational innovation elements. They found for the first time that PMOs transitions in terms of functions they perform along the time. They also mapped the main tensions that PMOs face in companies. According the authors, the myriad of PMOS found are direct consequences of mentioned tensions:

- economic relating PMO costs and Project performance;
- political meaning disputes over Project mandates and reports about success or failure;
- client relationship, internal or external ones;
- the trade-off among standardization or flexibility of PM procedures; and
- control over the Project resources between PMO, Project managers and functional managers.

Project Management Body or Knowledge (Project Management Institute, 2017), the most popular PM framework states that there are several types of PMOs in organizations according "... the degree of control and influence it has on projects within the organization". They identify the following types of Project offices: (1) supportive, with low control on projects, mainly providing consultancy and serving as Project repository; (2) controlling PMOs that provide support and require compliance to frameworks, methodologies and governance issues; and (3) directive, with high power over the projects taking control of them and demanding reports from Project managers.

This summary of PMO research shows they are subject to a large set of tensions and issues related to the fact that projects are temporary, and organization must to evolve continuously. Directive PMOs provide success in short time, but can strive organizational climate in the medium and long-term horizons. In spite of monitoring and control functions be necessary for company governance, they do not create value on project chains (Barbalho and Martins, 2019). The PMO researched in this study must to control project progresses, but other functions were necessary for creating a positive climate for PM practices and also for helping teammates in delivering project results.

Methodology

This research project as a whole was conducted under an action research approach (Coughlan and Coghlan, 2002), but the final phases here presented were planned and executed only by researchers for analysing the entire effort, and correct guidelines. A questionnaire was built and the personnel of the company involved in projects under influence of PMO implementation were asked to answer it.

The set of activities supported by the PMO were listed, but not classified according their dimensions of supportiveness, control or directive approach. Our goal was to understand the profile of satisfaction with PMO activities for suggesting guidelines for PMO implementation in this kind of company. The literature suggest that engineers are contrary to bureaucracy and their technical background commonly blind them to managerial demands of companies (Mintzberg et al., 2002).

Researchers submitted the listed activities to project teams. Instead of only listing activities, researchers converted them on affirmative and positive statements. For example, for progress reporting, one positive sentence evaluated its function for project status communication, and another evaluated the background it generates for improving project performance.

Nine developers from 21 involved on the projects researched answered the questions summing up 43% of people from projects impacted. This sample allow mixing personnel from different engineering backgrounds as mechanical, electrical and thermal technologies. They answered about their agreement to the affirmative statement in a likert scale written as “total agreement”, “agreement”, “indifference”, “disagreement” and “total disagreement”. All nine developers were interviewed for this research in form to explain about the PMO practice questioned, the statements and scale. PMO personnel were not involved in these meetings for interviewees.

Results

The researched company is a medium sized Brazilian company specialized on opto-mechatronic products. It develops and manufacture high precision surgical equipment for ophthalmology, satellite cameras for environmental monitoring, and defence products. In the time of this research, the company employed 350 workers, from which almost 60 engineers and highly specialized technicians. Only more impacted personnel were included on this research, mainly those senior engineers who are working on new project´s execution.

The context of this research is a situation in which a large new project started. Before it, the company develop mainly medical equipment, and had few projects from defence industry. The new project double company revenues and demanded more attention on project management issues. It was full of milestones and predicted fines for delays. A department unit previously in charge of quality audits was assigned to implement project management practices. This group started the PMO here researched. For doing this, it personnel ask for a research group in a large Brazilian University for help them on implementation, especially because of cultural resistance internal to the project teams.

Along of the action research, and as demanding by new contracts, the research group jointly to the PMO personnel, implemented some monitoring and control activities in form to prevent the company of fines by delays. These activities stay on traditional PMO functions according Hobbs and Aubry´s classification. A previous survey with project teams and managers had showed a degradation in work climate, because of pressures for project management compliance.

These results were interpreted as a necessity to add activities to comply with requests of a supportive and less mandatory profile of PMO actuation. These new set of activities were not contractual, but necessary for help project teams to organize and increase productivity without directly perform new tasks; and because of internal politics affecting work climate. They were implemented also for non-contractual projects; because the company senior managers would like that medical equipment projects had the same treatment of aerospace and defence efforts.

Table 1 presents the whole list of activities implemented by the PMO for PM process improvement, even before of adding tasks for avoiding PMO-teams conflicts, and the questions submitted for project teams as affirmative statements.

Table 1 – List of PMO activities and questions to evaluate them

PMO activity	Type	Statement
Develop the detailed Project schedule	A	The developed schedules have helped on running your Project activity.
Develop progress reports	A	Progress reports aid for your understanding about Project status.
	A	Progress reports brings information from which improvements can be created to improve Project performance.
Monitoring and communicating Project activities	A	The monitoring and communication of Project activities have helped to understand the whole project.
Support for document management from engineering to manufacture areas	B	The support for document Exchange have helped on reducing claims from manufacture.
Implementation of historical files of projects	C	Project notebooks and digital control of reports and schedules have helped on Project execution.
Monitor and manage technical demands from clients	A	The monitoring and effective communication of technical demands from clients have helped for your understanding of the whole project.
Monitoring and control of parts, materials and processes for project execution	B	The monitoring and control of parts, materials and processes have contributed to avoid problems with prototyping.
Project document management	C	The management of Project documents have been useful for Project daily activities.
Support for engineering and assembly activities	B	Activities for helping in logistics, as register, start purchase orders, incoming and storage have aided for planning and execution of Project activities.

After submitting these questions for project personnel, the research group classified them following the groups of functions identified by Hobbs and Aubry (2007). The type identified as "A" presents activities with a profile related to the monitoring and control of the project activities, that contractual agreed demands. They are performed under a controlled approach, according Project Management Institute (2017) classification. Activities of type "C" are those that can be considered as organization and control of documents and results of the project, denominated by the authors of "organizational learning". Activities of type "B" were related to the logistic activities added to the PMO to reduce the barriers imposed by the tension established between PMO and project teams and managers, as already discussed. They are thought as services provided by PMO to teams in form to reduce time pressures over project deliveries, a kind of partnering role as stated by Müller, Glückler and Aubry (2013). Activities “B” run through a traditional supportive framework (Project Management Institute, 2017).

Table 2 presents the results of interviews for evaluating the questions.

Table 2 – Agreement and disagreement with PMO activities

	Disagreement	Indifference	Agreement
All statements	27%	20%	53%
Type “A” activity	39%	23%	38%
Type “B” activity	16%	16%	68%
Type “C” activity	13%	20%	67%

The results presented in Table 2 merge profiles of disagreement and agreement in form to facilitate the discussion of results. In general, the designers interviewed considered PMO activities effective for helping them. We observed that the activities within the typologies "B" and "C" have a high percentage of satisfaction of the company's engineers, while the "A" type activities have almost the same level of "disagreement" and "agreement" in terms of satisfaction.

The results indicate that the activities with greater character of control over the work of the engineers were considered unsatisfactory according to their perception about the services offered by the PMO. PMO practices that support the daily activities of project personnel, such as monitoring the manufacturing status of parts, procurement of components, etc., were more satisfactory. The organization and control of the documentation generated in the engineering sector were almost as satisfactory as those of logistical support were, but the degree of responses that consider the service "indifferent" is greater, and its level of dissatisfaction in lower. As logistic support demands some inputs from designers for enabling the management of parts, materials and processes, this kind of activity has a major level of control than working with project documents. It means the lower the level of control, the higher the team satisfaction with PMO activities.

During the time of this research, the PMO develop and maintained schedules from 12 different new product projects, built and release progress reports from two large projects for 15 months, requested more than 2900 production orders, manage them and deliver their parts, materials and processes for helping project teams in design-build-test cycles. In this time, the PMO coordinate twenty-five week meetings for time monitoring and manage more than 200 documents from medical equipment and more than 500 from aerospace. These practices started to be monitored by performance indices. Summarily, in the beginning 3,5 days by a manufacture order are spent, and this indicator decrease to less than 2 hours lead time in average. Acquisitions for imported items decrease from 140 days to 50 in average, and projects cycle-time reduced from 1800 days to 260 days.

In general, the data allow us to infer that, although the PMO practices were considered very positive by the project personnel, this degree of satisfaction is strongly determined by the support activities for manufacturing the prototypes while the effective project management activities present a degree of satisfaction considerably lower than the others. Actually, if each type “A” activity would be analysed separately, some of them, as progress reporting issues or develop project schedules, are almost totally dissatisfied by respondents.

Conclusion

This article summarizes an effort to implement a Project management office in a company that historically developed medical equipment and was working on large

development contracts of aerospace industry. A pre-existent group of quality audits were assigned to implement Project management functions. The pressures over Project personnel to comply to PM functions and also deliver product results bring conflicts among them and PMO personnel. A new set of functions were implemented in form to increase partnering work among these groups as a way for decreasing tensions.

This way of working corroborate to previous literature in terms of conflicts in PMO structuration (Aubry, Hobbs and Thuillier, 2008) and PMO roles (Müller, Glückler and Aubry, 2013).

In this research, all new activities performed by researched PMO were submitted to project personnel for an analysis of satisfaction. Supportive functions are more satisfied for project personnel, such as monitoring parts, materials and processes necessary for manufacture product parts to enable assembling and tests. More control-based activities, traditionally implemented in project management efforts are less satisfactory as understood as project teams, which corroborate to previous literature on PMO tensions.

These results suggest that in new product development projects, activities of "logistic support" as prototype planning, prototype-parts purchase, prototype-parts production planning and control, can help PMOs to reduce tensions in the project´s work climate, because they bring PMO personnel to the value-added chain of the project. In other words, this kind of activity brings PMO to the project schedule. Consequently, teammates stop to see PMO works as only mandatory-based actions and start to see them as partners for project results.

Main limitations of this work stay on the unique case approach. More research must be done for confirm if and in which conditions the kind of activity of logistic support really help project teams and PMO personnel for improve project results and reduce tensions in new product projects.

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We have to integrate to engage in change: exploring sustainable project management

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Abstract
Recognising that sustainability in project management is a nascent field. For the need to build integrated models to support the development of an accepted school of thought, this paper uses the Deception Impact Model to explore the impacts from the current Boeing 737 MAX case to explore the impact of deception in the context of different phases of sustainable project management: product design, certification, and training. We highlight the importance of tracking deception in sustainable projects considering the severity of deception as the project moves through different stages and its impact on stakeholders and broader society.

Keywords: Sustainable project management, Ethical Practice, Deception,

Introduction

Sustainability in project management is a nascent field. Currently accepted schools of thought in project management include the optimization school, the governance school, the success school, the decision school and the process school. When analysing the components of a school of thought, three criteria defining a school are commonly acknowledged. These incorporate a shared vision or perspective and common methods and tools, a community in relation to an established publication base, and finally impact in terms of integration into practice and standards (Silvius, 2017). Recognising the global community acceptance of sustainability per se, evidence of increasing research and publication in this area (Silvius and Schipper, 2014; Silvius, 2017), and viewing the emerging discussion in terms of impact and integration of practice and standards (Hammadi et al., 2018; Silvius, 2017), it could be claimed that sustainability in project management is an emerging school. To further elaborate on the characteristics that

define the sustainability school of thought, Silvius (2017, p. 1491) presented four commonly shared characteristics relating to the criterion content: considering projects in a societal perspective, having a management for stakeholders approach, applying triple bottom line (TBL) criteria, and taking a values based approach to projects and project management. Thus having established the existence of the sustainability school of thought in project management, it is incumbent on researchers to explore the relevant criteria to develop and build the school of thought.

Hammadi et al. (2018) demonstrated the outcome of activities within business as being increasingly far-reaching and impacting at societal levels, they questioned the upstream and downstream impacts of activities on stakeholders and customers in the context of supply chain activities, investigated how this related to the triple bottom line of an organisation and queried organisation's taking a values-based approach to decisions at the strategic and operational levels. An outcome of this approach was the establishment of the use of deception often resulting from a gap between strategic CSR or sustainability goals and implementation of standards and practice. Indeed , one of the dangers highlighted by Prasad and Holzinger (2013) is the false implementation of CSR in companies and their projects as this runs the risk of turning this sustainable strategy into a simple marketing strategy that helps the company to make money without really inserting it in their processes and projects." (Marcelino-Sádaba et al., 2015).

The result of the integration of these dimensions when applied to ethical decision making in operations provided the foundation for the development of the Deception Impact Model (DIM). Drawing of this model and the principles of sustainability - economic, social and environmental - the aim of the current study is to explore sustainable project management by examining the current case of the Boeing 737 MAX, a project increasingly exhibiting the antecedents in terms of deception at a range of product design phases and project life cycle stages that clearly demonstrate that this project is not sustainable due to the use of deception.

The latest events of the Boeing 737 MAX demonstrate the disadvantage of the project (with 346 death on two flights/crashes - 157 Ethiopia/189 Indonesia) direct outcomes and the delayed impacts these might have on the triple bottom line. Project looks good, one event shows that the planning and execution might have involved deception to "cut curves". The aftermatch investigations reveal a lack of control, external independent inspection, stakeholder satisfaction, market competition, and downgrading risks.

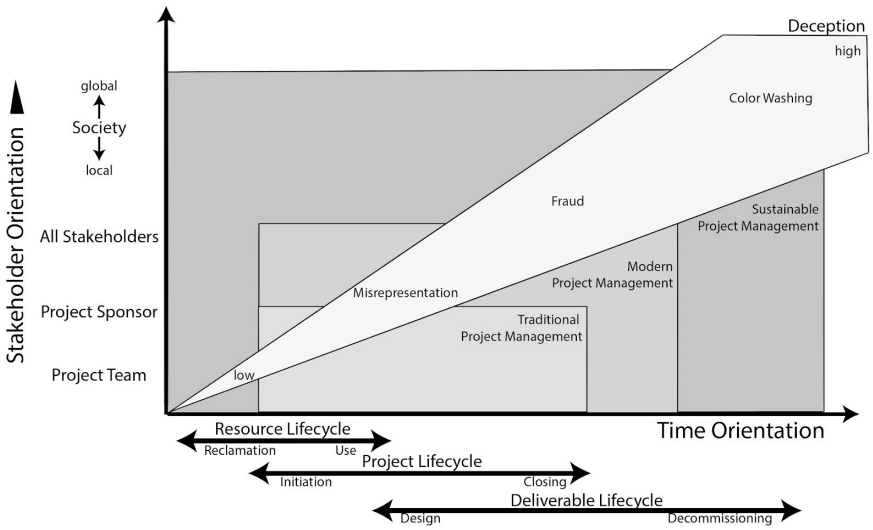

Figure 1: The broaden scope of sustainable project and severity of deception (Figure adapted from (Silvius et al., 2017))

New product development projects from a supply chain point of view include upstream and downstream stakeholders. New product development projects for sustainable products are complex, mainly due to the challenges of integration of sustainability dimensions into the processes of project management. These challenges include engaging stakeholders, project procurement, project risks, project communication, and the determination of the project team (Silvius, 2017). Not integrating sustainability dimensions may result in the end product that achieves project outcomes for one dimension of sustainability but at the cost of other dimensions. The gap between stated sustainable objectives and actual outcome of the project (not integrating all sustainability dimensions) is termed as Color-washing which is a form of deception. Figure 1 depicts that projects are difficult to manage if we include sustainability requirements and involve stakeholders globally. We notice that with small group of stakeholders or in a close group in a project the severity of deception is not high. But as we involve many stakeholders globally, severity of deception may increase because of the fact that aims of these stakeholders may be conflicting, so it is difficult to obtain sustainability outcomes from sustainable project management. In sustainable project management, stakeholders role is important in determining the sustainability objectives of the project. It is not an easy job, since the interests and aims of the stakeholders in a project may be conflicting and give rise to deception. The role of the focal firm is to balance/integrate these objectives by focusing on operations or by changing operations.

The purpose of this paper is to highlight the importance of tracking deception in sustainable projects by considering change in severity of deception as project moves a focal firm from one state to another state and to determine the impact it has on consumer.

Background on Project Management

Projects in operations management are characterised by their unique and generally resource-constraint objectives to implement organisational change. Projects are driven by exogenous factors to initiate a response to a changing situation or environment, with the expectation to exert positive impact for the executing organisation. Project,

operations and supply chain management are closely related, projects are often considered as the start of operations and have similar functions, if not identical, to those performed in operations management (Waller, 2003).

Projects, or their proposals, can be the response for an external future opportunity (e.g. bidding on large construction projects), changing market situation (e.g. changed competition on primary markets), or organisational change (new manufacturing process, change of strategy or management). Projects and their objectives must contribute to the corporate strategy, and it is successful when these objectives are accomplished within the given constraints. Projects are unique and temporary, involve many non-routine and complex tasks for specific deliverables or work products, and therefore face heightened levels of risks and uncertainty when contrasted with day-to-day operations (Slack and Brandon-Jones, 2018).

Managing a project often requires trade-offs and compromises, to ensure successful completion of the project. It also requires the ability to solve problems, set goals, and compromise. It is these goals that determine the process of planning, testing, evaluating and monitoring the improvement progress. A complex project requires a more detailed and comprehensive scope. Strong commitment in the definition phase of the project life cycle can result in less room for later changes during project execution and cause a team "lock-in" status, encouraging the team to find short-cuts if milestones cannot be achieved.

Climate change and therefore focus on sustainability has brought sustainable business practices to the forefront. Corporations today are under pressure to maximise returns for investors and need to conduct activities that are less detrimental to the environment and society. Project managers have to commit to the concept of Triple Bottom Line and implement sustainable practices to fulfil this. Multiple stakeholders, both public and private, are often acting with conflicting interest and different levels of influence are involved in the decision making and planning process (Aaltonen and Kujala, 2010). Furthermore, different user stakeholders have different internal opinions and are likely to have different interpretations and expectations of what will be produced (Atkinson et al., 2006).

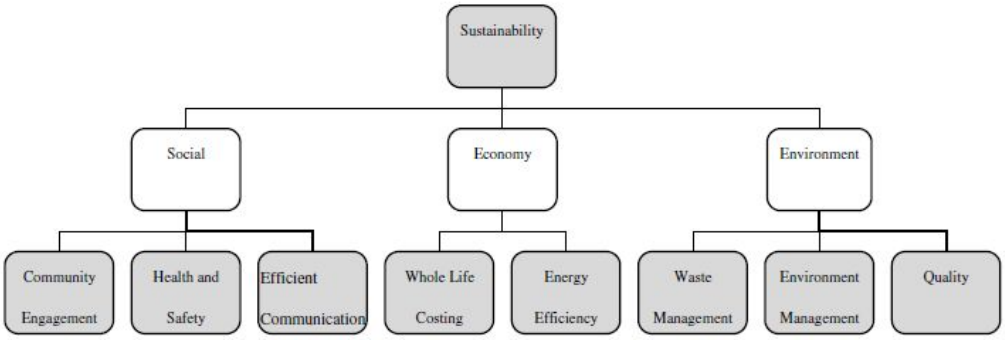

Figure 2: Criteria for sustainable project management (Source: Wang et al., 2014, p. 248)

Silvius and Schipper (2014, p. 79) define sustainable project management as "the planning, monitoring and controlling of project delivery and support processes, with consideration of the environmental, economic, and social aspects of the life cycle of the project resources, processes, deliverables and effects, aimed at realising benefits for stakeholders and performed in a transparent, fair and ethical way that includes proactive

stakeholder participation." Wang et al. (2014) summarises this clearly in Figure 2. Many definitions of sustainability encapsulate the intergenerational aspect to meet the present needs without harming future generations to meet their own needs (Bruntland, 1987). Sustainability ensures that the project contributes to the sustainable business of delivering goods and services for the project duration and to the future generations (Tufinio et al., 2013), thus ensuring the project lifecycle is integrated in sustainable project management. The United Nations also recognises the global importance of sustainability in the UN 17 Sustainability Development Goals (United Nations, 2015). SDG 12 of the 2030 Agenda for Sustainable Development aims to ensure sustainable consumption and production patterns along the entire supply chain "needs to be significant focus on operating on the supply chain, involving everyone from producer to final consumer" (United Nations, 2015).

Contrasts in characteristics between project management and sustainable project management relate to time orientation (short vs. long), intergenerational interests (stakeholders vs. future generations), objectives (deliverables vs. life-cycle), scope (time/budget vs. people/planet/profit), and complexity (reduced vs. increased) (Silvius et al., 2012, p. 167). This establishes the need to investigate the integration of sustainability and project management in an ethical approach, addressing the economic, social and environmental goals of the project whilst acknowledging the project stakeholders. Such a challenge requires exploration of customer impacts, deception, and implementation of TBL whilst acknowledging the characteristics of project management.

Emerging competitive markets and government regulations can compel organisations to meet certain standards. State agencies are responsible for the enforcement of public regulation have had very limited influence over corporate practices (Santos et al., 2017). On the other hand, the government agencies lack the capacity to enforce increasingly complex policies of environmental and sustainable development legislation (Labonne, 2016). Often the practice of industries engaging in self-monitoring with their measurement leading to the industry cutting corners to deal with growing economic pressures.

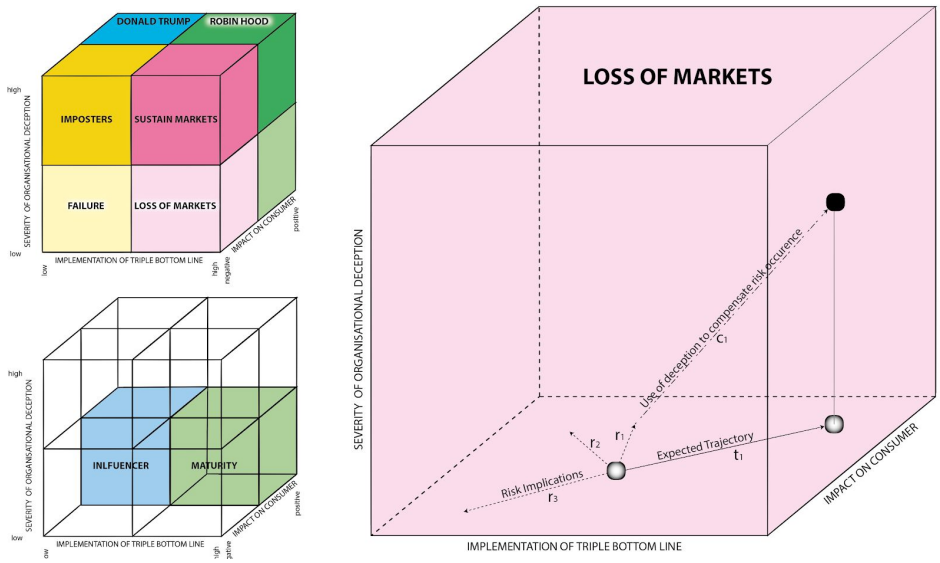

Figure 3: Deception Impact Model (left) and example for project trajectory (right)

Deception Impact Model for Project Management

The Deception Impact Model (Hammadi et al., 2018) is to set the severity of deception in the context of how organisations recognise the TBL as a strategic value and how consumers perceive the organisation. Figure 3 shows on the left the distinguished cubes describing the states we consider for an organisation; see Hammadi et al. (2018) for more details. The dimensions (deception, TBL, impact on the consumer) can be seen as a driver (progressive transition) or risk (regressive transition) organisations face and require consideration when defining strategies or values. Project management defines trajectories from initial positions (current states) to anticipated positions (objectives) for a (positive) change along all dimensions. Figure 3 shows the trajectory t_1 from s_1 to s_2, improving the TBL as well as the impact on consumers. The dotted vectors (r_1 to r_3) exemplify risk implications the project can experience. Here, each risk implication represents a TBL dimension; e.g. change on financial markets (economic), blocked approval due to protect animals (environmental), or causing long-lasting health impacts (society).

Even though the intention of the project is not deceptive, external causes can shift the mind toward the compensation trajectory c_1 of the occurred risk. To fulfil the objectives, it might be necessary to apply deception despite original intentions for the project; i.e., if the project might fail otherwise. As shown in Figure 1, the outcome is matching the objectives. The following section demonstrates the application of DIM using the latest Boeing scandal as an example.

Case Study Boeing 737 MAX

The current unfolding of the Boeing 737 MAX project after the crashes in Indonesia and Ethiopia with 346 deaths show how predominantly sustainability objectives caused in a chain of strategic and operational decisions the negative impact for all stakeholders including society. This section depicts the events and potential cases of deception. Information was gathered from manifold news articles, reports website; a complete list cannot be provided due to page restrictions. A starting page with references to sources can be found on Wikipedia (page “Boeing 737 MAX).

Case Description

The market is dominated by two key competitors offering medium and large airliners for the domestic and international flight sectors. Airbus has an extended family of aeroplanes based on the same framework and, thus, requiring only one type of license to operate all variants (e.g., A318-321, A320E, A320neo). Especially domestic low-fare airlines favour operations of only one family of aeroplanes to cut cost for maintenance and operations as well as increased flexibility for crew training and assignment. Airbus’ major success with the A320 family was the A320neo where more efficient engines reduced fuel consumption, emission, and noise (Airbus, 2019).

The Boeing 737 MAX project started on August 30, 2011, when Boeing under the pressure of their customers (airlines) and competitors (Airbus) decided not to develop a new aeroplane type but re-engineer the Boeing 737 aeroplanes with better fuel efficient engines. The project was thought of as a masterpiece as the new fuel efficient but larger in diameter engines initially resulted in difficulties due to the lower space under the wings and the changed aerodynamics during certain flight maneuvers. Boeing obtained (Federal Aviation Administration) FAA certification on March 8, 2017. The first delivery of Max 8 aircraft was to Malindo Air on May 6, 2017. The new Boeing 737 MAX was considered similar to other aeroplanes in the product family (Boeing 737),

thus airline pilots and crew members did not have to go through a time- and cost-intensive training program but could use digital training material as a source for handling differences.

When the project was launched, the initial aim of Boeing was to achieve 16% lower fuel consumption than Airbus A320eco and 4% lower than the A320neo through its newly designed engines. In terms of sustainability this was set to achieve less carbon emission and quieter engines.

In both crashes, the MCAS software was identified as a critical cause. Originally implemented to compensate for the changed aerodynamics problems resulting from a rushed re-design to retrofit larger engines in the Boeing 737 family, it relied on sensor data to be activated and take over control from the pilots. For both crashes, a combination of errors in the software, ineffective warning about wrong sensor reading, and lack of proper training is supposed to be the cause for the dramatic outcomes and the long-term grounding of the Boeing 737 MAX worldwide.

Failures and Deception

Regarding DIM, the corporation Boeing could be considered in the "Loss of Market" state when the project for the Boeing 737 MAX started. Here, Boeing negatively impacts on stakeholders (airlines) with no immediate response to the A320neo. The intended project objectives to develop a new plane failed to regain the anticipated impact with the stakeholders as it would not be economically feasible (negative impact on the TBL dimension). Boeing decided, despite the technological challenges, to refurbish the existing Boeing 737 with advanced engines; including the choice to cover problems in aerodynamics with software "patches". The misinformation about the severity of the decision and potential risk was part of the design stage of the project.

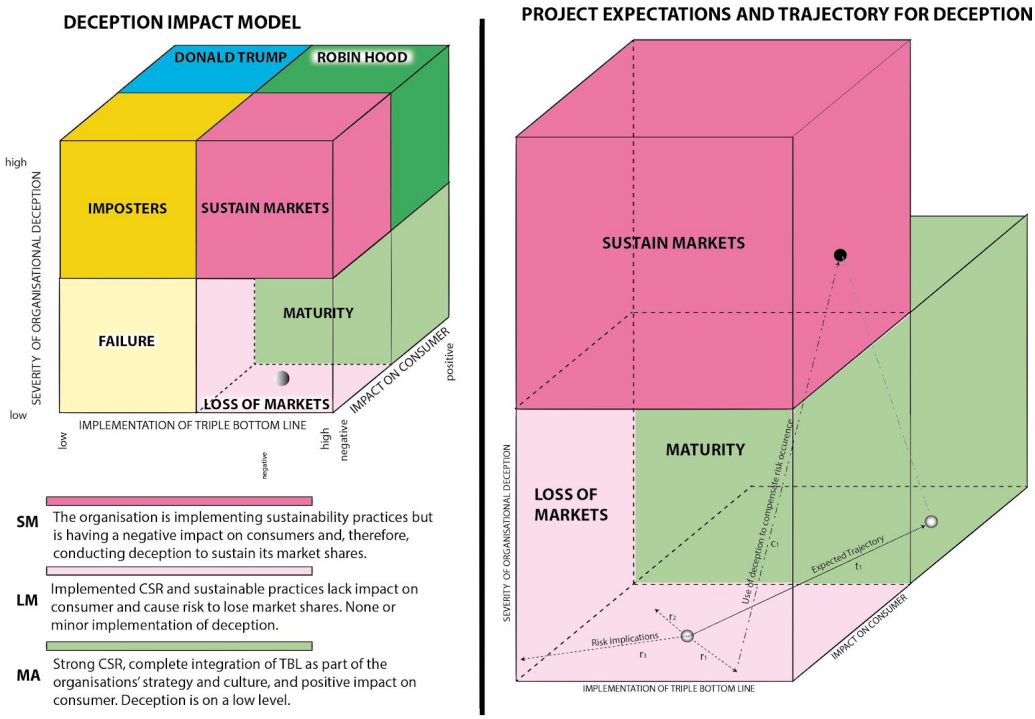

Figure 4: Deception Impact Model (left) and example for project expectations and trajectory for deception (right)

Figure 4 shows an anticipated position in the "Loss of Markets" state with an expected trajectory for the project, gain on the TBL dimension resulting from the new Boeing 737 Max) as well as having a competitive response to the A320neo. The number of orders and positive introduction confirmed the expected trajectory to the "Maturity" state; until the first incident raised negative publicity. Further, risk implications can be mapped in DIM to visualise the impact of the occurrence of a particular risk. For example, r1 represents an increase in sustainability (e.g., lower fuel consumption) but acceptance by the stakeholders (airlines, customers) is decreasing. According to revealed information after the crashes, Boeing considered that case but decided to deceive the airlines with multiple actions; see below. Figure 4 is representing the project design stage; during the project implementation the position, as well as risks and expected impacts, have to be updated.

The project Boeing 737 Max caused multiple problems throughout the product life cycle, from changing the sustainable objectives of a new plane to satisfying customers regarding a short time to market and replicating the product family extension for lower operating costs. Without replicating the full reports on this case, we depict critical incidents to demonstrate how the DIM can map Boeing over time.

In the production phase of the project, one of the main suppliers of *thrust reversers* for the engine, the **GKN**, was not able to fulfil the demand in the short period of time, Boeing switched to **Spirit Aerosystems** who is the main manufacturer of Boeing fuselage. Supplier problems showed throughout the implementation of the project; confirming the initial rush to regain competitiveness without including suppliers for the feasibility of production rates (increased from 42 in 2017 to 57 in 2019) to fulfil the customer demand (airlines)). The discrepancy between the design and production phase of the project should have been detected in the testing and certification stage.

During the testing and certification phase of the project, the FAA approved the product without much testing. The following problems were detected in the certification process. The process, on the other hand, shows the intention for deception by Boeing:

- one of Boeing's partner, CFM International, notified Boeing during testing of potential quality issues of the engine manufacturing. Boeing largely ignored them.
- during the certification process, FAA delegated parts of the inspection to Boeing or Boeing staff working for the FAA. The main reason was time pressure, lack of qualified FAA staff, and budget to evaluate the Boeing 737 MAX.
- creation of the MCAS software to fix problems with the aerodynamics.
- insufficient testing of the MCAS software; resulting in interfering with the pilots.
- lack of redundancy for critical sensors; supportive systems sold as extras
- no training for the pilots on the critical MCAS software (or information about it).

In summary, the following trajectory for Boeing 737 MAX case can be mapped in DIM (Figure 5)..

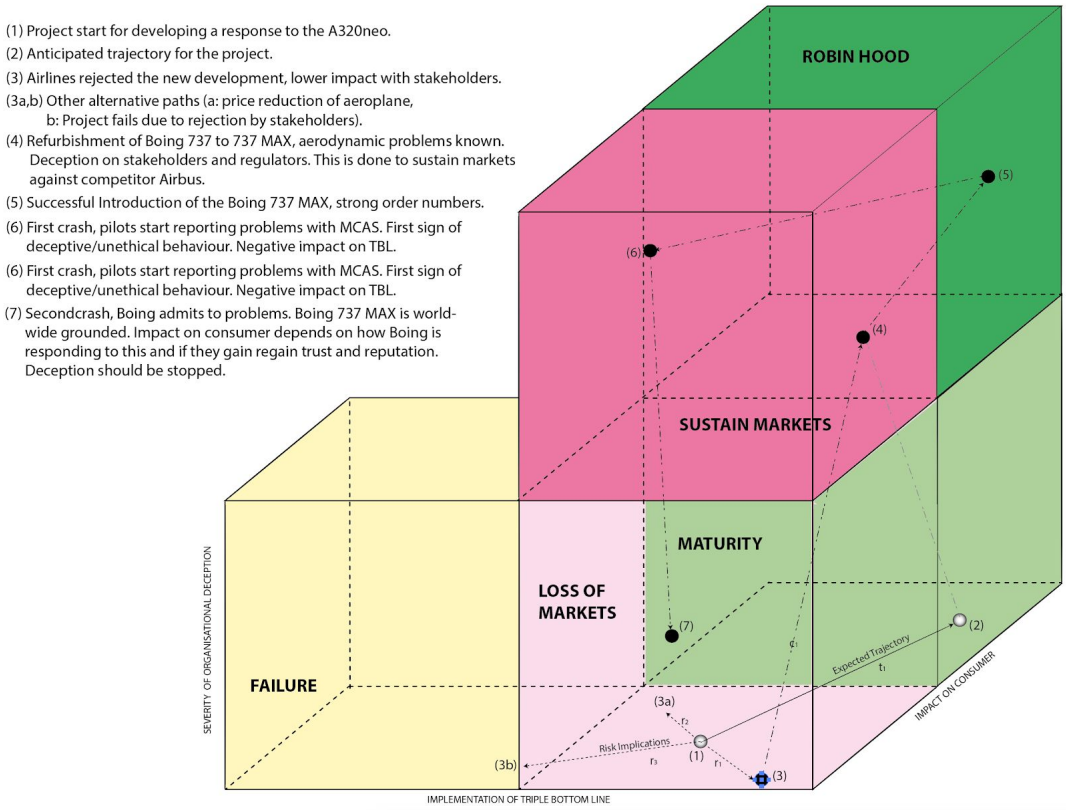

Figure 5: Trajectory of the Boeing 737 MAX project in the Deception Impact Model

Conclusion and Research Outlook

As shown through the Boeing 737 MAX case, the integration of sustainability perspectives including a societal perspective, having a management for stakeholders approach, applying TBL, and taking a values based approach to projects with project management tools provides a sustainable framework for developing impact models such as DIM. The Boeing case depicts the need for more research on mapping organisations in DIM and understand their trajectory to identify cases of deception before the damage to the TBL has happened. Boeing is one of many organisations in the recent past to admit taking advantage of disguising their malicious actions in complex supply chain networks.

This paper introduces the DIM for sustainable project management. The ongoing research is looking further into quantifying the positioning on the three dimensions in DIM using big data analytics for identifying anomalies in the literal search for the needle in the haystack.

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Shaping Systemic Innovation in Project-based Inter-Organisational Networks: A Structuration Perspective

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Abstract

Using a practice lens, we investigate the role of project team members' actions in constructing the social order and aligning inter-organisational elements to achieve digital congruence when implementing a digital and systemic innovation in construction projects, namely Building Information Modelling (BIM). We use a theory-building qualitative research design to induce a propositional theoretical model of key actions enacted in practice (e.g. technology-information management process basis alignment, knowledge integration) that contribute to a successful implementation of BIM. Our findings and the applied practice-based ontological approach extend existing literature by revealing some key conditions underlying how the phenomenon is constituted in practice.

Keywords: Systemic Innovation, Digital Transformation, Project-based Inter-Organisational Networks.

Introduction

Project-based industries, such as the construction industry, are amongst the largest in the global economy (Taylor and Levitt, 2004) and are major contributors to the global gross domestic product (GDP). The slow rate of innovation and low productivity in the construction industry, however, have been historically problematic (Hall et al., 2018). Certain types of innovation, such as systemic innovations, which affect inter-firm processes and redefine how work is done (Hall et al., 2018), are even less frequently implemented in project-based industries, such as construction (Arnold and Javernick-Will, 2013). Nevertheless, this type of innovation has a huge potential to offer productivity gains (Alin et al., 2013; Lindgren, 2016; Hall et al., 2018).

Given the relevance of the construction industry to the global economy and in an attempt to foster innovation in the sector and increase productivity, governments from different countries have included the digitalisation of the construction sector as a part of industry-wide development strategy agenda. Building information modelling (BIM), a type of systemic innovation (Alin et al., 2013; Lindgren, 2016), sits at the heart of

digitalisation in construction. BIM can be defined as the use of a shared digital representation of a built asset to facilitate design, construction and operation processes in order to form a reliable basis for decisions (The British Standards Institution, 2019). BIM is expected to bring major productivity improvements to the industry (Alin et al., 2013).

The digital delivery of projects through BIM is an important emerging phenomenon because as a systemic innovation, it alters the nature of the work of project-based firms and the relations in a project network (Lobo and Whyte, 2017; Papadonikolaki et al., 2019). Research on systemic innovation implementation in construction projects has sought to understand the influencing factors and enabling/required conditions for a successful implementation of systemic innovation in projects (Taylor and Levitt, 2007; Alin et al., 2013; Lindgren, 2016; Hall et al., 2018), such as practices that should be used to enable the multi-firm process of systemic innovation (Hall et al., 2018) and new capabilities that construction firms need (Lobo and Whyte, 2017). In the case of BIM as a systemic innovation, in particular, some international standards recommend information management processes and activities when managing information in projects with the use of BIM (The British Standards Institution, 2019). Existing research and industry standards have therefore focused primarily on the *what* of systemic innovation implementation and the conditions under which this change is accomplished successfully. Comparatively, *how* the implementation itself unfolds has been less explored. Understanding how systemic innovation unfolds in practice (Hall et al., 2018) and how it is enacted by people are important, as this is a determinant of the performance of systemic innovation implementation (Alin et al., 2013).

Actually, the majority of existing studies have considered aspects related to systemic innovation in project-based networks and, more specifically, BIM implementation, as entities or *things* that exist outside the practices and processes of those who enact them. Ongoing calls in the project-based literature have been made for more empirical investigation from a practical perspective and *from within*, with the aim of better understanding what occurs in practice in projects (Blomquist et al., 2010; Lalonde et al., 2012; Padalkar and Gopinath, 2016) and increasing the relevance of project management research to practice (Floricel et al., 2014; Clegg et al., 2018).

Therefore, we apply in this study a practice lens to investigate the implementation of BIM as a digital and systemic innovation in construction projects. More specifically, we focus on understanding how the alignment of inter-organisational elements following BIM implementation (e.g. process, technologies, structure), namely digital congruence in projects (Kane et al., 2016), occurs from a performative perspective. The practice lens facilitates a theoretical understanding of the constitutive role of project team members' actions in constructing the social order and aligning inter-organisational elements to achieve digital congruence (Kane et al., 2016) when implementing BIM in a project. We analyse the *black box* of what happens in the process of implementing a systemic innovation and aligning inter-organisational elements, aiming to answer the following research question: *How do project team members' actions bring about digital congruence in construction projects?*

We conceive of BIM implementation and achieving digital congruence in construction projects as both a set of rules aiming to establish social order in projects, making the conditions, work and human behaviour when managing information in projects more predictable and as an outcome that emerges from the application of these rules and alignment of inter-organisational elements over project lifetime. In other words, we draw on the recursive nature of action and social order and their mutual constitution (Giddens, 1984).

Framing the phenomenon from this perspective seeks to contribute to the project management literature in two main ways. First, this study is grounded in the need for research drawn from practice and the need for a plurality in perspectives on project work

that reveals the *lived experience* in projects (Van der Hoorn and Whitty, 2017). Second, understanding systemic innovation, more specifically, BIM implementation, in a project as a process that people enact involves a new ontological perspective. Calls in the project management literature have been made for theorising from new ontological perspectives to provide a more detailed understanding of phenomena as a result of a better understanding of their different facets (Joslin and Muller, 2016).

We begin by positioning the practice lens applied in this study, followed by a description of the research design. We use a theory-building qualitative research design to induce a propositional theoretical model of key actions in order to achieve digital congruence in BIM projects. We then discuss how the practice lens applied in this study allows us to add to existing research.

Theoretical Framework

Although project management research streams are based on assumptions of practices, the practice itself has been taken for granted in the project management literature (Hallgren and Soderholm, 2012). Scholars have acknowledged that many of the normative and traditional contributions to project management research are insubstantial in terms of understanding what occurs in projects (Blomquist et al., 2010; Floricel et al., 2014). More research on what project members do in projects is needed, rather than more research on the confirmation of best practice models (Blomquist et al., 2010; Lalonde et al., 2012).

Actually, the proponents of a project-as-practice approach argue that both practical and theoretical advances can result from studying the concrete actions of project participants (Floricel et al., 2014). These theoretical and practical developments can result from applying a practice–theoretical framework in the following three ways (Feldman and Orlikowski, 2011): i) through an empirical focus on how people act and the importance of practices in the ongoing operations of organisations, ii) through a theoretical focus on understanding the relations between the actions people take and the structures of organisational life and iii) through a philosophical focus on the constitutive role of practices in producing organisational reality. Through a philosophical paradigm, the project phenomenon is considered the sum of the actions of the people involved (Van der Hoorn and Whitty, 2017).

The philosophical approach, although less explicit in the use of practice theory in projects, is based on the premise that social reality is made up of practices (Feldman and Orlikowski, 2011). This approach is applied in this study to investigate BIM implementation and the alignment of multiple inter-organisational elements within multiple project team members' actions distributed across time and space. We use this philosophical approach by considering that BIM cannot be separated from project team members' actions when working in a BIM project and from the changing social ordering of inter-organisational elements' alignment produced by these members. In other words, we argue that BIM implementation (information management process using BIM) is not a discrete entity; rather, it is constituted within practices. Through an *ethnography of BIM*, we identify some of the key practices that socio-materially configure it, as explained next.

Research Design

Given the nature of the research question, we apply a qualitative method, which is also strongly associated with the practice turn lens (Van der Hoorn and Whitty, 2017). Ethnography is a popular method in practice research (Blomquist et al., 2010). Moreover, calls have been made for rich ethnographic studies when investigating practices in projects, with the aim of understanding human action and managerial action in concrete project situations (Lalonde et al., 2012). We therefore draw on the ethnographic data of eight construction projects at different lifecycle stages by using a from-within (capturing

the experience of those involved in it) and in-the-flow (studying the phenomenon whilst it is being enacted) approach to capture the aspects of digital congruence over time and across projects and to identify project team members' actions making up such configurations.

The fieldwork was carried out over 10 months (2018–2019), during which the first author of this paper was involved and immersed in the projects, playing the role of observer-as-participant (Bryman and Bell, 2011). The eight analysed projects involved new and refurbished educational facilities in two large organisation estates. All projects were digitally enabled projects, i.e. BIM projects. Estate organisations' projects were selected through purposive sampling (Bryman and Bell, 2011). As the goal is to investigate BIM as a systemic innovation and to identify project team members' actions that bring about digital congruence in construction projects over the entire asset lifecycle, we looked for BIM projects in which all stakeholders involved in the building's lifetime (e.g. client, facilities manager) were a part of the project team, aiming to identify the roles and actions taken by all members when enacting BIM. The collected data include project documentation, semi-structured interviews, access to organisations' intranet, meetings and workshops, as summarised in Table 1.

Table 1 - Sources of data on learning about BIM implementation.

Source	Details
Project documentation	Employer's Information Requirements, Asset Information Requirements, Building Information Modelling (BIM) Execution Plan, digital handover documentation
Intranet	Common Data Environment, internal intranet system: direct access to archived information on the studied projects
Interviews	Semi-structured interviews with project team members: the project manager, consultants, architects, contractors, sub-contractors, BIM coordinators, facilities managers, information managers. Questions related to their experience working on a BIM project, challenges faced, actions taken, etc.
Meetings	Project team meetings, design review meetings, workshops, Estate Management internal meetings, informal meetings
Visits	Visits to the construction sites

For each project, there was interaction with project personnel (e.g. the project manager, the lead designer, the information manager, the contractor, the facilities manager), who were selected for their potential to provide insights into the digital delivery of the project. Table 2 gives more details of the meetings, workshops and interviews associated with each project.

Our analysis followed the principles of grounded theory, starting with a detailed empirical reading and progressing to greater generality (Mantere et al., 2012). It started with a fine-grained reading of the data or a microanalysis of them (Strauss and Corbin, 1990). We used NVivo software to catalogue and code the data. Our first round of coding

focused on identifying descriptions that indicated the *praxis* undertaken by different project team members when working in a BIM project. Then, informed by our research focus, we concentrated our subsequent analytical efforts on identifying some categories of *praxis* that make up digital congruence in projects leading to successful BIM implementation. We derived propositions on some key practices enacted by project team members that led to successful BIM implementation and digital congruence in projects, as discussed in the next section.

Table 2 - Main data collection meetings and interview sources.

Project	Type of meeting/interview	Interview duration
Project 1	Semi-structured interviews with the project manager (client side), the project manager (main contractor), the facilities manager and the information manager (client side)	3h 40 min
Project 2	Semi-structured interviews with the project manager (client side), the project manager (main contractor) and the information manager (contractor side)	2h 25 min
Project 3	Semi-structured interviews with the project manager (client side), the project manager (contractor side), the information manager (contractor side) and the architect; BIM benefits workshop; digital handover meeting; risk assessment meeting	6h 40 min
Project 4	Semi-structured interviews with the project manager (client side) and the BIM coordinator (contractor side)	2h 20 min
Project 5	Semi-structured interviews with the digital engineer (contractor side)	44 min
Project 6	Design review meeting; project team meeting—project still at the design stage	3h
Project 7	Project team meeting, semi-structured interviews with the information manager (client side), the project manager (client side), the project manager and the information manager (contractor side), the facilities operator and the facilities management system provider, responsible for the digital transformation strategy (client side)	3h
Project 8	Semi-structured interviews with the architect and the information manager (designer side), risk workshop — project still at the design stage	56 min
Total = 23 hours of recorded and transcribed data		

Results

As acknowledged in existing literature, systemic innovations require related and complementary innovations (Lindgren, 2016). BIM implementation entails interrelated changes in existing processes by incorporating information management activities. It also requires changes in project structure and the use of new technologies and new skills. Our findings reveal that, in general. BIM is successfully implemented if there is congruence amongst the asset/project strategy, information management processes and activities, BIM skills, information management roles (structure) and BIM technologies as explained next by some of our propositions. That is, the systemic innovation is successfully implemented if an alignment exists amongst the new aspects related to the systemic innovation implementation itself, besides the alignment of the innovation with the existing project structure and existing work practices, as highlighted in existing literature (Taylor and Levitt, 2007; Alin et al., 2013).

Our data reveal a range of actions undertaken by multiple actors to promote the alignment amongst the inter-organisational elements leading to successful BIM implementation. Some of the actions that we have identified are related to the digital set-up of the project. For example, according to existing standards for the information management process using BIM (The British Standards Institution, 2019), one of the first information management activities is the definition of the information requirements by the client, considering organisational, project and asset information needs (i.e. the strategy). The client, however, may not have the experience or knowledge necessary to establish these requirements in a way that the information deliverables will be just enough and in the right format to support relevant decisions over the asset lifecycle and operational phase of the asset, even if an information manager is involved in the process. Therefore, aiming to guarantee the production and delivery of only essential information at the right time and in the right format, our data reveal practices that lead contractors are undertaking to align information production process and deliverables with the needs at the operational phase of the asset and its overall strategy: *'When we get on board, one of our first actions is to speak with the facilities management system provider and facilities managers in order to identify information requirements. So, then, we can select our suppliers'.*

Our data also show that successful implementation requires the client or another representative to take action to specify the information requirements and the level of information for such requirements in order to align the production of the information model and information deliverables considering each lifecycle stage's needs, as well as to consider the procurement route: *'So, if the way of procuring would have to change, I think it's then good for the client to understand what the contractor might want so that it's embedded in the contract of the design team from the start and doesn't require rejiggling, rehashing'.* When the information model is produced in a way that it does not consider the needs of the next project stage, there may be issues, as noted by a contractor: *'I think it's fair to say that effectively, we're taking bits of that, but we have to remodel a large proportion of it to suit how we actually want to use the project'.*

Current literature posits that when tasks are more interdependent, the diffusion of a systemic innovation decreases (Lindgren, 2016). We propose, however, that if aligning actions are taken, such as the ones previously described, a systemic innovation, such as BIM, can be successfully implemented, even if the degree of interdependency is high:

Proposition 1: BIM is successfully implemented when digital set-up actions are taken to ensure that information production and information deliverables are in alignment with the needs of project lifecycle stages, from design to operation of the asset.

The data also reveal that an alignment should exist between the BIM technologies intended to be used over the project lifecycle and the way the information models are produced, i.e. the information production process: *'I think 4D is there and has been there, and it's been used. I think it needs to come with a warning because you wouldn't 4D everything to the last screw, so it needs to be used for a defined purpose; either it's general presentation or it's very specific areas, but if you're doing 4D, for example, you need your model to be built in the way your programme is built'.*

Actions should be taken by project team members to align the information models with the technologies to be used, when necessary, as noted in one of the projects: *'Look at energy or thermal modelling. So, if you've got your building modelled as it is, you can't just press a button and put it into your thermal modelling software because the software won't understand any clashes; you need and certain M&E consultancies have developed scripts that basically take this rather complex model of a building and turn it into something that can be digested by the thermal modelling software and then to do something'.* Project team members also mentioned that there should be an alignment between the way the information models are produced and the intended use of multiple BIM technologies: *'In the same way for the 5D. You know, they need to be split in a way that is costed. Now, sometimes, these ways do not match with one another, so what you need for 4D might contradict with what you need for 5D, which is, I would say, another story, another challenge for that'.* Basing on these findings, we propose that the practice of aligning technologies and information management processes is critical:

Proposition 2: BIM is successfully implemented when actions are undertaken to align the technologies intended to be used with the information production processes and the deliverables.

Our data also show that actions to support knowledge integration, i.e. the process of combining disparate bits of specialist knowledge into a collective knowledge product (Ali et al., 2013), have been undertaken. Contractors are taking actions to align technology use across different disciplines, aiming to avoid interoperability issues, integrate different knowledge pieces properly and increase collaboration: *'At the technical kick-off, the contractor and sub-contractors were talking about what version of Revit everyone will be using and said, "Right, who has got the lowest version of Revit?" And I think it was 2017, with the engineers saying, "Right, everyone is going to do 2017"; architects are already on 2018. It doesn't matter. You will use 2017 for this until everybody is ready to go forward'.* Basing on our data and consistent with the finding of Alin et al. (2013), we propose the following:

Proposition 3: BIM is successfully implemented when actions to integrate knowledge across different disciplines are undertaken.

Additionally, contractors are acting to guarantee the proper alignment between the information management processes and the BIM skills required for the project. Aiming to align the skill bases across the supply chain, some contractors are taking actions to engage the supply chain in aspects such as the information exchange process by using a common data environment: *'We have supply chain days. They come into our regional offices. We talk about how BIM will affect the projects coming up'.* Another contractor also noted the following: *'Our supply chain partners play a pivotal role in our ability to deliver a BIM project, so we play an active role in training and upskilling supply chain partners. We hold regular training sessions for our supply chain and encourage a collaborative environment to stimulate the sharing of knowledge and expertise'.*

Moreover, when a misalignment occurs between the information management processes and BIM skills, such as in the case when suppliers or sub-contractors with the required BIM skills could not be appointed for some reason, contractors are taking other actions to align the process with the required skills: *'Our procurement strategy is to go for smaller, local companies, so we need to bring in a coordination company that's going to put the duct work contractor, the pipe work contractor, the electrical containment contractor, all of their information potentially'.* Therefore, although previous research has suggested that a large span (i.e. when many different boundaries of an inter-organisational network are affected) influences the diffusion of a systemic innovation (Lindgren and Emmitt, 2017), we propose that through skills–process alignment actions, such as the ones previously discussed, a systemic innovation can be successfully implemented, even in cases of a large span, such as in the case of a BIM project:

Proposition 4: BIM is successfully implemented when skills–process alignment actions are undertaken.

In summary, our data demonstrate that BIM implementation is thoroughly constituted within practices, i.e. it is not independent or fixed. Although standards provide useful guidelines, successful implementation is a result of BIM enacted in practice. The identification of some practical actions related to a successful BIM implementation drawn from real experience is useful for both systemic innovation in projects and the BIM literature, as discussed next.

Discussion

The practice-based ontological perspective used in this study allows us to extend existing literature in different ways.

First, existing literature on systemic innovation has posited that a successful systemic innovation implementation is governed by the existence of an agent who promotes project network change (Taylor and Levitt, 2007) and that a change in regulations is a key point for innovation (Lindgren and Emmit, 2017). By considering that BIM implementation cannot be considered separate from the practices and processes of those who enact them and that as a phenomenon, it is constituted by contingent practices, we reveal through our findings that implementation success is also dependent on the actions of project team members, i.e. the success of a systemic innovation is dependent on how it is socio-materially configured. Moreover, existing studies have argued that some actions are necessary to align the misaligned innovation with the existing work task allocation of the project network (Alin et al., 2013). We argued that actions to align the components of the systemic innovation itself are also necessary, as previously discussed, such as alignment amongst tasks and technologies across different project lifecycle stages.

Second, from a theory building on a project-as-practice perspective, the use of a practice lens allows us to understand *why* and *how* BIM implementation and the information deliverables are successful even when some of the rules and conditions aiming to establish social order in projects when managing information in projects that are more predictable are not present (e.g. Project 3). The practice approach allows us to demonstrate that actually, a successful BIM implementation is also a result of project members' actions and not just the implementation of standards. It points to a different way of thinking about BIM implementation, emphasising management interventions not highlighted in existing literature. The practice lens also offers valuable insights into practical actions or mechanisms that support the innovation diffusion, extending existing research on the conditions and factors that underlie systemic innovation implementation and diffusion in projects (Taylor and Levitt, 2007; Lindgren, 2016).

Furthermore, recent studies in the BIM literature have acknowledged that research thus far has emphasised mechanistic conceptions of BIM technology adoption that focus implementation efforts towards technology (Dowsett and Harty, 2018; Papadonikolaki et al., 2019) and that important links between implementation practices and outcomes are still missing (Dowsett and Harty, 2018). The propositions identified through a practice perspective, therefore, provide insights into such links. Finally, our findings also extend previous BIM research on the role of actors in driving BIM implementation (Vass and Gustavsson, 2017) by demonstrating that actually, their actions affect the performance of the innovation implementation. These findings also contribute to project-as-practice more specifically governance-as-practice literature (Brunet, 2019) by revealing that what is actually done by different actors influences the performance of the systemic innovation implementation.

Conclusions

Although BIM has become a popular paradigm in construction, recent studies have demonstrated that in practice, firms still struggle to implement and work in a BIM environment and that the managerial aspects of BIM implementation remain underdeveloped. By using a practice lens and identifying propositions on actions that underlie successful BIM implementation, we aim to contribute to practical knowledge on how BIM unfolds in practice. Our findings offer insights into practical actions that should be taken by practitioners.

Recent studies have recognised that a more comprehensive understanding of the phenomenon through practice lenses arises from the application of two perspectives and that further methodological, theory, and/or philosophical triangulation in project management research is needed. Therefore, the propositions identified in this study—drawing on ethnographic data—are just the first step in a mixed methods research design aiming to provide a more practice-relevant understanding of the phenomenon. One of the limitations of the qualitative phase of this study may be the focus on projects in the UK only, although it provided a realistic representation of the phenomenon being studied. By using triangulation to increase reliability, however, a new research method and data sources will be applied in a second stage of this research.

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Tax incentive and risk sharing for public private collaboration

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Abstract

This paper investigates the effect of tax reduction policy and completion risk sharing policy on the investment decision of the private investor in the public-private partnership project. The results manifest that: first, both incentive policies can promote the private investor to invest in the project earlier; second, the optimal debt level is not affected by completion risk sharing policy but displays a U-shape relationship with the incentive ratio under tax reduction policy; third, tax reduction policy can induce private investors to invest in the project a longer time. These results can help the government to make a better incentive policy.

Keywords: Public-private partnership, Tax reduction, Completion risk sharing

Introduction

To release the financial burden of government, attracting private investors to invest in infrastructure development through public-private partnership (PPP) has been a hot topic (Zhang et al. 2015, Wang et al. 2018). However, because of the large investment scale of the infrastructure, various unpredicted risks are involved. It is necessary for government to provide some incentive policies to increase the investment confidence of private investors (Park and Chang 2013, Soumaré 2016). One of the key factor that defer private investors from investing in the PPP project is the completion risk (Chan et al. 2014, Mouraviev and Kakabadse 2014). Under the PPP model, it is the private investor who is responsible to construct and operate the project (Zhang et al. 2015, Wang et al. 2018). Once the construction of the project cannot be completed on time, private investors may suffer a great loss. Therefore, one way that government can use to promote private investors to invest in PPP projects is to share the completion risk with them (Chan et al. 2014, Mouraviev and Kakabadse 2014). The other key factor that influences the investment decision of private investors is the profitability of the project. Because the main purpose of private investors to participate in the project is to make money, if the

infrastructure project cannot meet their requirement of internal rate of return, private investors will not be willing to invest in the project (Takashima et al. 2010). To increase the attractiveness of the infrastructure project, government usually provides some governmental guarantees in the PPP contract, e.g. the minimum revenue guarantee, the debt guarantee and the minimum traffic volume guarantee (Feng et al. 2015, Li and Cai 2017). Besides, government can also provide tax preference for the infrastructure project to attract the private investment. It is important for government to know how these incentive policies may influence the investment decision of private investors, so that a right incentive policy can be used in the right situation.

Some scholars have investigated the government support policy in PPP projects. Takashima et al. (2010) built a real options framework and analyzed how the degree of government guarantee and the cost sharing policy influence the investment timing of the private sector in public-private partnership (PPP). They concluded that when the guarantee of the government is large and the cost sharing rate is low, the private firm exercises the investment option earlier under the firm-maximum policy than under the value-maximum policy. Soumaré (2016) compared loan guarantee and direct investment through public-private partnership (PPP) under the perfect and asymmetric information situations respectively. The author argued that loan guarantee is better than direct investment for government under the perfect information situation, while this implication is mitigated under the asymmetric information situation due to the so-called plum problem. Feng et al. (2015) studied the impact of three types of governmental incentives, namely the minimum traffic guarantee, the minimum revenue guarantee and the price compensation guarantee, on the investment behaviour of private sectors, including the toll rate, the road quality and the road capacity. Shi et al. (2016) supposed that the government guarantee can serve as an instrument to induce the private sector to reveal true cost information under asymmetric information situation. Li and Cai (2017) investigated the impact of government incentive on the investment behaviour of the private sector under demand uncertainty. Although many governmental incentive policies in PPP projects have been investigated, the study related to the completion risk sharing policy and the tax reduction policy is still lacking. This study fills this knowledge gap to help government have a better knowledge about the influence of different incentive policies on the investment decision of the private investor, so that a better incentive plan can be made in PPP projects.

Modelling

The investment decision analysis of the private investor without any governmental incentives

This section provides a benchmark for further analyzing the influence of tax reduction policy and completion risk sharing policy on the investment decision of private investors. Suppose the cash flow of the project X satisfies $dX = \mu X dt + \sigma X dZ^{Q}$, where μ means the expected rate of return of the project, σ represents the volatility of the cash flow, and Z^{Q} satisfies a Wiener process. Because private investors have a minimum revenue requirement for the project, they will not invest in the project before the cash flow of the project reaches a threshold value X_I. On the other hand, private investors usually set up a special purpose vehicle (SPV) to construct and operate the PPP project and have limited liability for the project. When the project cannot make ends meet, private investors will abandon the project. In other words, there exists a cash flow threshold value X_D, when

the cash flow value is below this threshold value, private investors will withdraw from the project. Suppose the total construction cost is I, the debt capital used in the project is a tax-deductible perpetual coupon bond with coupon C, the risk-free interest rate is r, and the tax rate is τ.

During the operation period, the project value is denoted as $\overline{V}_O(X)$, the debt value is $\overline{D}_O(X)$, and the equity value is $\overline{E}_O(X)$. As in the study of Dixit et al. (1994), the equity value $\overline{E}_O(X)$ satisfies the following differential equation:

$$\frac{1}{2}\sigma^2 X^2 \frac{\partial^2 \overline{E}_O(X)}{\partial X^2} + \mu X \frac{\partial \overline{E}_O(X)}{\partial X} - r\overline{E}_O(X) + (1-\tau)(X-C) = 0 \quad (1)$$

Two boundary conditions need to be satisfied:

$$\overline{E}_O(X_D) = 0 \quad (2)$$

$$\left.\frac{\partial \overline{E}_O(X)}{\partial X}\right|_{X=X_D} = 0 \quad (3)$$

The first boundary condition captures the fact that private investors will abandon the project when their equity value equals 0 (the value matching condition). The second condition manifests that the threshold value should be optimally determined to maximize the total equity value of private investors (the smooth passing condition). Combining with the non-bubble condition used in the study of Dixit et al. (1994), the expression of the equity value $\overline{E}_O(X)$ can be derived.

$$\overline{E}_O(X_D) = \frac{1-\tau}{r-\mu}X - \frac{1-\tau}{r}C - \left(\frac{1-\tau}{r-\mu}X_D - \frac{1-\tau}{r}C\right)\left(\frac{X}{X_D}\right)^{\beta_2} \quad (4)$$

$$X_D = \frac{r-\mu}{r}\frac{\beta_2}{\beta_2 - 1}C \quad (5)$$

Where $\beta_2 = \frac{1}{2} - \frac{\mu}{\sigma^2} - \sqrt{(\frac{1}{2} - \frac{\mu}{\sigma^2})^2 + \frac{2r}{\sigma^2}} < 0$. According to the expression of the threshold value X_D, it can be seen that a larger debt capital value will make private investors abandon the project earlier.

The value of the project $\overline{V}_O(X)$ satisfies the following differential equation:

$$\frac{1}{2}\sigma^2 X^2 \frac{\partial^2 \overline{V}_O(X)}{\partial X^2} + \mu X \frac{\partial \overline{V}_O(X)}{\partial X} - r\overline{V}_O(X) + (1-\tau)X + \tau C) = 0 \quad (6)$$

When private investors withdraw from the project, the project asset will be transferred to the debt holder. Since there are fractions during the transfer process, a fraction of the cash flow value ($\alpha X_D, 0<\alpha<1$) will be lost. Therefore, the project value at the threshold value satisfies $\bar{V}_O\left(\bar{X}_D\right)=\frac{1-\alpha}{r}X_D$. Combining with the non-bubble condition used in the study of Dixit et al. (1994), the expression of the project value $\bar{V}_O(X)$ can be derived.

$$\bar{V}_O(X)=\frac{1-\tau}{r-\mu}X+\frac{\tau C}{r}+\left(\left(\frac{1-\alpha}{r}-\frac{1-\tau}{r-\mu}\right)X_D-\frac{\tau}{r}C\right)\left(\frac{X}{X_D}\right)^{\beta_2} \quad (7)$$

Private investors need to determine the capital structure of the project by maximize the project value, namely,

$$\underset{C^*}{Max}(\bar{V}_O(X)) \quad (8)$$

Solving this maximum problem, the optimal debt level of the project can be expressed as

$$C^*=\frac{r}{r-\mu}\frac{\beta_2-1}{\beta_2}AX \quad (9)$$

Where '*' means the optimal level, and $A=\left(\frac{\tau-\beta_2+\frac{(r-\mu)(1-\alpha)\beta_2}{r}}{\tau}\right)^{\frac{1}{\beta_2}}$. Denote $P=\frac{r}{r-\mu}\frac{\beta_2-1}{\beta_2}A$, then the optimal debt level can be expressed as $C=PX$. Furthermore, the threshold value and the project value can be expressed as $X_D=AX$ and $\bar{V}_O(X)=BX$, respectively, $B=\frac{1}{r-\mu}(1-\tau+\tau A)$. It can be seen that both the optimal debt level and the threshold value are a linear function of project cash flow value.

Before private investors make investment, there exists completion risk in the project. Suppose the probability that completion risk could happen is ρ, the project value is $\bar{V}(X)$. Then, $\bar{V}(X)$ satisfies the following differential equation:

$$\frac{1}{2}\sigma^2X^2\frac{\partial^2\bar{V}(X)}{\partial X^2}+\mu X\frac{\partial\bar{V}(X)}{\partial X}-r\bar{V}(X)+(1-\rho)\bar{V}_O(X)-I=0 \quad (10)$$

Besides, two boundary conditions need to be satisfied:

$$\bar{V}\left(\bar{X}_I\right)=(1-\rho)\bar{V}_O\left(\bar{X}_I\right)-I \quad (11)$$

$$\left.\frac{\partial\bar{V}(X)}{\partial X}\right|_{X=\bar{X}_I}=(1-\rho)\left.\frac{\partial\bar{V}_O(X)}{\partial X}\right|_{X=\bar{X}_I} \quad (12)$$

Just like the above analysis, the first boundary condition is the value matching condition, and the second boundary condition is the smooth passing condition. It can be derived that the expression of the project value satisfies:

$$\bar{V}(X)=\frac{I}{\gamma_1-1}\left(\frac{X}{\bar{X}_I}\right)^{\gamma_1} \quad (13)$$

$$\bar{X}_I=\frac{\gamma_1}{\gamma_1-1}\frac{1}{(1-\rho)B}I \quad (14)$$

Thereinto, $\gamma_1=\sqrt{\left(\frac{1}{2}-\frac{\mu}{\sigma^2}\right)^2+\frac{2r}{\sigma^2}}+\frac{1}{2}-\frac{\mu}{\sigma^2}>1$. It can be seen that the investment threshold value $\bar{X}_I$ increases with the construction cost I and completion risk probability ρ.

The investment decision analysis of the private investor under tax reduction incentive policy

This section will investigate the influence of tax reduction incentive policy on the investment decision of private investors. Suppose government promises to give δ percentage of tax benefits back to private investors during the operating period. We need to estimate the tax benefits first. The tax benefits (denoted as $G(X)$) satisfies the following differential equation:

$$\frac{1}{2}\sigma^2X^2\frac{\partial^2G(X)}{\partial X^2}+\mu X\frac{\partial G(X)}{\partial X}-rG(X)+\tau(X-C)=0 \quad (15)$$

Combining with the boundary condition $G(X=C)=0$ and the non-bubble condition, It can be derived that the expression of tax benefits satisfies:

$$G(X)=\frac{\tau}{r-\mu}X-\frac{\tau}{r}C-\frac{\mu}{r(r-\mu)}\tau C\left(\frac{X}{C}\right)^{\beta_2} \quad (16)$$

Under the optimal debt level $C^*=PX$, and denote $Q=\left(\frac{\tau}{r-\mu}-\frac{\tau}{r}P-\frac{\tau\mu}{r(r-\mu)}P^{1-\beta_2}\right)$, it can be derived that $G(X)=QX$.

Then, the equity value of private investors $\bar{E}_O^1(X)$ satisfies:

$$\frac{1}{2}\sigma^2X^2\frac{\partial^2\bar{E}_O^1(X)}{\partial X^2}+\mu X\frac{\partial\bar{E}_O(X)}{\partial X}-r\bar{E}_O(X)+(1-\tau)(X-C)+\delta QX=0 \quad (17)$$

Suppose the threshold value that private investors abandon the project in this situation is X_D^1, the expression of X_D^1 satisfies:

$$X_D^1 = \frac{r-\mu}{r}\frac{1-\tau}{1-\tau+\delta Q}\frac{\beta_2}{\beta_2-1}C \quad (18)$$

It can be easily demonstrated that $X_D^1 < X_D$, which means that tax reduction policy can effectively keep private investors invest in the project a longer time. Besides, the larger degree of tax reduction (δQ), the smaller threshold value (X_D^1) that makes private investors abandon the project.

In a similar way, the expression of the optimal debt level C_1^* can be derived:

$$C_1^* = \frac{r}{r-\mu}\frac{1-\tau+\delta Q}{1-\tau}\frac{\beta_2-1}{\beta_2}A_1 X \quad (19)$$

where $A_1 = \left(\frac{(\tau-\beta_2)(1-\tau+\delta Q)+\frac{(r-\mu)(1-\alpha)(1-\tau)\beta_2}{r}}{\tau(1-\tau+\delta Q)}\right)^{\frac{1}{\beta_2}}$. Denote $P_1 = \frac{r}{r-\mu}\frac{1-\tau+\delta Q}{1-\tau}\frac{\beta_2-1}{\beta_2}A_1$, then $C_1^* = P_1 X$. It can be found that there exists a threshold value $\overline{\delta} = \frac{1-\tau}{Q}\left(\frac{(r-\mu)(1-\alpha)(1-\beta_2)}{r(\tau-\beta_2)}-1\right)$, when it is satisfied that $\delta \le \overline{\delta}$, the optimal debt level decreases with the tax reduction ratio; otherwise, when it is satisfied that $\delta > \overline{\delta}$, the optimal debt level increases with the tax reduction ratio. The expression of the project value and the threshold value (X_D^1) can be expressed as $\overline{V}_O^1(X) = B_1 X$ and $X_D^1 = A_1 X$, respectively, $B_1 = \frac{1-\tau+\delta Q}{r-\mu}(1+\frac{\tau}{1-\tau}A_1)$.

Before private investors make investment, the project value $\overline{V}_1(X)$ satisfies:

$$\frac{1}{2}\sigma^2 X^2 \frac{\partial^2 \overline{V}_1(X)}{\partial X^2} + \mu X \frac{\partial \overline{V}_1(X)}{\partial X} - r\overline{V}_1(X) + (1-\rho)\overline{V}_O^1(X) - I = 0 \quad (20)$$

Combining with the value matching condition and the smooth passing condition, the expression of the investment threshold value $\overline{X}_I^1$ can be derived:

$$\overline{X}_I^1 = \frac{\gamma_1}{\gamma_1-1}\frac{r-\mu}{r-\mu-1}\frac{1}{(1-\rho)B_1}\frac{r-1}{r}I \quad (21)$$

It can be demonstrated that $\overline{X}_I^1 < \overline{X}_I$, which means that tax reduction policy can effectively motivate private investors to invest in the project earlier.

The investment decision analysis of the private investor under completion risk sharing incentive policy

Under completion risk sharing incentive policy, suppose government promises to reimburse a share of construction cost ($\delta_0 I, 0 < \delta_0 < 1$) to private investors once the completion risk happens, which does not affect the investment behaviour of private

investors in the operation period. The project value ($\overline{V}_2(X)$) before the investment is made satisfies:

$$\frac{1}{2}\sigma^2 X^2 \frac{\partial^2 \overline{V}_1(X)}{\partial X^2} + \mu X \frac{\partial \overline{V}_1(X)}{\partial X} - r\overline{V}_1(X) + (1-\rho)\overline{V}_O(X) - (1-\delta_0\rho)I = 0 \quad (22)$$

Combining with the value matching condition and the smooth passing condition, the investment threshold value can be derived:

$$\overline{X}_I^2 = \frac{\gamma_1}{\gamma_1 - 1}\frac{r-\mu}{r-\mu-1}\frac{1-\delta_0\rho}{(1-\rho)B}\frac{r-1}{r}I \quad (23)$$

It can be demonstrated that $\overline{X}_I^2 < \overline{X}_I$, which manifests that completion risk sharing policy can also effectively promote private investors to invest in the project. Besides, when the completion risk probability satisfies $\rho \le \frac{1}{\delta_0}\frac{B_1 - B}{B_1}$, the investment threshold value under tax reduction policy is lower than that under completion risk sharing policy, namely $\overline{X}_I^1 < \overline{X}_I^2$; otherwise, when the completion risk probability satisfies $\rho > \frac{1}{\delta_0}\frac{B_1 - B}{B_1}$, the investment threshold value under tax reduction policy is larger than that under completion risk sharing policy.

The Numerical Analysis

This section examines the property of the model with a numerical analysis. The value of the basic parameters are determined based on data from project finance for capital-incentive investments (Sarkar 2012, Soumaré 2016). $r = 0.05$ for the risk-free interest, $\mu = 0.02$ for the risk neutral expected rate of return, $\sigma = 0.2$ for the volatility of the cash flow, $\tau = 0.4$ for the tax rate, $\alpha = 0.1$ for the degree of the transfer loss. Assume the total construction cost $I = 2$ (million) and the initial cash flow value $X = 0.1$ (million), the value of them can be changed without any influence on the result.

The influence of incentive policies on the investment threshold value.

Figure 1 displays the influence of tax reduction policy and completion risk sharing policy on the investment threshold value of private investors. It can be seen that both policies can effectively incentivize private investors to invest in the project earlier. The relative effectiveness of two incentive policies depends on the value of the completion risk probability, the incentive ratio, and other project parameters. When the completion risk probability is relatively large ($\rho > \frac{1}{\delta_0}\frac{B_1 - B}{B_1}$), completion risk sharing policy is more effective to promote private investors to invest in the project (as is shown in the left figure); otherwise, when the completion risk is relatively small ($\rho \le \frac{1}{\delta_0}\frac{B_1 - B}{B_1}$), tax reduction policy is more effective to motivate private investors to invest in the project (as is shown in the right figure)

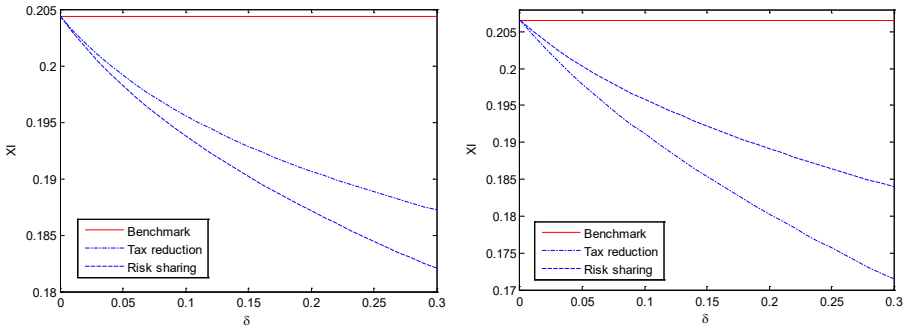

Figure 1 – The influence of incentive policies on the investment threshold value

The influence of incentive policies on the optimal capital structure of the project.
Figure 2 shows the influence of tax reduction policy and completion risk sharing policy on the optimal capital structure of the project. It can be seen that the optimal capital structure of the project is not affected by completion risk sharing policy. However, under tax reduction incentive policy, the optimal debt level increases with the incentive ratio when the transfer loss is relatively large ($\alpha = 0.1$), and decreases with the incentive ratio when the transfer loss is relatively small ($\alpha = 0.01$). This results manifests that government should be aware that inventive policies may not only influence the investment threshold value of private investors, but also change the capital structure of the project. If the purpose of government is just to induce private investors to invest in the project earlier, completion risk sharing policy should be first considered.

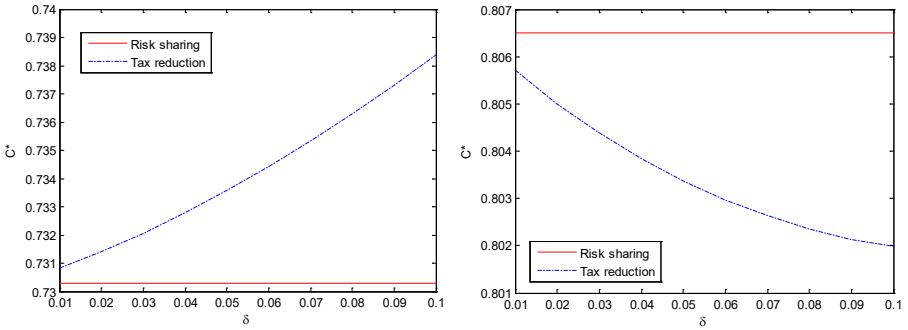

Figure 2 – The influence of incentive policies on the capital structure of private investors ($\alpha = 0.1$ and $\alpha = 0.01$, respectively)

The influence of incentive policies on the exit threshold value of private investors.
Figure 3 depicts the influence of tax reduction policy and completion risk sharing policy on the exit threshold value of private investors. It can be seen that the exit threshold value keeps unchanged under completion risk sharing policy, but decreases with the incentive ratio under the tax reduction policy. The result suggests that if government intends to induce private investors to invest in the project a longer time, tax reduction policy should be first considered.

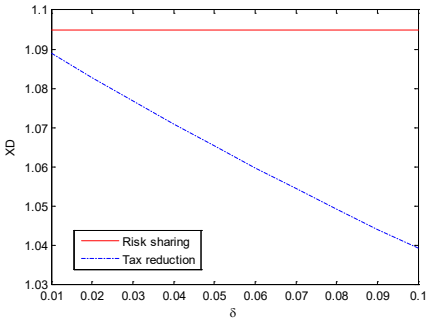

Figure 2 – The influence of incentive policies on the exit threshold value of private investors

Conclusion

This study investigated the influence of tax reduction policy and completion risk sharing policy on the investment behaviour of private investors, including their investment threshold value, optimal capital structure and exit threshold value. The results manifests that: first, both incentive policies can effectively reduce the investment threshold value of private investors; second, the relative effectiveness of two incentive policies depends on the value of the completion risk probability, the incentive ratio, and other project parameters; third, the optimal debt level is not affected by completion risk sharing policy but displays a U-shape relationship with the incentive ratio under tax reduction policy; finally, tax reduction policy can induce private investors to invest in the project a longer time. These results can help government to better arrange the incentive plan in the PPP project.

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The implementation of Building Information Modelling (BIM) in the construction industry: how necessary is organisation learning?

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Abstract

Adopting new technologies brings competitive advantage for organisations. One of the leading innovations in the construction industry is Building Information Modelling (BIM). Organisations need to make major changes to benefit from the BIM adoption. This paper first conducts a literature review to investigate different approaches to the BIM implementation. A conceptual framework is then proposed, based on Organisational Learning theory. This framework reveals how organisations can be involved in the process of learning so as to change the different social, structural, and procedural components of their organisations to effectively implement BIM.

Keywords: Organisational Learning, Technology Implementation, Building Information Modelling (BIM)

Introduction

Pursuing new technologies is essential for organisations to sustain their competitive advantage (Tippins and Sohi, 2003) through process and product improvement and the resultant market benefits (Edmondson et al., 2001). One of the pioneer technological innovations in the construction industry is Building Information Modelling (Lu et al., 2015) which can enhance project management and outcomes (Chien et al., 2014).

BIM is defined as a set of policies, technologies, and processes for managing the design and data of a construction project through its lifecycle (Succar, 2009). BIM provides a data-based virtual model of the building project, facilitating the distribution of information and knowledge management in the project (Deshpande et al., 2014; Meadati and Irizarry, 2010). BIM enables information sharing and communication dispersion to reach an effective and multi-lateral interaction between different specialists involved in the project such as engineers, suppliers, contractors, and the client (Sackey et al., 2015).

BIM involves a shared database which contains all the information of the components of the virtual model, and this can be used in further analyses and evaluations of the project, such as energy consumption, project time control, project cost estimation, and identification of design and execution errors affecting the time, cost, and quality of the project (Bryde et al., 2013; Mihindu and Arayici, 2008; Succar, 2009). Using BIM has been found to reduce project cost and completion time, to improve output quality, and to facilitate communication and coordination between project members (Bryde et al., 2013). Because of these advantages, construction companies have been encouraged to adopt and implement BIM.

Despite the advantages, recent studies have shown that implementing BIM as a new technology is challenging (Chien et al., 2014). Almost 90% of the organisations which already use BIM still need to undergo major changes in their implementation strategy to benefit the advantages of BIM (Sackey et al., 2015). Organisations need to reengineer their structures, processes, policies, and people to reap the advantages of BIM implementation (Eadie et al., 2013; Liu et al., 2017; Rezgui et al., 2013; Samuelson and Björk, 2014).

The underlying principle of change is "learning" (Bresman, 2013; Crossan et al., 1999) which can explain the dynamics of change. Organisation learning helps us to understand the process through which new actions and routines can be adopted (Edmondson et al., 2001). Also, the learning concept plays a vital role in defining the result of IT implementation (Tippins and Sohi, 2003). In other words, when a new technology interrupts the current operating routine of an organisation, the organisation should go through a learning process so as to adopt the new routines effectively (Edmondson et al., 2001).

This paper aims to focus on the literature concerning how organisations in the construction industry learn to use BIM optimally for increasing project productivity. In this paper, the 70 articles recognized by Olawumi et al. (2017) for "learning, adoption and practice" are analyzed and compared. After the literature review, a conceptual framework regarding the organisational learning process in the implementation of BIM will be proposed.

Literature review

Definition of BIM

BIM is one of the most recent developments in the architecture, engineering, and construction (AEC) industry (Kim, 2012). BIM is defined as a set of policies, technologies, and process for managing the design and the data of the project through its lifecycle (Succar, 2009). This information and communication based technology (Bråthen, 2015; Froese, 2010; Xu et al., 2014) allows specialists in the construction project to make a virtual model of the building. This virtual model contains the geometry of the building project as well as the related data which can be used in the construction, fabrication, and procurement activities (Eastman, 2012). The BIM database can be a platform for storage and distribution of data and information during different phases of the project such as design, construction (Deshpande et al., 2014), and even facility management and maintenance (Froese, 2010; Lindkvist, 2015).

The use of BIM has been found to lead to economic and non-economic benefits. Economic outcomes include increased efficiency, profitability, and cost savings, and the non-economic results comprise increased skill and ability, increased decision quality, and improved business processes (Lindblad and Vass, 2015)

To achieve these benefits of using BIM, organisations should be prepared to undergo a major paradigm shift (Giel and Issa, 2016; Kim et al., 2016) where all the components of the organisation need to be aligned to the new working platform created by BIM.

Approaches to BIM implementation

In recent years, the amount of organisations using BIM has increased, and there has been a rise in the number of studies addressing different aspects of BIM implementation (Olawumi et al., 2017; Santos et al., 2017).

Olawumi et al. (2017) conducted a literature review of BIM related research, covering 445 articles, forming a baseline for understanding the different approaches to BIM adoption and its accomplishments in the construction industry. In this study, the authors categorized the papers, based on the subject in 10 different groups and evaluated them with regards to the project type influenced by BIM and the funding resource for BIM research. Their findings show that one of the main research categories, comprising 70 papers, is "*learning, adoption and practice*". This category includes 11 different themes (Olawumi et al., 2017), viz.,

- BIM usage and adoption
- BIM curriculum development
- Construction stakeholders' BIM adoption strategies
- BIM teaching and support
- Drivers of BIM adoption
- Cost-benefit analysis of BIM implementations
- BIM adoption barriers
- BIM standardization and intellectual property rights
- Competency assessment
- BIM ethics and professionalism, and
- Practice paradigms and governance approach.

None of the 70 papers proposed an implementation framework which, as Olawumi et al. (2017) believed, could empower the process of technology adoption.

As a further categorisation, the above papers in the "BIM learning, adoption & practice" category can be classified into two main groups regarding the application of BIM, viz., in the education field and the construction professional use of BIM.

In the first category, the use of BIM in the education field, there are two groups of research. One group, studies on teaching BIM in the universities, suggests methods and frameworks to review the curricula of universities and to include courses which train students in the usage of BIM (Pikas et al., 2013; Sacks and Pikas, 2013; Sampaio, 2015; Solnosky et al., 2014; Wu and Issa, 2014). It is advocated that students learn to work with new software, follow new procedures in the lifecycle of the project, and develop their soft skills so as to work in collaborative environments with other members of the projects (Pikas et al., 2013). In the other group, BIM is considered a tool which can accelerate the teaching of construction units (Gnaur et al., 2015; Kim, 2012; Sacks and Barak, 2010). For example, BIM helps students to understand construction details (Kim, 2012) and help them to develop their collaborative skills (Gnaur et al., 2015).

From the growing attention in the subject of BIM education, there is an inference that there is a shortage of graduate engineers who are able to work in the BIM context (Wu and Issa, 2014). This present deficiency creates problems in organisations within the construction industry (Matthews et al., 2018) where there is an expectation of these companies' ability to work on projects in the BIM environment. To cope with this deficiency, the responsibility of the process of learning BIM skills seems to have shifted

from universities to construction organisations. People in organisations should be encouraged to work with each other (Tsai et al., 2014) to cope with both technical and nontechnical issues (Gu and London, 2010), and to change their attitudes toward collective work (Liu et al., 2017).

In the second category, the construction professional application of BIM, studies consider the different aspects of BIM adoption in organisations. For example, some studies measure the benefits of using BIM in different stages of the project lifecycle (Eadie et al., 2013); recognize the BIM adoption success factors (Tsai et al., 2014), or barriers (Chien et al., 2014); factors affecting the decision to adopt BIM (Kim et al., 2016); cost-benefit measurement of BIM implementation (Giel and Issa, 2013; Lu et al., 2014); and, regulations and intellectual property rights in BIM (Fan, 2014). These studies scrutinize some aspect of the BIM implementation and address the "what" questions of BIM implementation. They do not go deeper to understand "how" the implementation of BIM occurs.

However, some papers address the BIM implementation process with a deeper perspective. Some of these in-depth studies discuss the change strategies considering the structure of the organisation and the training plan of BIM implementation (Ahn et al., 2016). Some others developed decision frameworks for BIM adoption considering different levels of the construction industry (individual, organisation, inter-organisation) (Samuelson and Björk, 2014) and based on BIM implication concerns (strategic goals and domain, work road map, technical provisions of BIM and partner assessment) (Gu and London, 2010). Even though these studies try to help AEC organisations understand the requirements of the BIM implementation, they do not explain the dynamics of BIM adoption process.

Sackey et al. (2015) take a step forward and claim in their in-depth case study that what matters in the implementation of BIM is the placement of people in the learning loop. People must learn how to execute the optimal BIM and achieve the desired results. Nevertheless, based on organisational learning theories for successful implementation of BIM, in addition to individual learning, organisations should learn too (Senge, 1990). Despite the importance of organisational learning in the technology implementation (Roberts et al., 2017; Robey et al., 2000; Tippins and Sohi, 2003; Woldesenbet and Klay, 2016), the learning process seems to be neglected in the BIM implementation studies.

To shape the conceptual framework, a mind map of the literature review which shows the relation between different notions of the research is presented (Figure 1).

This paper aims at providing a conceptual framework based on the organisational learning perspective to address the implementation process of BIM as an IT solution in construction organisations.

Theoretical background and conceptual framework

The purpose of having a conceptual framework is that it "lays out the key factors, constructs, or variables, and presumes relationships among them" (Miles and Huberman, 1994, p. 440). In other words, the conceptual framework gives a structure of the concepts and their relationship and shows how ideas can be related one to another within the framework (Grant and Osanloo, 2014).

There are no best theory/theories to be selected as the basis to shape the conceptual framework, and it is the responsibility of the researcher to choose a theory or theories aligning the study's purpose, research question, and design (Grant and Osanloo, 2014). Since the goal of this research is to include concepts of organisational learning in the implementation process of a new technology in the construction industry, the conceptual framework can be established based on Organisation Learning theory.

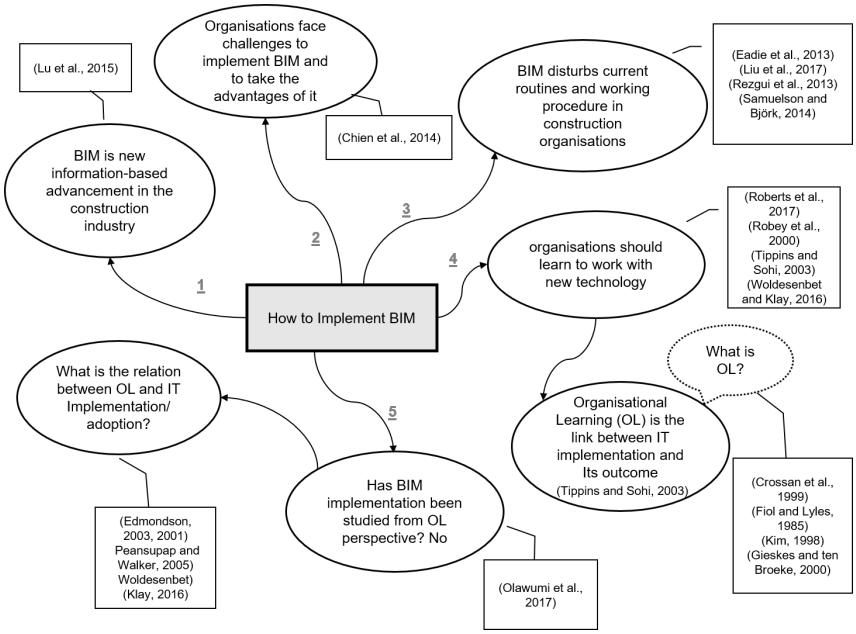

Figure 1- Mind map literature review: Organisational learning to implement BIM

Organisational learning

Learning is the process of enhancing the capacity to perform efficient functions (Kim, 1998). Learning is a set of activities including knowledge acquisition, information distribution, and information interpretation which consciously or unconsciously affects the changes in the organisation (Templeton et al., 2002). Learning can occur in different levels such as individual, group, and company. Individual learning is the main component of organisational learning. However, organisational learning is not equal to the sum of the individuals' learning (Fiol and Lyles, 1985; Kim, 1998). Organisations need some methods and techniques to facilitate learning and the transfer from individual level to organisational level (Gieskes and ten Broeke, 2000).

The main concept of individual learning is "mental model" (Kim, 1998) or "frame" (Edmondson, 2003). The mental model or frame demonstrates individual perspective of the world and how a person gives meaning to new material. Each mental model is a set of viewpoints or beliefs and activities. Organisational learning happens when individual mental model or frame reaches to a collective level and shapes the shared mental model. To make a shared mental model, it is essential to make individual mental models explicit. Using particular language or tools can accelerate the process of sharing individual mental models. When the shared mental model is shaped, it is independent of any specific individual one (Kim, 1998).

In the case of technology implementation, people should get involved in the actual experiments and practices to build up a new frame about the aims and patterns of work emerging with the new technology (Edmondson, 2003). They should try to expose their mental model through actions and communication to shape the shared mental model.

In the following, the conceptual framework (Figure 2) regarding the process of organisational learning will be presented.

Conceptual Framework

As stated above, BIM is an innovative development which affects all the aspects of the construction industry. Researchers have studied BIM implementation process from different perspectives. The organisational learning aspect is the fundamental issue in technology implementation process but this has been overlooked (Woldesenbet and Klay, 2016). To fill this gap, this paper presents the BIM implementation conceptual framework, based on the organisational learning theory literature review (Figure 2).

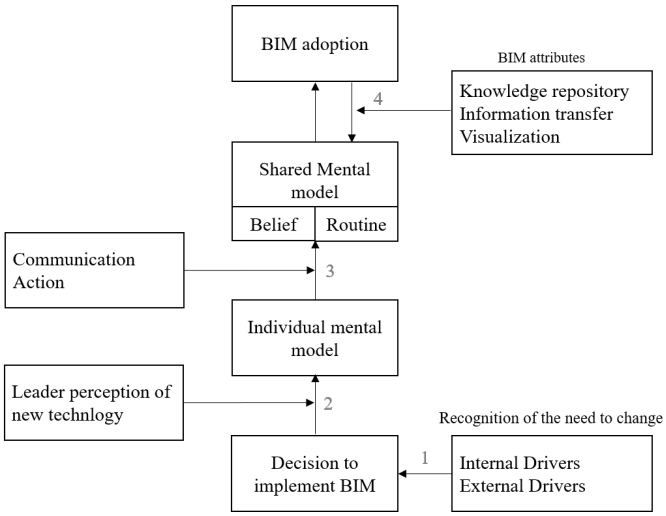

Figure 2- Conceptual framework based on literature review

BIM, as a technology and innovation in the construction industry, calls for change (Davies and Harty, 2013). The starting point of the change in organisations is people. There are various external and internal drivers affecting the decision of change. People may decide to adopt a new technology based on various drivers and different factors such as prior belief, the amount of information available, and costs (Young, 2009). Straub (2009) claims that three main categories of characteristics may affect the adoption or diffusion of a new technology. These categories are personal traits which push people to seek change, innovation characteristics such as the ease of use of the new technology, and the working context. (Link 1 in Figure 2).

In the next step, the decision to adopt a new technology should be operationalized through infusion and implementation of the technology in the organisation. Here, the leader's attitude towards the new technology can be a critical point in the learning process. Leaders can reframe mental models of the people with their powers to interpret the implications of new technology. People tend to consider the action and the word of the leader more than those of peers and colleagues (Edmondson, 2003). Whether leaders consider the new technology as simply a "plug-in" which may improve their traditional way of work or consider the new technology as a "new innovative project" (Edmondson et al., 2001), this can affect the framing of individual mental model and learning process in the organisation. This is important because the way users comprehend the technology's "pros" and "cons" affect the way they respond to the new technology implementation (Edmondson, 2003) (Link 2 in Figure 2).

The next step is to make a shared metal model regarding the use of new technology. Shared mental model consists of shared belief and activities. When the foundation of shared belief enlarges in the organisation, the capacity of the organisation to action

efficient coordinated activities increases accordingly. This is similar to the routines and actions being the auto reflection of beliefs (Kim, 1998). Based on this assumption, making shared belief regarding the new technology is an important step in organisational learning. The shared belief or understanding regarding the new technology can be achieved through communication, and the active participation of all the team members in the activities (Crossan et al., 1999). Active engagement in the practices and free communication throughout the implementation help people to obtain a better understanding of their roles and responsibilities in the technology implementation process (Edmondson et al., 2001).

Amoako and Salam (2004) further support the assertion that a shared belief is a key driver to implementing new technology in organisations. Shared belief regarding the benefits of the new technology can be facilitated through training and communication and can ultimately affect the ease of use and perceived usefulness of new technology (Link 3 in Figure 2).

There is a mutual relationship between organisational learning and IT implementation. Robey et al.,(2000) believe that the successful implementation of IT not only needs organisational learning but can also facilitate organisational learning. They indicate that IT can facilitate learning by providing virtual presentations, diagrams and pictures, and bring a collaboration atmosphere in a virtual environment. BIM, as an information-based technology, provides facilities such as easy access to information, virtual visualizations, and knowledge repository. These attributes in the project context, enhance the capacity of organisations to absorb new knowledge and transfer information efficiently which in turn increases the capability of learning organisations (Link 4 in Figure 2).

Conclusion

In the construction industry, BIM has recently been introduced as a communication and information technology (Bråthen, 2015; Froese, 2010; Xu et al., 2014) which can increase the capacity and capability of organisations to execute construction projects and enhance their outcomes. However, BIM as a new technology can disrupt the current procedures and strategies of organisations, as well as their social climate. Organisations which seek to realize full benefits of new technology implementation should change their structure, processes and strategies (Weston Jr, 2001). Organisational change occurs through learning (Styhre et al., 2004). Learning is the main element of consideration in technology implementation in organisations (Edmondson, 2003; Peansupap and Walker, 2005; Woldesenbet and Klay, 2016) and is the means to review and change organisational strategies (Crossan et al., 1999). Technology users should learn how to work with others through new patterns of work that emerge from new technology implementation (Edmondson, 2003). Thus, organisations wanting to adopt BIM, should go through an organisational learning process to be able to use the new technology effectively (Tsai et al., 2014).

To adopt a new technology effectively, both social and technical aspects of the implementation process should be addressed. The team members should reach a shared belief about the usefulness of BIM to be able to use it and share data in the BIM context (Samuelson and Björk, 2014). It is not enough to provide access to the shared database of the projects' documents, as the users should be conscious of the purpose underlying the implementation of a new approach. In previous studies, some of the technical and non-technical issues of the BIM implementation process were addressed (Gu and London, 2010). In addition, the importance of people learning as the fundamental concept of BIM implementation was argued (Sackey et al., 2015). However, there has not been a

framework to look at the implementation process from the point of organisational learning. This paper has tried to fill this gap by proposing such a conceptual framework.

Discussion

There are some pertinent factors which are not discussed in the proposed framework and these should be considered in the learning process of BIM implementation in further research. One of these factors points to external stakeholders. Governments, as an external influencer, can play a vital role in the implementation process, expanding the use of BIM across the construction industry (Bygballe and Ingemansson, 2014). For example, the Australian Cooperative Research Centre for Construction Innovation (CRC CI) found that investment in the BIM implementation program helped construction organisations to refine their routines and increase their capacity to acquire knowledge and improve their capabilities so that the national benefit increased (Kraatz and Hampson, 2013).

Another factor is the role of top management. Although the implementation process may seem bottom-up at the initial phase, the role of top management in implementation of a technology in the organisation is crucial (Tsai et al., 2014). Top management of the organisations should provide individuals with formal training and build the atmosphere of free communication which would then increase the collaboration and coordination among personnel and help them to reach a shared belief regarding the use of the technology.

The above factors may very well affect the learning process in different contexts and should be included in future studies.

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Project Failure: A systematic literature review and future research directions

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Abstract

The objective of this paper is to extend the understanding of process improvement project failure by systematically reviewing the research on project failure and develop research propositions and a future research agenda. In total 118 papers on general- and process improvement projects are reviewed for contributions on project failure. This review reveals three categories in project failure research that lead to research propositions. The first category consists of the causes for project failure and their relative importance, the second category is about causality and relatedness between project failure factors and third and final is research on project failure mitigation strategies.

Keywords: Process improvement project, Project failure, Systematic Literature Review

Introduction

The organizational task of operations management is commonly divided into directing, designing, delivering and finally developing the operations (Slack et al. 2018). The task of developing the operations entails the continuous pursuit of improvement in both processes and products, generally embodied by process improvement projects based on established improvement methodologies such as Lean, Six Sigma, Total Quality Management and Lean Six Sigma (Antony, 2009).

To date many organizations have achieved significant results with the implementation of process improvement projects (e.g. Lucier and Seshadri 2001 for General Electric; Dedhia, 2005 for Samsung Electronics, American Express, Du Pont and others). Despite the reported successes there has also been criticism on the results of improvement project implementations (Easton and Rosenzweig, 2012). These mixed results about the effectiveness of process improvement project implementation provide the motivation for this systematic literature review.

In many industries and organizational domains organizations are operating, changed and improved by project based activities (Lundin & Söderholm, 1998). In this systematic literature review, research on process improvement project failure and general project failure from operations management and adjacent disciplines such as information systems, information technology and engineering are reviewed. Questions we seek to answer are: What characteristics do improvement projects share with general projects, what are common themes that are known to cause project failure, and what are the implications of the findings on project failure research to date for process improvement project failure research?

Characteristics of process improvement projects

Operations management research to date has focused on the unique characteristics that are essential for success of process improvement projects. These are for one a clear focus on project goals (improvement of the critical dependent "Y" metric) that drives and encourages learning about the problem at hand and the organizational context (Linderman, 2003, Easton and Rosenzweig, 2012). Secondly the use of improvement specialists that are trained in a structured improvement method (such as the DMAIC structure for Six Sigma) and operate in a parallel project organizations (Schroeder et al. 2008) is recognized. Finally the prioritized selection and contribution of improvement projects to corporate strategy realization (McAdam and Lafferty, 2004), leadership support (Schroeder et al. 2008) and selection of suitable methodology frameworks for specific improvement objectives (Pyzdek and Keller, 2014) are recognized characteristics of successful improvement projects.

Comparing the definition and characteristics of general projects to improvement projects reveals many similarities. First the research on the characteristic of general projects similarly defined that projects are executed by temporary parallel organizations (Lundin & Söderholm, 1995) that are structured to perform a set of activities and create a unique result, with limited resources and a predetermined beginning and end (Gilbreath, 1986). Widely adopted criteria to define the success of a project similarly entail a costs, quality and or time metric associated with execution, also known as the Iron Triangle (Atkinson, 1999). Commonly a project is defined as being temporary, with an explicit beginning and end, and similarly to improvement projects is not a routine operation. Projects are similarly going through a certain life cycle, which commonly includes the four stages of conceptualization, planning, execution and implementation and finally termination (Adams & Barndt, 1983). As projects are often defined by boundedness in time, their structure and composition varies. General project organizations similarly have teams with specific expertise, and project- size and complexity can vary across industries (Radas & Bozic, 2012). Organizations can either implement in-house projects or outsource the execution of projects (Brady & Davies, 2004) and projects can have either a functional structure or matrix structure which runs across various functional units (Larson & Gobeli, 1989).

Hence improvement projects and general projects have many similar characteristics. Main differences lay in the explicit recognition of in-house or outsourced execution of projects and project governance structures. By means of a systematic literature review methodology that is described next we review and discuss the dominant project failure research themes and distil propositions for future research on process improvement project failure specifically.

Systematic review methodology

The systematic literature review methodology that is applied is based on the suggestions by Webster & Watson (2002) and Tranfield et al. (2003) which are the basis for the research methodology and presentation of results (figure with process flow of systematic review process available). The search for publications on project failure started with the keywords "project" and "fail" or "failure" in publication titles in the Google Scholar-, Web of Science-, the EbscoHost- and the Scopus journal database. After duplicate checks the initial sample comprised 877 articles for which a quick scan for inclusion and exclusion criteria in both titles and abstract was performed (table with criteria available).

After the first round of selection, 118 peer-reviewed publications remained for further consideration. Secondly a complete article read was performed and based upon the in- and exclusion criteria 22 more articles were excluded from the sample. Premier reason for exclusion in this stage is identification of research that addresses the failure of initiatives (projects), for instance in developing countries. Finally the rigorous search and selection procedure resulted in 96 articles that are part of this systematic literature review. Then research database with article citations was set up and the process of extracting relevant information from the sample of articles commenced. The information of interest from the articles per article in a data spreadsheet is recorded. To ensure the validity of this humanly performed data collection- and coding process, the information of interest was coded by making use of pre-defined labels (author, author profile, country, year, title, journal, finding, methodology, type and industry). After each round of coding, a second researcher independently validated the coding for error-sensitive information (author profile, journal finding and methodology). Conflicting coding results were discussed and resolved, thereby enhancing reliability of the resulting database (Chugh & Wang, 2015).

Descriptive analysis of the data

Distribution of research papers over time

With an increasing trend the average number of publications steeply rose from 1998 – 2004 to noticeably more articles per year during 2005 - 2016. The majority of the mostly cited articles stems from 2005 or after that, which signals the growing research interest in project failure (figure available).

Geographical distribution of research papers

The geographical distribution of the publications in shows that the Unites States (N=39, 41% of total sample) is the leading continent were research has been performed, followed by Europe (34%), Asia (17%), Middle East (5%) and Africa (3%). The earliest studies originated from North America whereas Europe entered into project failure research in 1995 (Beynon-Davies, 1995) (figure available).

Distribution of research methodologies

Results show that research on project failure is mostly performed by case-based research methods (N=31, 32% of total sample) (figure available). Also empirical research has received good attention from researchers (32%), which is mostly based on cross-sectional surveys from project managers and executives. Cross-sectional research was represented far more than longitudinal research in the empirical researches in the sample. In more recent theoretical studies, project management literature has been

linked with mainstream management theories (such as stakeholder-, institutional-, organizational- and agency theory), which signals maturity of the research area.

Distribution of research papers based on industry
Most research originates from the public sector (20%), professional services (18%) or covers multiple sectors (12%) (table available). Research papers that covers multiple sectors are predominantly surveys aimed at project practitioners. Project types that are predominantly represented in the sample comprise Information Technology (IT) (33%) and Information Systems (IS) (23%).

Distribution of research papers across journals and author profile
The research on project failure has been published in management and technically orientated journals. The top five publishing journals account for about 25% of the total publications, and the top twenty accounts for about 50% (Figure available). This indicates a wide range of journals that are publishing on project failure.

Critical analysis of the review
Systematically studying the existing literature review has revealed a taxonomy whereby the results and the propositions for future research are discussed. The categories that are discussed are (1) the types of project failure factors and their relative importance, (2) how project failure factors are related by topic and in time and (3) before, during and after the project failure mitigation strategies.

Project failure factors
The largest and most researched category in the sample is on project failure factor identification. Project failure factors are primarily established through empirical and case-based research and are discussed per category (Table 1).

Table 1: Categorized project failure factors

No.	Project failure categories	Number of references
Project managerial		
1	Rationale, scope and objectives	15
2	Requirements- analysis and delivery	18
3	Project management methodology	21
4	Change management	21
5	Stakeholder management	11
6	Project team availability and skills	18
7	Project team roles, responsibilities and relationships	11
8	Sponsorship and commitment	17
Technological		
9	Technological novelty	4
10	Technological complexity	7
11	Technological compatibility	5
Organizational		
12	Organizational culture	6
13	Organizational structure	6
External		
14	Regulatory requirements	2
15	Public justification	1
16	Alliances and collaborations	6

Prior research on project failure factor identification (detailed discussion of review available) listed in Table 1 revealed whether a failure factor appeared significant in research. More recent research has recognized the relative importance of project failure factors. A distinction is made between critical- and catalysing failure factors, whereby the latter are not sufficient on their own to induce project failure, but does contribute to project failure if other factors coexist. Review of the literature yields a fragmented and inconclusive understanding of the relative importance of project failure factors. Critical project failure factors identified are software development difficulties, management capacity and procurement methods (Brown, 2001), poor project planning and project management and control issues (Yeo, 2002), stakeholder capabilities and fit between technological solution, and strategy and cultural fit (McLaughlin, 2009), organizational structure (Elkadi, 2013) and project planning, team experience and poor initial- and often changed designs (Nguyen & Chileshe, 2015).

Reviewing the literature on criticality of project failure factors shows agreement on the existence of critical failure factors, though ambiguity on the origins of critical project failure factors (e.g. in- or outside the sphere of influence of the project organization). There is a predominant focus on failure factor that originate within the project organization (the project managerial and the technological categories, see Table 1) and less focus is on failure influenced by forces outside of the project organization (the organizational and external categories) which leads to the following proposition for future process improvement project failure research.

Proposition 1: Failure factors that originated from within the project organization have a stronger positive influence on the likeliness for process improvement project failure than failure factors that originated outside the project organization.

Interdependency of project failure factors

Recent research has started to address the interdependency of project failure factors, mostly hypothetical and based upon author experiences (Lehtinen et al. 2014). One important reason for the scarce empirical research to date is that researching interdependency and causality is requiring a post hoc reconstruction of a string of events. Research methods that are being applied comprise case study research based upon causal mapping (Ackermann & Eden, 2005) and interpretive structural modelling (Hughes et al. 2016). These methods in itself are subjective due to partial reports of the involved actors and provide an inevitably selective presentation of the events (Brown & Jones, 1998). For instance, Brown & Jones (1998) found that the narratives of project failure is simplifying events (to produce a coherent interpretation) and is attributing causes to elsewhere (to fate or the action of others). Hence, multiple researches have proposed models of interdependency, though all the following discussed researches refrain from conclusive results.

Causality is being proposed by Belassi & Tukel (1996), whereby five exogenous project failure factor categories (factors related to the project manager, the project team members, the project, the organization and the external environment) are expected to influence four endogenous failure factors (client consultation and acceptance, project manager performance, project estimates and availability of resources) that are expected to determine project failure. Poon & Wagner (2001) researched the application of Critical Success Factors (CSF) on project outcome and similarly find that factors related to the project (adequate sponsorship, adequate resources and the link to (strategic) business objectives) are important in causing project failure. Research by Cerpa & Verner (2009) finds that fundamental in the chain of causality are project managerial factors, being unrealistic delivery date, project resource underestimation, inadequate

risk management and overburdening of project staff. Additionally, Lehtinen et al. (2014) found that a lack of cooperation, weak task backlog, and lack of software testing resources were most influential for project failure. Hughes et al. (2016) discussed how driving project failure factors are in the project managerial domain, being executive support and project sponsorship, size and complexity and whether a pilot and initial project evaluation was performed.

Reviewing the above literature for interdependency of project failure factors shows a pattern of initially project managerial failure factors and causes for failure in predominantly the earlier project phases (e.g. definition of objectives, ensuring sufficient resources and sponsorship, application of project management methodology). Research by Ahonen & Savolainen (2010) corroborate the likeliness of serious mistakes before a project has started as sales, negotiations and project start-up processes are full of opportunities for project failure. Hence there is agreement on the existence of interdependency between project failure factors, though there is ambiguity on the origins of the independent (the causing) project failure factors. Reviewing the literature reveals a pattern of predominantly project managerial failure factors that originate in early project phases, which leads to the following proposition.

Proposition 2: Project managerial failure factors in early phases of the project lifecycle have a stronger positive influence on the likeliness for process improvement project failure than project managerial failure factors in later phases of the project lifecycle.

Mitigation strategies for project failure factors

Knowing what project failure factors are likely to disturb project execution is raising the need for project failure mitigation strategies. Research into project failure has identified mechanisms that allow for before-, during- and after- the project failure mitigation.

Before the project failure mitigation strategies: Known preventive factors for project failure are skill gap identification and training programs for project sponsors, -managers, -members and -stakeholders to ensure technical competency (Kilkelly, 2011) and intercultural competency (Kealey et al. 2005). For preventing project failure due to suppliers Chen et al. (2010) propose to use contracts wherein suppliers agree on the costs *and* penalty (calculated based on the probability of failure) when they fail to deliver as promised. Jørgensen (2014) proposes that project failure can be predicted by the failure rate of previous projects by the provider and suggests that increased emphasis on low price and project size increases the risk for failure. Clear and shared understanding of the project scope must be in place through transparent and effective communication in the early stages to reduce the chances for project failure (Gray and Anantatmula, 2009).

During the project failure mitigation strategies: While the project is in execution mode, close monitoring of progress allows for learning at regular intervals or following significant events (Robertson & Williams, 2006). To do so, Dalcher (2003) proposes a five step feedback loop and Matta & Ashkena (2003) propose small projects that quickly deliver mini versions of the bigger project's end result to ensure fast feedback. In a typical improvement project execution stage, a reporting system is designed to meet the needs of the organization (Snee and Hoerl, 2018). Abdul-Rahman et al. (2012) suggest that strategies related to user involvement and project- planning and communication are most influential in preventing failure and Janssen & Klievink (2012) advocate the guiding use of enterprise architecture structures. Research by Vit (2011) suggests that project failure is hard to detect and prevent as different mechanisms such as the rules, cognitive routines and ideological pressures of an institutional environment

can override technical and economic rationality. Chen (2015) proposes that occurring project failure can be detected by monitoring seven performance factors. When project failure is imminent and commitment to project success is failing Keil & Robey (1999) showed that actions to turn troubled projects around are redefinition of the project and its objectives, improvement of the project management methods applied, and a change in project leadership. For project leadership, Jani (2008) found that when project managers believe the failing project is under their control it is unlikely they recommend alternative courses of action other than continuation. Jani (2011) found that project managers are likely to underestimate endogenous (within the project) risk factors and point to a 'self-efficacy' bias, where project managers with a higher self-efficacy underestimate the risks of a troubled project. Additional research by Ivory et al (2005) has proposed implications for management in complex-project failure situations, being multi-nodality (design intervention at differing hierarchical levels), top-down and bottom-up intervention (allow for flexibility of local response to emerging problems) and the requirement for organizational slack (ensure availability of time and resources).

After the project failure mitigation strategies: The element of learning and the execution of retrospectives is named often as after the project failure mitigation strategy (Bierwolf, 2016), such as cognitive- and causal mapping (Robertson & Williams, 2006; Ackermann & Eden, 2005) and decomposition of a project in a complex set of linear and non-linear interactions (Ivory et al. 2005). Learning at the individual, team and organizational levels is essential for the sustainable deployment of process improvements projects (Antony and Gupta, 2018). Sauser et al. (2009) suggest that adopting contingency theory will enhance project failure understanding. The researchers advocate that what works well in one situation may not work in another, and therefore engagement in after the project learning should be characterized by a contingency perspective.

Reviewing the literature on project failure mitigation reveals a predominant focus on learning and adaption, before the project (training) while the project is in execution (feedback mechanisms) or after the project (evaluations and retained learnings) which leads to the following proposition for future research.

Proposition 3: Presence and use of mechanisms that allow for frequent evaluation, learning and adaption negatively influence the likeliness of process improvement project failure.

Conclusions, future research agenda and limitations

Managers and practitioners that are confronted with the task of managing projects may find direction in the typology of project failure factors and the consecutive strategies for project failure mitigation. Certainly many idiosyncratic causes for project failure will exist, however improvement project management is better served when managers and practitioners have a grasp of the known mechanisms underlying project failure.

The review identified predominantly cross-sectional and case study research methods that have yielded a list of project failure factors, mostly in the project managerial sphere of influence. Subsequent research has identified the level of criticality and causality between project failure factors and the project phases where project failure factors start to emerge. Conclusively we see a growing interest in explaining project failure while it is happening and future research methods should focus on better understanding project failure as it unfolds by for instance process study research methods (Langley, 1999).

Contingency factors that are identified in research to date are organizational culture, politics, organizational structure and other external factors such as regulatory requirements and the influence of external parties. Explanation of improvement project

failure through the research lenses of contingency- (Hofer, 1975) or stakeholder theory (Freeman, 1994) is especially valuable for creating a better understanding of effective project leadership behaviours in different organization context where for instance differences in strategy, technology and size are expected to affect improvement project outcome.

Theoretical streams of research can further enhance the understanding of process improvement project failure. The organizational behaviour literature provides insights in the internal dynamics and functioning of project teams (Hackman & Wageman, 2005) and can contribute to a better understanding of project failure. Research that presumes more fundamental management theories such as the resource-based view (Wernerfelt, 1984) or dynamic capabilities (Teece et al., 1997) will be particularly valuable in exploring the interrelatedness of the project organization with the broader organization and how this is affecting improvement project failure (Chandrasekaran et al. 2016). Such research can establish new and different conceptions of project failure beyond the traditional failure factors and develop more refined contingency frameworks.

Additional future research lies in several directions, being the research methodologies applied and the types of improvement projects for which failure factors are being studied. Furthermore, most of the studies that have been conducted on project failure factors have limited cross-cultural perspective and are based mainly on data from the United States and Europe, have focused mainly on the public- or professional services sector or have focused predominantly on IT and IS types of projects.

This systematic literature review has limitations. Discussions and conclusions on project failure research is based upon our sample, which is a product of the research methodology applied and journal databases wherein the search is performed, and is therefore limiting the generalizability of our findings. Also we acknowledge that project failure is a label we have chosen after initial exploratory research. Publications that apply different labels to similar concepts may thereby be missed and not included in our sample.

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Purchasing and Procurement

Antecedents of Purchasing and Supply Management Performance in Project Business Companies

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Abstract
This paper object is to study factors of purchasing and supply management performance in project business. In project business where the usage of external suppliers is extensive, supply chain effectiveness and procurement are one of the key capabilities influencing on the project outcomes. This paper focus on exploring the drivers of purchasing and supply management performance in the project business environment. The paper applies quantitative methodology and survey data. The initial finding of the study is that supplier relationship management (SRM), purchasing policies, and supply chain risk orientation predicts significantly purchasing and supply management performance in the project-based companies.

Keywords: Supply chain, Purchasing performance, Project business

Project Business, Purchasing and Supply Management

A project is a typical form of organizing operations and searching for efficiency in operations. Projects are often considered as dynamic and complex activities within a period of time and unique, one-off settings. Project characteristics include a specific goal, specified resources (people and budget) and clearly defined schedule. The complexity of a project derives from its size, value and the number of personnel involved and things like uniqueness. Furthermore, projects carry inherited risk and uncertainty because of their temporary nature (Baily et al., 2008). Even though project management is widely studied research field, only a few researches has attempted to focus on project business as a research field. Artto and Kujala (2008) have research the topic considering the number of involved firms and projects to compile four distinctive management areas of project business:

(1) management of a project;
(2) management of a project-based firm;
(3) management of a project network; and
(4) management of a business network.

In this study focus is on several firms' contributions to projects as nowadays not all tasks are done within one firm and therefore projects often include many companies. Moreover, project business is a part of business that relates directly or indirectly to projects that involve a firm or several firms (Artto and Wikström, 2005). From this perspective project business in this study is understood in context of the third and fourth management areas; "management of project network" and "management of a business network"

Project business differs from standard manufacturing business drastically as projects are often considered as dynamic and complex activities within a period of time and unique, one-off settings. Furthermore, projects carry inherited risk and uncertainty because of their temporary nature (Baily et al., 2008). Also projects often include many companies as nowadays not all tasks are done within one firm. In this respect it is no wonder that studies have found that purchasing and supply management can have a major impact on the success of project business (Eriksson and Westerberg, 2011). There are, however, several challenges how to perform effective purchasing in projects. The success of the overall project is in many cases highly dependent on the success of purchasing activities and performance of selected suppliers. In large industrial projects parts of the engineering may be done by external parties as well as components and parts that are critical for the end result. At the final phase the installation often is done by the collaborating companies having expertise in these activities.

In the project management literature, purchasing is seen as a one part of the scheduling challenges. It is also suggested that time-critical purchases should be included into the overall schedule and these should be observed strictly. In addition, these factors high monetary value of project purchases makes these purchases strategically important for firms and their supply chains. Consequently, this dependency sets companies vulnerable to supply chain disturbance and risks. It has been explored that the economic consequences of supply chain risks can be vast (Norrman and Jansson, 2004).

Project Purchasing Performance Factors

In several studies, purchasing and supply management had a major impact on the success of the project business (e.g., Ahola et al., 2008; Eriksson and Westerberg, 2011). Furthermore, a transparent purchasing process is critical for the success of a project (Bing et al., 2005). However, an integrated supplier network and close supplier relationships have not yet been widely adopted in project business (Crespin-Mazet and Portier, 2010), and numerous barriers to pursuing effective purchasing in projects have been reported in the previous literature (Akintoye, 2010).

There are, however, several challenges how to perform effective purchasing in projects. The nature and type of the project, for example, the length and location, can be critical factors from the perspective of supply management. The success of the overall project is in many cases highly dependent on the success of purchasing activities. In many projects the whole projects time span from initiation to the end include companies and experts from different areas.

Supplier Relationship

In supply management, several arguments favor integration. Economies of scale and increased efficiency help management establish a global supply view and deepen their knowledge of the supply market. Integration allows the available supply management skills to be used efficiently and knowledge to accumulate internally. Furthermore, integrating supply management is a prerequisite for cost-effective partnering with suppliers, in developing new products with suppliers and in global supply management (Leenders and Blenkhorn, 1988; Faes et al., 2000; Quintens et al., 2006). Moreover, knowledge of the supply markets and a strong power position in negotiations require more coordinated supply actions (Matthyssens and Faes, 1996).

In project business predictability and reliability are found to be the explanatory factors of project performance. According to Cheng and Carillo (2012) research, a supplier partnership can enhance operational efficiencies, but partnership alone does not guarantee an increase in revenue. Moreover, according to Walker and Nogeste (2008) stakeholder influence on project procurement delivery (how well the project met stakeholders needs) clearly indicated the importance and high impact of project stakeholders to project management success. Therefore, standardization of suppliers will lead to better results (Micheli et al., 2008) and experience former work relationships is an element that reduce supplier risks (Veres, 2009). These findings support the relevance of collaborative relationships in improving project business performance by bringing supplier reputation and perceived risk together.

Supplier Collaboration

Another research angle is the project management literature and how it deals with purchasing. In this field, studies and understanding are lacking, as stated by Venkataraman (2004). In the project management literature, supplier and purchasing issues are dealt within the project risk management chapter or ignored almost completely. Although adopting and implementing complete SCM-related strategies is quite prevalent in retail and the manufacturing industries and the benefits are well understood, project-based organizations have lagged in accepting and using such strategies. There is an urgent opportunity to adopt the practices of total supply chain management to reduce inefficiencies, and optimize value (Venkataraman, 2004). In this, procurement department play key role in managing the multifaceted aspects of supplier collaboration. According to Veres (2009), supplier recommendations or good references suggest less risky cooperation. On the other hand, Patrucco et al. (2019) found that attractiveness functions as a key variable to manage buyer–supplier relationship and that customer attractiveness is not only related to innovation performance but also positively affects costs offered by suppliers to buyers due to supplier collaboration and transparency.

Risk Orientation

In the project business environment, different project characteristics moderate between purchasing procedures and project performance. The more challenging the project characteristics (complexity, customization, uncertainty over value/size and time pressure) are, the more the cooperative purchasing procedures improve overall project performance (Eriksson and Westerberg, 2011). Hence, risk management is a significant element of a firm's strategic supply management. Zsidisin (2003) divides the supply risks to the sources of risks and to the outcomes following the risk incidents. Decisions regarding the sources of risks and their outcomes are highly critical in nature and, thus, risk management should be considered

as a significant element of strategic supply management. As Smeltzer and Siferd (1998) state, substantial risks are more likely to occur when purchasing is not included in the strategic planning process.

These studies have shown that purchasing and supply risk management has a major impact on the success of the project. Furthermore, an integrated supplier network and close supplier relationships have not been widely adopted in project business. However, studies examining the main barriers to and challenges of purchasing in the project business environment could not be found. Hence, Clearly, a research gap exists.

Project risks are associated with different project characteristics: therefore, project purchasing can on the one hand cause huge problems to projects and on the other hand be a major source of business success to a company. According to (Shishodia et al. 2018) projects comprise of "numerous geographically dispersed but interdependent activities, suppliers, and stakeholders that are exposed to different types and degrees of risks." Therefore, proper supply chain risk identification can help to identify non-fit projects and increase proactiveness to overcome foreseen difficulties. Also, an increased understanding of the key supply chain risks will lead to the formulation of more realistic plans and expectations (Rudolf and Spinler, 2018). Risk management is therefore major area for investigating supply management performance. Managing procurement risk not only need to mitigate the risk of price and lead time, but also need to have sophisticated analysis to realize the correlation between supply risk and profit impact – and by that, to decide the appropriate procurement strategy (Hong et al., 2018)

Sustainability and Code of Conduct

Sustainability aspects have had growing importance in the supply chain risk management. Sustainability practices have an important role in managing non-compliance and economic and reputational damage (Hofmann et al., 2014). Companies that are aware of sustainability -related risks will often use codes of conducts with their suppliers (Hoejmose and Adrien-Kirby, 2012) for managing supplier relationships and in ensuring the sustainability of suppliers. Code of conducts include the utilization of different certificates and standards for environmental management or securing the social responsibility (Marshall et al., 2015). Furthermore, code of conducts reflects the values a company applies to its business and expects its suppliers to follow these values and requirements. Supplier code of conducts are especially needed in project business where supplier relationships are typically discontinuous and relationships can be in inactive phases that can often last several years.

Purchasing policies

It is stated that the purchasing strategy selected in projects affects value creation. Short-term value elements have product focus and a competitive tendering basis whereas long-term value elements in projects focus on relationships with customers and suppliers and innovations (Ahola et al., 2008). In the project business environment, various project characteristics moderate purchasing procedures and project performance. The more challenging the project characteristics (complexity, customization, uncertainty value/size, time pressure) are, the more cooperative purchasing procedures improve overall project performance (Eriksson and Westerberg, 2011).

Because projects are unique, one-off settings and carry inherited risk and uncertainty because of their temporary nature (Baily et al., 2008) decentralized purchasing in projects

and competitive tendering is the prevailing practice in buying companies. Thus, the firms' motive of buying determines which purchasing strategy it uses (Svahn and Westerlund, 2009).

Research Approach

A survey was conducted to collect data from companies engaged in project business in Finland. The main industries included were machinery and mechanical engineering, marine and MRO industry, and construction and civil engineering. A total of 99 responses were received yielding a satisfactory response rate of 37% per cent (99/265). The collected data were analyzed with quantitative methods. The results showed that the level of supply strategy and capability increase risk management in firms. Furthermore, it can be concluded that from the total cost elements - the cost before purchasing and after it - are related with risk management whereas actual purchasing costs such as price, transportation and ordering do not impact on risk management. In addition, it is found that the project length influences risk management. The survey instrument items are presented in Appendix 1. The main latent constructs include Purchasing Policies, Risk Management orientation, Supplier relationship management (SRM) and Purchasing Performance. The Likert scale (1-7) was used for assessment of the survey items.

Survey instrument

We validated the survey measurement model by measurement reliability, validity of the factor structure, and discriminant validity (Henseler et al., 2009). Construct reliability (CR) and the average variance extracted (AVE) were used to assess the measurement reliabilities of latent construct by average variance extracted (AVE) (Fornell and Larcker, 1981). The measurement reliabilities are illustrated in Table 1, which shows that all of the latent variables had decent reliabilities for further modeling and analysis. According to Kline (2011), the CR coefficient should exceed .50 to indicate acceptable if the model validity otherwise is good. The CRs of the latent constructs were varying between 0.87 and 0.93 indicating acceptable level, we analyzed the measurement model (factor structure) by significance of factor loadings, reliability, and validity. We also assessed the cross loadings between latent factors.

All loadings in the measurement model were above 0.4, which can be regarded as acceptable (Hair et al. (2016). AVE convergent validity values were greater than 0.50 for all measured latent factors implying acceptable construct validity (Fornell and Larcker, 1981). Furthermore, we used the square root of AVE (i.e., Fornel-Larcker criterion) (Henseler et al., 2015) for evaluating the heterotrait-monotrait ratio of correlations (HTMT) of the measurement model. According to criteria (Henseler et al., 2009) if the HTMT value is below 0.90, discriminant validity has been established between two reflective constructs. There are no correlations higher than 0.5 manifesting in a good discriminant validity of the measurement model.

Table 1 - Measurement reliabilities and descriptive statistics

	Loading	t-value	p-value	Mean	SD	AVE	CR
Purchasing Policies						**0.659**	**0.931**
Policy1	0.796	12.960	****	2.257	1.535		
Policy2	0.959	74.322	****	2.791	1.607		
Policy3	0.947	55.928	****	2.788	1.562		
Policy4							
Policy5							
Policy6							
Policy7							
Risk Management orientation						**0.556**	**0.860**
RiskMgmt1	0.836	17.573	****	1.963	1.404		
RiskMgmt2	0.878	21.559	****	2.043	1.518		
RiskMgmt3	0.949	50.326	****	1.973	1.437		
RiskMgmt4	0.931	50.940	****	2.122	1.497		
RiskMgmt5							
Supplier Relationship Management SRM						**0.619**	**0.889**
SRM1	0.861	18.971	****	2.851	1.630		
SRM2	0.844	14.333	****	2.906	1.669		
SRM3	0.862	16.828	****	2.464	1.739		
SRM4	0.826	15.925	****	2.448	1.684		
SRM5							
Purchasing performance (SCPerform)						**0.521**	**0.907**
PurchPerform1	0.766	16.506	****	3.241	0.938		
PurchPerform2	0.671	9.590	****	3.323	0.908		
PurchPerform3	0.790	21.548	****	3.325	1.128		
PurchPerform4	0.803	19.051	****	3.128	0.868		
PurchPerform5	0.830	16.939	****	3.248	0.978		
PurchPerform6	0.839	20.131	****	3.223	0.862		
PurchPerform7							
PurchPerform8							
PurchPerform9	0.760	13.008	****	3.285	0.849		
Indirect Latent Constructs:							
Code of Conduct in Purchasing						**0.615**	**0.828**
Risk Mgmt Tools						**0.689**	**0.816**
Supplier Collaboration						**0.611**	**0.916**

n) Not significant, *) Statistically significant at $p < 0.1$, **) Statistically significant at $p < 0.05$, ***) Statistically significant at $p < 0.01$, ****) Statistically significant at $p < 0.001$

Analysis of paths in the Research Model

We analyzed the main effects in the model based on the hypotheses 1–3. In the analysis, the bootstrap the resampling of the data was repeated 5000 times (basic bootstrapping) in the analysis, which is adequate for estimating the parameters in the model (Henseler et al., 2009; Kline, 2011). We tested and validated the quality of the structural model through the explanatory power and path significances.

The r-squared for the latent variables in the path model were “Purchasing Performance” = 0.55, “Purchasing Policies” = 0.39, “Risk Management Orientations” 0.57, and Supplier Relationship Management “SRM” = 0.21. Overall, it can be stated that the explanatory power

of the model is satisfactory, regardless of the relatively low sample. The model is relatively capable of predicting purchasing performance in the studied environment.

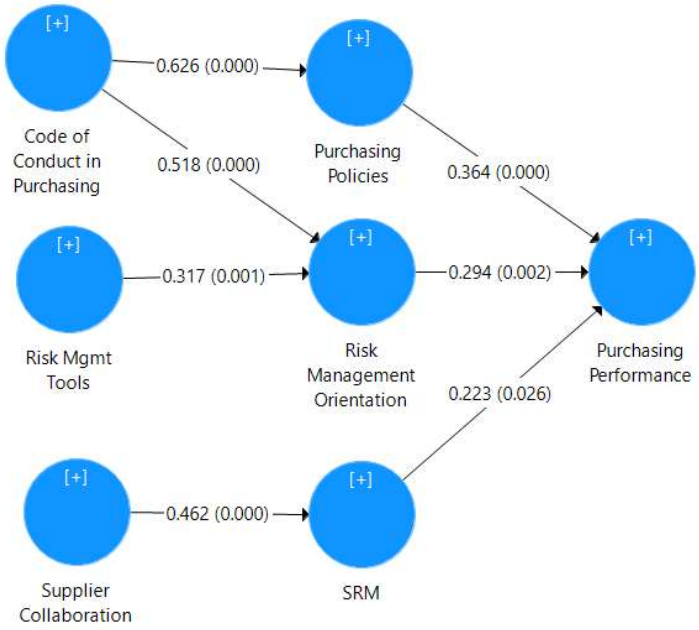

Figure 1 - The structural model to test the main paths and hypothesis (Coefficient and p-values).

The tested path model (see Fig. 1) shows that all of the latent constructs "Purchasing Policies" and "Risk Management Orientations" 0.57, and Supplier Relationship Management "SRM" had a strong direct influence on the "Purchasing Performance". There were also interesting indirect paths that are regarded significant. According to analysis "Code of Conduct" influence significantly on both "Purchasing Policies" and "Risk Management Orientation". Furthermore, "Risk Management Tools" influence significantly on "Risk Management Orientation". Thus both "Purchasing Policies" and "Risk Management Orientation" mediating role in the research model between variables. Finally, our model indicates significant relationship between "Supplier Collaboration" and "SRM" and indicates positive mediating role between "supplier Collaboration" and "Purchasing Performance".

Research Findings

The results of the empirical survey study conducted in the project-based industries in Finland indicated the factors that explain the purchasing performance in the project business. Based on the finding of the empirical study, Supplier Relationship Management (SRM), purchasing policies, and supply chain risk orientation predicts significantly to the purchasing and supply management performance in the project-based companies. It is surprising how purchasing tools and code of conduct (sustainability) have no straight impact on purchasing performance in project business context. However, this finding is in line with the literature; uniqueness and complexity of a project requires more relationship and previous experience from suppliers (SRM) and different approach in purchasing and supply management. Supplier Relationship Management itself might work as a risk management method but as the results

indicates, risk management objective is evident in procurement performance. Project business literature also supports risk management high agenda in project management and project performance. Collaboration with suppliers did not showed direct influence on the purchasing performance, however, the study showed partial evidence that SRM meditates the relationship between supplier collaboration and purchasing performance.

Conclusion

From the perspective of purchasing and supply management, project environment creates various challenges that should be understood better. The aim of the empirical study is to explore the factors affecting to the supply management performance in the project-oriented companies. Firstly, the aim is to investigate the supply management characteristics in the project business. Secondly, the objective is to study the relationship between supply management practices and organization on the purchasing and supply management performance. In this paper we highlighted the challenges of purchasing in project business context, contemporary issues.

Our study provided some interesting findings related to purchasing performance in a project environment. Supplier Relationship Management (SRM), purchasing policies, and supply chain risk orientation predicts significantly to the purchasing and supply management performance in the project-based companies were found to have high impact on projects' outcome. Overall, the research findings correspond with the literature review. Projects uniqueness, dynamic and complex activities sets challenges to procurement. Procurement should at the same time mitigate risks by exploiting well known and well performing supply base but still try to search for better cost from novel suppliers (transactions) at the same time. Taking this into consideration, procurement should involve several external resources such as suppliers and subcontractors to ensure performance and expected project outcome. Hence, procurement in projects reminds more management of a business network rather than transactional buying adopting risk management procedures. The research results suggest that procurement performance in project business is a field to pay attention to.

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APPENDIX 1– Survey Instrument

Purchasing Policies – Policy (1-7 scale) Corporate policies related to purchasing activities are well established and documented Corporate policies give guidance and direction to purchasing activities A comprehensive purchasing ethics policy exists and is widely communicated Supply management practices conform to corporate policies The purchasing process is well documented Written procedures cover purchasing documents such as forms, orders, and legal contracts Written procedures also exist for MRO, emergency and extraordinary purchases
Risk Management Orientation – RiskMgmt (1-7 scale) *How much do you pay attention to the following risks in your business?* Country risk (politics, economy, social stability) Financial risk (loans, collateral, investors, interest rates, currency fluctuations) Delivery risk (because of the supplier) Business relationship risk (contract violation, knowledge leak, negotiation power) Risk related to a third party (transport, sub-contracting) Risk related to corporate social responsibility (CSR, social, ecological and economic responsibility)
Supplier Relationship Management SRM – SRM (1-7 scale) *Evaluate how well supplier relationship management is conducted in your company* Daily routines and operations with suppliers are well performed The supply chain is managed holistically Building of trust-based relationships is the goal Suppliers are treated ethically and all contracts are legal Information is readily shared and communication is open between the supplier and buyer
Purchasing Perormance - PurchPerform (1-7 scale) *Please evaluate how well the following statements describe the performance of supply management in your company.* The products the supply management has purchased meet well the given requirements/specifications The products the supply management has purchased arrive/are produced in time as agreed Supply management does not exceed the given target costs Supply management does not exceed the given inventory level targets Internal customers are satisfied how their problems are dealt with in supply management The contracts negotiated by the supply management meets well the different needs Supply management delivers relevant information to its interest groups Supply management delivers high quality products and services

An empirical investigation of the drawbacks of SME-friendly public procurement policies: The UK experience

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Abstract

The paper explores the potential weaknesses and limitations of key policy measures implemented to support SMEs in public procurement in the UK. We conducted semi-structured interviews with a sample of SME owners/managers competing for public contracts within North West NHS Trusts in England and evaluated the data through qualitative thematic analysis. The five key themes that emerged from the data through the process of inductive coding are: 1) implementation and compliance issues, 2) experiential barriers, 3) participation is not a given, 4) unattractiveness, and 5) inability to maximise policy benefits. This paper contributes to the emergent SME-public procurement nexus discourse.

Keywords: SMEs, public sector, procurement.

Introduction

An important aspect of UK government policy is to increase SMEs participation in public procurement. The government previously set a target of 25% of public sector procurement spending to reach SMEs by 2015 (Department for Business Innovation and Skills, 2013). Several policy measures are being implemented across public organisations to achieve this target; the most notable ones are the rule that requires public organisations to eliminate Pre-Qualification Questionnaire (PQQ) for small value contracts, the prompt payment rule, division of contracts into lots, establishment of contracts finder, acceptance of consortium bidding and promoting of subcontracting opportunities. Despite the growing adoption of these policy measures (Loader, 2018), the latest available data shows that SMEs are still under-represented in public procurement markets.

For example, data published by the UK government (Cabinet Office, 2017; Cabinet Office, 2018) show that public sector spending with SMEs fell to 24% in 2015/16 and 22.5% in 2016/17, respectively. If this trend persists, the government is off-track to reach its latest plan of directing 33% of public procurement spending to SMEs by the end of 2022 (Home Office, 2018). Therefore, key policy measures being applied to promote SME participation in public procurement should be reviewed to ensure that they remain relevant and effective. Research conducted by Loader and Norton (2015) in the UK's

Heritage sector, revealed that SMEs would prefer to deal directly with the procuring authorities rather than acting as subcontractors to larger firms or forming consortia to boost their tendering capabilities. However, the authors did not provide much detail about the reasons for this preference.

To address this gap, we examined issues that SMEs face regarding key policies implemented in public organisations in the UK. First, we conducted a review of relevant literature to identify studies on measures designed to help SMEs improve in public procurement in the UK. These included relevant articles published in academic journals, policy notes, consultation papers, guidance documents, press releases and other government publications. Six most frequently cited measures identified in the literature were examined through empirical data collected from SMEs supplying NHS trusts in North West England. The findings include five key themes derived through qualitative analysis of empirical data. We provide a discussion of the findings and highlight the implications for theory, practice and policy.

SMEs participation in public procurement in the UK

The political push for making public contracts more accessible to SMEs stemmed from the adverse effects of the 2008 global economic recession (Flynn et al, 2013). The recession restricted access to finance for small businesses, leading to decline in cash flow and subsequent negative effects on sales and profit margins (Prince et al, 2013). Since then, increase SME access to public procurement has been a key commitment of the UK government. Consequently, a major consideration for policy makers and experts has been to leverage the public procurement spending for promoting growth in the small business sector.

In a comprehensive review of current evidence, Loader (2013) discovered low involvement of SMEs in public tendering in the UK over a twenty-year period . The author also found that there has been no significant improvement in the success of SMEs winning public sector contracts. Although it can be argued that Loader's finding is no longer current, there is paucity of evidence to prove that the situation has improved significantly since then. Results of another study conducted around the same year by Federation of Small Businesses (FSB) provide a clearer picture, concluding that 78% of SMEs had not bid or worked on public sector contracts (FSB, 2013). The FSB is the biggest pressure group influencing government policy in the interest of small business owners in the UK. It has a panel membership of 6,394, all of whom were invited to participate in the survey.

Similar findings emerge in a more recent report by Minority Supplier Development UK (MSDUK), demonstrating that SME participation in public procurement in the UK is amongst the lowest in Europe (MSDUK, 2014). Researchers (e.g. Loader and Norton, 2015; McKevitt and Davis, 2015) have linked the low participation of SMEs in public procurement to several barriers. Various policy measures have been adopted to address these barriers, which we shall discuss in subsequent sections of this paper. Yet, there is not enough evidence to suggest that efforts to help more SMEs bid for public sector contracts is yielding the expected outcomes. Government spending with SMEs fell from 27% to 22.5% between 2015 and 2017 (Cabinet Office, 2018).

Barriers facing SMEs in public procurement in the UK.

An early attempt to consider the challenges faced by SMEs competing for public sector contracts in the UK was by Glover's (2008) committee review. A key finding of this review was that SMEs do not have access to information on available public contract opportunities in the UK. This is because individual public organisations used to advertise

contract opportunities on their own websites, which might necessitate SMEs to use their limited time and resources in searching for tenders on various web-portals. Since then, there has been increasing interest by researchers to understand the barriers facing SMEs in public procurement. We have summarised some of these in Table 1.

Table 1- Key barriers facing UK SMEs in public procurement

SMEs key challenges in public procurement	Sample literature
• Transparency issues: lack of access to information about existing contract opportunities	Glover (2008)
• Lack of, or insufficient skills to develop winning bids: e.g. legal, administrative, customer services, IT skills	Karjalainen and Kemppainen (2008),
• The size of available contract opportunities: contract value is sometimes unattractive, contract duration is short, and the sizes are too large, discouraging SMEs from participation	Freshminds, 2008), Loader (2011)
• Overly prescriptive requirements: technical requirements are too high, and the specification is inflexible	Yukiko (2014),
• The procurement process is cumbersome: tendering process is time consuming; involving too much paperwork and unrealistic tender timescales	Loader (2011), Pickernell et al (2011),
• Pro-large-business culture of public buyers: preference for incumbent suppliers, rationalisation of supply base and emphasis on cost savings	Loader (2013)
• Slow payment: delays in payments to contractors and sub-contractors	Loader (2015)

The UK government has designed several policy measures to tackle these barriers. We have identified six notable measures that are being implemented in public organisations including the NHS, to help support SMEs in public procurement. These are included in UK public procurement regulations, consistent with European Code of Best Practices Facilitating Access by SMEs to Public Procurement Contracts, and Public Contracts Directive, 2014/24/EU. In Table 2, an attempt will be made to summarise these key measures along with the barriers around SME participation in public procurement which they seek to mitigate.

Table 2- Liking policy measures to barriers facing SMEs in public procurement in the UK

Key Policy Measures	Summary of attributes of the policy measure	Barriers being addressed
1. Elimination of PQQ for smaller contracts	Designed to: • Reduce unnecessary qualification requirements by ensuring that selection criteria are proportionate to the contract value. • Make the procurement process less time-consuming, by	• SMEs have complained about the volume of paper work/ documents that should be completed by firms seeking public contracts (Glover, 2008). • As part of the pre-qualification process, pubic buyers require proofs of

	reducing the administrative burden placed on bidders • Make the supplier eligibility criteria less difficult to meet, • Allow bidders to self-certify their ability to meet the required selection criteria (e.g. financial and insurance requirements).	financial capacity that are disproportionate to the value/size of the contract opportunities (Pickernell et al, 2011).
2. Prompt payment rule	Designed to: • Alleviate the impact of prolonged delay in payment under public procurement contracts (Nicholas and Fruhmann, 2014). • Impact on the cash flow of contractors and help subcontractors to be financially healthy (Rostek, 2015). • To inspire existing/potential contractors to be on the lookout for new contract opportunities (National Audit Office, 2015).	• SMEs are discouraged from participating in public tendering because they perceived that public sector organisations delay payments to their contractors (Preuss and Walker, 2011). • There is a widespread concern about delay in payments to contractors and sub-contractors (Loader, 2013).
3. Consortium bidding	Designed: • To enable SMEs improve technical capability and increase resource through collaboration • To allow two or more SMEs to pool knowledge together or combine unique expertise to submit high quality bids (EU, 2009). • Drive skills transfer among firms forming a consortium to deliver contracts (Palacios-Marqués et al, 2015) • Reduce geographical immobility of contractors for delivering (Competition & Consumer Protection Commission, 2014).	• Bidders with little /no experience of public tendering are also expected to demonstrate tract record of performance in similar contracts (Loader, 2013). • Lack of ability to meet the resource and capability requirements to participate in public tendering (Loader, 2013) • SMEs performance in public tendering is impeded by lack of resources namely legal, customer services, IT skills marketing, administrative and human capital resources (e.g. Karjalainen and Kemppainen, 2008).
4. Contracts finder	Designed to: • Make contract opportunities more • Enable prospective bidders to keep an eye on forthcoming tender opportunities	• Lack of awareness of opportunities and insufficient communication with the public procurement officers (GHK, 2010).

	• Reduce the time and stress that SME go through to search for information on existing tender opportunities • Increase transparency of sub-contracting opportunities • Simplify the procurement process Sources: (Department for Business Innovation and Skills, 2013)	• Perceived lack of transparency in the public procurement process (Glover, 2008). • SMEs often do not know where to get information about the existing tenders and instructions on the processes involved.
5. Division of contracts into lots	Designed to: • Reduce the large size of contracts, which often create difficulties for small suppliers (Loader, 2013). • Enable SMEs to compete on the same level with larger companies (Glover, 2008), • Enable SMEs to target opportunities corresponding more closely to their specialisation (Perry, 2011). • Increase ability to bid for more than one contract within a single procurement exercise.	• Major concerns for UK SMEs are relating to large sizes of contracts (Glover, 2008; Loader and Norton, 2015). • The technical requirements for tenders are too high • There is a pro-large business culture amongst public buyers (Loader, 2013).
6. Sub-contracting	Designed to: • Be a less difficult route for SMEs to participate in public procurement markets (Department of Enterprise, Trade & Employment, 2009). • Facilitate skills transfer from large prime contractors to SME sub-contractors (Carayannis and Sipp, 2005).	• UK SMEs are discouraged from the large sizes of public tenders (Glover, 2008; Loader and Norton, 2015). • The technical requirements for tenders are too high • There is a pro-large business culture amongst public buyers (Loader, 2013).

Research Methodology

The purpose of this research is to examine the opinions of SMEs supplying NHS organisations in the North West of England, regarding key policy measures implemented to improve their participation in public procurement. The analysis unveils issues and concerns that should be addressed to improve effectiveness of policies designed by the UK government to support SMEs bidding for and winning public contracts. A qualitative research approach has been adopted to help us unearth SMEs' experiences and thoughts about these policy measures.

We conducted semi-structured interviews with 25 SMEs, located in the North West region of England, who act as suppliers to different NHS trusts and have some knowledge of public procurement policies for small businesses in the UK. The North West is the 3rd biggest of the 9 regions, accounting for 13.7% of the total annual healthcare spending in England (Full Fact, 2018) and was selected because the authors can gain

access to NHS trusts in this region and obtain information about SME suppliers that can be recruited as participants in this study. Using existing contacts with relevant NHS trusts, we selected the sample firms from their database of suppliers.

Data collection

In depth interviews were conducted with the manager or owner of each firm to obtain data. These were structured to determine experiences of tendering for contracts within the NHS, and issues of concerns about the supporting policy measures. We began the interviews by asking participants to share their stories of how they started their business and came to be a supplier to the NHS. This allowed them to elicit their experiences willingly in an informal setting, following the narrative conversational style recommended by Edwards and Holland (2013). Although the questions were structured to maintain focus, the interview process was flexible (Silverman, 2010), enabling better conversation about different policy measures to support SMEs in procurement. Not only does this approach allow participants to show knowledge of these policies, it enables them to express opinions and develop arguments about the benefits and drawbacks of implementation.

All interviews were conducted face-to-face on the premises of each firm so that participants can feel more comfortable to express their experiences and opinions. The interviews were jointly conducted and recorded by the first two authors after obtaining the interviewees consent. The third author took notes to capture important information during the interviews and transcribed the recorded interviews with the support of the first author.

Data analysis

Transcripts from qualitative interviews were analysed using thematic analysis (Miles, Huberman and Saldana, 2013), to help us make sense of the data. We conducted inductive coding of textual data to identify, categorise and discuss themes that represent the drawbacks and limitations associated with six policy measures designed to support SMEs in public procurement in the UK, namely 1. Elimination of PQQ for smaller contracts, 2. Prompt payment rule, 3. Consortium bidding, 4. Contracts finder, 5. Division of contracts into lots, and 6. Sub-contracting. After each author finalised their coding, the themes were compared, any inconsistencies that occurred were debated and resolved. Themes were then adjusted where necessary before full analysis. This process has two advantages; first, it enabled us to guarantee inter-coder reliability and validity given the extent of agreement between the different coders (Weber, 1990). Secondly, it enhances the extent to which the final coding results represents what we intend to measure. The findings of our analysis are presented and discussed in subsequent sections of this paper.

Participant firms' characteristics

To gather the relevant data and determine representativeness, firms in the sample were required to have experience of competing for contract opportunities in the NHS and have not more than 250 employees. Hence, all firms that participated in this study can be classed as SMEs based on employee numbers, in accordance with the UK government's definition of SMEs (Wand, 2014). In addition, we identified the varied characteristics of the sampled firms before presenting the findings, by distinguishing them according to size: namely micro-sized (with less than 9 employees), small-sized (less than 50 employees) and medium-sized (having not more than 250 employees). Apart from the number of employees and firm size, the locations and industry sectors attest to the

diversity of the firms. Although we do not include these firm characteristics in our data analysis, in line with the qualitative nature of the study, they suggest the possibility to examine SMEs' different experiences of the various policy measures to help them improve participation in public procurement.

Results

Five key themes emerged from our qualitative data to represent the limitations of policy measures designed to support SMEs in public procurement in the UK. These are discussed below under the following subheadings; implementation and compliance issues, experiential barriers, participation is not a given, unattractiveness, and inability to take full advantage of the policies.

Implementation and compliance issues

Lack of implementation and non-compliance are the most common issues raised by participants about all the policy measures examined in this study. This was most likely caused by the lack of penalties or consequence for non-compliance, the negative attitude of public buyers towards small suppliers and a desire for cost savings in procurement process, which may not materialise through buying from small firms. For example, some (15) participants reported that tender specifications are still frequently skewed in favour of large firms, irrespective of whether the tender is divided into lots or not. Our findings support previous research that policy actions to support SMEs in public procurement remain "more rhetoric than reality" (e.g. Flynn and Davis, 2015).

Experiential barriers

The fact that NHS organisations seek suppliers with a proven track record of success in contract delivery was another important concern expressed by participants in this study and identified as a major drawback of SME-friendly procurement measures. This suggests that despite the supporting policies that are being implemented, firms without public tendering experience are still not likely to compete effectively against large firms who have dominated the public sector market (Loader, 2013). We argue that this is a key issue that cannot be ignored because it can potentially discourage start-ups or new SMEs from seeking public contracts. If bidders are always required to have previous experience of supplying the public sector to qualify as contractors, it is nearly impossible for young SMEs (or start-ups) to win contracts.

Participation is not a given

The idea that key policy measures do not guarantee participation and success in public tenders was another issue raised by our respondents. For example, there were concerns that dividing contracts into small lots does not preclude competition between small and large firms. Irrespective of size, all firms are required to contend against each other in the tendering process. This suggests that efforts to open the public procurement market to competition (Thai, 2006), could have a negative impact on effectiveness of SME-friendly policy measures. This finding supports the initial argument by Andrecka and Trybus (2017) that public procurement reforms, particularly in EU countries like the UK, cannot be regarded as actions favouring the small business sector.

Unattractiveness

Evidence from this study reveals that participants have apparent lack of interest in subcontracting. The finding is consistent with previous research (e.g. Loader and Norton, 2015) that SMEs supplying the UK's heritage sector would prefer to contract directly

with public organisations rather than via the Subcontracting route. Our results, however shed more light on this by identifying the probable reasons for this disinclination for taking part in subcontracting opportunities. These include unfair treatment by prime contractors, risk of losing intellectual property and lack of transparency in the selection process.

Inability to take full advantage of the policies
The underutilisation of policy benefits was identified as another factor limiting the efficiency of the policy measures. This point was raised in relation to Consortium Bidding, Prompt Payment Policy and The Contracts Finder. Some participants expressed a lack of understanding of how to form a consortium when bidding for contracts. The problem of identifying which firm to collaborate with when bidding for a public contract was also mentioned. Furthermore, most NHS trusts use electronic invoicing solutions to pay suppliers, which may pose challenges to some SMEs who have limited ICT capability. A similar issue was raised about the online portal used for contracts advertisement (i.e. Contracts Finder).

Discussion
We examine the potential drawbacks and limitations of policy measures being implemented to facilitate SMEs participation in public procurement in the UK, from the experiences of firms supplying NHS trusts in North West England. Our findings reveal some factors which might explain why UK government policies have not been yielding the expected results in terms of increasing SMEs share in public sector spending. First, the findings suggest that government should increase efforts to bridge policy–practice gaps by introducing stricter penalties for noncompliance and incentives to increase enthusiasm for SME suppliers to the public sector. Secondly, SMEs as potential beneficiaries need to develop the necessary capabilities to maximize policy benefits, e.g. by leveraging social media for networking to share information, knowledge and experiences about public tendering, as well as explore potential partners for consortium bidding opportunities. The evidence generated from this study offers new insights into factors that can potentially affect the effectiveness of SME-friendly procurement policies in the UK.

Contribution to knowledge
Previous research (e.g. Kidalov and Snider, 2011) have claimed that government policies and actions for promoting SME participation in public procurement are ineffective and their implementation is more "rhetoric" than reality (Flynn and Davis, 2015). However, many of these studies did not attempt to explain the reasons for this. The paper contributes to knowledge in this area by highlighting key issues that need further attention, to translate government policy intentions around SME participation in public procurement into expected outcomes.

Implications for research
Researchers can build on the findings in this paper to formulate hypothesis to test different ways in which government policies might be modified or changed to demonstrate better outcomes for SMEs in public procurement markets.

Implications for practice
The findings can guide policy makers and public procurement managers in identifying where modifications and improvements of existing policy measures are needed for promoting SME participation in public procurement.

Limitations
Our findings are based on a qualitative study conducted in one of the nine regions of England, which limits its generalisability. Notwithstanding, the evidence gathered from the experiences of SMEs supplying NHS trusts in North West England provide insights into areas of focus for translating policy to reality, particularly about SMEs participation in public procurement.

Conclusion
The overall conclusion from the study is that while SME-friendly procurement policies of the UK government seem good in principle, it is not a given that implementation will yield expected results. This is because there are several limitations which can make the policies inadequate and ineffective.

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The Role of Trust in Brand Representative in B2B Procurement Process.

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Abstract

Buyer-supplier relationship performance is significant in industrial markets. While the extant literature points to the importance of interpersonal trust mechanism for a long-term buyer-supplier relationship, we propose that more informed supplier 'brand representatives', rather than traditional sales representatives, can improve the quality of information that is transferred between suppliers and buyers. We conducted in-depth interviews and collected survey data from procurement managers in Australia. We found that suppliers' brand representatives significantly and positively influence buyer's trust through their communication of both functional and emotional roots of trust.

Keywords: Interpersonal Trust, Buyer-Supplier Relationship, Risk Reduction

Introduction and Literature Review

The development and maintenance of trusting relationships between buyers and suppliers plays a critical role in in enhancing the competitiveness and efficiency of manufacturing processes. The decision-making process for procurement personnel – understanding suppliers' products and services and supplier selection – involves a significant amount of uncertainty (Devaraj et al., 2012, Riedl et al., 2013). Because of the asymmetric nature of information and new transactions, developing trust reliably, can be difficult (Zhang et al., 2011, Zaheer et al., 1998). One way in which suppliers can more credibly and efficiently communicate the nature of their business, and reduce buyers' procurement risk, is through supplier's brand (Leek and Christodoulides, 2011).

We propose that more informed supplier 'brand representatives', rather than traditional sales representatives, can improve the quality of information that is transferred between suppliers and buyers. We also propose that trust in supplier brand representative has both functional and emotional roots. Brand representatives can transfer information that goes beyond basic product details, and which more effectively informs whether trust will

develop in the relationship. This in turn reduces overall risk for buyers, thus improving the efficiency of the procurement process.

Method

Given the limited empirical work on the role of brand representatives in B2B markets, exploratory research was undertaken. Scholars recommend a qualitative research phase where extant research may be inadequate (Venkatesh et al., 2013). Nine in-depth interviews were conducted with procurement managers from a variety of manufacturing organizations including foot ware, chemical, automotive, and steel amongst others. This was followed by administering a survey collecting data from Australian senior managers responsible for purchasing or recommending products to their organizations.

Measurement items for trust in brand representative and its antecedents were generated using existing scales and based on the interview phase by following procedures recommended for operationalization and measure development (Churchill, 1979, DeVellis, 2012). A total of 204 completed questionnaires were collected.

Result and Discussion

Results confirmed hypotheses developed and pointed to the importance of proposed relationships. Consistent with the extant literature (Dowell et al., 2015, Homburg et al., 2011), our findings suggest that trust in a supplier's brand representative has both functional and emotional roots. The positive direct relationships that emerged between these factors and trust in brand representative were substantiated. Further, trust in brand representative was found to reduce buyers' risk, thereby enhancing relationship loyalty, which is consistent with similar findings (Nicolaou et al., 2013).

The extant literature has underscored the complexity of the concept of trust and the shortcomings of its operationalization (Seppänen et al., 2007). In line with research advocating the multi-dimensionality of trust (e.g. Butler, 1991, Singh and Sirdeshmukh, 2000), our findings contribute to theory by providing empirical evidence that trust in brand representatives has both functional and emotional roots. This study further demonstrated the critical role of brand representatives in directly and indirectly influencing trust development between buyers and suppliers during the procurement process, reducing risk and enhancing relationship loyalty.

Our study suggests several managerial implications. *First,* as B2B brands continue to grow in importance, managers should be aware of the strategic role brand representatives can play in articulating a brand promise during the procurement process. Our findings support prior propositions regarding the importance of human representatives in B2B markets when engaging with customers (Lynch and de Chernatony, 2007). *Second,* our findings show that brand representatives play a central role in improving buyers' understanding of suppliers.

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What is the right purchasing portfolio model for your purchase?

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Abstract
Purchasing portfolio models (PPM) are the number one tool for purchasers and various versions exist that help to increase the effectiveness of the function. Yet, PPMs are also criticized for being too simplistic. This study aims to provide a more differentiated approach to PPMs by considering the objective of a purchase. Employing mixed methods drawing on scenario-based survey data and 29 interviews (41 cases) this research explains how for a given objective different PPMs might be suitable. In doings so, we not only add important insights to PPM theory, but also help practice to increase the usefulness of portfolios.

Keywords: Purchasing Portfolio Models, Objectives, Mixed Methods

Introduction
Purchases cannot be managed uniformly (Ateş et al., 2015) due to a diverse set of strategies and tactics that may apply for various purchases (Hesping and Schiele, 2016). Purchasing portfolio models (PPMs) are the number one tool for purchasers to differentiate purchasing approaches due to their simplicity and flexibility (Montgomery et al., 2018). By segmenting purchases into prototypical sourcing categories PPMs allow to derive suggestions on how to manage a purchase in the most suitable way. However, applying strategies in practice is frequently not that simple as there is often more to consider in categorizing purchases than a single PPM can offer (Hesping and Schiele, 2016). As such, identifying further differentiation possibilities drawing on PPMs could help to progress the field of purchasing.

One fruitful avenue for differentiation is the objective of a purchase (i.e. the envisioned accomplishment) such as cost savings, delivery performance, innovation or quality improvements (e.g., Lee and Drake, 2010). Previous research considering the purchasing objective shows that purchases can be clustered based on the importance of a purchasing objective (Luzzini et al., 2012) or that the objective affects the structure of the supply base (Ateş et al., 2015). Furthermore, Pagell et al. (2010) observe that purchases focused on sustainability do not follow the proposed approach of the original Kraljic PPM. A question that arises is: why use a PPM as a starting point in categorizing purchases (as suggested by e.g., Olsen and Ellram (1997)) rather than considering other aspects (e.g., the objective) up front? To advance the ways purchasing can add value to an organization we ask: *to what extent and how does the objective of a purchase influence the choice of the most suitable PPM?*

While PPMs are not a theory in itself, they have the key component of a theory as they help to allocate limited resource in the proper manner to increase performance (Pagell et al., 2010). As such, by addressing the above research question we not only contribute important practical, but also valuable theoretical insights. In particular, drawing on mixed method data, we address the lack of a sound theoretical background, a proper framework, and usable metrics regarding PPMs (Luzzini et al., 2012). In doing so, we contribute important new insights to the field of purchasing on how to allocate resources in the most effective way by differentiating the operationalization of PPM dimensions so that PPMs can be used in their true intention.

Theoretical Background

Purchasing Portfolio Models

PPMs allow firms to develop differentiated approaches for various purchases while reducing administrative complexity and increasing the effectiveness of available resources (Montgomery et al., 2018; Olsen and Ellram, 1997). The basic idea of PPMs is to categorize purchases based on two dimensions (each assessed from low to high) into four homogenous categories; individual categories require a similar management approach for which norm strategies are recommended (Hesping and Schiele, 2016). The most acknowledged and established PPM in theory and practice is the Kraljic Matrix (1983) (e.g., Ateş et al., 2015; Montgomery et al., 2018). Based on the underlying dimensions of the importance of the purchase and the complexity of the supply market the Kraljic PPM distinguishes non-critical, leverage, bottleneck and strategic category items with non-critical and leverage items requiring a transactional, and bottleneck and strategic items a relational approach (Lee and Drake, 2010; Olsen and Ellram, 1997). The transactional versus relational approach has been further linked to aspects of dependence as Caniels and Gelderman (2007) found relatively high buyer's dependence for bottleneck and strategic items and relatively low dependence for non-critical and leverage items. As such, the Kraljic (1983) PPM allows an organization to maximize purchasing power and value while minimizing supply risk (Padhi et al., 2012) i.e. to match external risks and opportunities with internal needs of the firm (Dubois and Pedersen, 2002).

Efforts to operationalize the dimensions of Kraljic, have led to many extensions of the PPM since 1983 (Luzzini et al., 2012) (see also Table 1). These PPMs derive the same four categories, but with different means to get there: they adjust one of the PPM dimensions. Olsen and Ellram (1997) change the complexity of the supply market to the difficulty of managing the purchasing situation. In doing so, they add more detail and focus to the dimension. Gelderman and Mac Donald (2008) and Padhi et al. (2012) consider profit impact and supply risk in an alteration to Kraljic. A different PPM is introduced by Bensaou (1999). His portfolio focuses on different types of relationships using buyer's and supplier's specific investments as dimensions. Bensaou recommends investing into relationships for the categories of strategic partnership and captive buyer while focusing on transactions for the market exchange and captive buyer quadrants.

While the overall usefulness of PPMs is widely acknowledged (e.g., Caniëls and Gelderman, 2007; Padhi et al., 2012) these models are not without criticism. In particular, the simplicity of the models and the difficulty of operationalizing and choosing dimensions have been highlighted (Dubois and Pedersen, 2002; Luzzini et al., 2012; Olsen and Ellram, 1997). Moreover, the origins of PPMs date back to a time when purchasing was mainly focused on costs. Since then, it has long been acknowledged that the value of purchasing to an organization goes beyond costing savings such as contributions to innovation (Ateş et al., 2015). Hence, Lee and Drake (2010) propose that purchasing approaches need to be aligned with the competitive objective of a firm.

Table 1: Overview and Operationalization of Portfolio Dimensions

	Classification Dimensions (see Montgomery et al. (2018)	**Operationalization in this study** (adapted from [a]Ellis et al., 2012; [b]Hesping and Schiele, 2016; [c]Olsen and Ellram, 1997, [d]Bensaou, 1999)
Kralijc (1983)	**Importance of the purchase** Volume purchased, percentage of total purchase costs, impact on product quality, business growth **Complexity of the supply market** Availability, number of sources, competitive demand, make-or-buy opportunities, storage risks, substitution possibilities	**Strategic Importance [a, b]** Strategic importance of purchase to firm, annual purchasing volume of purchase as proportion of annual spent, extent to which management prioritizes purchase **Supply Risk/ Complexity [b]** Supply risk of purchase to firm, number of alternative suppliers if supplier is eliminated, number of alternative sources
Olsen & Ellram (1997)	**Strategic importance of the purchase** Competence, economic, image factors **Difficulty of purchasing situation** Product, supply market and environ. characteristics	**See Strategic Importance** **Difficulty of managing purchase [c]** Product, supply market (supplier power, supplier's tech. competence) and environ. characteristics (risk, uncertainty)
Gelderland & Mac Donald (2008)	**Profit Impact** Volume purchased, percentage of total purchase costs, impact on product quality and business growth, expected growth in demand **Supply Risk** Market conditions, availability/ scarcity, number of sources, competitive demand, make-or-buy opportunities, storage risks/ substitution possibilities, on-time delivery, cultural differences, lack of log. knowledge, supply interruptions, duty customs regulations, shortage of qualified personnel, import complexity, payment cond.	**See Strategic Importance** **See Supply Risk/ Complexity**
Bensaou (1999)	**Buyer's specific investments** Tangible investments (buildings, tooling, equipment), Intangible investments (people, time , effort, best practices, knowledge) **Supplier's specific investments** Tangible investments (plant/ warehouse location, specialized facilities), Intangible investments (sending guest engineers, developing information systems)	**Buyer's specific investments [d]** Investments buyer is willing to make in relationship with supplier, investments buyer is willing to make in supplier's facilities, investments buyer is willing to make in sharing knowledge with supplier **Supplier's specific investments [d]** Investments supplier is willing to make in the relationship, investments supplier is willing to make in buyer's facilities, investments supplier is willing to make in sharing knowledge
Padhi et al. (2012)	**Profit Impact** Impact on profitability, criticality of purchase, value/ cost of purchase **Supply risk** Market, performance and complexity risk	**See Strategic Importance** **See Supply Risk/ Complexity**

Purchasing Objectives

In its origin, purchasing was expected to minimize the costs of a purchase related to unit price, total cost of ownership (TCO), processes, asset utilization (Ateş et al., 2018). Yet, today it is well acknowledged that purchasing is more than achieving cost efficiency, but also quality, innovation, sustainability or delivery performance (Ateş et al., 2015; Lee and Drake, 2010; Luzzini et al., 2012; Pagell et al., 2010). Purchases conducted with a quality

objective are concerned with the conformance to specifications and meeting customer expectations (Luzzini et al., 2012). This can include sustainability goals that are also based on compliance and conformance (Luzzini et al., 2012). While innovative purchases are often linked to improving introduction rates and timing of new products/ services (Ateş et al., 2018), purchases with a delivery performance goal concern speed, reliability and availability of the product/ service (Lee and Drake, 2010; Luzzini et al., 2012).

The different purchasing objectives can predict differences in purchasing practices (Hesping and Schiele, 2016). For instance, previous research has shown that objectives can affect the structure of the supply base (Ateş et al., 2015) and that in some purchasing categories one objective is more important than others (Luzzini et al., 2012). Yet, it was also found that buyers sometimes use the same purchasing practices and strategies across all Kraljic quadrants (Ateş et al., 2015; Lee and Drake, 2010). This indicates that PPMs do not seem to serve their purpose in creating uniform management categories. At the same time, however, current PPM approaches consider the objective of a purchase secondary to the categorization based on two dimensions, even though it seems that different strategies need to be employed depending on the objective. As such, considering the objective of a purchase up front, before categorization, might allow to differentiate dimensions that are important for an objective and as such suggest different PPMs for different purchases. Accordingly, the aim of this study is to explore to what extent and how the objective of a purchase influences the choice of the most suitable PPM.

Methodology

We conducted a two-step mixed method research approach and study purchases (unit of analysis) with different objectives. The first step was exploratory with the aim of investigating different aspects that could allow for a more differentiated approach to PPM. The objective of a purchase, product vs. service characteristics and the buy class were included in this first step as possible differentiation factors. We conducted 15 interviews in eight large organizations (X, A-G) asking each interviewee about two different purchases in the last 12 months. The analysis of this data showed that the objective was the main aspect to focus on when looking for differentiation in purchasing approaches.

In a second step, we engaged with two large organizations (X and Y) in-depth collecting an additional 14 interviews as well as scenario-based survey data. We once again asked purchasers to recall two specific purchases made in the last 12 months and asked questions about applied strategies, the evolution of the purchasing process and reasons behind choices made. We sought out an even spread of objectives (innovation, cost, quality, delivery performance) over the 28 purchases following a theoretical replication logic. We further included those cases of the first step in the data analysis that yielded additional insights. This allowed us to analyze 41 cases: 9 cost focused purchases (C1-9), 14 quality focused purchases (Q1-14), 8 innovation focused purchases (I1-8) and 10 delivery performance focused purchases (D1-10). Table 2 gives an overview of the cases in the context of the organizations and interviews collected. In both the first and second step, all interviews were recorded, transcribed and coded following good standards of qualitative data analysis (see Miles and Huberman, 1994).

Additionally, we collected quantitative data of 52 purchasers (80% of the populations of purchasers in organizations X and Y, 80% male, 96% Dutch). Participants were asked to rate the importance of portfolio dimensions (see third column Table 1) in four scenario-based purchases (Rungtusanatham et al., 2011), each with a different objective. In our scenarios we asked the participants to act as the purchaser responsible for the sourcing of four modules of a combiner project for MachineTooling, a manufacturer of high-end agricultural machinery: straw walker (quality), grain tank (cost), driver's cab

(innovation), engine (delivery performance). We first provided a general scenario description and then asked questions about the importance of the portfolio dimensions (constructs were based on multi-item measures using a 7-point Likert scale from 1, not important at all to 7, very important) per module (module sequence was at randomized). All items were based on existing scales in the literature or were developed using conceptualizations of the literature (see Table 1). Except for difficulty of managing the purchase dimension (Cronbach alpha of 0.675) the Cronbach alpha scores are all above 0.7, indicating satisfactory levels for internal consistency reliability. We tested whether portfolio dimensions were considered more important within a certain performance objective (i.e., differences within objectives) using a paired sample T-test (see Table 3).

Table 2 - Overview of purchases in the context of organizations and interviewees

Organization	Industry	Interviewee(s)	Interview Length	Case(s)
X	Chemical	Category Manager (2x)	72min	Q1, Q2, I1
		Purchaser	65 min	Q3, Q4
		Category Manager	83 min	Q5, D4
		Purchaser	61 min	Q6, I2
		Purchaser	76 min	Q7, I3
		Category Manager	55 min	I4, D5
		Purchaser	77 min	C4, C5
		Purchaser	62 min	C6, D6
		Head of Purchasing	78 min	D7, D8
Y	Energy	Senior Purchaser	60 min	Q8, D1
		Senior Buyer	66 min	Q9, D2
		Strategic Purchasing Manager	49 min	I5, C3
		Senior Buyer	73 min	I6, C1
		Category Lead Buyer	76 min	C2, D3
A	Chemical	Category Manager	80 min	Q10, Q11
		Purchasing Manager	82 min	C7
B	Steel	Purchasing Manager, Category Manager	77 min	Q12, C8
C	Food	Project Leader Purchasing	56 min	Q13
D	Food	Director Sourcing	63 Min	C9, D10
E	Food	Head of Purchasing	60 min	Q14
F	Food	Project Manager Outsourcing	41 min	I7, I8
G	Food	Project Manager Purchasing	59 min	D9

Findings

In line with the aim of this study, the quantitative data show to what extent portfolio dimensions are important within objectives. These results are depicted in Table 3. Following, we present the findings of the qualitative data along the purchasing objectives. In doing so, we first outline the main mechanisms identified and then link it to the PPM dimensions to be able to explain how the objective of a purchase influences the choice of a suitable PPM while also reflecting on the significance levels of the quantitative data.

Table 3 - Comparison of Importance of Portfolio Dimension within Objective

	Cost	Delivery Performance	Innovation	Quality
Strategic Importance	0	0	0	--
Supply Risk/ Complexity	+++	+++	0	0
Difficulty of the Purchase	--	0	0	+
Buyer-specific Investment	--	---	0	0
Supplier-specific Investment	---	---	0	0

Significantly more important +++ ($p<0.001$), ++ ($p<0.01$), + ($p<0.05$);
Significantly less important: --- ($p<0.001$), -- ($p<0.01$), - ($p<0.05$);
Not significantly more or less important: 0

Cost

We identify two re-occurring themes in the qualitative data for cost focused purchases: issues around dependence (number and availability of sources) and linked to that financial concerns (benchmarking, competitive bidding, switching costs, TCO). More specifically, we find that when there is little dependence on suppliers (i.e., many alternative options available) our data suggest that buyers tend to "*create a supply base from which you can draw*" (C6) and "*play the game of negotiation with the suppliers [...] reasonably hard*" (C2) as "*they [suppliers] think twice, before they do something wrong*" (C3). The low dependence on a specific supplier allows buyers to not only apply competitive bidding, but also to benchmark other aspects of the purchase (e.g., quality or delivery performance) while ensuring *"that we can complete that project within the budget.*" (C1). "*If you have three or four parties that offer [product], well, then you have one or more samples taken so you can [endurance] test them*" (C6). This purely transactional approach changes slightly if there are many alternative suppliers in the market but a need to commit to a dependent, single sourcing relationship e.g., IT solutions or energy supply. While for such purchases benchmarking and competitive bidding are used to determine the lowest TCO, more attention is paid to relational aspects to mitigate the increased dependence. The data indicates that once a dependent relationship is established, or in the case of high dependence from the outset, a relational focus is much more important as "*it is much easier, if things don't go well*" (C4).

As such, the analysis of the interviews confirms the findings of the quantitative data that considerations of supply risk/ complexity are significantly more important than other portfolio dimensions when purchasing with a cost focus. The qualitative data show, that this is due to concerns of dependence. We find that if a buyer can choose between many alternative supplier (i.e. low supply risk) competitive bidding and benchmarking are used to keep TCO low. Accordingly, next to supply risk the data indicate that strategic importance (based on financial concerns) needs to be considered for cost based purchases, which was found to be more important than other dimensions, but with no significance in relation to others in the quantitative data. In line with the quantitative results that show that the difficulty of managing the purchasing situation as well as buyer- and supplier-specific investments are significantly less important, we see no indication in the qualitative data that purchasers pay attention to these aspects.

Delivery Performance

The analysis of the data shows, that there are two underlying reasons why purchases are focused on delivery performance: availability (number of sources) and timing (risk). More specifically, we find that in eight out of ten delivery performance cases the number of alternative suppliers available to supply a product/ service is limited. This is according to our results either due to product (D6, 9), supply market (D1, 4, 5, 7, 10) or environmental characteristics (D8). The data indicate that the product, supply market and environmental characteristics that make availability difficult and the resulting dependence on suppliers often means that purchasers aim for long-term relationships. "*We've seen that [market pressure] coming pretty soon, so we quickly concluded a long-term contract with the suppliers*" (D7). The aim for long-term relationship due to concerns in availability is opposed to concerns of timing. In D3 we find that time is essential due to risk concerns: *"... you want the goods to be there at the right time, but you don't want the goods to stay there for a week, for example. Then you only run the risk that it will be stolen, broken or damaged.*" In case D2 timing is important too, here however, linked to a change in legislation which meant that a purchase for a simple product with high availability of alternative suppliers had to be done focusing on delivery performance

rather than costs. Hence, the mechanisms of cost focused purchases competitive bidding and benchmarking were applied. Accordingly, also in D2 and D3 underlying environmental conditions make delivery performance the main objective, yet it does not lead to the need for long-term relationships as dependence is limited. As such, the qualitative data highlight the importance of the difficulty of managing the purchase as a portfolio dimension for delivery performance focused purchases. This is different to the quantitative results that show that this dimension is not significantly more or less important than others while highlighting that supply risk/ complexity is significantly more important. At the same time, we find in the qualitative data that supply risk/ complexity arises from the difficulty of managing the purchase as it causes supply risk/ complexity, eliminates alternatives of supply and leads to an overall low number of alternative suppliers.

Furthermore, we find in all cases that focus on availability (D1, D4-10) that disruptions in supply will cause higher TCO than paying a higher price upfront. This was highlighted extensively throughout the cases, for example: "*The only interest we had was to secure supply. So we didn't really care about price [or] contractual conditions. It was all about availability.*" (D10). In D1 transportation modes are changed from 2.5 months shipping to 1 week flying to ensure availability. This adds 3000€ in comparison to 10-20000€ per hour in case the company is not able to deliver to its customer. These examples illustrate the strategic importance portfolio dimension for availability related delivery performance purchases. This is different to the quantitative data that found the strategic importance dimensions to be neither significantly more nor less important than other dimensions related to delivery performance. At the same time, in line with the quantitative data that shows that buyer- and supplier-specific investments are significantly less important, we see no indication in the qualitative data that purchasers payed attention to these aspects.

Innovation

The analysis of data highlights the importance of investments and commitment for innovative purchases. Consequently, we find that even when there are many alternative suppliers available competitive bidding is not used. It appears that this is due to the fact that in all innovation cases specialist knowledge is required: organizations realized that they need the help of a supplier to innovate as the product/ service entailed technical complexity "*so high that we couldn't put it down on paper ourselves*" (I1) or "*so specific, it was really hard to make a complete specification from scratch*" (I7). Accordingly, the characteristics of the innovate purchase were "*so customized that they were looking for a supplier that was willing and interested in co-development in a partnership*" (I1). A focus on a one-on-one relationship was highlighted throughout the cases "*especially if you want to achieve innovation together*" (I6). "*We found this supplier and together we developed their processes to be able to produce this product*"(I8). Beyond seeking a close relationship and as the previous quotes indicate, all cases but I2 engaged in co-development. We find that such co-development requires buyer- as well as supplier-investments. "*We flew in 'the knowledge' and they had to do some small investments [in their production facility], but they're really seeing that is was for a good outcome.*" (I8) Similarly in I3 they "*brought in a lot of knowledge and expertise, but the supplier also had a lot knowledge and expertise*" (I3). As such a partnership might go as far as being "*so transparent that you tell them what the budget is and what the planning is and then ask them if they can do something with it*" (I3) and lead to high dependence "*because those [products] are really very specific to us so we were really tied to that supplier*" (I3).

Given these aspects, we find that risk assessment, in terms of the size of the supplier or their financial status, is more important than competitive bidding. Particularly the size of the supplier kept emerging from the data. On the one hand, we find that it was considered a "*risky situation, because it was a really small supplier, and really dependent on us*"(I8). "*For those very large parties, on the other hand, I had the idea: I'm just one of many parties, so how fast are you going to run (work) for me (doubts)?*" (I2). In essence, what emerged from the data is that "*you should look for a party that is technically skilled, but still has the interest to do such a development trajectory*" (I1). However, different to cost and delivery performance focused purchases this finding seems to not link to dependence, but rather to ensuring commitment (i.e. supplier investments).

The qualitative findings show that innovative purchases are always strategically important and that the difficulty of managing the purchase is a given due to the product characteristics. Furthermore, concerns about supply risk/ complexity are not highlighted as in the search for customized solutions organizations often aim to develop one-on-one relationships. Hence, organizations are less troubled by the amount of alternative suppliers and dependence. Similarly the quantitative findings for these three dimensions show that neither is significantly more or less important than others. Additionally, the quantitative findings demonstrate positive but non-significant importance of buyer- and supplier-specific investments. This is underlined by the qualitative data. Buyers seek out suppliers that can commit to the innovation and are willing to co-develop with both parties investing time and resources to find a feasible solution.

Quality

The data indicate two re-occurring aspects for quality focused purchases: product characteristics (conformance to specifications) and the importance of the purchase. More specifically, we find that for quality focused purchases specifications are of immense importance as "*delivering not according to our 'specs' is non-negotiable*" (Q13). In all cases the data show that the type of product/ service and the need for quality lead to complex and detailed specifications. "*Think about five binders of specifications, very detailed*" (Q12). Different to innovation focused purchases, these could, however, be derived completely internally. At the same time, similar to delivery performance focused purchases the product characteristics in all cases had a large influence on the purchasing approach as conformance to specifications was key. We find one-on-one relationships in most of the cases (Q1-4, 6-9, 12); in some it was highlighted that no matter how many suppliers are available a single supplier was preferred to ensure "*there is also a lot of good support and guarantee from the supplier*" (Q8). The data indicate that organizations only deviate from this if one supplier cannot ensure availability in terms of quality and/ or quantity. However, also environmental factors such as natural deviations (Q10, 13, 14), consumer trends (Q14), weather (Q2) or safety (Q9) seem to play a role in defining and ensuring quality. Hence, the qualitative data support the findings of the quantitative in highlighting that the difficulty of managing the purchase is significantly more important than other portfolio dimensions when focusing on quality.

A second aspect that became apparent in our data is that fact that the strategic importance of quality focused purchases seems to be high throughout all cases as "*if one [product] is missing we cannot run the furnace*" (Q10) or "*if the [products] are not running well, the complete line isn't running well either. So it has a pretty high impact*"(Q11). The strategic importance of quality focused purchases was evident in the use of cross-functional teams with close collaboration between purchasing and other departments and the involvement of higher management in the purchasing process: "*In the end we went to the supplier with our COO and the CPO*" (Q5); "*Even the board*

members and stakeholders in the UK are needed for that [consent] […] it was myself and the CEO of Europe doing the final negotiation." (Q12). Furthermore, the strategic importance of quality focused purchases also became apparent in the fact that organizations engaged in extensive site visits (Q1, 3, 8, 10), asked suppliers for a pilot (Q1, 4) or required certificates/ inspections to proof quality (Q2, 3, 10).

As such, we find similarly to delivery performance focused purchases that the strategic importance and the difficulty of managing the purchasing situation are important PPM dimensions to consider for purchases with a quality objective. As a matter of fact, it appears that quality cases are often linked to delivery performance. In 10 out of the 14 quality cases delivery performance was close to if not of equal importance to quality. We find that this was often linked to the strategic importance of the product/ service meaning that if it was not available at the right time ("*one day late means one year late*" (Q1)) within the specified quality, production might stop or a window of opportunity would be missed. This is in sharp contrast to the quantitative data where results indicate the strategic importance PPM dimension is significantly less important than other dimensions. Yet, given the extensive reference to the strategic importance of the purchase and overlap with delivery performance objective (findings), we consider it vital.

Discussion and Conclusion

The goal of this study was to explore to what extent and how the objective of a purchase influence the choice of the most suitable PPM. While practice and most research (e.g., Ateş et al., 2015; Pagell et al., 2010) draw on the well-established Kraljic Matrix, we find that when considering the objective of a purchase upfront, his PPM is not the most convenient for all purchasing situations. Rather, depending on the purchasing objective different PPMs are appropriate as depicted in Table 4.

Table 4 - Link between Objectives and Portfolios

Objective	**(Significantly) Important Portfolio Dimensions**		**Portfolio Recommendation**
	Quantitative Data	*Qualitative Data*	
Cost	Supply Risk/ Complexity	- Supply Risk/ Complexity - Strategic Importance	- Kraljic - Gelderland & Mac Donald - Padhi et al.
Delivery Performance	Supply Risk/ Complexity	- Difficulty of Purchase - Strategic Importance	Olsen & Ellram
Quality	Difficulty of Purchase	- Difficulty of Purchase - Strategic Importance	Olsen & Ellram
Innovation	-	- Buyer-specific Investment - Supplier-specific Investment	Bensaou

The results of this study allow us to address some of the shortcomings of current PPM theory in terms of their simplicity and their operationalization of dimensions (e.g., Dubois and Pedersen, 2002). In particular, while a wealth of PPMs have been based on Kraljic (1983) trying to extent and operationalize PPM dimensions, our findings indicate that it is not about a single operationalization of a dimension, but more about a differentiated selection of operationalization for purchases with various objectives. This is reflected in the suggestion that for cost focused purchases the original Kraljic PPM seems most suitable, but for purchases focusing on delivery performance or quality Olsen and Ellram's (1997) PPM with the modification of one of the PPM dimensions appears to be more appropriate. Furthermore, this study extends and compliments previous research considering purchasing objectives (e.g., Lee and Drake, 2010). In particular, the findings of Ateş et al. (2015) show that the structure of the supply base for innovation focused purchases is somewhat contradicting with recommendations derived from the Kraljic

PPM. One explanation for this could be, that a different PPM should have been used, based on our findings Bensaou (1999), differentiating buyer- and supplier-specific investments. Additionally, we compliment the findings of Luzzini et al. (2012) by linking their defined purchasing strategies in terms of competitive priorities to specific PPMs. These insights also provide valuable guidance to purchasing managers on how to best allocate their scarce resources.

In conclusion, insights from this study contribute to a differentiated approach in PPM theory. In particular, we show how PPMs can be used more holistically and at the same time more tailored to the specific category being managed. While the link to purchasing levers/ strategies is missing in this study it offers an interesting and valuable avenue for further research.

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Integrating small and startup suppliers in the supply base: The role of innovation intermediation

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Abstract

Buying organisations aiming to leverage the innovation potential of small and startup suppliers may face challenges related to increasing supply base complexity, and to the ability of small firms to engage effectively given their limited scale, resources and knowledge. One possible solution is innovation intermediation. Drawing on an in-depth case study, we show how innovation intermediaries support and connect small suppliers to buyers, while managing trade offs (innovation vs. cost and risk) involved in supply base management. However, intermediaries' impact can be limited by behaviours, goals and incentives within buying organisations that are less conducive to small supplier-led innovation.

Keywords: innovation sourcing; startup suppliers; innovation intermediaries

Introduction

This paper investigates how innovation intermediaries contribute to innovation sourcing by supporting innovative small firms and startups to become suppliers to large buying organisations. Existing literature on innovation sourcing is mainly concerned with how large focal firms utilise their suppliers' capabilities, integrating them with internal resources and knowledge to drive innovation performance (Lawson, Tyler et al., 2015). Buying firms are assumed to be in control of the innovation process and to actively manage supplier involvement, but they may be underutilising the technological potential of innovative small firms and startups as possible new suppliers (Narasimhan and Narayanan, 2013). Existing research tends to focus on existing suppliers and supply networks (Nair et al., 2016), and there is limited knowledge of the process by which buyers integrate, manage and develop startup suppliers in the context of innovation sourcing (Wagner et al., 2017).

Although buyers can benefit from forming relationships with startups and small suppliers of technological solutions to fulfil their unmet needs, interactions with such small firms are challenging, given their lack of scale and resources (Arjbjørn and Paulraj, 2013). In addition, engaging direcly with innovative small suppliers means that a buying firm has to expand its supply base and deal with a more heterogenous and diverse set of suppliers. While this increasing complexity in the supply base can have a positive impact on supplier-led innovation (Choi and Krause, 2006), it may also undermine transaction

cost reduction and relational benefits associated with long-standing supply-base reduction strategies.

One approach that buying firms can follow to manage these trade offs and to structure interactions with small firms is to use the services of innovation intermediaries, but their role is little understood in the context of innovation sourcing. In this paper, we draw on the innovation intermediation literature (Howells, 2006; Kivimaa et al., 2019) to answer the following research question: *How do innovation intermediaries suppport small supplier-led innovation whilst managing complexity in the supply base of a buying firm?*

Literature review

This section synthesises literature on innovation sourcing, supply base management, and innovation intermediation to develop the analytical framework of the study.

Innovation sourcing

Existing literature on innovation sourcing and supplier involvement in NPD stresses how focal buying firms combine their innovation inputs and capabilities internally with those of their suppliers to drive innovation outcomes (Oke et al., 2013). Literature on supplier involvement has long emphasised a buyer's ability to control the innovation process and to involve its suppliers as and when required (e.g. Lawson, Tyler et al., 2015). Key process issues include the exact timing of involving suppliers (Zhao et al., 2014), the stage of the NPD process at which to involve them (Wowack et al., 2016), and the extent of supplier involvement (Koufteros et al., 2007). Overall, this line of research stresses the importance of developing a structured approach to supplier involvement and of effectively managing supplier relationships (e.g. Van Echtelt et al., 2008).

In keeping with the above, recent studies of supply chain innovation highlight the role of firm- and network-level attributes. For example, buying firm's absorptive capacity, supplier's innovativeness and supply network accessibility and interconnectedness can all have a positive influence on innovation performance of a focal firm (Narasimhan and Narayanan, 2013; Bellamy et al., 2014).

Overall, the empirical literature appears to converge to the conclusion that effective management of supplier involvement contributes to significant performance benefits in terms of reduced development time and cost and improved product quality (Van Echtelt et al., 2008). However, it is less clear whether involvement of existing suppliers is beneficial in cases of high technological uncertainty or radical innovation requirements. In such contexts, it may be more effective to involve new suppliers and benefit from their diverse knowledge (Johnsen, 2009). Involving new suppliers in innovation activities influences the structure and management of a buying firm's supply base.

Supply base management and innovation

The design and management of a firm's supply base structure is a key strategic sourcing issue (Gadde and Håkannson, 1994). Conceptually, the supply base refers to a lower unit of analysis as compared to the supply chain or supply network (Lu and Shang, 2017). According to Choi and Krause (2006), the supply base is the part of the supply network that the focal firm manages actively through contracts and purchased products, materials and services. In practical terms, a focal firm will be mostly active in managing its first-tier suppliers. However, the supply base need not be restricted to first-tier suppliers, as a buying firm can also actively manage interactions and control relationships with its second- or third-tier supplier (Choi and Hong, 2002).

The existing literature has identified a number of dimensions determining the supply base structure of a buying firm. Gadde and Håkannson's (1994) early treatment, for

instance, referred to the number of suppliers, and the way these suppliers are organised (e.g. existence of tiers in the supply base). Subsequent literature has emphasised complexity as a way to construe supply base design and management decisions (Choi and Hong, 2002; Bode and Wagner, 2015). This is because the notion of complexity combines structural (e.g. number of suppliers in the supply base) and behavioural or relational elements e.g. interactions among suppliers of a focal firm (Lu and Shang, 2017).

Choi and Krause (2006) use the term 'supply base complexity' to refer to the number of suppliers a focal firm actively manages, the degree of differentiation among suppliers, and how inter-related suppliers are. The larger the number of suppliers, and the higher the differentiation and inter-relatedness among suppliers, the higher the level of supply base complexity. Ates et al. (2015) have contributed two additional characteristics determining supply base structure: contract duration (time dimension) and supplier information sharing (transparency dimension), as these two characteristics can affect cost and innovation performance outcomes sought by a buying firm.

One strategy buying firms can deploy to manage supply base complexity is reducing the number of suppliers they actively manage (Cousins, 1999). Such supply base reduction or rationalisation strategies are grounded on arguments regarding the need to reduce administration costs, although such arguments have been long been disputed (e.g. see Gadde and Håkannson, 1994). In other words, reducing supply base complexity by rationalising the number of suppliers a buying firm deals with helps to reduce transaction costs (Choi and Krause, 2006).

Beyond transaction cost considerations, supply base design and management decisions can influence innovation outcomes. Working with fewer suppliers may positively contribute to innovation performance in that closer relationships with these suppliers incentivises them to invest in new technologies or to share knowledge with the buyer (Ates et al., 2015). On the other hand, supply base reduction strategies may entail opportunity costs related to the loss of knowledge and resource advantages that pertain to a buying firm interacting with a larger, more diverse set of suppliers (Gao et al., 2015), incuding small firms (Narasimhan and Narayanan, 2013). Indeed, Choi and Krause (2006) suggest that reducing supply base complexity may reduce the focal firm's ability to tap into supplier innovation, as they posit a positive relationship between supply base complexity and supplier innovation: the higher the number of differentiated and closely related suppliers, the higher the potential for supplier-enabled innovation. Key factors influencing supplier-led innovation include the ability of suppliers to network with each other and share information and resources, the level of supplier autonomy, and buyer direction to innovation activities of suppliers (Choi and Krause, 2006).

Reducing the supply base may also increase supply risk due to dependence on fewer supply sources, thus making buyer efforts and investments in supplier development relevant (Choi and Krause, 2006). Supplier development programmes can positively contribute to innovation sourcing when buying firms invest in developing supplier technological capabilities and creativity (Lawson, Krause et al., 2015). As part of their supply base management efforts, buying firms can also intervene to suggest collaboration or integration of smaller suppliers (Choi and Krause, 2006), they can directly manage and control relationships with second- or third-tier suppliers (Choi and Hong, 2002), or they can delegate responsibilities for supplier control to first-tier suppliers (Cousins, 1999).

Research focusing on supply base design and management has not explicitly considered how small or startup suppliers may influence supply base complexity. Such a focus is particularly relevant in innovation sourcing settings, as small suppliers and startups can be a valuable source of technological novelty and radical innovation ideas (Wagner et al., 2017). At the same time, engaging with small suppliers is challenging as

they often lack scale and resources required (Arjbjørn and Paulraj, 2013). Buying firms may not have the time or resources to explore how such (potential) suppliers can contribute to product or process innovation, and they may not be willing to invest in their development. From a supply base complexity perspective, engaging with small firms and startups is likely to increase complexity not only because of an increase in the number of suppliers a firm is dealing with, but also due to increasing supply base heterogeinity (Ates et al., 2015). Small and startup suppliers tend to be different from established, larger suppliers in terms of size, culture, management style and practices, and governance structure (Kull et al., 2018), hence increasing the degree of differentiation in the supply base (Choi and Krause, 2006). One approach that buying firms can follow to structure interactions and relationships with innovative small suppliers and startups is innovation intermediation, a concept originating in innovation policy and management studies.

The functions of innovation intermediation

An inherent characteristic of innovation intermediary organisations is their ability to broker connections and facilitate interactions between buyers and suppliers of innovative technologies, products and services (Edler and Yeow, 2016; Kivimaa et al., 2019). Research on innovation intermediation collectively stresses the multiple roles that intermediaries assume as part of the innovation process (Howells, 2006).

The empirical literature has examined a diverse set of intermediary organisations spanning from public organisations and government-affiliated agencies, to research and technology organisations, web-based business platforms, and consultancies and other types of knowledge intensive business services (e.g. Klerkx and Leeuwis, 2008a; Colombo et al., 2015). These intermediaries can either operate across industries or have a narrow remit e.g. promoting innovative solutions in the energy sector (van Lente et al., 2003). They can provide their services either to the buyer side or the supplier side, as evident in the literature (Howells, 2006).

Innovation intermediaries perform various functions in supporting buyers and /or suppliers of innovation. They contribute to definition of unmet needs and requirements, articulate demand for innovative solutions, perform horizon scanning and promote appropriate technological options (Kivimaa, 2014; Klerkx and Leeuwis, 2008b). They can also assist in filling managerial gaps related to innovation project management and innovation adoption (Bessant and Rush, 1995), and may also provide access to funding necessary to set up and execute R&D and innovation demonstration projects (Polzin et al., 2016). Additional functions that intermediaries can fulfill include processing and (re)combining knowledge from several sources, matchmaking to connect suitable partners, commercialisation support, and validation and evaluation of technological innovations (e.g. Howells, 2006; Lichtenthaler, 2013).

The empirical literature suggests that intermediaries operate both in private and public sector settings. In the specific context of health innovation procurement and adoption processes, for instance, Edler and Yeow (2016) show how the intermediaries involved filled important capability gaps of the public buying organisation with regard to definition of unmet needs, analysis of supply options and innovation promotion and adoption. Although this research stream, overall, stresses the positive role of intermediaies in the innovation process, the peformance impact of such interventions is less evident. In addition, the literature suggests that perceptions regarding neutrality and impartiality of intermediaries, and their ability to continue operating in spite of financial, institutional and policy-related constraints have a bearing on their impact (Klerkx and Leeuwis, 2008b).

Research method

We adopted a single, embedded case study design (Voss et al., 2002) to develop an in-depth understanding of how innovation intemediaries contribute to involving, developing and managing small and startup suppliers as part of innovation sourcing initiatives. Our research setting is the supply chain of the UK National Health Service (NHS). The NHS is a large buying organisation attempting to engage actively with startups and small firms and to leverage their technological potential to improve patient outcomes and reduce service costs.

The innovation intermediary in focus, henceforth referred to as InnoMed, is one of the 15 regional innovation agencies known as Academic Health Science Networks (AHSNs), whose remit is to spread innovation in the health and care system ”at pace and scale”. InnoMed, like other AHSNs, is funded by NHS England and the UK Government Office for Life Sciences and operates based on a five-year licensing commitment agreement with NHS England (which was recently renewed).

Case selection followed a purposive sampling logic (Patton, 1990). We selected the NHS as our empirical setting since in the UK public health and care system innovation procurement and adoption is, at best, challenging. In this context, intermediary organisations assume an important role in supporting buyers and /or suppliers and in accelerating innovation development and adoption (see Edler and Yeow, 2016). We selected InnoMed due to its various support programs for small and startup firms.

Crucially, the embedded case design allowed the analysis of InnoMed’s roles and contribution to the NHS’ innovation sourcing efforts, as well as studying a sample of 20 small and startup suppliers as recepients of InnoMed’s support. The majority (17) of these firms operate in the ’MedTech’ and ’Digital Health’ segments of the health and life sciences sector in the UK. The other three firms operate in different areas e.g. mental health. Table 1 provides an overview of the innovative solutions of the studied firms.

Table 1: The studied small /startup suppliers and innovative solutions

Market segment	Small /startup supplier solutions
MedTech	S1: medical 3D-printing applications; S2: snoring relief device; S3: latex-free surgical gloves; S4: nasogastric feeding tube confirmation device; S5: evacuation foldable stretcher; S6: portable ultrasound device for GPs; S7: fall prevention device; S8: thermal imaging fall detection solution.
Digital Health	S9: Real-time info for children (0-5 years) ailments; S10: Hospital data management solution; S11: Preventive health IT solution; S12: GP engagement and self-case platform; S13: hospital auditing system; S14: interactive physiotherapy platform; S15: remote assessment of swallowing problems; S16: kidney disease assessment app; S17: health transport planning app.
Other	S18: hospital /ambulance infection control solutions; S19: Children’s mental health treatment method; S20: clinical R&D services

Data collection involved 32 semi-structured interviews with innovation intermediary staff, founders /executives of small firms and startups, and NHS procurement professionals. The interviews covered multiple themes such as the types of support that InnoMed provides, suppliers’ perceptions of the quality and impact of InnoMed’s support, and of the NHS as a (potential) customer. The interviewees were also asked to offer their views and opinions on challenges related to innovation procurement and adoption. To complement and triangulate interview data, we analysed in excess of 20

documents (e.g. hospital procurement strategies, InnoMed reports and presentations) and other sources of publicly available data (e.g. AHSN Network communications, health policy reports). We used the ATLAS.ti software to analyse and code the data, and to identify key themes in the data.

Findings

This section presents the analysis of the case. Table 2 summarises the key findings regarding the innovation intermediary's functions, the nature and impact of the support it provides to small /startup suppliers, and implications for the NHS' supply base management.

Case analysis suggests that InnoMed performs, on behalf of the NHS, several functions as part of the innovation sourcing process. The intermediary contributes to identifying and articulating the unmet needs of patients /citizens and of the health and care system, which innovative solutions could help fulfill. While this occurs primarily at regional level given that InnoMed's health innovation remit concerns a specific UK region, the intermediary contributes to definition of unmet needs nationally. InnoMed performs technology horizon scanning activities and plays an important role in identifying solution options and potential suppliers that could help meet the needs of the NHS. The intermediary also assumes a matchmaking role, introducing potential small suppliers and startups to hospitals and other healthcare providers (e.g. GP clinics) that face problems that these small suppliers could help solve. In addition, InnoMed performs a validation function by evaluating and vetting products and promoting to the NHS the most promising solutions. The NHS also benefits from the ability of InnoMed to receive, combine and share knowledge about national health innovation trends and to raise awareness regarding high-impact innovations developed at other parts of the country.

Table 2: Summary of the case analysis

Key themes	Contribution of InnoMed
Innovation intermediary contribution to innovation sourcing process of buyer	1) Definition of unmet needs (at regional level), 2) horizon scanning and options identification, 3) matchmaking and introductions to innovative startups, 4) solution vetting and promotion, 5) knowledge sharing and awareness raising.
Innovation intermediary support to small and startup suppliers	1) Evaluation of product, business model and /or sales approach, 2) Brokering connections, 3) Education and capability development of small firms /startups, 4) Funding-related support, 5) Organisation of clinical trials /demo projects to help generate evidence.
Impact of support and related challenges	Some evidence of small /startup firms generating NHS contracts and sales. However, in general the rate and pace of adoption of small firm-led innovations by the NHS is rather low. Multiple challenges e.g. NHS procurement goals and incentives; supply risks and cost-to-serve related to dealing with small /startup suppliers
NHS supply base management implications	*Innovation:* engagement with increasing number of small firms and startups through InnoMed fosters innovation. InnoMed directs innovation activity of startup suppliers and connects them. *Risk and transaction costs:* InnoMed vets and qualifies solutions and small suppliers, thereby reducing risk and administration costs. Cost-to-serve a key issue for procurement managers, though.

The empirical evidence shows that a central duty of InnoMed is to provide support to small firms and startups that have the potential to become new suppliers to the NHS. This support takes multiple forms, as interviews with both InnoMed staff and small /startup firms revealed. The intermediary evaluates early on in the engagement process the technological solution, the business model and /or the sales approach of the firm, depending also on the company's stage of maturity in relation to the process of product development and commercialisaton. InnoMed's feedback to firms can result in redirection of the small firm's innovation efforts to match better the NHS' unmet needs. InnoMed brokers connections between small firms and clinicians and decision makers in hospitals. It also performs a wider networking function by connecting small /startup suppliers to each other, as well as to other (larger) suppliers of complementary products and technologies.

Another key area of support is contributing to knowledge and capability development of small /startup firms through the organisation of education workshops (e.g. on health economics, NHS governance systems) and through one-to-one coaching and expert advice (e.g. regarding the sales approach and NHS procurement procedures). A key goal of InnoMed is making startups commercially astute and helping them to navigate the complexity of the NHS, and that of its procurement and supply procedures. InnoMed also provides finance-related support mainly by signposting funding opportunities and providing funding-related advice, and less frequently by directly funding promising innovation projects. InnoMed is also involved in setting up clinical trials or demo projects, which enable small suppliers to generate required evidence to validate and certify their medical devices /solutions.

In terms of the impact of InnoMed's contribution, there is evidence to suggest that small /startup firms that receive support have succeeded in penetrating the supply base of the NHS and to secure contracts and sales. More specifically, of the thirteen studied companies in the sample that already have a developed product /solution, nine of them have generated NHS sales, while the other four are in the process of doing so. Seven small /startup firms from those interviewed are still in the process of developing or validating their solutions, and therefore it is premature to evaluate the impact of InnoMed's support in terms of NHS sales and company growth.

However, interviews with all stakeholders suggest that, more broadly, the rate and pace of adoption of small firm-led innovations by the NHS remain rather low. There are several reasons for this, such as InnoMed's limited ability to influence innovation adoption decisions. Another challenge is the lack of meaningful engagement of NHS procurement professionals with small /startup firms, and with the intermediary's efforts in infusing new products and technologies into the NHS more broadly. A key related finding is that the NHS procurement system's objectives and incentives are not aligned with InnoMed's agenda. Specifically, the NHS' centralised procurement function as well as procurement teams at hospital level operate based on stringent annual cash-releasing savings targets. These targets incentivise awarding multi-year contracts to large suppliers, and working with established suppliers to drive cost efficiencies. Procurement directors at hospitals seem to be less well-disposed toward dealing with small suppliers, not least due to considerations of supply capacity and cost-to-serve an order (a key NHS procurement criterion), which tends to be higher when dealing with small /startup firms.

Regarding the implications of InnoMed's involvement for the NHS' supply base management, the analysis suggests that innovation intermediation can be an effective approach to managing trade-offs between innovation and risk /transaction cost outcomes related to supply base expansion. Specifically, engagement with an increasing number of small firms and startups, through InnoMed, increases the NHS' ability to leverage the

(radical) innovation potential of these suppliers-in-the-making. At the same time, InnoMed appears to mitigate certain types of supply risk (mainly product quality risk) and to reduce transactions costs related to innovation process interactions by vetting solutions and promoting to the NHS small suppliers that hold high promise. However, this approach does not seem to address other aspects of supply risk (small supplier scale /capacity) and transaction costs (cost-to-serve orders), as analysed above.

Discussion and conclusions

The empirical findings suggest that innovation intermediaries serve as a means for the identification and exploitation by buying organisations of new technologies, products, and services that can potentially improve quality and reduce costs. The case reveals the multiple ways through which intermediaries can support small firms and startups and help them to penetrate the supply base of large buying organisations, in this instance the NHS. It also highlights, however, the challenges associated with influencing mind sets and behaviours within large buying organisations in relation to small/startup suppliers considering also diverse goals and misaligned incentives between different functions.

The study contributes to existing research on innovation sourcing and supply base management in multiple ways. First, it extends existing research on innovation sourcing by focusing on the approaches buyers may use to manage the involvement of startup suppliers (e.g. Wagner et al., 2017). More specifically, we highlight the role and potential impact of an intermediation model of innovation sourcing. We demonstrate how innovation intermediaries can contribute to innovation sourcing efforts of a buyer by: a) identifying and involving small and startup firms and connecting them to the buyer, b) educating and supporting the development of small firms and startups as potential suppliers, and c) supporting these small suppliers to overcome innovation adoption barriers within the buying organisation, and to penetrate the supply base of the buyer. In other words, we show how innovation intermediaries work to link in small and startup suppliers. This is different from existing innovation sourcing literature which largely presumes that buying firms engage and interact directly with their supply base or supply network (e.g. Oke et al., 2013).

Second, the research stresses the mechanisms underlying the support and development of small firms and startups as suppliers that could potentially penetrate the supply base of a buying organisation. Existing literature on innovation sourcing and supply base management implicitly assumes that it is the *existing* supply base and suppliers that contribute to innovation (e.g. Choi and Krause, 2006), and ignores the role of *suppliers-in-the-making.* Comparatively, our study offers insights into how small firms and startups can become suppliers of innovative solutions to a buying organisation, and contributions of innovation intermediaries in this process.

Third, the study highlights the involvement and potential impact of small firms and startups as *new* (to the buyer, at least) suppliers. Existing research on supply base design and management has underplayed the influence of small /startup suppliers in relation to a buying firm's innovation strategies, and the implications for supply base complexity. In this study we emphasise the contribution of innovation intermediation in relation to the above issues. Using intermediaries to go beyond the existing supply base and to develop relationships with small /startup firms as potential suppliers can be an effective way to manage supply base complexity: by reconciling requirements for innovation on the one hand, and transaction costs and risk on the other. Being knowledgeable about the buyer's unmet needs, innovation intermediaries can provide some direction to startups' innovation efforts. Through their networking function, they can also strengthen the interconnectedness of these small suppliers-in-the-making. Both aspects can in turn foster

an environment of innovation (Choi and Krause, 2006). Overall, intermediaries offer a way of orchestrating the buyer's supply base expansion to pursue innovation goals in a way that mitigates some types of supply risk and transaction costs (e.g. by vetting and promoting only highly promising suppliers and solutions). However, such an orchestrating role may be limited by an overemphasis on price and short-term cost savings within the buying organisation.

The study is based on a single case focusing on a rather peculiar (and public sector) context, which potentially limits the transferability of findings. Further empirical research cutting across public and private sector supply chains is needed to build a more comprehensive theory regarding the role of innovation intermediaries in innovation sourcing initiatives. In addition, the empirical study has not explicitly addressed the dynamics of the process by which small firms and startups get involved, develop and potentially penetrate the supply base of buying organisations. Process-based studies, of longitudinal nature, would be suitable for pursuing this future research avenue.

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Reliability and Maintenance

Causal based spare parts forecasting exploiting product-in-use data: a mixed method case study in a heavy vehicle aftermarket context

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Abstract
The purpose of this paper is to find relevant relations between spare part types and explanatory factors, as well as evaluate propositions regarding improved forecast accuracy by applying regression methods on the demand by using the explanatory factors. The analysis reports both promising and expected results, mainly an improved forecast accuracy applying regression-based forecasting with explanatory factor. Although some of the findings requires further research. This model and the process used could serve as a foundation for other companies striving for enhancing their spare parts forecasting capabilities.

Keywords: Spare parts, Demand forecasting, Connected vehicles, Internet of things, Product-in-use data

Introduction
Internet of Things (IoT), smart devices, increased computing capabilities (faster hardware, smarter software etc.) and the vast amount of internal and external data available (Kache and Seuring, 2017) are amongst the key drivers of the "big data" revolution. For automotive manufacturers, a 'connected vehicle' generates a vast amount of data that is captured

Traditionally, spare parts forecasting research has focused on improving time series forecasting methods using the historical demand solely (Bacchetti and Saccani, 2012). The main problem with these models is that they do not consider the underlying demand, which is the need for exchanging spare parts in a maintenance or repair context (Romeijnders et al. (2012). Several studies show that there is a potential to base spare parts forecast on causal relations with explanatory factors, such as sensor data, fault codes, mileage, running hours and installed base (product-in-use data) instead (Van der Auweraer et al., 2019, Andersson and Jonsson, 2018). Furthermore, contextual factors such as life cycle stage, demand pattern and specificity (Huiskonen, 2001) is expected to influence the potential of causality of the underlying explanatory factors positive effects on predicting the future demand.

The purpose of this paper is to find relevant relations between spare part types and explanatory factors, as well as evaluate hypotheses regarding improved forecast accuracy by applying machine learning methods to predict the demand utilizing these explanatory factors. The empirical analysis is based on case data, both qualitative and quantitative

data, from the aftermarket service of a global heavy vehicle manufacturer. Furthermore, this paper sets out to categorize the spare parts based on variables explaining the underlying demand and develops a generic process on how a causal based forecasting process can be developed.

Literature review

The focus of this paper is to study utilization of explanatory factors (product-in-use data) in causal based forecasting for heavy vehicle spare parts. Causal based forecasting is closely related to installed based forecasting (Auweraer et al., 2019) or leading indicator forecasting (D'Amuri and Marcucci, 2017).

Causal based forecasting methods

Various regression methods with exogeneous, explanatory variables have been used for a long time in econometric analysis. For examples of methods, see e.g. Hansen (2017). To predict spare parts demand, some research applying causal based methods with regression techniques are for example: Hua *et al*. (2007) describe a method applied in the process industry combining regression analysis of explanatory variables correlated with non-zero demand within the lead time and bootstrapping. Ghobbar and Friend (2002) propose a method predicting the demand interval for aircraft spare related to operating usage and the spare part life cycle, Dekker et al. (2013), describes different install base forecasting methodologies. They propose to use the failure rate, use of planned preventive maintenance (PM) and by collecting data from remotely monitored machines (CBM). Fritzsche et al. (2014) aims at optimizing the total maintenance cost, but particularly in an airline industry context. Their concept, called: prognostic health management (PHM), is using data such as; performance degradation, physical degradation, vibration and usage-based factors. The data produced by on-board sensors, monitoring data and data from previous maintenance and inspections are then used to produce the status and prediction of next maintenance occasion. In a paper by Andersson and Jonsson (2018) it is proposed that positive performance effects on spare parts forecasts are expected for medium to high frequent demand, especially in phase-in situations.

Product-in-use data

The explanatory variables in forecasting are the underlying factors causing the demand. For spare parts these underlying factors are closely related to the maintenance and repair need. For the automotive industry we adopt the definition of product-in use data for description of the explanatory, demand driving variables. (see table 1, Andersson and Jonsson, 2018).

Table1: Data categories for causal based forecasting (Andersson and Jonsson, 2018)

Data category	**Example of data items**	**Source of the data**
Operational data	Mileage driven, running hours, location, average speed, RPM	Vehicle on-board
Fault codes	Malfunction of critical components and alerts	Vehicle on-board
Sensor data	Oil quality, pressure, temperature, dimensions of brake disks, vibrations	Vehicle on-board
Install base	Current and future number of vehicles per vehicle type and region	Manufacturing system
Item usage	Items included in specific maintenance repair operations. Vehicle repair maintenance history. Failure rate and service intervals	Maintenance system

According to e.g. Huiskonen (2001) also the classification variables, such as demand pattern, life cycle stage and type of spare part, should have an impact on the causation between the underlying variables and the demand.

Methodology

Data collection

This paper draws upon results from a case study in a heavy vehicle aftermarket context comprising of both qualitative and quantitative components. Since the possible explanatory factors (available product-in-use data elements) encompass more than 3000 data elements, it was necessary to reduce these in order to make the quantitative analysis feasible.

The qualitative study was guided by RQ1: What data has a potential impact on the demand for different groups of spare parts for heavy vehicles? To find relevant explanatory factors with a potential impact on the demand, meetings and interviews with maintenance engineers and workshop managers were carried out. The outcome of this qualitative data collection was to use data on the fault codes that have the highest impact on the demand, as well as average driving distance and operating time per vehicle. To determine which fault codes to use, the correlation between demand and number of vehicles reporting the various fault codes were used. Due to the great amount of data the top three fault codes were selected to be included in the quantitative analysis. The selection of spare parts to include were guided by the proposal from e.g. Boylan and Syntetos (2008), and Axsäter (2007) who suggest a potential improved forecast using explanatory variables for phase-in parts. To test this proposition, spare parts with an age less then five years were selected. Additionally, spare parts with too low demand and intermittent demand patterns were excluded. An arbitrary selection was made, in order to make the forecast analysis feasible, in discussion with data scientists at the case company, resulting in the exclusion of spare parts with less average demand per period during the last year than 1.5 pieces and with number of periods without demand less then 4.

In order to create a dataset appropriate for analysis of the causality of the explanatory factors on the demand (the causal based forecast model), data from several large databases

at the case company were retrieved and matched. The principal data model is depicted in Figure 1, with more details in table 2 below.

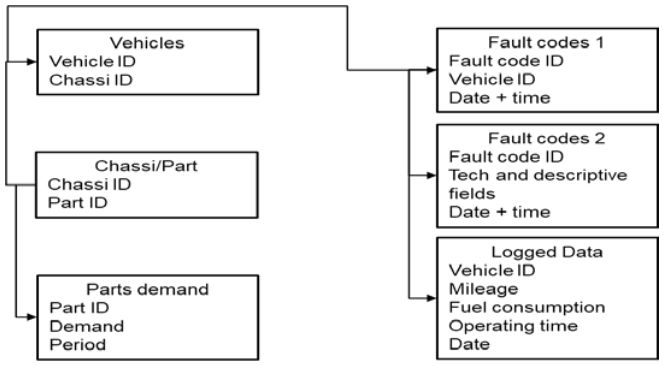

Figure 1: Description of the data collected for the forecast model

Table 2: Data tables used to create the sample for analysis

Table description	Number of records	Number of columns	Keys	Data types
Vehicle ID's	~7 Million whereof ~ 700 000 are in scope	99	Vehicle ID	Many different date fields + vehicle configuration, age, Chassid ID etc.
Fault codes by vehicle and date/ time	2.9 Billion	16	Fault code ID	Vehicle ID Date + time
Fault code records incl technical data	2,9 Billion	17	Fault code ID	Descriptive + technical data Date + time
Spare parts per vehicle	~ 5 billion in scope	7	Chassis ID	Chassi ID connects to vehicle ID Parts per unique chassi ID
Historical demand data	~1 Million	131	Part ID + demand period (13 4-week periods per year	Part ID Demand quantity Period 10 years of historical data
Spare parts master data	~50 000	6	Part ID	E.g. price, age, function (classification variables)
Operational Data	~ 1 Million	9	Vehicle ID	Mileage etc.

This data was merged into a data file and used as input to the forecast model, containing the following fields: spare part number, period number, demand, fault code frequency 1-3, average distance per vehicle and average operating time per vehicle. Number of spare parts are 611, number of periods are 65.

Data analysis

The beforementioned data was used to analyze RQ2: What is the performance effect of causal-based forecasting using product-in-use data in an aftermarket setting? By applying a multivariate linear regression method, a causal-based forecast was calculated and compared to a set of traditional forecasting methods in a forecasting competition (Makridakis and Hibon, 2000), evaluating the result using Mean Absolute Percentage Error (MAPE) and MAE (Mean Absolute Error), see Kim and Kim (2016). The applied regression model used the explanatory variables in a stepwise approach, i.e. for each added variable the adjusted R square value was compared to the previously calculated value. Moreover, an analysis was performed to classify spare parts into groups (Huiskonen, 2001) based on the categorical data (e.g. life cycle and demand frequency), determining which forecast model has the best fit, i.e. lowest MAPE and/or MAE.

As part of RQ2 the quantitative analysis aims at testing the following hypothesis: Positive performance outcome can be achieved by combining multiple causal-based forecasting interventions using product-in-use data (a) between different life-cycle phases and, (b) with time-series methods.

Finally, a causal based forecasting process is developed and validated with demand and inventory specialists and data scientists at the case company. To predict the forecast one period ahead we used an autoregressive forecasting model, using demand as well as exogenous variables.

Pre-mature analysis of the data showed that no well-performing general regression method was to find, i.e. due to differences in the slope and intercepts for individual spare parts. As a consequence, an individual model had to be created for each spare part. The autoregressive equation has the following form: $Y_{it} = \alpha_i + \beta \mathbf{X}_{it} + u_{it}$.

Results

Initial findings of the hypotheses testing analysis (RQ2) show promising results for five product groups (spare parts) using the explanatory factors: mileage and fault codes. The findings draw on the result from explorative studies and aims at increasing the scope, both in terms of relevant product groups and number of spare parts in the sample, as well as in terms of developing the analytical forecasting method. Preliminary tests at the case company show that the potential effect of causal-based forecasting is highest in the phase-in stage in the product life cycle (0-5 years), which is in-line with conceptual causal based forecasting studies (e.g. Andersson and Jonsson, 2018).

The forecast analysis using fault codes with the highest correlation with demand and operational data, also comparing with traditional time series forecasting methods gives the following result, presented three different stages in the life cycle (table 3):

Table3 - Forecast error per forecast model and length of historical variable values

	5 Years		3 Years		1 Year	
	MAE	MAPE	MAE	MAPE	MAE	MAPE
Single exp smoothing	28.3843	0.6641	23.4096	0.7215	19.0755	0.9092
Double exp smoothing	29.5529	0.6881	23.1997	0.7407	19.8198	0.9749
Simple linear regression	21.4742	0.5222	15.8026	0.5725	11.5703	0.5603
Regression with FC1	18.7310	0.4903	14.3762	0.5416	10.5110	0.5067
Regression with FC1+FC2	18.3029	0.4812	13.9380	0.5299	10.1265	0.4757
Regression with FC1+FC2+FC3	17.9082	0.4580	13.5923	0.5177	9.6770	0.4418
Average distance added	17.6891	0.4768	13.2533	0.5252	9.0561	0.4388
Average time added	17.4649	0.4746	12.9558	0.5252	8.3229	0.3267

The forecast accuracy of the model (MAPE and MAE) clearly shows improved performance of the model. First, we can see that the simple linear regression model outperforms both the single and double exponential models. Secondly, for the series with a three- and five-year history, MAE shows an increased forecast performance for each added explanatory variable, although the forecast accuracy measured with MAPE shows improvements for the model adding fault codes one to three, but no improvements due to adding the variables distance and time. Since MAE (measured as an average over all forecasts) is sensitive to large errors that typically are more common for spare parts with high demand, it is difficult to draw any conclusion just by that. This result needs to be examined more in detail to see where and for what type of parts the errors are better or worse. However, the forecast accuracy measured by MAPE could be considered more trustworthy since it is scaled and expressed as a percentage error.

For the series forecasted and measured after one year the results show an improved accuracy, both with MAE and MAPE, for each added explanatory variable. What stands out with this result is the rather high-performance effect when the last variable was added (average time). This result is most likely an effect of a high interaction between vehicle usage and a willingness to maintain and repair a new vehicle. Still it remains further analysis to statistically prove that proposition.

In order to see the effects of the causal forecast model on spare parts with different demand frequency, frequency classes were created and the result (see Table 4) is also presented for these classes. The frequency classes are: 1) slow moving parts with an average demand per period < 5, 2) medium frequent parts where the average period demand is between 5 and 25, and finally, fast moving spare parts where the average period demand > 25.

Table4 - Forecast error per forecast model and demand frequency

	Slow		Medium		Fast	
	MAE	MAPE	MAE	MAPE	MAE	MAPE
Single exp smoothing	3.2923	0.7382	7.9438	0.9934	19.0755	0.8300
Double exp smoothing	3.3346	0.7709	8.0727	1.0440	19.8198	0.8504
Simple linear regression	4.5567	1.1670	8.0956	0.8852	11.5703	0.5199
Regression with FC1	4.0425	0.9285	7.1538	0.8016	10.5110	0.4858
Regression with FC1+FC2	3.9066	0.8825	6.9472	0.7833	10.1265	0.4742
Regression with FC1+FC2+FC3	3.7942	0.8558	6.7851	0.7702	9.6770	0.4588
Average distance added	3.6854	0.8401	6.6263	0.7680	9.0561	0.4589
Average time added	3.6175	0.8179	6.5199	0.7583	8.3229	0.4507

For medium and fast-moving spare parts, the regression model with explanatory variables outperforms the traditional times series methods. Furthermore, the result is improved for each explanatory variable added. For slow moving parts, both the traditional methods show better result than the regression methods. Moreover, the more frequent spare parts are the better the forecast gets (measured by MAPE of obvious reasons), which is not a surprise. The same improvement is seen for both single and double exponential smoothing methods.

Based on the qualitative data collection we also performed tests with the same regression methodology as previously described. The expectations of these analysis were high since the fault codes in this case were derived from experience by maintenance specialists and technicians. However, we could not see any significant improvement of the forecast in this case, so no details of that analysis are presented here.

Discussion and conclusion

The results showed some expected results and some that were unforeseen upfront. The impact of the fault codes regarding different length of the time series were partly as expected (three and five years of history. However, the negative impact on the operational variables (driving distance and driving time) needs further research. It could be due to covariance with the other explanatory variables, i.e. the fault codes. More surprising was the improvement of the forecast accuracy for the one-year time series when adding the last variable (driving time) to the analytical model. Also this finding requires further analysis and research. A possible explanation could be that the vehicle owners are more compliant to maintenance recommendations in the very beginning of the life cycle.

Regarding the analysis divided by the frequency of the spare parts it is showing promising results according to the a priori expectations.

One unexpected outcome in the analysis were that no improvements could be seen for spare parts with qualitatively judged fault codes. In order to analyze the root cause of that result, a deeper study is needed, invoking both statistical analysis and discussions with maintenance specialists and field technicians.

The study contributes to the spare parts forecasting field by presenting a detailed empirical analysis of real product-in-use data and its impact on spare parts forecasts. Furthermore, a proposed process/framework for choosing types of spare parts feasible for causal-based forecasting and usable relevant data has a practical relevance for firms that wants to develop their forecasting process for spare parts using product-in-use data. The proposed process contributes to the calls in the literature to conduct practically relevant

and empirically based studies on forecasting using explanatory factors (Auweraer et al., 2019). We are now working on further developing and testing the causal-based forecasting model in relation to the purpose. The final part to propose a process/framework for matching forecast method and spare parts is developed in interaction with the case company.

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Public Procurement of Railway Infrastructure Maintenance: A Linear Regression Analysis

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Abstract

Swedish railway infrastructure maintenance has been outsourced through gradual exposure since 2002. The idea behind outsourcing was to reduce cost and improve efficiency. However, railway maintenance cost has increased faster than railway maintenance operations, resulting in neglected railway maintenance. Since railway operation is governed by the contract design the purpose of this paper was to explore the relationship between contract design and maintenance outcome within Swedish railway infrastructure maintenance. To explore this relationship linear regression analysis was used. The result indicates that asset knowledge and accessibility to the track are important to consider for improving maintenance operations.

Keywords: Public Procurement, Railway Maintenance, Contract Design

Introduction

Railway maintenance outsourcing has been a popular choice for European countries during the last decades. One motivation behind the outsourcing decision is to reduce overall cost without jeopardizing track quality. According to Odolinski and Smith (2016), outsourcing through gradual exposure has reduced cost by 12 per cent in Sweden. Gradual exposure creates a learning process for railway custodians regarding both procurement strategies and contract design (ibid.). However, large changes in the contract design can only occur during the procurement process not during the contact period, since the law of public procurement only allows for smaller changes (Lagen om offentlig upphandling [LOU], SFS 2016:1145). Smaller changes include unpredictable circumstances, minor additions and changes as well as change of contractor (ibid.). However, the contract is arguably fixed during the contract period, making design especially important. Hence, there is a need to understand the impact of contract design on maintenance outcome.

In Sweden, railway maintenance has been outsourced through gradual exposure since 2002, with the last contract exposed to competition in 2013. Due to expensive machines, there is a high economical barrier for maintenance companies to enter the market (Lingegård, Lindahl 2015). Therefore, the railway maintenance market in Sweden is oligopolistic, that is, it only involves a few actors. Alexandersson and Hultén (2007) indicates that a market with few actors open for more negotiation then actual competitive tendering during a procurement process. However, governments often try to avoid such collaboration techniques (i.e. negotiations) during a public procurement process (Meehan, Ludbrook et al. 2016). Another unique characteristic in a client-contractor relationship in maintenance is that the infrastructure already exists. Usually client-contractor relationships involve construction of infrastructure (sometimes including maintenance). When the infrastructure is new the knowledge about the condition is high, and the predictability for maintenance needs is also peaking. However, most railway infrastructure is several decades old, complicating maintenance requirement predictions. Hence, an accurate description of the condition of the railway infrastructure is needed. Without accurate knowledge of the railway infrastructure there is a risk of inaccurate contract design (Olsson, Espling 2004), causing a misalignment between infrastructure condition and contract design (Andersson, Hultén 2016). Andersson & Hultén (2016) suggest that Swedish railway maintenance costs are increasing four to five times faster than railway operations, caused by a misaligned governance structure of railway maintenance, costing up to 2 billion SEK annually. Governments need to better understand the effects of procurement strategies and contract design, especially since railway maintenance has received little research attention. Hence, the purpose of this paper is to examine the relationship between contract design and maintenance outcome.

Theoretical perspective

Maintenance Contracts

The purpose of a contract is to have a written agreement between different economic actors on a subject that they may have a different perspective on (Borg, Lind 2014). However, it is difficult for the client to design a contract that minimizes its cost without changes to the overall quality of the railway infrastructure. While minimising cost and maintaining asset quality, the contractor's payment should be sufficient enough to minimise moral hazard (Borg, Lind 2014), something that is hard to achieve in practice. The contract design within railway infrastructure maintenance depends on the asset knowledge and pricing of these assets (Olsson, Espling 2004). Cross (1988) mentions three factors that affect maintenance services; pressures for reducing costs; reorganization to allow an improvement of the service given; withdrawal from providing a particular service towards introduction of suppliers (i.e. outsourcing of the maintenance service). Today, client organizations often try to find an optimum between cost control and operational improvements through outsourcing. Contracts need to specify the content of service as accurately as possible in order to design financial incentives (Rahman, Chattopadhyay 2010, Olsson, Espling 2004, Tarakci, Tang et al. 2006), otherwise there is a risk of conflicts (Abdi, Lind et al. 2014, Borg, Lind 2014). In Sweden, the overall contract describes a function that the contractor has to satisfy, e.g. the track should be available for traffic 24 hours every day of the year. However, the working instructions for each railway asset are specific resulting in procurement of a contractor that only follows specification (Lingegård, Lindahl 2015). Creating a situation where the contractors have freedom to organize the maintenance activities (i.e. logistical solutions), but not the maintenance itself.

Pricing and payment are sources for conflict in contract situations (Abdi, Lind et al. 2014) and as such, the payment scheme must be designed carefully (Borg, Lind 2014). The careful consideration in designing this payment schemes is of vital importance to minimise conflicts and to distribute the right amount of risk. Simplified, there are two types of pricing; fixed-price and actual cost. Fixed price is simply fixed payment for the maintenance activities. Actual cost is payment according to reality, including factors such as time, personnel and equipment. Railway maintenance contracts in Sweden have, of course, a mixture of the two payment types. However, Sultana et al. (2013) mentions problems with such traditional way of contacting and procuring. Procurement of the lowest cost may result in a neglect of quality for the reduction of cost. The client has to ensure, by either inspections or governance, that the quality is not jeopardized.

Partnering in railway maintenance contracts has been used in the Swedish contracts. The main idea is to make contacts more flexible to change by close cooperation between client and contractor (Abdi, Lind et al. 2014). By close cooperation, the aim is to drive innovation, increase productivity and implement new ways of working (Eriksson 2015). The client is expected to drive both the partnering process and the knowledge transfer by encouraging to partnering activities (Havenvid, Hulthén et al. 2016, Olsson, Espling 2004). However, clients have had problems with both understanding and implementing

partnering (Eriksson 2008). Because railway maintenance is complex by nature, there is a need for partnering in such an environment (Pesämaa, Eriksson et al. 2009). Olsson and Espling (2004, p. 245) mentions four key factors to partnering within railway infrastructure maintenance: requirements for partnering; partnering process; success elements; measurements. Requirements for partnering handles the complexity of the project (i.e. complex projects requires more partnering). Partnering process handles the type of collaboration and has to be driven by the client (Eriksson, Larsson et al. 2017, Eriksson, Westerberg 2011). Success elements regard knowledge transfer of tacit knowledge between maintenance personnel and honest communication. Measurements regard the performance of the contractor and should be done in such a way so that the client can assess both the railway assets and the contractors' performance, agreeing with the findings of Sultana el al. (2013). However, Tadelis (2012) suggest that the law of public procurement hinders the partnering process. He argues that the flexibility of the partnering process is difficult since larger changes cannot be done due to the law. Partnering can be used in any type of contract (Borg, Lind 2014) and the law of public procurement can be managed (Abdi, Lind et al. 2014).

Methodology

The case study was related to Trafikverket (Swedish transport administration) and empirical data was mainly collected from two sources. One source is the contract data base, where the contracts and their design are described together with additional information such as contactor and covered geographical area. The other source is LUPP, which is Trafikverket's tool for business intelligence within the maintenance area, i.e. SAP BusinessObjects. Through LUPP information about events that occur can be collected. Examples of information that have been used in this study is the occurrence of faults, which can be related to the spatial domain (e.g. contract area and track section), the temporal domain (e.g. year, month, week and day), the system domain (e.g. track, signalling and power supply). Also time measures related to corrective maintenance activities initiated by occurred faults can be extracted, e.g. time to respond and be at the location, active maintenance time, and total correction time. Also consequences due the faults, such as number of disturbed trains and delay times can be extracted. The two sources of data are then related to each other by specific contracts as the common denominator. Hence, in this way the contract design are related to the occurred events and its consequences within the geographical area that the contract covers. Data was exported from LUPP and the contract data base to Excel, where they were combined by the logic described above. Thereafter, the combined data base was imported to statistical tools such as Minitab for linear regression analysis.

Collected data covers the time period of 2010-2017. The lower limitation is based on the coding structure of occurred events, which was changed by STA in 2009. This means that data before 2010 is difficult to compare with later data. The upper limitation of 2017 is due to the fact that whole years were preferable to be used within the study. 22 out of 34 different contracts from different regions in Sweden were collected and analysed to be able to connect to the maintenance data. These contracts are procured under different times and contain both high and low amount of traffic.

Contract data were qualitative and describes for instance contractor name, contract type, length of contract, type of pricing, etc. Most of the data were in written form and had to be manually transformed to a data sheet. LUPP data were quantitative and describes number of inspections, error reports, inspections errors, response time, repair time, train delays, etc. LUPP data were connected to the contract data via contract number and track section number to create one common database. Most of these quantitative measurements can be affected by the maintenance contractor. However, some of them can be disrupted by external factors. These external factors could be age of the track, condition of the track, traffic intensity, animal or vegetation. There is also a gap of information between maintenance outcome and maintenance activities. The railway assets condition could have been improved by either reinvestment or maintenance actions. However, this information is not available in the LUPP data, causing uncertainties regarding the estimates of asset condition.

Data analysis

Railway maintenance contracts in Sweden contain many work descriptions and regulations regarding how maintenance should be performed. Since contractors are obliged to follow these regulations, contractors can, in practice, only affect logistical solutions. By logistical solutions we mean how contractors get to the railway tracks and how they organize maintenance activities. Hence, response time to corrective maintenance was selected as response variable for the regression analysis. However, there are some aspects that need to be considered. Firstly, larger contact areas will have a longer response time, simply because of geographical distances. To accommodate for these geographical differences the response time was divided be the length of the track section. Secondly, the contact state that contractors cannot exceed a fixed response time without receiving a fine. These fixed response time are adjusted according to traffic amount, i.e. a track section with heavy traffic have a lower time limit before a fine. Since this paper seeks the outcome of maintenance activities derived from the contract, this aspect is noted but not adjusted for in the regression model.

When the response variable has been selected the data must be cleansed of errors and irregularities. Firstly, response time plus repair time of more than one day or negative amount of time was removed ($t < 1$ and $t > 1441$ minutes). This limitation accounted for around 13 percent of the data. Secondly, the data is divided into 64 different railway assets. To determine what asset types that are relevant for a regression analysis a pareto-chart was constructed, Figure 1.

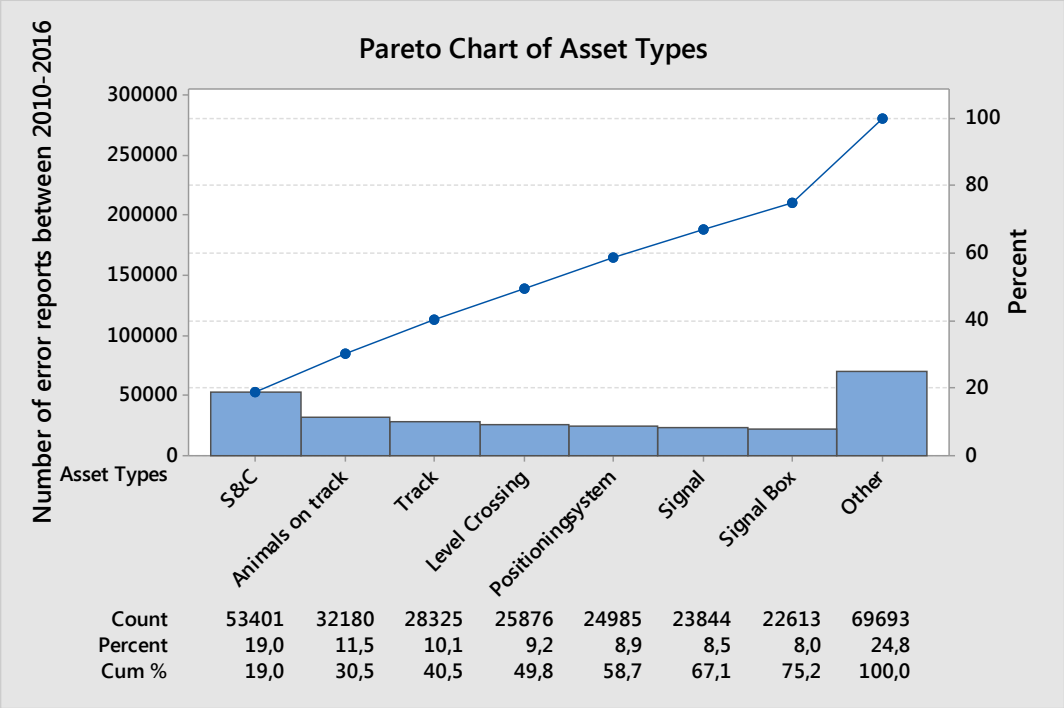

Figure 1 - Pareto chart displaying the total amount of error reports divided into the 64 different asset types

Seven of the 64 railway assets are responsible for 75 percent of all errors on the railway tracks. Three of these seven was selected for the regression analysis; Switches and Crossings; Track; Level Crossing. These three was selected because they are primarily affected by the contractors' maintenance activities and can be reduced by preventive maintenance. Because there is a significant difference in repair time between these three assets, they have to be analysed independently.

From discussions with experts in the field they gave a unanimous view that it takes three years for a contractor to establish themselves within the contract. Therefore the data was divided into two observations (where possible), one during the first three years and one during the last three years. Of the 22 contract, 10 were able to be divided into two observations. Another aspect of a three year average is the reduction of seasonal dependence. Maintenance during winter conditions takes longer than during the summer. Also, contracts in the north have a longer winter period than contracts in the south of Sweden. By having a three year average this effect is reduced.

An initial residual analysis concluded that the response was not normal distributed. To resolve this issue the response was transformed by a logarithm transformation. The residuals then took a more normally distributed form. This indicates that the normal distribution assumption cannot be discarded, making the regression analysis valid. Non-significant regressors were then eliminated by backwards elimination with a level of 10 %.

Findings

The result from the three separate regression analysis determined that four regressors had a significant correlation with response time; number of operating places; number of safety inspections; contract area and track classification. Each data point is the average response time of a track section over a period of three years. The result indicates that more operating places and safety inspection could result in a lower response time for the contractors. The R^2 values were 71.54 % (Track), 63.37 % (S&C) and 76.56 % (Level Crossing), with a significant p-value for the models (all ≤ 0.05) there is a statistical significant relationship between the variables.

Discussion

From the linear regression analysis two continuous variables were significant (number of operating places and number of safety inspections) and two categorical variables (contract area and track classification). When selection response time as the response for the linear regression analysis we initially had two considerations, seasonal and traffic variation. Seasonal variation was adjusted for by using a three year average. Traffic variation was associated with the track classification and was not adjusted for in the model, since we are seeking the relationship between contract and maintenance. Therefore, the two categorical variables were not surprisingly significant for the response. Since the contracts regulates the response time according to the track classification, it would have been a surprise if the variable was not significant. The same argument can be made for the contract area, since there is a difference between contract areas in both the contract themselves but also in geography (e.g. seasonal variation). Although contract area and track classification was expected the results indicate that there is a difference between the contract areas in Sweden. As previously stated, since 2013 STA has moved to a more standardized approach for maintenance contracts in Sweden. The result of this paper indicates that maintenance contracts need less standardization and more individualization. The contract for each contract area should be designed according to the preconditions for the specific area. However, more research is needed to determine this relationship.

Number of operating places is strongly connected to the length of the track, i.e. a longer track section will have more operating places. To simply construct more operating places on a smaller area is therefore not the solution. However, the result does indicate the importance of logistical solutions (as were one of our prerequisites) by the active contractor. When procuring new contracts, number of operating places can indicate the accessibility to the tracks for a contractor. Track sections with high accessibility can have a stronger connection with maintenance outcome, and be more favorable for a contractor to place a bid, although more research is required.

Arguably there is a connection between individual contract design and track accessibility. Today, contractors receive a fine if they exceed a preset limit for the response time. This limit is mostly regulated according to the track classification, rather than existing accessibility. Since number of operating places had the strongest correlation with response time of the four significant factors, accessibility should have a

strong effect on maintenance outcome. This result further emphasizes the need for individualization of the maintenance contracts.

Number of safety inspection was significant in all three regression analysis, with more inspections leading to a lower response time. One interpretation of the significant correlation could be that the contractor that preforms more inspections can use the opportunity to fix issues directly, reducing the inspection time. However, the same argument can be made for maintenance inspections, which were included in the linear regression analysis. Maintenance inspections did not have a significant correlation with the response. The differences between these two types of inspections are that safety inspection are much stricter and follow a detailed instruction from the client. Maintenance inspections are described as a more "gut feeling" approach, and result differ between the technicians preforming the inspection. Due to the more technical focus of a safety inspection the reason behind the correlation can be in the learning process for the contractor. By performing many technical safety inspections the contractor gains knowledge about the asset condition. With this increased amount of knowledge the contractor can plan and predict maintenance more efficiently. Also, the contractor learns the geography of the track and where the assets are. This in turn can reduce the response time for corrective maintenance activities.

Conclusion

This research is a first step of investigating the relationship between contract design and maintenance outcome using linear regression. In this paper three separate linear regression analysis was performed on maintenance and contract data for three asset types: track, S&C and Level Crossings. With response time as response four factors had a significant correlation with the response in each of the three linear regression analysis: contract area; track classification; number of operating places and number of safety inspections. Contract area and track classification were expected to be significant, since response time is regulated via fines in the contract. However, the factors number of operating places and safety inspections were not expected. The results indicate three primary conclusions; individual contract design; accessibility to the track and asset knowledge.

Since the response in the linear regression analysis was response time for corrective maintenance, there is still a need for more research to create a larger picture. However, the research does agree with previous findings of individual contract design (e.g. Abdi, Lind et al. 2014) and the importance of asset knowledge (e.g. Espling, Olsson 2004). For railway clients the procurement and contract process should value asset knowledge, both in-house and by their contractors. With accurate asset knowledge the contract should be designing individually based on the prerequisites of the contract area. By doing so there is a possibility of the increased efficiency of predicting and planning maintenance activities.

Future research should conduct additional analysis on other response variables (e.g. repair time). Response time is only one aspect of the contractor's ability to conform to the contract design. To fully understand the relationship between contract design and

maintenance outcome, additional variables should be explored. Also, a multivariate analysis (e.g. principal component analysis or cluster analysis) could be beneficial to explore the relationships between the different variables in the dataset.

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Graphical methods for railway track condition assessment and prognostics

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Abstract
This paper presents graphical methods for monitoring, diagnostics, and prognostics of the condition of railway infrastructure as support to maintenance planning. The paper also uses graphics to aid univariate, bivariate and multivariate analyses of large datasets of secondary data for linear asset condition assessment in the temporal and spatial domains. We present graphical methods useful for evaluating how the asset degrades and how maintenance actions affect the track condition within different time horizons. Hence, the infrastructure manager and the contracted entrepreneur can share a common view of the asset's current and future condition, as well as maintenance effectiveness.

Keywords: Graphical methods, Prognostics, Railway infrastructure

Introduction
In Sweden and elsewhere, condition assessments are increasingly often used for decisions on when and where to maintain different systems of the railway infrastructure, e.g. power supply, signalling, track, and catenary systems. Special measurement trains that regularly measure important variables are currently the predominant way to perform inspections to obtain condition measurement data for the track and the catenary systems. The infrastructure manager or contracted entrepreneurs plan for the needed maintenance when measures surpass certain threshold limits. The importance of the variable and the severity of the deviation from the designed limit dictates the time bounds before actions are required, as well as the type of action itself. In Sweden, such times can range from acute, requiring immediate corrective traffic management and maintenance actions, up to planned maintenance actions within three years after detection (Stenström, 2015). Thus, measurements trigger much of the maintenance and its planning. If the timetable (i.e., set 18 months before execution) does not allow inclusion of the required maintenance, there is a significant risk that the required maintenance action disturbs the railway traffic, requiring line shutdowns, train delays or cancellations. Condition measurements are thus of utmost importance. However, current diagnostic practice only uses measurements from the last passage of the train to monitor the asset's current condition.

However, to use only the last measurement makes the maintenance decision more susceptible to measurement uncertainty. Uncertain measurements do on the one hand force the infrastructure manager to lower maintenance threshold limits to maintain low system risks for accidents due to undetected faults. On the other hand, this practice increases the false alarm rates.

Additionally, many maintenance actions may themselves reduce the life of the infrastructure items (Arasteh Khouy, 2013; Famurewa, 2013), so the maintenance cost is not limited to the replacement costs of items worn by use and of costs for personnel and machinery (Patra et al., 2009). One example is ballast tamping; an action performed to realign the track. Tamping involves lifting the rails and sleepers while pushing a fork like equipment into the ballast beside the sleepers. The forks will then vibrate, which will fluidise the ballast so that it will flow in under the sleepers. When the machine lowers the track, tamped segments will be higher, which will hopefully reduce some geometry faults. Tamping is expensive, and the vibrating forks crush some of the ballast rocks, reducing ballast life and at the same time producing fine material, which reduces the dewatering properties of the superstructure. A rule of thumb used by the Swedish Transport Administration is that the ballast can withstand ten tampings before it needs replacement or ballast cleaning; maintenance actions that are classified as reinvestments and should improve the condition in such a way that it is considered to restart the life cycle of the ballast.

In the north of Sweden, geometrical deviations may indeed be real, but temporary. A temporary displacement of the track may be due to ground frost, which in turn, is a condition that is due to water in the superstructure or substructure. Hence, a temporary speed restriction until conditions settle may be the proper action for some geometrical deviations, rather than to perform maintenance and possibly worsen the situation. Underestimating (false alarms) or overestimating (undetected faults) will both degrade the condition decision quality thus increasing cost and degrade system usability. (Bergquist & Söderholm, 2012, 2014)

Better data analysis and better asset condition knowledge thus become essential. When the maintenance personnel acquire asset condition data, they usually screen them for causes for alarm, that is, to check whether some assets need attention shortly. Those areas where there is an acute need, or where it is evident that things are about to become acute are further studied, and those areas will be scheduled for maintenance. The rest of the measurement data will likely be stored away for later reference. However, an approach that stops with storing data for later without anyone analysing them is only a waste of storage space. A better way is to use data to help gain an understanding of the asset condition and how the condition changes over time. Data analytics in general (Levrat et al., 2008; Karim et al. 2009) and the reoccurring measurements allow for time series estimations of how the track conditions evolve (Bergquist and Söderholm, 2016). Additionally, it is possible to display, extract and analyse vital information from large datasets. Hence, condition assessment based on proper methodologies and technologies could substantially reduce maintenance-related costs and increase infrastructure capacity while maintaining traffic safety (Arasteh Khouy et al., 2014; Soleimanmeigouni et al., 2018).

Aim

This paper aims to demonstrate how graphic representations and modelling may aid monitoring, data quality assessment, diagnostics and prognostics of the track condition to support asset management maintenance planning.

Method

The method we use is to study stored condition monitoring data for asset measurements, and here we study railway track geometry data.

The studied case, the Boden – Luleå track section

The data for this study stems from measurements of the Swedish Iron ore line. Measurement cars measure the geometry with some regularity and with current regulations, the measurements are performed six times yearly. Four different measurement trains and trollies produced the data between 2007 and 2018. The measurement trains and trollies have somewhat different measurement performance and measurement profiles, such as top speed of measurements, and they have different axle loads.

The studied track section 119 links the cities of Boden and Luleå and is 35 km in length. Besides the Luleå and Boden stations, the section also has stations at a regional hospital in Sunderbyn, a freight terminal station in Gammelstad and a commuter station at Notviken. Track 119 is relatively straight and does not include short radius curves. The track is a single track with meeting point sidetracks, and both passenger and goods traffic use it. Track 119 is a heavy haul line classified to handle a maximum of 32.5 metric tonnes axle load.

Dataset issues

The data analysis of historical data usually starts with an analysis of the data itself; that is, a study of the data quality. One way of discussing big data is the 4V-model of Katal et al. (2013), comprising of data volume, velocity, variety and value. To those, a fifth V have been added, veracity (e.g. Lukoianova & Rubon, 2014). The value of the data depends on their trustworthiness. The dataset in this paper relates to numerical data, in which data veracity may refer to erroneous measurements, and the objectivity of the data and the collection systematics are not problematic per se. However, the veracity may be hurt from poorly calibrated or faulty instruments, erroneous data pre-processing and erroneous data positioning when several data sources are combined to one dataset.

Data may thus be erroneous, may be missing, and measurement data always contain noise. In all likelihood, the data needs cleaning before the data quality is sufficient for the analysis task. Often, the quality will remain too low, for instance, because of a too low information-to-noise ratio even after the analyst has cleaned the data. The risk that the database does not contain all that is relevant to the goals of the study is always present. Assume that the analyst will use the data for a regression task to find correlations among properties or variables. If the database lacks information about important events, the regression analysis will, at best, be poor or fail to find significant correlations. At worst, the correlations will be strong and significant, but pointing in the wrong directions. Data correlations may just be reactions to an external, but unknown signal, so rather than each other's causes, both are reactions to the underlying event.

The analyst extracting data from numeric databases should be aware that the data often is secondary, i.e. it was collected for other purposes than the intended goals of the present analysis. Using secondary data means that the analyst must scrutinise the original objectives to see if they interfere with the questions that the analyst is trying to answer. If the original goal may have been to supply measurements for a highly critical process where accuracy is paramount, and where one would like to spot any errors immediately, great trust in the data may be warranted. Even so, also safety-critical data contain errors that are readily obvious when they are scrutinised from a new vantage point. The analyst must also check the appropriateness of the data from other viewpoints, such as if the

statistical properties of the data are compatible with the necessary analyses techniques that are to be employed.

Poor accuracy may also result from organisational gaps, for instance, because the user of the data has not made the data supplier aware that there are issues with them. Such issues may, for instance, not being forwarded to the correct recipients since the information channels are not working correctly. Proper use of the statistical methods relies on the assumption that data are independent and normally distributed. Data seldom are, but one can often salvage datasets where these assumptions are violated by choosing proper statistical tools or data transformations.

Data quality assurance in the studied case

The data for the current graphical approach to railway track condition monitoring entails many of the previously discussed issues. They are secondary data since they were sampled to evaluate the current asset status, rather than to form the basis for condition prognostics, that is, for forecasting purposes. The ultimate purpose of the analysis is to forecast asset conditions with enough accuracy so that appropriate maintenance planning can commence far enough into the future so that train schedules are not disturbed.

While this distinction between assessing asset condition and obtaining condition data useful for forecasts may seem like a minor one, there are issues with the data that a diagnostic analysis of the current asset status will not reveal. Diagnostics of the current state assessment is a snapshot of the asset condition, but it is not a motion picture, whereby one could estimate how the condition will develop over time. Prognostics require both. The measurement trains measure with differing times between measurements, and the measurements need to be linked together to evaluate the speed of change of the measured property. A reasonable way to do this that will allow for is to estimate conditions within regular intervals, based on some method, for instance by using interpolation of historical data, for instance using splines, linear regression, or just to use the latest measurements as the best estimated for the condition at a specific time. All methods have their strengths and weaknesses. Here we used averaging of measurements obtained within the latest quarter to estimate the condition, due to simplicity and extrapolation stability.

To link measurements over time means that one needs to certify that the second record relates to the same asset or asset segment as the first record. Better still if measurements have been obtained with the same equipment and personnel, with updated calibrations. To acknowledge such errors, one needs a frame of reference, that a single measurement will not provide. It is, therefore, not surprising that condition datasets obtained for a particular asset within a short time difference can differ substantially due to measurement issues rather than condition variation. Maintenance personnel did not find such issues when they only used the last and most current measurements.

Positioning is, due to the linking of measurements in time, a central property. Since we are discussing railway assets that often remain in position for tens of years (for instance track) and sometimes hundreds of years (for instance, bridges and tunnels), one may assume that positioning is trivial. If the spatial information of the data is correct, it probably easy to link measurements. If not, the analyst needs to use some strategies for overcoming the spatial errors to estimate the speed of change of the properties. In the studied case, positioning errors have been considerable, and the strategy to overcome them has been to use data binning to split the track into segments long enough for failures to have a high probability of falling into the same segment during consecutive measurements, see also Bergquist & Söderholm (2012, 2015).

Another potential difficulty is that some external disturbances have affected the asset or the measurement equipment between measurements, which would lead to errors in the rate of asset degradation. Usually, maintenance prognostics aim to predict when the condition of the asset has degraded to such a poor state that it needs maintenance. The degradation rate of the asset property is, therefore, often what one seeks to combine this information with the state itself for condition predictions. However, sometimes the recorded asset condition has improved between measurements. Some of these unexpected events may be due to maintenance actions that one can find in other databases. If there is a viable reason for an improved asset condition, the proper way to handle things could be to remove prognoses until the deterioration rate is reasonably stable. A procedure to monitor improvements could include triggering alarms for larger improvements than a threshold level based on the expected normal variation. Improvements that are larger than what can be expected just by measurement uncertainties and which cannot be explained by external factors would mean that the current model is not valid for describing current data. In the case of the subarctic railway track maintenance studied here, such improvements that are known to influence readings could be ground frost effects, maintenance or due to changes of the measurement equipment such as calibrations. Some detective work may reveal the actual causes. Generally, events that are due to pure measurement errors, such as zero recordings, are easy to find and remove.

Other unusual observations may also be easy to determine as erroneous, such as when the recordings are orders of magnitude different from the regular measurements. A multivariable bi-variate scatterplot as depicted in Figure 1 is useful to get an overview of the data. Two of the studied variables, two standard deviations of twist with 3 m or 6 m base has had several recordings stemming from another distribution, which is an illustration of the data with different orders of magnitude. The twist fault that can lead to derailments and it is thus safety critical and regularly measured. Figure 2 shows this deviation in detail. The twist data also contains zeros, which given the segmentation approach and the standard deviation studied here used is almost impossible, and the analyst should remove such observations. The time interval where ground frost events are likely should be possible to estimate for railways using local knowledge.

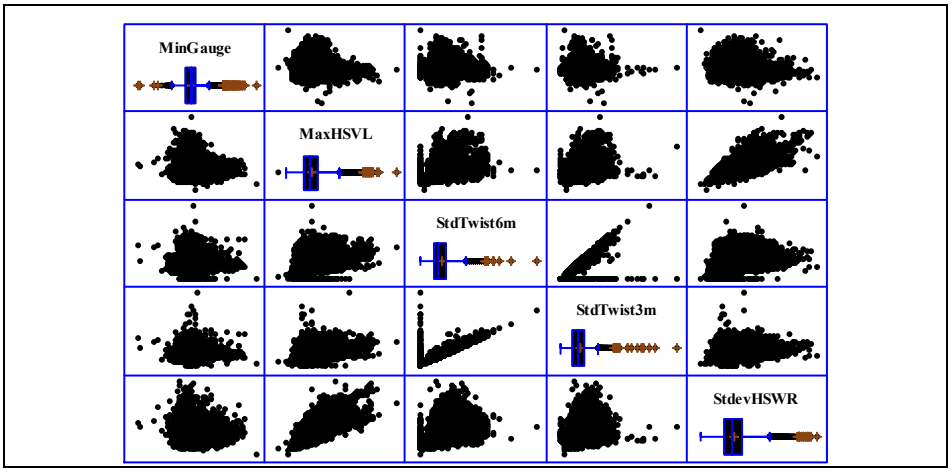

Figure 1. Matrix plot of some measured track properties important for railway track safety, equipment reliability and passenger comfort. Note that the twist measurements split correlations into two groups.

In many cases, strange observations will remain mysterious. The analyst should consider all possibilities and consequences for keeping or disposing of the strange data where the culprits are not obvious. If, for instance, the intended use of the data is condition prognostics, a restart of the prognostic model could help, depending on the model design.

For track geometry conditions, the maintenance itself will often unsettle the track superstructure. The first or first few measurements after maintenance may indicate that the superstructure geometry is well within its targets, but then the conditions may degrade rapidly until the superstructure has obtained a new, predictable, deterioration rate. If this happens, it may be advisable to restart the model. If the empirical prognostic model uses recent data to estimate future conditions of the property, the model is likely to generate poor predictions until the asset has settled. In the track case, a steady condition deterioration indicates that that the track has been subjected to sufficient transported weight or temperature variations for the ballast to wiggle into a more stable configuration.

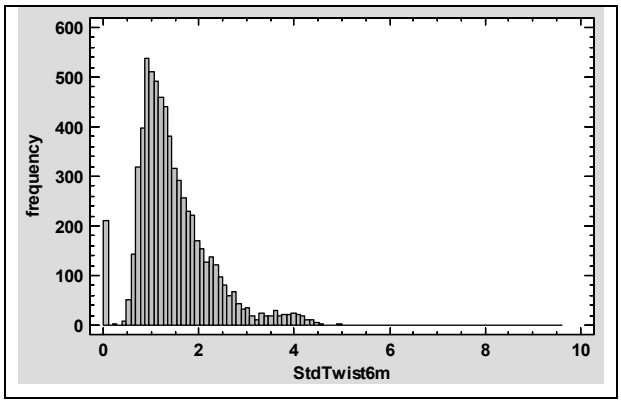

Figure 2. Histogram of the 6 m twist standard deviation reveals that two distributions have been combined, one centred just above zero. Further studies show that part of the data has a mean that is orders of magnitude lower than the rest, which indicates erroneous measurements.

Seasonal effects may be necessary to include in the prognoses models. As already stated, reoccurring events such as winter frost may influence conditions. Geometrical conditions after the spring thaw or the autumn frost seasons may improve by themselves until the next measurement since frost is a function of the local water content of the substructure and temperature. Frost may, therefore, affect the track substructure or superstructure differently with considerable local variation; differences that dissipate as the frost thaws or has settled over the whole track segment. Temperatures themselves are also important as they force the material to expand and contract, causing stresses in the linear assets due to different thermal expansion coefficients.

All of the above effects can be studied using time series plots. Figure 3 shows a time series plot of one of the critical geometrical properties, twist over 3m. The figure displays both the measurement data (circles) and quarter means (crosses). The figure also shows a Kalman filter model including a prediction confidence interval for the model based on the variation in the sample, as well as an upper confidence interval of the model data. The Kalman filter is based on the quarterly average since the sampling is not regular. The measurement frequency is too low and too irregular, so the model does not allow a standard seasonality component of the time series, but the Kalman filter is used to assess the current state but also predict future conditions. The model does in this case a poor job of estimating the data behaviour. The vertical dashed lines represent known maintenance (tamping). The twist variable must not exceed certain threshold values for comfort and

safety, so large absolute values are problematic. The expectancy is that maintenance will reduce the absolute twist, at least in the short term. Studying the observations in this plot reveals that in 2009, the absolute value decreased without obvious reasons. Since the model needs to have some degree of robustness against random variation such as measurement noise, it did not respond to the rapid decline, nor did it pick up the rapid degradation rate between 2010 and 2015. The 2009 improvement suggests some maintenance action that was not recorded in the data. Interestingly, the 2013 tamping does not appear to have improved the twist. A speculation is that the degradation rate has lessened as a result of the tamping. The 2014 tampings did, however, reduce the absolute value of the twist. Judging from the data, it appears that the situation again improved in 2016, so it is possible that had been maintained or that there was something done with the measurement equipment, but this is not clear from available data. Another possibility is that the track measurement systems were updated or calibrated during these episodes. The situation improved again in 2017, to such a large extent that the model had automatically restarted.

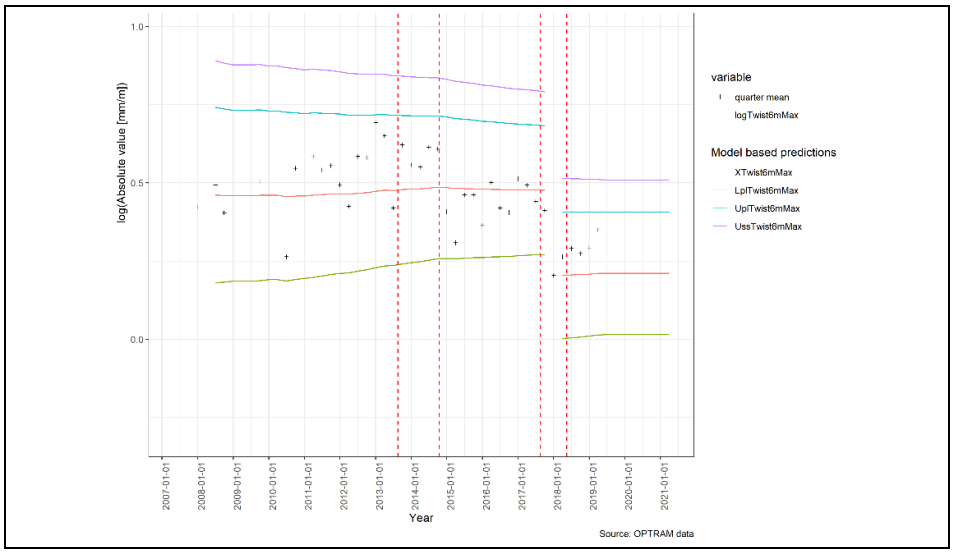

Figure 3. Time series model of the 3m twist variable for a 200 m segment obtained from track section 119 between 2007 and 2019.

Graphical condition assessment and prognoses

Graphics that are pictorial representations of data have the inherent property that they can make complex phenomena more easily interpretable (see, e.g., Bergquist & Söderholm, 2012, 2015). We will here discuss pictorial representations of data in the form of 2D heatmaps, and use colours to represent dimensions beyond the 2D imagery. Figure 4 shows a heatmap of data representing the condition of the track twist.

Figure 4 shows railway twist, here the 6m twist. The vertical axis represents the spatial information, and the horizontal axis represents the temporal information. The colours of the heatmap denote the twist values. The plot was created in R, using the ggplot2 package and the geom_tile command. The colours appear as streaks of mostly orange or yellow from left to right. The figure represents quarterly averaged data from ten years. The horizontal segmentation is a representation of 200 m segments of the track section. The data for the maximum twist of the segment constitute the foundation for the model output, and the maximum twist values are those that are essential for safety concerns. Figure 4 does not show maintenance actions, but all segments were tamped at least three times.

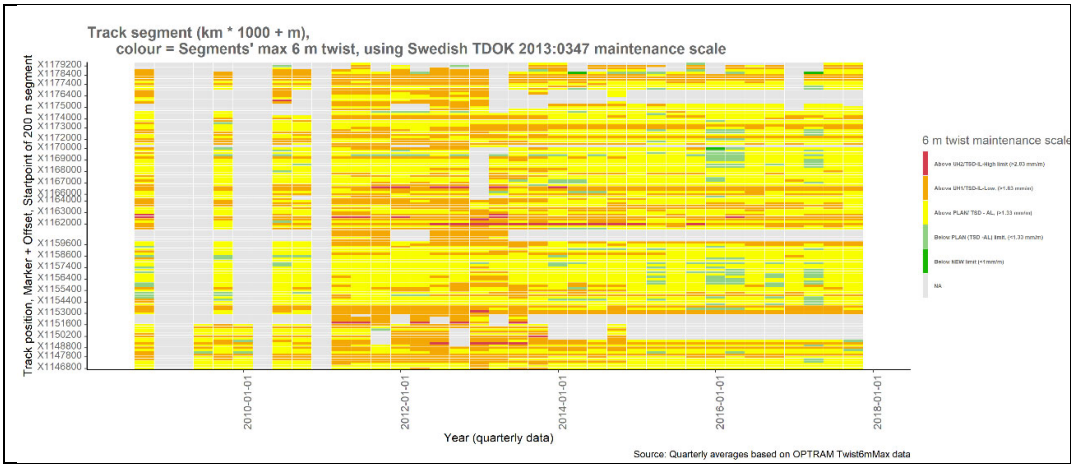

Figure 4. Graphical representation of track section 119 twist (6m) data from 2008-01-01 to 2018-03-31. The vertical axis represents the spatial dimension of the track, and the horizontal represents the temporal.

The observations have been segmented into bins representing maintenance classes, where dark green represents segments and times where the maximum 6 m twist for the segment was lower than the stipulated maximum for new tracks. Many conditions are worse than new, but they are still not of any concern (below the PLAN limit). Worse still are segments that are above the PLAN limit, which means that the maintenance organisation should consider maintaining the segment. The plot also shows even further degradations. When the track conditions have surpassed the UH1 (maintenance 1) limit, the maintenance organisation is required to plan maintenance so that they have performed it before the condition has reached the next level, UH2 (maintenance 2). If the condition exceeds the UH2, the maintenance organisation is required to maintain immediately. If the condition surpasses the KRIT (critical) limit, the track manager needs to close the track or impose speed restrictions until conditions have improved.

It is possible to add another layer to the plot, showing the performed maintenance, and Figure 5 shows the plot with a maintenance layer added. In this figure, it is clear that problematic segments usually remain as problematic even after tamping, since the colour remains the same.

The use of a geographical map for localisation purposes is attractive for linear assets such as railway track, but also for localising point assets (e.g. switches and crossings, bridges, and level crossings) as part of the infrastructure. Hence, a combination of heatmaps and geographical maps are useful for maintenance planning purposes. The use of GIS-applications and layers can also be used to integrate further information about the track surroundings that are useful for diagnostic and prognostic purposes, e.g. soil and water conditions. Furthermore, data about the weather should be useful for diagnostic and prognostic purposes. One example is the temperature, where low temperatures increase the risk for rail break and high temperatures increase the risk of buckling.

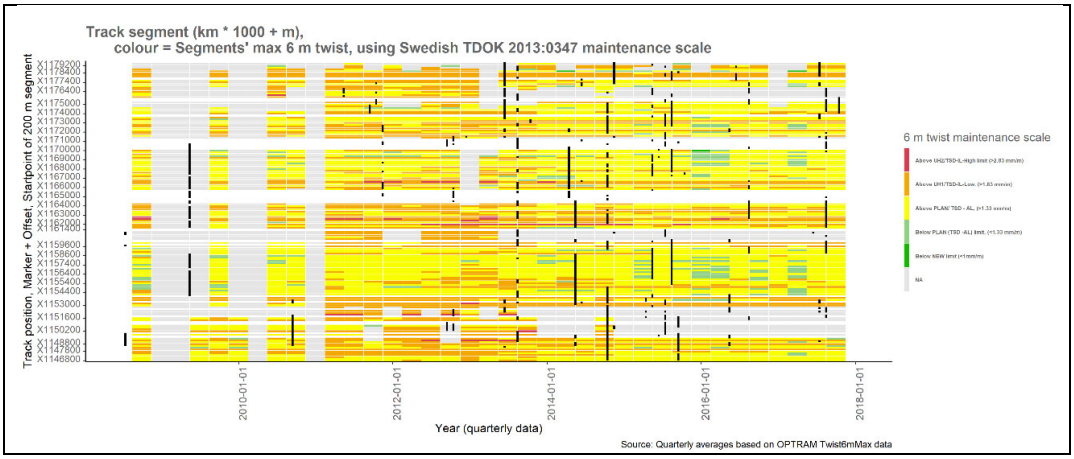

Figure 5. The image properties correspond to Figure 1, but here, the maintenance actions are also added (vertical black lines).

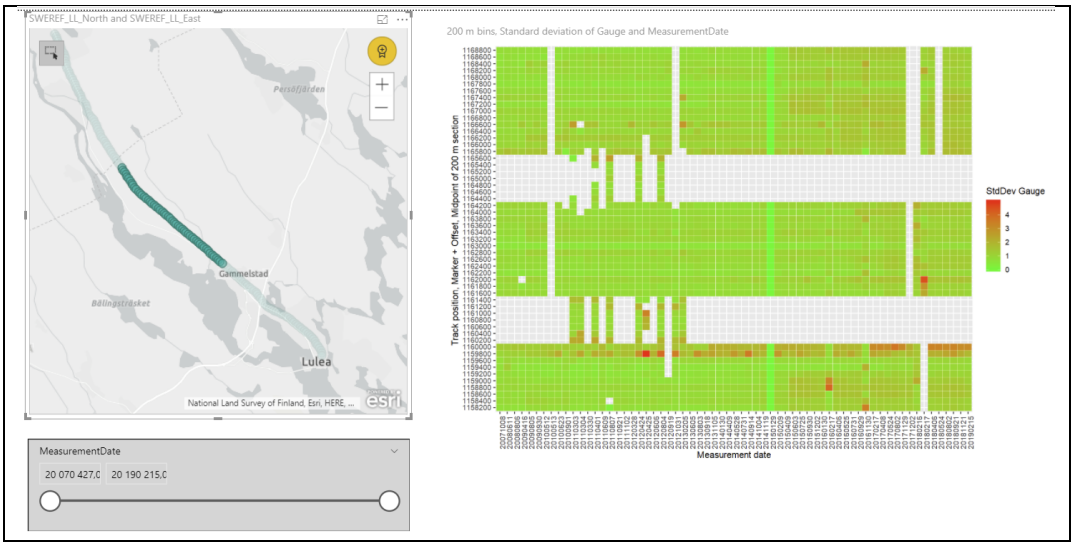

Figure 6. Power BI Desktop colourmap representation of, in this case, the gauge variation, where red segments vary the most.

Microsoft Power BI Desktop can also use R scripts and allows the user to run a collection of R packages for graphical presentations and analyses. This feature also allows for zooming, and Figure 6 shows an interactive display, allowing the user to zoom in on particular periods and track segments. In this plot, the colours are auto-scaled, from green in the colourmap representing segments with little gauge variation, to red where the variation is considerable. The Plotly package in R can also produce an interactive plot.

Another source of information that should be valuable when performing diagnostics and prognostics is the actual maintenance actions done on a segment (Arasteh Khouy, 2013; Famurewa, 2013). However, when dealing with the basic maintenance contracts, this information is stored locally within each contract (often in scanned PDF within a Share point solution) and not easily accessible for aggregated analysis. Appropriate usage of a standardised maintenance system (e.g. Maximo) should enable a more comprehensive analysis of performed maintenance actions (see, e.g., Al-Chalabi, 2018). The inspection system Bessy (e.g. inspection occasions and inspection remarks), the fault

reporting system 0Felia (e.g. faults, repair times, and repair actions) also contain some useful additional information about maintenance actions and the asset condition. The asset register (BIS) also contains some information that might be useful for analysis purposes, e.g. type of items and installation year. The relevant age of infrastructure items can be calculated by a combination of the calendar time and the yearly tonnage.

Contributions

The datasets that the measurement trains produce are large and riddled with defects, and things to consider for sifting out the relevant results are presented. The graphical plots show that some maintenance actions are not effective, that there are underlying factors that make some track segments to outperform others, that continue to be troublesome despite repeated maintenance actions. Such sections that have been troublesome for years may eventually need non-standard corrective maintenance or reinvestment stand out in the spatiotemporal graphical overview. The findings show that a proper analysis may reveal how much a maintenance action improves the asset condition, not only directly after the action, but also if the long-term deterioration rate is affected. Hence, both the infrastructure manager and the contracted entrepreneur can share a common view of the asset's condition and maintenance effectiveness as a basis for continuous improvement.

Acknowledgements

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CBM Maturity Model (CBM^3) for asset owners in the process industry

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Abstract

While the attention for Condition-Based Maintenance (CBM) has been growing, both academically and in practice, many organizations are struggling with the adoption and deployment of advanced condition monitoring technologies. The purpose of this research is to develop a CBM Maturity Model and CBM Maturity Assessment that can aid asset owners and maintenance managers in the development of their CBM practices. The maturity model, assessment instrument and assessment procedure have been developed with and tested at two large asset owners in the Dutch process industry following the design science methodology.

Keywords: Condition-Based Maintenance, Maturity model

Introduction

Condition-Based Maintenance (CBM) is one of the means to optimize the utilization and useful lifetime of our current asset base and thereby, to make our industries more sustainable. CBM aims to predict future malfunction of an asset by monitoring several conditions (e.g., temperature, vibrations), so maintenance can be executed at "just the right time" (Jardine, Lin & Banjevic, 2006).

In recent surveys in northwest Europe up to 60% of organizations indicated they have concrete plans or intentions to use predictive maintenance in the near future (PwC & Mainnovation, 2018). In those same surveys, only 11% of organizations indicated they are already employing predictive maintenance practices. In reality, many organizations are struggling with adopting advanced condition monitoring (CM) technologies (PwC & Mainnovation, 2018) and, when adopted, with fully diffusing these technologies throughout the organisation (Van de Kerkhof, Akkermans & Noorderhaven, 2016). Unfortunately, there is a lack of relevant, actionable guidance for industrial maintenance organizations to meet their maintenance ambitions (Bokrantz, Skoogh, Berlin & Stahre, 2017), as well as a lack of understanding of what optimal usage of CBM entails for maintenance organizations (Tiddens, 2018).

Maturity models are helpful tools for addressing these issues (Wendler et al., 2012). Based on the assumption of predictable patterns, maturity models represent theories about how organizational capabilities evolve in a stage-by-stage manner along an anticipated, desired, or logical maturation path (Pöppelbuß & Röglinger, 2011). In general, the term 'maturity' refers to a state of being complete, perfect, or ready (Schumacher et al., 2016). The main purpose of maturity models is to help an organization or entity reach a more sophisticated maturity level (Mittal et al., 2018), by enabling the organization to assess the as-is situation, by picturing the desired 'final' stage of maturity and by providing guidance on how to improve (Wendler et al., 2012).

Although the maturity concept emerged out of quality management (Shewhart, 1931), the first instruments with maturity stages building on each other were developed by Crosby (1979: quality management process maturity grid) and Nolan (1979: maturation of data processing). The development of maturity models really took off since the Software Engineering Institute introduced the Capability Maturity Model (Paulk, Curtis, Chrissis & Weber, 1993). Since then, the maturity concept has been widely applied across many domains, such as software development (e.g., Haase, 1996; Subramanian, Jiang & Klein, 2007), project management (e.g., Kerzner, 2002; Hilson, 2003; Pennypacker & Grant, 2003), knowledge management (e.g., Hsieh, Lin & Lin, 2009; Khatibian, Hasan & Abedi, 2010), and many more (see Wendler et al., 2012 for an overview). Recently some maturity models have also been developed in fields that are related to CBM, such as digitalized manufacturing (e.g., Mittal, Khan, Romero & Wuest, 2018), big data (e.g., Comuzzi & Patel, 2016), asset management (The IAM, 2016), and reliability-centred maintenance (Hauge & Mercier, 2003). Yet, an actual CBM maturity model is still missing.

In this paper we aim to develop a descriptive maturity model (Pöppelbuß & Röglinger, 2011) for the deployment of Condition-Based Maintenance by (the maintenance organizations of) asset owners in the process industry. The main purpose of this descriptive maturity model is to enable asset owners and their maintenance managers to assess their current practices and capabilities. The outcomes of these assessments can then be used to create improvement plans. To achieve these objectives, the maturity model (the reference model) is translated into an assessment instrument and accompanied by an assessment procedure. Hereby we answer the call for relevant, actionable guidance for industrial maintenance organizations (Bokrantz et al., 2017).

Methodology

We have adopted the design science paradigm (Hevner, March, Park & Ram, 2004) for developing and evaluating the maturity model, the assessment instrument and the assessment procedure. Typically, design science research seeks to create innovative artefacts that are useful for coping with human and organizational challenges by following an iterative process of development and testing (Hevner et al., 2004). Our methodology, as depicted in Table 1, is based on the procedure of Becker et al. (2009), who have translated the design science principles into a dedicated procedure for the development of maturity models. Following the recommendations of Wendler et al. (2012), we have applied a combination of multiple methods in different research states to evaluate the maturity model's completeness, validity, usefulness and ease of use. Specifically, the study has been performed in three consecutive phases: (1) scoping, (2) development and testing of the maturity model, and (3) development and testing of the assessment instrument and assessment procedure.

Table 1 – Methodology

Phase	Activity	How
1. Scope	a. Identify need	Based on literature review and practitioners' request
	b. Define problem, design requirements and development strategy of maturity model	Based on focus group session with future users and domain experts
2. Iterative development of maturity model	a. Design first version of maturity model	Based on literature review and interviews with domain experts
	b. Evaluate first version of maturity model	Domain expert evaluation: focus groups and in-depth interviews
	c. Design second version of maturity model	Incorporate feedback from first evaluation
	d. Evaluate second version of maturity model	Domain expert evaluation: survey
3. Development of assessment method	a. Design assessment instrument	Based on maturity assessment instruments in industry
	b. Design assessment procedure	Based on maturity assessment procedures in industry
	c. Evaluate assessment instrument & procedure	Practical setting evaluation: test at multiple facilities and survey participants

The maturity model and assessment method are developed in cooperation with two large asset owners in the Dutch process industry: Tata Steel and BP. Seeing practice impact in new ways, we followed a leading pathway (Simsek, Bansal, Shaw, Heugens & Smith, 2018), working with Tata Steel's central domain expert to establish the research design, as well as the first version of the maturity model, the assessment instrument and the assessment procedure. Most focus group sessions, as well as the practical setting evaluation, have been held with domain experts from these organizations. To safeguard the external validity of the developed maturity model, additional focus group sessions have been held with domain experts from other asset owners and knowledge institutes in the Netherlands.

Scope

In the first phase, scoping, we evaluated the practical and theoretical need for the development of a new maturity model. The theoretical need was assessed by identifying calls for research and guidelines (Bokrantz et al., 2017; Tiddens, 2018) and by reviewing existing maturity models – no maturity model yet existed for the usage of CBM. The practical need was assessed by interviewing managers and domain experts from the organizations involved in our research program, asking whether or not and how a maturity model would aid them in improving their CBM practices. The results from both endeavours confirmed the need for a CBM maturity model.

Then a focus group session was held with maturity model experts and domain experts from Tata Steel to define the problem, the design requirements, the development strategy, and the future user group.

Development of maturity model

The maturity model has been developed in four consecutive steps. First, we have reviewed the structure and content of existing and accessible maturity models – from

scientific journals, conference proceedings, and knowledge institutes, as well as Tata Steel's prior developed maturity models – to identify what structure best fits the application of CBM by asset owners and to ensure a structural fit with Tata Steel's maintenance related maturity models. The content of the maturity model was developed first and foremost by studying scientific literature and reports, books and guidelines from knowledge institutes, and by reviewing interviews with domain experts that had been held before within the research program (139 at Tata Steel, 154 at BP, 32 with other asset owners and service providers). The few gaps that initially remained were closed by performing (5) additional interviews with domain experts.

After the first version of the maturity model had been developed, 12 focus group sessions were scheduled with domain experts from the two asset owners and two knowledge institutes (see Table 2). The participants for the sessions were selected as such that, as a whole, their knowledge covered all maintenance disciplines and all types of CM technologies, and the key stakeholders within the organisation were represented (maintenance, operations, projects, IT, R&D).

During these sessions participants were asked to evaluate the maturity levels (would you add/remove levels, would you adjust the description of levels? If yes, why and what/how?), the categories (would you add/remove/adjust categories? If yes, why and what/how?), and the description of each category-level combination (would you adjust the description? If yes, why and how?), based on the evaluation template of Salah et al. (2014). All sessions were recorded and transcribed.

Table 2 – Focus group sessions

	Focus groups	**Total participants**	**Length of each focus group**
Tata Steel	3	17	1-2 hours
BP	7	18	1-2.5 hours
Other	2	4	1.5 hours

After the sessions the written feedback was aggregated per maturity level, category and description. All feedback that was considered relevant was used to adapt the first version of the maturity model into the second version. This was done primarily by the main researcher, in accordance with Tata Steel's central domain expert.

As the final step, a survey was sent to all participants of the focus group sessions to evaluate the maturity model's relevance (the elements are relevant to CBM maturity), comprehensiveness (all elements are included), accuracy (elements are correctly assigned to maturity levels) and mutual exclusiveness (elements are clearly distinct), following the evaluation format of Salah et al. (2014).

Development of assessment method

The assessment method consists of an assessment instrument and an assessment procedure that describes how the instrument should be used. The design specifications for both were determined in focus group sessions with future users at Tata Steel and BP. As Tata Steel's central asset management department had over 10 years of experience with developing maturity models and performing maturity assessments, we could build on their instruments and procedures for designing the CBM Maturity Assessment.

After development, two assessments were performed to test the usefulness and ease of use of the assessment instrument and procedure, one at Tata Steel and one at BP. In these assessments we followed the prescribed procedure. Both sessions lasted 2 hours. At the end of each session, the participants received a survey to evaluate the usefulness

and ease of use of the assessment instrument and procedure, following the evaluation format of Salah et al. (2014).

Findings

We define CBM maturity as a state in which a 'facility' (an organizational subunit) makes optimal usage of CBM. In particular, when a facility has reached CBM maturity, the facility applies the optimal combination of CM technologies (that are currently available) to all assets that could benefit from CBM and optimally uses the information provided by these CM technologies.

According to the domain experts, a facility is the most meaningful unit of analysis in the process industry: for most sites the entire production process is too large to manage by a single production and maintenance department, thus the organization is divided into smaller teams, each responsible for a subset of the asset base. A facility is the organizational unit that is responsible for managing their subset of the asset base, such as a production line or cracker unit. Each facility has their own production teams, maintenance team(s) and management.

It should be noted that the exact features of the optimal state of a facility are likely to differ per facility and change over time. First, the applicability and usefulness of CBM is dependent upon the characteristics of the assets (e.g., degradation mechanisms) and the production process (e.g., consequences of breakdown). Secondly, new CM technologies and the capabilities of existing CM technologies are still being developed. To stay mature, the organization thus needs to keep track of changes in their asset base and innovations in CM technologies, and adapt their CM technology portfolio accordingly.

CBM Maturity Model

In our observations of CBM practices and in line with maintenance (e.g., Macchi & Fumagalli, 2013; Hauge & Mercier, 2003) and asset management maturity models (e.g., The IAM, 2016; Volker, Van der Lei & Ligtvoet, 2011), we identified five logical states of using CBM. In the first state, CBM is not used, for example because assets are not maintained. In the second state, CBM is used reactively. None of the assets are monitored structurally, but when an operator or a maintenance technician encounters an anomaly with an asset, an external CM service provider is asked to properly investigate the asset in order to better prepare maintenance activities.

In the third state, CBM is used structurally and planned, mainly to improve the efficiency of maintenance. In this state, the organization has built some internal capabilities with easy-to-learn and easy-to-use CM technologies (Nicholas, 2016) and uses CBM to reduce corrective and periodic maintenance activities.

In the fourth state, CBM is used proactively to increase the reliability and productivity of (mainly important) assets. Here the organization has decided to invest more heavily in CBM and has started experimenting with multiple hard-to-learn, hard-to-use and specific CM technologies, for example in a dedicated Condition Monitoring Program. Better equipped CM specialists have become important partners in reliability improvement initiatives, as insight into the assets' condition aids in identifying why the assets failed. In this state, the higher costs for CBM are justified by even higher gains from reliability and asset productivity improvements.

In the fifth state, CBM is used optimally, or World Class, to increase the value realised from the asset base. Here the facility has ramped up all successful CM technologies, while maintaining the exploration for new CM technologies. The facility has embraced asset management (as described in ISO 55.000) and information about

the assets' condition has become an essential component of many asset management decision processes, including optimization of production, inventory management, project prioritization, and designing new assets. Because processes become more stable and predictable now, the facility starts actively reducing buffers, such as redundancy and stocks. To facilitate this, CM teams have gained a central position in the organization and have become well-connected to knowledge institutes, equipment and CM technology manufacturers and specialist CM service providers.

Through our studying of the diffusion of CBM practices (Van de Kerkhof et al., 2016), a literature review and additional interviews at Tata Steel and BP, we distilled twelve categories of elements that are required to perform CBM successfully. These categories describe characteristics of the technology, the organization or the people involved.

In the technological realm, five categories were relevant. First, the category *CM technologies* describes what CM technologies are used by the organization and how they are used, starting off with ad hoc and infrequent inspections and moving towards high-frequent and automated measurements. Second, the category *Assets* describes to what assets CBM is applied, starting with the assets that are easy to monitor, but incorporating more and more assets for which the highest value of monitoring can be attained towards higher maturity levels. The third category, *Decisions*, describes what decisions are (also) based on information about the assets' condition, starting with maintenance decisions only, but moving gradually towards other asset management decisions as well. The fourth category, *Data*, describes what data are needed to be able to perform the CM analyses and make the decisions thereafter, including for example master data, financial data, failure data, production data, and environmental data. The fifth and last technological category, *IT-infrastructure*, describes the characteristics of the IT-infrastructure, starting with stand-alone systems for each CM technology, but moving towards a standardized IT-infrastructure that enables smooth ramping up of successful CM technologies.

Also in the organizational realm, we identified five main categories. The category *Strategy and goals* describes the strategy of the organization (or facility) and the main KPIs for the facility, moving from minimizing maintenance costs to improving reliability, production and the value realised from assets. The category *Structure* describes how the monitoring is organized, first relying mostly on external CM service providers, but moving towards a structure in which centralized and decentralized CM teams work in close cooperation with specialist external CM service providers. The category *Budget and capacity* describes what budgets and capacities are reserved for condition monitoring, CBM, experimenting with new CM technologies and maintaining adopted CM technologies, moving from no or very limited budget and capacity to structural and dedicated budget and capacity for each of these purposes. The category *Processes and documentation* describes the processes and documentation that are used for the CBM practices, gradually defining processes and documentation for monitoring and decision-making, for experimenting with and implementing new CM technologies, and for evaluating and managing the CM technology portfolio. Important documentation includes standard CM reports, maintenance concepts, CM concepts (how an asset type is monitored), a list of critical assets, and an overview of what CM technologies are applied to each asset. The final organizational category, *Governance*, describes how the CBM practices are governed, including defined procedures, specified acceptance criteria, certification of CM specialists, formal agreements about data rights and responsibilities, and obligations for project managers to consider CM technologies in their projects.

Finally, we classified two categories that focus on the characteristics of the people involved in the CBM practices. First, the *Knowledge, skills and abilities* of those people is one of the key determinants of the success of a CBM practice. Specifically, domain knowledge about the asset and its (production) context – what is 'normal', how can it fail, what influences degradation, how does degradation influence production – and proficiency with CM technologies are determining the quality of analyses and decisions. Second, the *Culture* of the organization has to match the CBM practices for the practice to be sustainable. Typically organizations progress from a firefighting culture towards a bureaucratic culture, after which the organization can transition to a reliability and asset management culture.

In addition, multiple maintenance managers indicated during the domain expert evaluation that the rationale was lacking in the first version of the CBM Maturity Model: "why should our facility aim pursuing a higher maturity level?" Therefore we added one category to the maturity model: *Value*. This category describes the primary gains that can be realised at each maturity level, going from better and more efficient maintenance to increased productivity and return on assets. The design for the CBM Maturity Model is shown in Table 3.

Table 3 – CBM Maturity Model design

		Level 1: No CBM	**Level 2: Reactive CBM**	**Level 3: Planned CBM**	**Level 4: Proactive CBM**	**Level 5: World Class CBM**
Value	Value					
Technology	CM technologies					
	Assets					
	Decisions					
	Data					
	IT-infrastructure					
Organization	Strategy & goals					
	Structure					
	Budget & capacity					
	Processes & documentation					
	Governance					
People	Knowledge, skills & abilities					
	Culture					

CBM Maturity Assessment

The assessment instrument and procedure are designed as such that they can be integrated in Tata Steel's assessment program. This program focuses on facilitated and self-assessments to aid facilities in improving their asset management practices. Specifically, the assessments help in understanding how well a facility performs certain asset management practices, in identifying gaps, in creating improvement plans, and in transferring knowledge between facilities.

The design of the assessment instrument is displayed in Figure 1. For each of the twelve categories, the assessment group can assign the best fitting maturity level (score and description). When selecting a score, the group has to present evidence that supports their choice, such as data or references to documentation, interviews or

observations. If the maturity level's description doesn't perfectly match their current situation, they can outline the differences in the comments. The scores are automatically converted into a vertical spider diagram, making it easy to see what categories are at a lower-than-desired maturity level.

Category		Score	Description	Evidence of score	Comments with score
Technology	CM technologies	4			
	Assets	3			
	Decision	3			
	Data	3			
	IT-infrastructure	4			
Organisation	Strategy & goals	2			
	Structure	3			
	Budget & capacity	2			
	Processes & documentation	3			
	Governance	2			
People	Knowledge, skills & abilities	3			
	Culture	3			

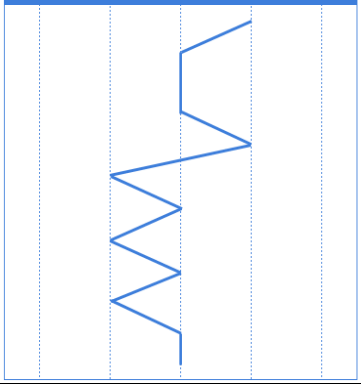

Figure 1 – Design CBM Maturity Assessment instrument

In the practical setting evaluation it was confirmed that the assessment can best be performed with an independent facilitator who understands the CBM Maturity Model, clarifies descriptions with examples, and challenges the participants to get a shared and correct view of the situation.

The assessment procedure consists of six steps. First, the facilitator and the facility's initiator (often a management position) agree on a plan for carrying out the assessment, including the date, who is going to participate, and whether or not a preparatory session is required. If so, a brief CBM awareness session is held for the assessment's participants two weeks prior to the assessment. Then, secondly, the CBM Maturity Model is shared with the participants about one week prior to the assessment. This gets the participants thinking about the topic and their maturity already, and it speeds up the introduction during the assessment session.

The third step is the assessment itself, guided by the facilitator. The ambition is to get a common shared view on the maturity of each element in the assessment. If the group does not reach a consensus or the score is in between two scores, the lowest score is to be selected. In these cases, the comments box is used to explain the score. It was noted by the practitioners that low scores are at least as valuable as high scores, since these provide opportunities for improvement. These scores were supported by comments as well, so that it was easier to define the steps to improve the maturity in the next step.

In the fourth step, the facility's management translates the assessment results into an improvement plan. At this stage it is sufficient to have a prioritised list of improvement areas, rather than a detailed plan. If needed, the facilitator can support in this step, but the facility's management should take responsibility for drafting and executing the improvement plan. Then, in the fifth step, the facilitator and facility's management decide upon a realistic timescale for re-assessing, dependent on the planned improvement process.

Lastly, after each assessment process, the facilitator reviews the assessment process and communicates learning points to the people who were involved in conducting the assessment and to the people who will be involved in setting up and facilitating future assessment sessions.

Conclusion

The CBM Maturity Model provides scholars with more insight into the multi-faceted nature of CBM and, when used by practitioners, shows the areas asset owners have most difficulties with. This can guide future (practice-oriented) research. Managers from asset owners can use the CBM Maturity Model's assessment instrument and assessment procedure to assess their as-is situation and derive opportunities for improvement.

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Retail Operations

Sustainability performance in retail supply chain: a comparative study of national and international food retailers

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Abstract

This paper aims to explore and compare national and international food retailers in terms of analyzing and examining linkages between innovation and sustainability performance at three levels: actor, dyad and network in order to examine food supply chains. The research applies a comparative study across those food retailers. Qualitative multiple cases are applied to provide a more holistic view of similarities and differences in innovation in food supply chains and how they are linked to sustainability performance. The research reveals key themes of innovation that are implemented to support retail firms and how these innovations are linked to sustainability performance.

Keywords: Sustainability Performance, Retail Supply Chain, Food Industry

Introduction

The importance of enhancing sustainability in supply chains has escalated significantly over the last decade (Petljak et al., 2018). As organizations face challenges concerning sustainability and global competitiveness, they come across increasing demands to reduce costs, improve customer service and reduce harmful environmental influences to ensure the continuity of supply chains (Barnes and Liao, 2012). In this context, we consider food retailers. There are challenges faced by these retailers, hence there is a need to understand the similarities and differences between national and international food retailers linking innovation and sustainability performance and examining

this link at the three levels of focal actor, dyadic relationship and chain networks (Yakovleva and Flynn; 2004; Awaysheh and Klassen, 2010; Esfahbodi et al., 2016).

In this study's empirical context, the Jordanian food supply chain, the retail sector is increasing due to high demand for food supplied by large and well-established retailers (MoA, 2018) and the population growing rapidly, especially in urban areas within the country and also having several nationalities who have moved from neighboring countries (DoS, 2018). Therefore, international food retailers are establishing branches across Jordan.

In prior research, there is limited theoretical understanding of the link between innovation and sustainability performance in retail supply chain at the actor, dyad and network levels (Yakovleva and Flynn; 2004; Esfahbodi et al., 2016). Therefore, it is important to understand the innovation in supply chains and its link to economic, social and environmental sustainability challenges that retailers face (Awaysheh and Klassen, 2010) at international and national levels. Moreover, the implementation of innovative practices and activities require both types of firms to effectively manage innovation and any barriers from their supply chain dyads and networks (Petljak et al., 2018). Thus, the research aims at examining the linkages between innovation and sustainability performance at international and national retailers at the actor, dyadic and network levels, to better examine retailers' practices in food supply chains. Hence, the following research questions are addressed:

1) What are the contextual dimensions for innovation in a food supply chain?
2) How do international and national retailers implement innovation dimensions and technologies at actor, dyad and network level to enhance sustainability?

Literature Review

Innovation Perspective

Innovation in supply chains is *"the creation of new combinations. These new combinations can be a new product, a new technology for an existing application, a new application of a technology, the development, or opening of new markets, or the introduction of new organizational forms or strategies to improve results. This means that an innovation can be not only a new product, but a new production process, a far-reaching re-organization of production and distribution, […]" (Omta, 2002, p. 73).* Food supply chains induce innovation by means of technology, either adapted or invented, including product technology, information technology, process technology, transportation technology, standards and systems (Trienekens et al., 2003; Rueda et al., 2017). An effective way to generate sustainable practices with technology in the food supply chain does not build on a completely "new" set of skills (Shah et al., 2017). To understand the innovation perspective, three components, product, process and organizational innovation, are explained in order to explore and compare how retailers implement innovation to enhance sustainability performance.

Product innovation is concerned with "*developing new products, staying competitive and seizing market opportunities, responding to external demands, competing in niche markets, capabilities and competencies, and engaging in ecopreneurship*" (Klewitz and Hansen, 2014). It involves the replacement of raw materials with sustainable materials, as well as energy saving

properties or sustainable product characteristics that respond to customer, buyer, or future developments (e.g. Behnam et al., 2018). Enterprises can utilize their uniqueness to compete in niche markets, for instance their ability and flexibility to respond swiftly to different demands in the market (Jenkins, 2009). Enterprises are capable of taking hold of market opportunities with environmental product innovation, for example via product differentiation (e.g. Martín-Tapia et al., 2010; Bellamy et al., 2014).

Process innovation consists of the subtopics of "*economic benefits, response to external pressures and anticipation of regulatory changes, adoption of new technologies, pollution prevention/recycling/waste management/resource efficiency as well as capabilities and competencies*" (Klewitz and Hansen, 2014). In that way, enterprises attain economic benefits through cost saving in their production processes, among others (e.g. Behnam et al., 2018). From external pressure or expectation of regulatory alterations, enterprises benefit from innovations in their procedures, whereby they minimize material usage, consumption of energy and waste, generally, moving in the direction of cleaner and more eco-efficient production. Enterprises improve their environmental performance, gain economic benefits, and engage in pollution prevention through eco-efficient practices. Eco-efficiency can even aid towards further radical process and ultimately product innovations (Michelsen and Fet, 2010).

Organizational innovation is commonly known as a firm-level style of innovation in management initiatives (Anzola-Román et al., 2018). Organizational innovation "means the implementation of a new organizational method in the undertaking's business practices, workplace organization or external relations. Changes in business practices, workplace organization or external relations that are based on organizational methods already in use in the undertaking. As well as changes in management strategy, mergers and acquisitions, ceasing to use a process, simple capital replacement or extension, changes resulting purely from changes in factor prices, customization, regular seasonal and other cyclical changes" (Union, E., 2006). Organizational innovation improves creativity enhance enables the development of technological innovations (Mothe and Nguyen, 2010). Organizational innovation is recognized as a source of competitive advantage and supports technological innovation in a context of enhancing sustainability and increasing competition (Sapprasert and Clausen, 2012; Anzola-Román et al., 2018).

Food Supply Chains

"*Supply Chain Management (SCM) is the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders*" (Global Supply Chain Forum in (Lambert and Cooper, 2000, p. 66). SCM as encompassing four distinct echelons: internal supply chain, the dyadic, the chain and the network (Harland, 1996). SCM emphasizes in the ways by which firms make use of their suppliers' processes, technology, and capability to enhance competitive advantage. Most food supply chains tend to involve the following stages: origin of the resource, agricultural production, primary processing, further processing, final manufacturing, wholesale, retail, food service and domestic consumption (Hugos, 2018). According to Revoredo-Giha et al. (2012), a supply chain is seen as a network of organizations or actors that have economic and social relationships that

allow the working of the supply chain to produce goods and services. This shows that there are three different levels of supply chain: actors, dyadic relationships and network, helping enterprises (e.g. focal firms) link innovation orientation and sustainability orientation in a food supply chain (e.g. Gómez-Cedeño et al., 2015).

A focal firm can be defined as the one that is responsible for the direct link with the end-customers; at the same time it has direct and indirect links with different actors across the supply chain such as wholesalers, retailers, packaging providers and distributors (Hugos, 2018). As actors change their roles across the supply chain levels, they may face opportunities and/or risks (Beske and Seuring, 2014). The major focus of the focal firm is based on how to link the supply and demand, focusing on the product value (Aarikka-Stenroos et al., 2014). In this study, the retailer of meat supply chain is the focal actor.

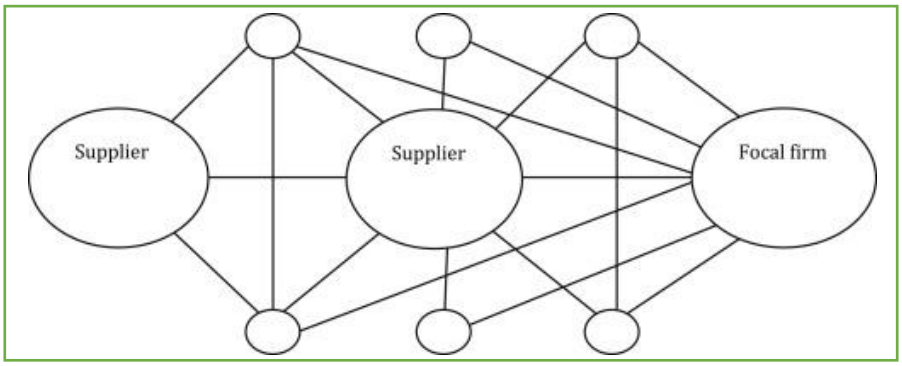

*Figure 1- Focal Actor (**Source**: Frostenson and Prenkert, 2015).*

Dyadic relationships can be defined as the interactions of actors amongst each other to create a more collaborative dynamic and facilitate innovation (Wilson, 1995; Michalski et al., 2018). The relationships developed between the retailer as a focal actor and other actors have become a high priority, as they are either vertical or horizontal relationships (Petljak et al., 2018). In these relationships, "*Issues of trust and risk can be significantly more important in supply chain relationships, because supply chain relationships often involve a higher degree of interdependency between companies*" (La Londe, 2002, p. 10). Omta (2002, p. 75) defines a network as "*all of the actors within one industrial sector, or between related industrial sectors, which can (potentially) cooperate to add value for the consumer.*" In fact, there is a lack of research on SCM from the perspective of retailers (Petljak et al., 2018). Retailers are acknowledged as an important actor in the supply chain that contributes to change (Lehner, 2015). Addressing retailing's innovation and sustainability, the *"…food retailing is very important because of time pressure due to perishability, the need of cooling and the related waste management challenge"* (Petljak et al., 2018, p. 2). Several authors (e.g. Lambert et al., 1998; Michalski et al., 2018) have suggested fundamental aspects for how and why channels are structured and created. Hence, the supply chain structure is the network of actors that forms relationships between members of the supply chain (Michalski et al., 2018) to facilitate innovation in food supply chains.

Research Methodology

Research Design

This is a qualitative case study and examines socially constructed dynamic reality (Creswell, 2007). Through an in-depth, comparative study of two food retailers (international and national), this study is to understand the linkages between innovation and sustainability performance at the actor, dyadic and network levels, to better examine food supply chain chains (Yin, 2018). After reviewing literature, a multiple case study strategy is applied since rich findings are needed to maximize reliability and validity. As a comparative study, case studies were conducted and later compared the findings. Several sources of secondary data were analyzed such as retailers' websites, sustainability projects and related past surveys. For the primary data collection, multiple cases of interviews and observations were compiled during January 2019. A method of analytic generalization is followed, where a prior developed theory of innovation perspective is utilized as a template to compare the empirical findings (Bryman and Bell, 2015). The unit of analysis is the meat supply chain of retailers, specifically beef products.

Sampling, Data Collection and Analysis

Multiple cases of two large food retailers, where R1 is an international retailer and R2 is a national retailer. For each case, five face-to-face semi-structured interviews were conducted, giving 10 interviews in total. The cases followed a snowball sampling, where mangers recommended several different relevant managers from the retailers (Patton, 2015). Those managers were supply chain managers, hygiene and safety managers, fresh food managers, product development managers and managers of sustainable sourcing. The multiple case strategy was conducted to understand similarities and differences in the themes (Yin, 2018) between international and national retailers from the innovation perspective in food SCM at the actor, dyad and network levels. This is to explore and explain their links to innovative technologies and in turn to sustainability performance. Each interview of 60 minutes was conducted voluntarily, voice recorded and later transcribed. For each case, three observations of 60 minutes were performed (Yin, 2014), where the researcher attended one meeting combined with field tours as a non-participant at both retailers, including the actor level (the retailer), the dyad level (retailers with a direct relationship) and the network level (retailers with an indirect relationship). These actors were chosen to be observed to create multiple sources of evidence to support the interviews' findings (Aarikka-Stenroos et al., 2014). The slaughterhouse, beef distributor, beef packaging and a government body, were chosen to be observed based on a convenient sample.

Ethical consideration was applied throughout this study. Thematic analysis was followed to group themes and indicate contextual dimensions from the collected data in order to enhance the thoughts and provide meaningful findings (Miles et al., 2014). NVivo was used to organize, store and retrieve the research data (Bazeley and Jackson, 2013).

Findings and Discussion

Several key dimensions emerged during data analysis in association to the key themes of innovation in relation to enhancing sustainability performance at the actor, dyadic and network levels, to better examine food supply chain. This is in line with prior research that emphasized the significance of innovation at their retailer in order to be successful and overcoming any challenges (Omta, 2002; Bellamy et al., 2014). As supported by R1, Product Development Manager, *"I*

believe that our innovative ideas are what keeps us thriving in our competitive market and seizing market opportunities." This is also supported by the observations conducted at R1 and R2. Table 1 represents the key dimensions for the innovation themes that emerged. These were clustered into three key themes, product, process and organizational innovation.

Table 1 – Key innovation themes to manage meat supply chain.

Themes	Dimensions	Respondents Quotation
Product Innovation	- Staying competitive - Engaging in environmental aspects	*"[…] I believe our meat product differentiation is innovative as not all our competitors have a huge variety of meat like us, we have local beef and we import from six countries […] We offer these products at an acceptable price and this in return we support our suppliers for their implementation to be environmentally friendly."* **R1, Head of Sustainable Sourcing**
	- Responding to external demands	*"[…] With everything going on in our economy and our competitive market, we are pressured from the supply chain to improve our environmental performance through product innovation, for example, product design […]".* **R2, Product Development Manager**
Process Innovation	-Attain economic benefits -Improve their environmental performance	*"We always try to be up-to-date with all the new trends and technologies locally and internationally. […] I believe adopting new innovative technologies, such as the solar panels we just installed was a great decision as we improved our environmental performance as well as cut our costs."* **R2, Hygiene and Safety Manager**
	- Response to external pressures and regulatory changes	*"When there are external pressures we try to respond quickly, wisely and innovatively.[…] When we receive regulations from government bodies we need to begin the process of implementing them."* **R1, Fresh Food Managers**
Organizational Innovation	- Engaging employees in developing a sustainable business	*"Last week we had trainings discussing different things we have in our organization for sustainability and how important it is. These types of trainings are provided regularly for all employees and during the trainings they motivate us to come up with something innovative that would help our environment or even cut our costs and in return they give us a reward."* **R2, Supply Chain Manager**
	- Health and safety issues	*"Our organization structures regulations on health and safety issues. […] As an international retailer we have regulations on health and safety issues from both the Jordanian government bodies and our international HQ."* **R1, Hygiene and Safety Manager**

Contextual dimensions leading to perceive innovation at actor, dyadic and network level in the supply chain were identified (Table 2). Previous research highlighted the importance of innovation in an organization, at the actor level, but there was a lack of research at the dyad and network level in order to have a greater involvement of all the members across the supply chain and enhance

social, economic and environmental sustainability in SCM (Bellamy et al., 2014; Behnam et al., 2018).

Table 2 demonstrates the level of innovation implementation at the actor, dyadic and network level, in relation to achieving sustainability in SCM. R2, Product Development Manager highlighted, *"We believe for our retailer to be successful in achieving sustainability we need to be differentiated in our competitive market and be as innovative as possible".* Though it was identified that at the actor level, innovation is applied well, at the network level is lower. R1, Supply Chain Manager explained, *"Our company has tried many times to collaborate with the government with several ideas and programs such as hygiene issues, recycling, and certificates; however very rare cases have been applied with very little resources. I believe that if more joint programs are implemented between us this will encourage us to be more innovative and sustainable."* Therefore, the results revealed enhancing sustainability performance in SCM is achieved when innovation is successfully implemented at actor, dyadic and network level. Based on the results of this study a comparison between Retailer 1 and Retailer 2 was conducted. It was found that Retailer 1 implements innovation more than Retailer 2, as it is an international organization that adopts and adapts international ideas and concepts hence has a wider opportunity to implement them in a developing country.

Table 2 – Contextual dimensions leading to perceive innovation at actor, dyadic and network level.

		Retailer 1			**Retailer 2**		
		Actor Level	Dyadic Level	Network Level	Actor Level	Dyadic Level	Network Level
Product Innovation	Staying competitive	**H**	**H**	**L**	**H**	**M**	**L**
	Engaging in environmental aspects	**H**	**M**	**L**	**M**	**M**	**L**
	Responding to external demands	**M**	**M**	**M**	**M**	**L**	**M**
	Aggregate	**H**	**M**	**L**	**M**	**M**	**L**
Process Innovation	Attain economic benefits	**M**	**M**	**L**	**H**	**M**	**L**
	Improve their environmental performance	**H**	**M**	**L**	**M**	**M**	**L**
	Response to external pressures and regulatory changes	**M**	**M**	**M**	**M**	**L**	**M**
	Aggregate	**M**	**M**	**L**	**M**	**M**	**L**
Organizational Innovat	Engaging employees in developing a sustainable business	**H**	**H**	**M**	**H**	**M**	**L**
	Health and safety issues	**H**	**H**	**M**	**H**	**M**	**L**
	Aggregate	**H**	**H**	**M**	**H**	**M**	**L**

*H= High, M= Medium, L= Low (These are measured on a three-point scale (high, medium and low). Based on the level of implementation of innovation at actor, dyadic and network level. Further information is available upon request).

Retailers implement innovative technologies at actor, dyad, and network levels to achieve sustainability in food supply chain. This study has illustrated that some actors across the supply chain implement more than others depending on their implementation of innovation; they integrate more dimensions. R1, Head of Sustainable Sourcing explained, "*We always work to be a part of the whole supply chain as this will bring sustainable benefits for all of us. For example, we are not computer connected via ERP between the Food and Drug Association, hence delaying inspections, trainings, etc. So it would be great if someone came up with an innovative idea to overcome this challenge."* In addition R2, Hygiene and Safety Manager highlighted, *"Our transportation vehicles between us and the meat suppliers are very innovative. The vehicles are refrigerators and have a cooling tracking device which track the temperature of the refrigerator as the meat is being transported. This allows us to make sure that the temperature is in the appropriate range."* R1, Supply Chain Manager explained, *"Our retailer and the other actors in our supply chain are concerned with the economic situation in Jordan. We have a variety of prices for meat and other products, we try our best to be innovative even with cost."* This is supported by the observations conducted at R1 and R2. Table 3 demonstrates that actors across the supply chain implement innovation more than others, where Retailer 1 compared to Retailer 2 implements innovation more.

Table 3 – Innovative technologies applied at international and national retailers.

		Innovative Technologies			**Sustainability Performance**
		Transportation Technology	*Standards & Systems*	*Information Technology*	
Retailer 1	Actor Level	**H**	**H**	**H**	*Environmental + Economic + Social*
	Dyadic Level	**M**	**M**	**H**	*Environmental + Economic*
	Network Level	**L**	**L**	**M**	*Environmental+ Economic*
Retailer 2	Actor Level	**H**	**M**	**M**	*Environmental + Economic*
	Dyadic Level	**M**	**M**	**M**	*Environmental + Social*
	Network Level	**M**	**L**	**L**	*Environmental + Economic*

*H= High, M= Medium, L= Low (These are measured on a three-point scale (high, medium and low). Based on the level of implementation of innovation at actor, dyadic and network level. Further information is available upon request).

Conclusion

The interest of sustainability in food SCM in research is growing especially in the innovation perspective (Behnam et al., 2018). This study concluded the significance of implementing innovation, either product, process and organizational innovation, in order to enhance sustainability performance at the actor, dyad and network level. Key contributions to knowledge

will be a theoretical association to understand how to enhance innovation in SCM from the perspective of innovation. Key implications made for retailers are to support their employees to be innovative and to understand the different types of innovation technologies that they can adopt or adapt at different levels in order to enhance sustainability. From the empirical context view, this research contributes to critically examine the food supply chain context in a developing country, Jordan, and in a retailing industry. A limitation to this study is conducting interviews only with the retailers; a suggestion for future research is to conduct interviews with all the actors across the supply chain to gain a more holistic picture of how to enhance sustainability in SCM at all three levels from the perspective of innovation**.**

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Optimal sourcing strategies of fresh agricultural product retailers

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Abstract:

This paper models the optimal sourcing strategies of fresh agricultural products among alterative sourcing strategies of retailers based on the scenario of a supply chain of one retailer and two suppliers. The retailer can choose from two types of suppliers – preservation effort supplier and non-preservation effort supplier – to maximize profit. Based on numerical examples, the optimal retailer sourcing strategies are explored under two scenarios: the traceable scenario and the non-traceable scenario. The results offer insight for retailers, regulators and consumer groups on how to encourage quality sourcing practices, so that to maximize food quality in the supply chain.

Keywords: Fresh agricultural products, Preservation efforts, Sourcing strategy

Introduction

In recent years, consumers' requirement for fresh agricultural products (FAP) has grown significantly due to concerns about food safety, food quality and healthier diets (Soto-Silva et al., 2016). Retailers are the final link in the food supply chain serving consumers. Their sourcing strategies can have major impact on the quality and safety of the food in the supply chain. Previous studies suggest that intrinsic factors, such as contracts (Yang et al., 2017), retailer's corporate social responsibility (Maloni and Brown, 2006), and management's perceived risk (Fearne et al., 2001) play important roles in the sourcing strategy of retailers. In addition, extrinsic factors such as inspection policies (Omari, et al., 2018), monitoring (Srbinovska et al., 2015), regulations (Kraft and Raz, 2013), as well as cost of violations, willingness-to-punish for violations, and willingness-to-pay for responsibility are also highlighted (Guo, et al., 2015). Limited previous studies considered more comprehensively the contributing factors of the retailer's optimal sourcing strategy of fresh agricultural productions, and hence the focus of this paper.

This paper focuses on five factors which affect the sourcing strategies of retailers of fresh agricultural products: (1) consumers' quality-sensitivity; (2) level of preservation

effort of suppliers; (3) risk of food safety incidents; (4) potential price premium; and (5) level of potential penalties for unsafe products. The retailer can choose one or more suppliers in its sourcing portfolio to maximize its profit. To understand the mechanism of optimal sourcing strategy of retailers, we focus on two scenarios. The first being the traceable scenario, within which suppliers and retailers implement traceability systems designed to track the quality of the products for optimization purposes (Aiello, et al., 2015). The second being the non-traceable scenario, within which food products are non-traceable due to lack of labeling and supplier information (Saak, 2016).

This study intends to answer two questions: (1) what are the key factors and how do they determine retailer's optimal sourcing strategy? (2) how can retailers optimize their sourcing strategies to ensure higher food quality and higher profitability? We applied the deterioration inventory model to determine the order quantity of fresh agricultural products either with preservation or without preservation. Retailer's optimal sourcing strategies under the two traceability scenarios are determined and the expected profit associated with each scenario is derived using MATLAB. The sensitivities of key model parameters are analyzed to investigate their impact on the optimal sourcing strategy.

Model development and analysis

Assumptions

Before model formulation, the following assumptions are imposed:

a) Demand rate D is a known constant (Dye, et al., 2007).

b) A supply chain of one retailer and two suppliers of different preservation efforts are considered, one being a supplier with preservation efforts and the other being a supplier without preservation efforts. The two suppliers are the same in all respects except for preservation efforts. Because of the investment in preservation efforts, the supplier with preservation effort has a higher cost and product per unit price.

c) During the replenishment period [0, T], there isn't replacement and treatment for the deteriorated products (Teng, et al., 2016).

d) Consumers have equal willingness (p) to pay for the FAP.

Model formulation

The following is the forecast model of retailer's order quantity of FAP. Using above assumptions, the inventory level of the retailer is described by the following differential equation (Dye, et al., 2007):

$$\frac{dI(t)}{dt} = -D - \lambda I(t) \quad (0 \le t \le T) \qquad (1)$$

FAP are necessities of living, thus in the absence of unexpected events, the demand rate D is relatively stable within the order period, hence market demand $Q=\int_0^T D\,dt= DT$. λ is the deterioration function of FAP, where $0 \le \lambda \le 1$. $I(t)$ is the inventory level at any time t, $0 \le t \le T$.

We then construct the preservation decay function $\theta(t) = \theta^t$, $0 < \theta \le 1$, which

indicates the freshness of FAP. If $t = 0$, hence $\theta(t) = 1$, which means the products are in the freshest state when the supplier sells the product to the retailer. $\lambda(t)$ denotes the loss caused by natural and human factors such as temperature, handling, simple packaging, extrusion, and transportation from the initial stage of the order cycle to the retail process. Suppose $\lambda(t) = -ln\theta \cdot \theta^t$, where $\theta \to 1, ln\theta \to 0, \lambda \to 0$, so $ln\theta$ can be used as a coefficient to describe the loss rate of FAP.

If there are no preservation efforts, we have deterioration function $\lambda_l(t) = -ln\theta \cdot \theta^t$, with the boundary condition $I_l(T) = 0$. Solving the differential equation (1), we get the inventory level $I_l(t)$. When $t = 0$, the retailer's order quantity for each cycle in the case of no preservation efforts $Q_l = I_l(0)$, and inventory cost of the retailer during the order cycle T is $H_l = h_l \int_0^T I_l(t)\, dt$, h_l is retailer's inventory price per unit without preservation efforts.

If there are preservation efforts, a preservation effort factor α $(0 < \alpha < 1)$ is introduced. The smaller the value of α, the better the effect of preservation. Then $\lambda_h(t) = -\alpha ln\theta \cdot \theta^t$, we get the inventory level $I_h(t)$. When $t = 0$, the retailer's order quantity for each cycle in the case of preservation efforts $Q_h = I_h(0)$, $H_h = h_h \int_0^T I_h(t)\, dt$, h_h is retailer's inventory price per unit with preservation efforts.

Sourcing strategies under the traceable scenario

We will explore when each of these sourcing strategies will be optimal.

Single channel low-cost (SCLC) sourcing

Under this strategy, there is a single sourcing channel for the retailer, which can choose to purchase all FAP from the low-cost supplier without preservation efforts. Therefore, retailer's order proportion $q_l = 1, q_h = 0$. Those FAP are prone to spoilage and corruption due to the absence of preservation efforts. If the consumer purchases this kind of products, there are two possible consequences to the retailer: a decrease in demand and an increase in cost. The former consequence is due to consumers who experience food safety incidents stop purchasing the product, a proportion (ε) of consumers known as "quality-sensitive" respond to the incidents by withdrawing from the retailer and purchasing from other retailers. The latter consequence is due to penalties (κ) charges from the food safety incidents. Consequently, the expected profit of the retailer under this sourcing strategy is:

$$\Sigma_1 = Q\gamma(1 - \varepsilon\eta)(p - c_l) + Q(1 - \gamma)(p - c_l) - Q\eta\kappa - c_l(Q_l - Q) - \mathrm{H}_l \qquad (2)$$

In the above formula (2), c_i is purchasing price per unit, subscript $i = l$ represents no preservation efforts, subscript $i = h$ represents preservation efforts. p is average price per unit. η is the probability of complaints due to food safety incidents without preservation efforts $(0 \le \eta \le 1)$. γ is the proportion of quality-sensitive consumers who are willing to pay high prices $(0 \le \gamma \le 1)$. The first part of formula (2) is the

profit that the retailer obtains from the quality-sensitive consumers. The second part is the profit from the non-quality sensitive consumers. The other three parts are the violation cost, deterioration cost and inventory cost, respectively.

Dual channel (DC) sourcing

Under this strategy, retailer source from two types of suppliers simultaneously. Low-cost FAP are sold to the ordinary consumers at the price p, high-cost FAP are sold to quality-sensitive consumers at a higher price than p, then the retailer reaps the price premium (p_r). Hence, $q_l = 1-\gamma, q_h = \gamma$. The expected profit of the retailer is:

$$\Sigma_2 = Q\gamma(1-\varepsilon\eta)(p+p_r-c_h) + Q(1-\gamma)(p-c_l) - Q\eta\kappa - (1-\gamma)c_l(Q_l-Q) - \gamma c_h(Q_h-Q) - (1-\gamma)H_l - \gamma H_h \quad (3)$$

Single channel high-cost (SCHC) sourcing

Under this strategy, the retailer only sources from one channel, that is, high-cost supplier with preservation efforts. The order proportion is $q_l = 0, q_h = \gamma$. The retailer is now only selling to quality-sensitive consumers and gains the profit from price premium. Thus, the expected profit of the retailer is:

$$\Sigma_3 = Q\gamma(p+p_r-c_h) - \gamma c_h(Q_h-Q) - \gamma H_h \quad (4)$$

Single channel high-cost mass-market (SCHCMM) sourcing

Under this strategy, the retailer sources FAP from the preservation supplier and sells FAP to two types of consumers (quality sensitive and not quality sensitive) at the same price p. In this case, the expected profit of the retailer is:

$$\Sigma_4 = Q(p-c_h) - c_h(Q_h-Q) - H_h \quad (5)$$

According to the above description of sourcing strategies, Figure 1 graphically shows the relationship between sourcing strategies and order quantity.

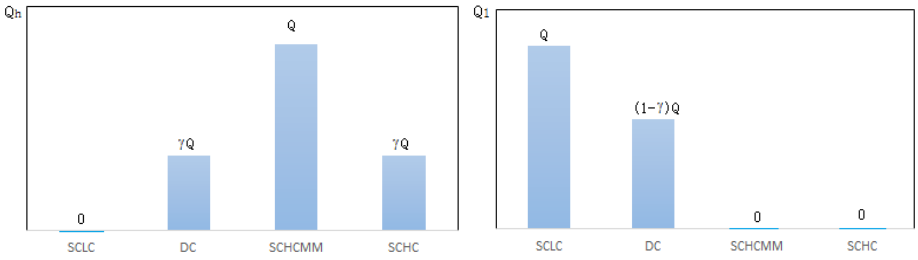

Figure 1- Relationship between sourcing strategies and order quantity

The optimal sourcing under the traceable scenario

Based on the four possible retailer sourcing strategies discussed above, we now explore when these strategies will be optimal. A key factor that determines this is whether

customers are willing to pay more than the incremental cost of preservation efforts, i.e., whether p_r is greater than $\omega = \frac{c_h(Q_h-Q)-c_l(Q_l-Q)+H_h-H_l}{Q(1-\varepsilon\eta)} + c_h - c_l$, which is the cost difference between preservation effort supplier and non-preservation effort supplier.

The retailer's optimal sourcing strategy under the traceable scenario are as follows:

Proposition 1.

(i) If $p_r < \omega, and\ Q_h c_h - Q_l c_l > Q\eta\kappa + Q\gamma\varepsilon\eta(p - c_l) + H_l - \gamma H_h + max[Q\gamma p_r - (1-\gamma)(Qp - Q_h c_h - H_h), 0]$, single channel low-cost sourcing strategy is optimal;

(ii) If $p_r > \omega, and\ \gamma\varepsilon\eta(p + p_r - c_h) + \eta\kappa < \frac{1-\gamma}{Q}\min\left[(Qp - Q_l c_l - H_l), (Q_h c_h - Q_l c_l + H_h - H_l) + \frac{Q\gamma}{1-\gamma}p_r\right]$, the dual channel sourcing strategy is optimal;

(iii) If $p_r > \frac{1-\gamma}{Q\gamma}(Qp - Q_h c_h - H_h)$ and the strategies of (i) and (ii) aren't optimal, the single channel high-cost sourcing strategy is optimal;

(iv) If $p_r < \frac{1-\gamma}{Q\gamma}(Qp - Q_h c_h - H_h)$ and the strategies of (i) and (ii) aren't optimal, the single channel high-cost mass-market sourcing strategy is optimal.

We observe some customers value quality and might pay a premium for it. As a result, the retailer must decide whether to source some or all of its FAP from a preservation supplier and what price to charge customers. If the willingness of consumers to pay for the preservation efforts is small, i.e., $p_r < \omega$, dual channel sourcing strategy can never be optimal. Sourcing from non-preservation supplier occurs if the loss in profit from quality-sensitive consumers and penalties due to food safety incidence are less than the incremental cost for preservation efforts. Proposition 1 shows that even if the willingness of consumers to pay for the preservation efforts is low, the retailer may still source from the preservation supplier despite the seeming unprofitability. Results are due to the reduction in penalties.

Proposition 2. If $p_r < \omega$ and $Q_h c_h - Q_l c_l < Q\eta\kappa + Q\gamma\varepsilon\eta(p - c_l) + H_l - \gamma H_h + max[Q\gamma p_r - (1-\gamma)(Qp - Q_h c_h - H_h), 0]$, the optimal sourcing strategy may change from single channel low-cost to either single channel high-cost mass-market or single channel high-cost with the increase of γ. The retailer may reduce the order quantity from the preservation supplier at a turning point $\gamma = \frac{Qp-Q_h c_h-H_h}{Qp_r+Qp-Q_h c_h-H_h}$, meanwhile, the optimal sourcing strategy may change from the single channel high-cost mass-market to the single channel high-cost.

When γ and p_r are small, the retailer may choose single channel high-cost mass-market for fear of penalties caused by food safety incidents and quality-sensitive consumers withdrawing from the retailer sourcing from the non-preservation supplier. As γ and p_r increase, the premium obtained from quality-sensitive consumers is more attractive to the retailer. The retailer raises price to reap the premium to achieve higher profit. Therefore, the optimal sourcing strategy may change from the single channel high-cost mass-market to the single channel high-cost. Non-sensitive consumers are

expelled from this market, causing the retailer to reduce the order quantity of preservation supplier from Q to γQ, as shown in Figure 1.

Proposition 3. Q_h will decrease sharply and Q_l will increase sharply, if the optimal sourcing strategy transfers from single channel high-cost mass-market to dual channel and γ increases from less than to greater than $\frac{Q_h c_h - Q_l c_l - Q\eta\kappa + H_h - H_l}{Q\varepsilon\eta(p+p_r-c_h)+Q_h c_h - Q_l c_l - Q p_r + H_h - H_l}$ with the increase of p_r.

Proposition 3 shows that the retailer following the dual-channel sourcing strategy can obtain more profits from quality-sensitive consumers than following the high-cost mass market sourcing strategy. However, the dual-channel strategy has more order quantity from the non-preservation sourcing supplier which leads to the reduction of freshness of the whole supply chain, as shown in Figure 1. Retailer's optimal sourcing strategies are determined by both proportion of quality-sensitive consumers (γ) and potential premium (p_r) rather than by only one or the other. Therefore, there is a risk of reducing the freshness of the whole supply chain by increasing the proportion of quality-sensitive consumers or the willingness to pay for the preservation efforts (price premium) to influence the retailer's sourcing strategy.

Proposition 4. Whether $p_r > \omega$ or not, as long as κ is large enough, the optimal sourcing strategy may be single channel high-cost mass-market or single channel high-cost. Although the retailer may reduce the order quantity from the preservation supplier, the retailer will not increase the order quantity from the non-preservation supplier. Therefore, increasing penalties or the intensity of disclosing violations will have a positive effect on promoting the freshness in the supply chain.

Sourcing strategies under the non-traceable scenario

Under the non-traceable scenario, there is a lack of information sharing between retailers, suppliers and consumers. Therefore, it is difficult for consumers to tell whether FAPs were supplied with preservation efforts. Food package and label will be the only source of information for consumers to tell different FAPs. There are two typical sourcing strategies, high-cost sourcing and double-label selling (HSDS) strategy and low-cost sourcing and double-label selling (LSDS) strategy.

High-cost sourcing and double-label selling (HSDS) strategy

Under this sourcing strategy, the retailer will source from the supplier with preservation efforts, but will label some products with preservation logos and some products with ordinary logos. Retailer sells the FAP with preservation logos at a higher price due to better market recognition or media coverage. Hence, the expected profit of the retailer is as follows:

$$\Sigma_5 = Q[\gamma(p + p_r) + (1 - \gamma)p - c_h] - (Q_h - Q)c_h - H_h \quad (6)$$

If quality-sensitive consumers are so sophisticated that they find it unfair to buy high-priced FAP, therefore, they will switch to purchasing products with ordinary logos

because the quality of the products with preservation logos and ordinary logos is the same.

Low-cost sourcing and double-label selling (LSDS) strategy
Under this strategy, there is a single sourcing channel for the retailer, and all FAP are sourced from non-preservation supplier. However, as a fraudulent behavior, the retailer may label some FAPs with preservation logos to capture the premium. Thus, the expected profit of the retailer is as follows:

$$\Sigma_6 = Q\gamma(1-\varepsilon\eta)(p+p_r-c_l) + Q(1-\gamma)(p-c_l) - Q\eta\kappa - (Q_l - Q)c_l - H_l \qquad (7)$$

Proposition 5. Under the non-traceable scenario, high-cost sourcing and double-label selling strategy is optimal, if $Q_h c_h - Q_l c_l < Q\gamma\varepsilon\eta(p+p_r-c_l) + Q\eta\kappa + H_l - H_h$; and the low-cost sourcing and double-label selling strategy is optimal if $Q_h c_h - Q_l c_l > Q\gamma\varepsilon\eta(p+p_r-c_l) + Q\eta\kappa + H_l - H_h$.

Numerical analysis
In this section, some numerical examples are developed to analyze the results in different sourcing strategies proposed.

The influence of γ (proportion of quality-sensitive consumers) and p_r (potential price premium) on the sourcing strategy

The sensitivity of some key parameters of the model (γ and p_r) are discussed. We consider the following data set (Wang and Dan, 2015): $D = 1; T = 10; c_l = 0.2; c_h = 0.5; h_l = 0.1; h_h = 0.015; p = 1.5; \kappa = 3.2; \eta = 0.1;\ \alpha = 0.8;\ \theta = 0.95; \varepsilon = 0.2$.

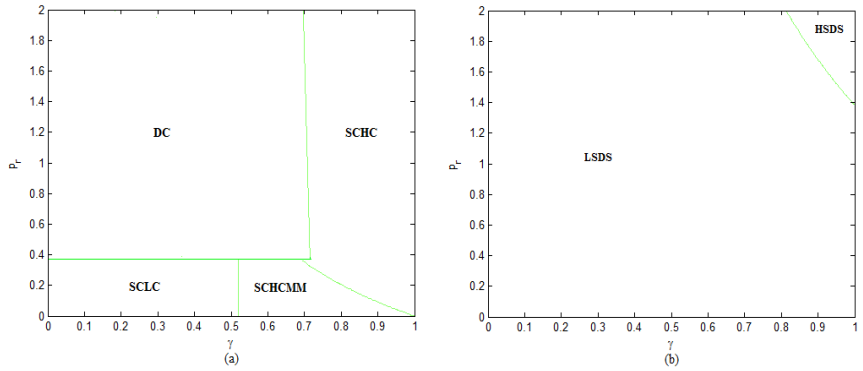

Figure 2 - γ vs p_r (Green Lines are the demarcation lines of each source strategy)

Under the traceable scenario, the optimal sourcing strategy is the single channel low-cost, if γ and p_r are small, as shown in Figure 2 (a). The optimal sourcing strategy has to be changed to single channel high-cost mass-market and finally to single channel high-cost with the increase of γ to 1. We found that the retailer may source from the preservation supplier at a higher price even if consumer willingness-to-pay for

preservation is low. When p_r are bigger, the optimal sourcing strategy has to be changed from the dual channel to the single channel high-cost with the increase of γ. These results are in line with Propositions 1, 2 and 3. Under the non-traceable scenario, the optimal sourcing strategy may be transformed from LSDS to HSDS with the increase of γ and p_r, as shown in Figure 2 (b).

The influence of ε *(proportion of quality-sensitive consumers withdrawing from non-preservation efforts market) and* η *(risk of food safety incidents due to non-preservation efforts) on the sourcing strategy*

We consider the following data set (Wang and Dan, 2015): $D = 1; T = 10; c_l = 0.2; c_h = 0.5; h_l = 0.1; h_h = 0.015; p = 1.5;\ \alpha = 0.8;\ \theta = 0.95;\ \gamma = 0.3;\ p_r = 0.38; \kappa = 0.3$ (and 2.3).

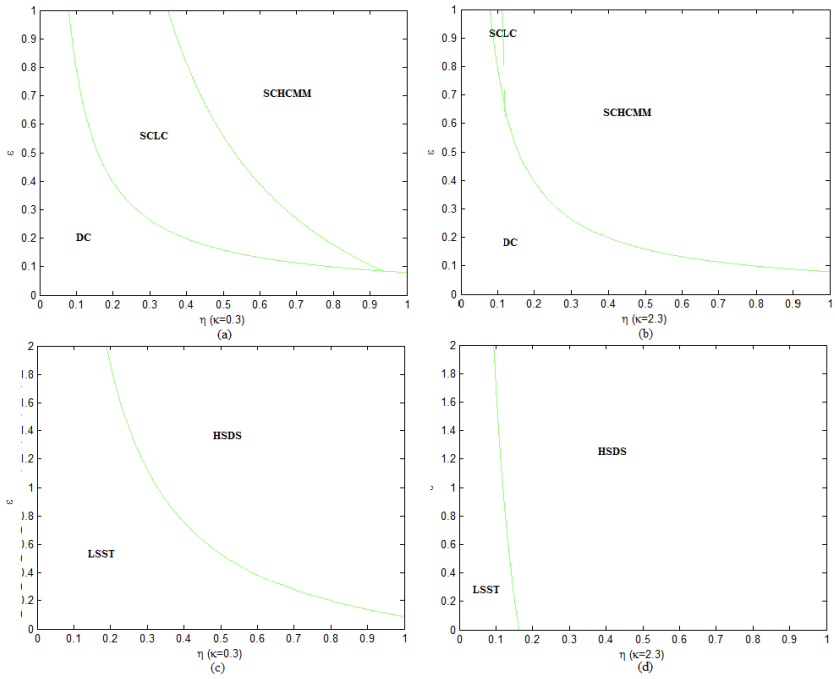

Figure 3 - ε *vs* η *(Green Lines are the demarcation lines of each source strategy)*

Under the traceability scenario, when ε and η are small, the optimal sourcing strategy is the dual channel sourcing strategy, as shown in Figure 3a and 3b. With the improvement of consumers' quality awareness, consumers' complaints may also increase due to deterioration of FAP (ε and η increase). Therefore, the retailer has to change their sourcing strategy to reduce risks. Under the non-traceability scenario, with the increase in ε and η, the optimal sourcing changes from LSDS to HSDS, as shown in Figure 3 (c and d). This is because the increase in ε and η leads to increased operating cost and risks of the retailer, hence the benefits from LSDS cannot offset the penalty and complaints. The higher the penalty, the greater the order quantity from the preservation efforts supplier.

The influence of α (preservation efforts factor) and p (average price) on the sourcing strategy

We consider the following data set (Wang and Dan, 2015): $D = 1; T = 10; c_l = 0.2; c_h = 0.5; h_l = 0.1; h_h = 0.015;\ \theta = 0.95;\ \varepsilon = 0.2;\ \eta = 0.1;\ \gamma = 0.5;\ p_r = 0.38;\ \kappa = 3.$

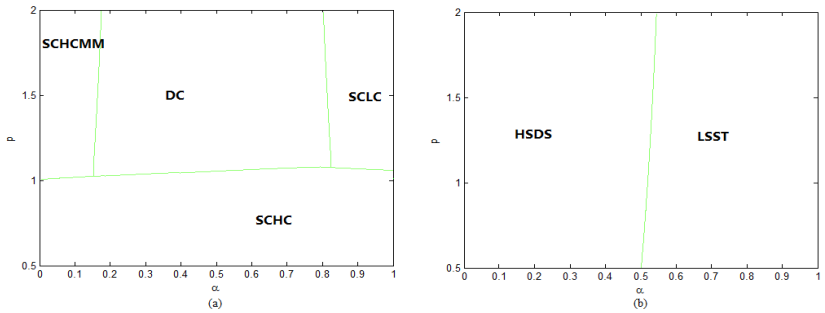

Figure 4 - α vs p (Green Lines are the demarcation lines of each source strategy)

The result shows that, preservation efforts level (α) is an important factor affecting the retailer's profit. The bigger α, the lower the preservation efforts level. Under the traceability scenario, SCHC is the optimal strategy if p is small. This is because the price premium from quality-sensitive consumers is more attractive. The optimal strategy changes from SCLC to DC and SCHCMM with the increase of α. There is no obvious difference between the preserved and non-preserved agricultural products if α is low, so retailer can capture more profit by SCLC. With the increase of α, deterioration loss is reduced and the risk of food safety incidents is lower, so DC and SCHCMM become the optimal strategies. Under the non-traceability scenario, similar to the traceability scenario, the optimal strategy is changed from LSDS to HSDS with the increase of α.

Conclusion

This study shows the optimal sourcing strategies FAP retailers under different traceability scenarios. This study also illustrates the importance of key factors played in the retailer's optimal sourcing strategy. Basically, the findings suggest that consumer-oriented promotion approaches of retailers (i.e., focusing on increasing consumers' potential price premium or increasing the proportion of quality-sensitive consumers) can have a negative impact on retailers' order quantity from suppliers with greater preservation efforts, and hence worse freshness and food quality in the supply chain. On the other hand, higher penalty levels and more exposure to risk of food safety incidents by retailers will lead to increased order quantity from suppliers with greater preservation efforts, and hence higher food freshness and quality in the supply chain.

However, simply relying on increased regulation does not address the root of the problem. Among the five factors (γ, p, α, ε and η) examined in this paper, only α is within the control of retailers. Therefore, retailers should cooperate with suppliers to find a good way, for instance, to set up risk sharing and benefit sharing mechanism to

enhance preservation efforts that would improve profitability, quality and freshness of the FAP in the supply chain.

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Sales & Operation Planning

Managing the dynamic needs of engineering resources through sales and operations planning

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Abstract

This paper explores the uncertainty related to medium-term engineering needs considering sales and operations planning (S&OP). The areas of uncertainty and how they are addressed by S&OP are investigated in an engineer-to-order setting. Uncertainties stem from customer orders and critical competences and are minimized through integrating engineering resource planning into S&OP sub-processes and organization, and through explicating methodologies using IT tools that also support scenario planning. To improve the effect of S&OP, measuring short- and long-term performance is recommended, and aligning S&OP with the bidding and organization development processes is important. Future research may replicate this study using multiple cases.

Keywords: S&OP, Case study, Engineer-to-Order

Introduction

This paper focuses on the requirements put by engineer-to-order (ETO) environments on the sales and operations planning (S&OP) process. The ETO planning environment has several challenges. The competition in ETO markets is based on providing substantial customization beyond standard product options to embrace very heterogenous customer needs. Allowing product customization in conjunction with incoming customer orders, contracts or inquiries requires intensive and frequent engineering work whereby new or existing products and manufacturing systems are either developed or adapted.

Providing the required engineering competences to conduct the engineering work is crucial to compete on contracts and to successfully deliver orders. Competence requirements change overtime as the heterogeneous ETO market needs evolve. Also, availability of engineering resources and expertise vary. Moreover, obtaining critical engineers is often expensive and takes relatively long time. Therefore, in ETO environments, the criticality of engineers needs to be identified and managed at the tactical planning horizons, i.e. within the scope of S&OP.

Several studies related to the resource-based view (RBV) depart from a strategic perspective to address critical resources as sources of sustainable competitive advantage

(e.g. Kraaijenbrink et al., 2010). How to plan critical resources within tactical terms in ETO environments is however still lacking. Therefore, we explore how ETO business characteristics put requirements on and can be handled by an S&OP process.

S&OP is an aggregate planning process that – through cross-functional integration – seeks to balance demand and supply within tactical timeframes (Jonsson and Holmström, 2016). However, limited number of S&OP studies deal with ETO environments (Kristensen and Jonsson, 2018). To the best of our knowledge, no study addresses how S&OP manages the uncertainties associated with the dynamic medium-term needs of engineering resources in an ETO environment. Therefore, to fulfil the purpose of this study, two research questions are formulated as follows:

- RQ1: Which areas of uncertainty can be related to engineering resources within the S&OP process in an ETO environment?
- RQ2: How does S&OP manage the dynamic medium-term needs of critical engineering resources in an ETO environment?

Conceptual framework

Sales and operations planning (S&OP) integrates the plans for sales, supply, and production into an overall aggregate plan (Noroozi and Wikner, 2017) and aims at balancing the targeted customer demand, shaped by marketing and sales functions, and the supply capacity, shaped by procurement and operation functions (Jonsson and Holmström, 2016). Therefore, S&OP is defined as: "*a business process that links the corporate strategic plan to daily operations plans and enables companies to balance demand and supply for their products*" (Grimson and Pyke, 2007, p. 33).

Although S&OP is simple in theory, companies vary in how S&OP is implemented. According to Danese et al. (2017), literature mainly addresses implementation that characterize four main S&OP maturity dimensions, including *people and organization*, *process and methodologies*, *information technology (IT)*, and *performance measurement*.

In this paper, the definition of ETO production adopted by several researchers (e.g. Willner et al., 2016, Gosling and Naim, 2009) is applied as to be distinguished from make-to-order (MTO) production, which allows for limited configuration within a pre-defined solution space. Accordingly, ETO production is perceived as directly linked to a customer order with the decoupling point in the design stage dedicated to adapting products. This implies uncertainties affecting the S&OP process. However, ETO literature does not explicitly address the areas of uncertainty that influence critical capacity planning. Therefore, this paper addresses such areas of uncertainties drawing on their generic sources: *customer demand* and *supply capacity*.

The main source of uncertainty stems from demand. Depending on the depth of the product structure and the amount of jobbing needed to process such requests, ETO environments range from basic to complex settings (Hicks et al., 2001). In complex settings individual customer orders typically require large investments in plants, machines, equipment, and engineering resources. Each customer order, inquiry or contract calls for careful considerations that may result in substantial consequences in terms of engineering resources. Therefore, ETO companies need to deal with several areas of uncertainty stemming from *customer orders*.

It is not unusual that the resource preparation process does not conform to the lead time requirements that ETO customers are willing to accept (Olhager et al., 2001), which is crucial in winning customer orders in addition to cost and quality. The competition enforces ETO companies to embrace more uncertainties related to resource requirements through – for instance – rushing up the acceptance to process inquiries without being carefully studied as customers need quick response. This explains the tendency of ETO

companies to build and maintain excessive capacities in a capacity lead strategy. Accordingly, ETO companies arguably need to deal with uncertainty areas stemming from *critical competences*.

Figure 1 summarizes the theoretical framework of the paper, which focuses on the interfaces between the generic process of S&OP and the specific areas of uncertainty embedded in ETO settings, which are empirically identified under the main categories of customer order and critical competence to answer RQ1. The arrows in the figure highlight the bidirectional focus of RQ2, where the influence of S&OP on the areas of uncertainty identified to answer RQ1 as well as the influence of these uncertainties on the S&OP maturity dimensions are addressed.

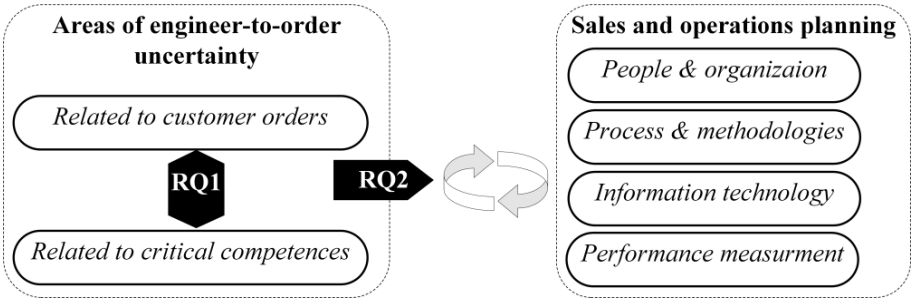

Figure 1 – S&OP and ETO uncertainties

Methodology

To answer the research questions, an exploratory single case study was conducted at a leading multi-technology first-tier aerospace supplier. According to Yin (2017), a single case study can be used to represent a unique or extreme case. The uniqueness of the selected case stems from being an ETO-oriented firm that possesses a structured S&OP process that includes engineering resource planning.

Drawing on the conceptual framework presented in Figure 1, an interview protocol was developed to collect empirical data. The data was gathered through semi-structured interviews and process-related documents. In total six interviews were held with an average length of 100 minutes. Three interviews were audio recorded and conducted with one participant, while the other three interviews involved a relevant group of participants. The three group interviews were held with management representatives from the logistics and operations planning function. Then, an interview was conducted with the marketing manager, the S&OP coordinator, and a representative from the management team of the engineering function who is part of the S&OP development team.

The unit of analysis was the five main stages of S&OP including data gathering, demand planning, supply planning, pre-S&OP meeting, and executive S&OP meeting (see Wallace and Stahl, 2008). The data was elicited to explicate the uncertainties associated with engineering competences and how they were addressed throughout the process, i.e., identified, communicated and minimized.

Through content analysis, the collected data was analysed, and relevant constructs were identified after iterations of inductive coding (Glaser and Strauss, 2017). Through empirical evidences, areas of uncertainty associated with engineering competences were suggested as constructs under the main categories of customer orders and critical competences. The empirical data on how such areas of uncertainty were addressed throughout S&OP allowed for identifying several requirements for the process design.

Research quality was considered through neutralizing biases and ensuring transparency. Detailed documents describing the S&OP process at the company were

studied before interviews. The documents contained the latest update of the standardized process; the inputs, objectives, decisions, and outcomes of each activity; the methods, process and systems used to perform and support the activities; and the representatives from each function and the coordinators involved in each activity. This helped in mapping out the S&OP process at the case company to more effectively gather relevant data.

Interviews were conducted in a sequence that ensured logical data gathering through which the questions about specific areas were posed to the right respondents. S&OP is started by the marketing function to plan demand. This part was well defined and documented, and thus easy to start with to identify the uncertainties. Having done this from the demand planning perspective, the interview with the S&OP coordinator then helped to further explore and describe the issues from the supply planning perspective. Consequently, more holistic knowledge about the uncertainties related to the critical resources within the implemented S&OP was captured, which then helped to identify specific root causes through the interview with the engineering function. Finally, to avoid the single researcher bias, the interviews were transcribed by one researcher and analysed collectively based on the transcripts and the company documents.

Case description

The case company provides customized components to three aircraft engine manufacturers. The components are grouped into six main product groups, which are continuously adapted to new components originating from new contracts typically awarded after tendering. The designs of new components are iteratively specified and agreed upon with respective customers. The production processes need to be upgraded to deliver the agreed quantities and specifications according to the new contracts and life cycle plans. Usually, three main production development phases are followed for each life cycle plan. Small quantities are first produced in the production start-up phase, before the ramp-up, and finally, the termination phases. In the aerospace industry, even though the product lifecycle is relatively long, phasing in and out components is complex and requires unique engineering competences that may take up to two years to be fully prepared for proper utilization. Therefore, the case company incorporates activities in S&OP that specifically address the medium-term need of engineering resources.

The S&OP process is conducted with monthly planning buckets and planning frequencies, and with a planning horizon of 36 months. The main logic is that each product group puts forward the future demand and supply needs that are then reviewed and met by the related functions. Forecasts and demand plans are reviewed by marketing, engineering resource requests are reviewed by engineering, while internal and external capacity requests are reviewed by operations and supply chain. When the functions are unable to fulfil the requests within the present budget, escalations are made to the top management that respond through decisions during the S&OP meetings.

Analysis

Investigating where the need for engineering resources emerges within S&OP activities lead to identifying 11 areas of uncertainty (see figure 2), 5 of which are related to *customer orders*, while 6 of which are related to *critical competences.* The analysis of each area of uncertainty includes insights into the planning consequences. Then, the ways for how the S&OP process maturity helps to deal with such challenges are presented.

Five areas of uncertainty stem from customer orders including *the source and timing of customer orders*, *customer order specifications*, *the probability of winning customer orders*, and *customer reliability*. The S&OP process starts with each product group developing or updating the demand plan. Inputs from the bidding process (process for

screening and reviewing tender requests and preparing competitive bids) provide insights into the future potential customer orders. The *sources of customer orders* are three aircraft engine manufacturers. According to the marketing manager, the source of customer order can be an area of uncertainty for other ETO environments where more potential customers exist. However, since this does not apply in this case, it is difficult to foresee the consequences of having such uncertainty and how S&OP mitigates for it.

The marketing manager also emphasizes that the *timing of customer orders* is uncertain leading considerable consequences on engineering resource plans. Supposedly, learning about the accurate timing of customer inquiries as early as possible allows for higher resource utilization, and timely recruitment and preparation of engineering competences to fulfil the needs from bidding processes and subsequent engineering work.

The S&OP coordinator states that customers are typically uncertain about the *detailed component specifications and quantities*, which increases the uncertainty concerning the future amount and type of engineering work. Underdefined customer specifications also imply increasing the uncertainty concerning the coordination workload needed to compile inputs for engineering resource planning. In the first place, product groups are usually uncertain about if they will *win future customer orders*, which is why they tend to delay crucial decisions concerned with extending and upgrading the engineering resource base. The consequence is that top managers in the S&OP executive meeting approve the recruitment of critical engineers when the work for customer orders needs to start within less than 6 months, whereas the corresponding recruitment and preparation process may take more than a year until these engineers live up to the working standards.

According to the interviewees, *customers* sometimes transmit overestimates (approximately 10% more than the actual demand) as to mitigate the risk of scenarios where the case company runs into production disturbances. That is, customers enforce the case company to build excess capacity, but without sharing such costs.

To mitigate for the areas of uncertainty related to customer orders, the monthly S&OP cycle starts with gathering relevant assumptions from the product groups. The assumptions serve as a foundation for predicting the timing of future customer orders, customer order specifications, win-rate and customer reliability, not only based on figures (forecasts), but most importantly based on events. The assumptions are tracked, reviewed and updated throughout the consecutive S&OP events. The bases of the assumptions originate from the collaboration with customers, which is evident from the marketing team activities associated with the bidding process and the component life cycle reviews. The assumptions are also based on internal business intelligence that has been developed and accumulated over years. The marketing team – which is represented in each product group – then compiles the updates of the forecasts and assumptions prior the demand review that is conducted by the marketing manager who, in turn, validates the updates through questioning the reasons on which they were based. Consequently, the medium-term demand – in terms of the customer orders over 36 months – is updated and approved.

On the other hand, six areas of uncertainty stem from critical competences including *competence type and quantities*, *the availability of internal and external competences*, *competence qualification period*, and *inter-resource equivalences*. Product group takes the responsibility of detailing the consequences of the updated demand on tools and equipment, which in turn shapes the future need of production infrastructure and engineering competence. The product groups, through representatives from engineering and production functions – chief manufacturing engineers (CMEs) and chief design engineers (CDEs), respectively – define the specific engineering capacities required for production and product design. CMEs and CDEs rely on the inputs from the updated reviews of demand, tooling and facility. However, *how such inputs are transformed into*

future needs of engineers is not explicitly documented, but rather based on rules of thumb and personal experiences. Furthermore, the identified needs are often generic specifying high-level skills or expertise, which arguably increases the uncertainty about *if these identified engineering resource needs perfectly match the actual need* of the updated demand. Such uncertainty increases the possibility of having either under- or overcapacity in engineering resources. It is even possible to experience scenarios of both under- and overcapacity, where overqualified engineers (with broader skillsets than needed) are recruited, but still do not live up to the quantity needed to fulfil the actual demand. Here, the case company will incur the cost of excess capacity that is not well utilized, and the cost of potential delay in form of penalties, for instance.

CMEs and CDEs use a roadmap to visualize how the required engineers need to be aligned with the ongoing and future parallel projects. Moreover, they use a workforce planning tool to communicate the type and quantity of competences that will be requested from engineering by each product group. These requests are processed by the various engineering divisions given the internal competence availability. Similar to the way the engineering resource needs are identified, the engineering divisions assess the availability and suitability of internal competences against the requests raised by CMEs and MQEs from product groups. Controlling the availability of engineering resources is not different from other labour categories. That is, the *uncertainty about engineering workforce availability* rests in unforeseeable absenteeism due to, for instance, injury, sickness and contract termination. These risks are typically mitigated through building excess capacities whereby engineering assignments temporarily can be performed temporarily by one or more individuals. However, the suitability of available engineers compared to the requests is still based on subjective judgment, meaning that there is *uncertainty about whether the internal resources being continually configured to best meet the future demand* with maxim utilization and to avoid the scenarios of under- and overcapacity.

The engineering function consists of divisions. Each division identifies the types and quantities of competences that are lacking and escalate deficits to the higher management level. Here, the second-line managers, the head of engineering and the external resource manager address the different options to secure the supply of engineering workforce. This includes recruiting new engineers, acquiring consultants, and reorganizing the engineering resource base. The latter option is based on the outcomes of a parallel process for planning the organizational structure that is aimed at determining how the organization should evolve given the strategic business objectives. This includes foreseeing the probable changes in the resource base such as the retirements and promotions of individuals. Usually, *the consequences of promoting a group of engineers on future demand are uncertain*. However, the S&OP process and the organizational planning process are not formally or coherently linked to each other.

As for *external resources*, the case shows that there is always *a lack of knowledge concerning the type and quantities of competences* that can be found externally. Consulting and newly recruited engineers are different in nature, i.e. in terms of skills, expertise and personalities. Therefore, the time needed to prepare such engineers in line with the respective task requirements varies, meaning that *the preparation period* also represents an area of uncertainty. The interviewee from the engineering department emphasized that there is much uncertainty concerning *how a group of engineers can be allocated in equivalent configurations of teams to produce the same effect*, which allows for advantageous flexibility. That is, engineering resource planning within S&OP is mainly done through individuals from each division, which limits the visibility of the embedded flexibility and equivalences among engineers across the different divisions. The higher-level managers who review the respective plans still see this more

comprehensive picture of how all engineers are allocated. Again, these managers rely on their own experience and ad-hoc approaches to optimize such resource plans.

The case company partially measures the S&OP performance through indicators from few activities including forecast accuracy, customer scheduling adherence, inventory turnover, and service level. That is, the performance of S&OP as a whole is not measured due to the lack of consensus on the effect to be measured. Some participants consider the periods the S&OP process is able to address beyond the budgeted activities as an indicator, while others relate the S&OP performance to the progress made on strategic goals. On the other hand, the interviewees confirmed that the performance of S&OP had been assessed at least against maturity criteria to identify major gaps. Consequently, a dedicated team of 10 members prioritized the improvement of activities, which were not followed up according to an action plan in each S&OP cycle, but rather used as guidelines. Involving engineering in S&OP is an example of such improvements. Another example is improving the processing conditions and clarifying the descriptions of several sub-processes. The team continuously refines the data that should be prepared upfront before the executive S&OP meeting to enable quicker and better decisions. That includes how the data should look like as well as how and when the data should be communicated. Figure 2 presents the areas of uncertainty related to engineering resources and the S&OP activities through which these areas are captured and addressed (i.e. the grayed out cells).

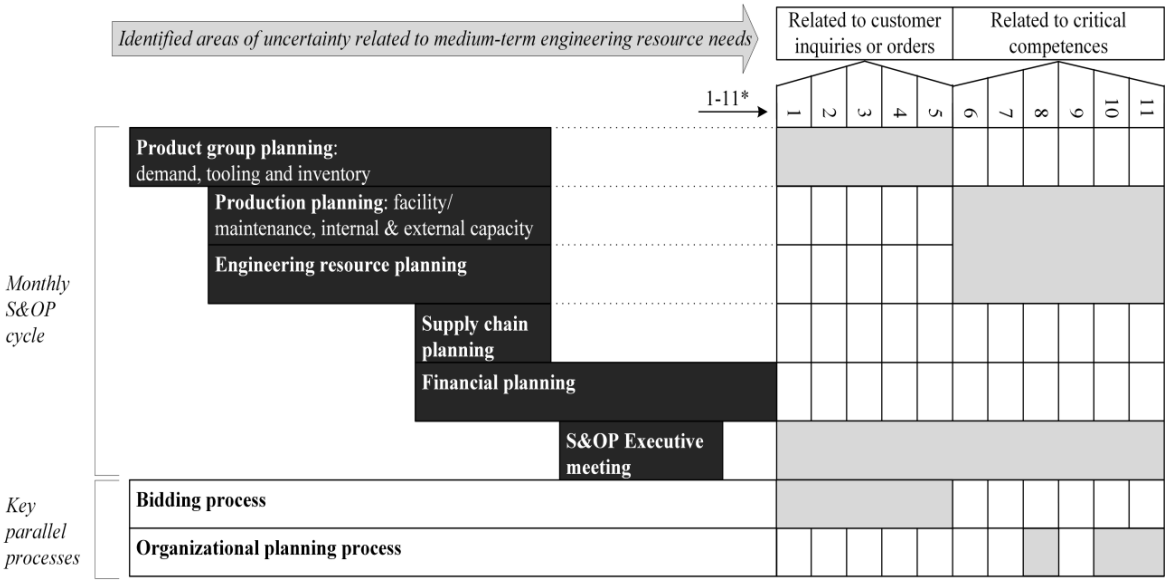

Figure 2 – Areas of uncertainties related to engineering resources within S&OP

Discussion

The case analysis explores how to manage ETO challenges in an S&OP process, in terms of *people & organization*, *process & methodologies*, and *performance measurement*. It also explores how the S&OP integration with other processes is important in this context.

As revealed from the case analysis, the frequent engineering changes caused by incoming demand calls for incorporating a function for identifying and tracking the medium-term needs of engineering competences in addition to what has been referred to in previous literature (e.g. Wallace and Stahl, 2008) as a traditional *S&OP organization*. By involving engineering representatives in the demand planning conducted by product

groups, the S&OP organization facilitates the translation of demand plans into engineering resource needs. However, within the engineering functional organization, the hierarchical gap between management levels can be reflected from limiting the respective cross-hierarchical communication to certain escalation conditions. When this applies, top managers are often not able to question such escalations and thus delay related decisions as they are not fully aware of the grounds on which the identification of engineering needs were based. This corresponds to a general need and absence of early communication of uncertainties and structured communication of assumptions as part of a demand management and S&OP process (APICS, 2019). We see that such need of early and structured communication is critical in ETO environments. In accordance with the cross-functional integration framework of Oliva and Watson (2011), we also see that S&OP may enable improved engineering information quality and constructive engagement even within the engineering function – cross-hierarchically.

As for the *processes and methodologies* used in S&OP, to address the uncertainty areas identified in Figure 2, the case company seems to rely on assumptions and implicit ad-hoc approaches. For instance, the translation of engineering workload requirements into man-hour per engineering skill is based on subjective judgements, rules of thumb, and personal experiences. Findings show that the uncertainties stemming from an ETO environment require more structured/advanced methods of capacity planning compared to other contexts. While such identification of engineering needs can be "good enough" as claimed by an interviewee, the lack of method transparency still hinders making quick decisions by higher-level managers and does not allow for establishing a consistent engineering planning process among product groups and engineering divisions. The lack of using systematic methods to plan capacity for job shops was also discussed by Tenhiälä (2011). This lack was attributed to the practitioners being often unaware of the possibilities RCCP methods can bring. Apart from that, there seems to be a strong requirement on the integration between the key sub-processes of S&OP (i.e. demand and supply planning) in ETO settings as to be able to run the S&OP cycle in a monthly basis despite the extra need of continually identifying engineering needs. The case company enables considerable integration between demand and supply planning through a matrix organization that takes the form of product groups, which in turn serve as collaborative cross-functional platforms. The cross-functional teams from the respective product groups are involved in almost all demand and supply planning events of S&OP, which ensures that both planning processes are somehow integrated throughout the process.

Information technology (IT) has been recognised in several S&OP literature as a key process enabler in many contexts, and the case analysis shows that ETO settings are not an exception. The case company dedicates internal databases of business intelligence and tools for competence road mapping and collaborative workforce planning, which is – according to the interviewees – far from being enough to deal with several ETO challenges. The dominant type of information that can be made available in ETO settings is highly descriptive due to the uniqueness and ambiguity embedded in demand. Manipulating and processing such type of information requires considerable manual human work as information systems are not yet mature enough to automatically arrange descriptive information into systematic codes (Evers, 2018). Instead, findings show that the information systems used in ETO environments for S&OP should at least enable intuitive explicating of the ad-hoc approaches used by individuals to define the required engineering workload given a certain demand, the required type and quantity of engineering competences given a certain workload, and the possible allocation(s) of competences to fulfil the requirements of a certain workload given their availability. Besides, ETO environments are surrounded with several risks and assumptions such as

engineering critical resource absenteeism, and IT tools that support scenario planning is much needed under such circumstances. High-performing firms use scenario planning in S&OP (Danese et al., 2017). The scenario-planning support for S&OP in ETO settings also needs to enable modelling the consequences of recruiting new engineers, acquiring consultants, and reorganizing the engineering resource base as these activities are frequently performed. Consequently, our findings indicate relative high IT needs for S&OP in ETO settings, already on lower maturity levels.

As for *S&OP performance*, the case shows an evident lack where limited performance indicators are used such as scheduling adherence and forecast accuracy. According to Hulthén et al. (2016), the performance of S&OP can be measured through measuring the efficiency of, for example, respective meetings. Meetings are highly important to make timely decisions in ETO settings, especially when it comes to approving the recruitment of additional engineering competences. This is because certain engineering competences need long-lasting preparation and training before they can be properly utilized. The S&OP process in large is also more complex in ETO settings (e.g. more functions involved, more supply planning activities) which may motivate a need for measuring process efficiency.

Finally, the case emphasizes the importance of tightly *integrating certain planning processes* in ETO contexts. Since the majority of ETO markets are based on tendering (Hicks et al., 2001), the bidding process plays a crucial role in shaping the medium-term demand. This calls for having S&OP and bidding highly integrated. Similarly, the lifecycle of products also influences the timing and volume of future demand, which is extremely important for ETO environment as discussed earlier, and thus needs to be tightly integrated into S&OP. Apart from that, S&OP outcomes should be integrated into organizational plans as S&OP captures in a monthly basis the potential future competence gaps that the organizational plans need to be aligned with.

Conclusion

This study explores how S&OP manages the uncertainty associated with the dynamic medium-term needs of engineering resources in an ETO environment. A relevant single case study was investigated leading to three main areas of contribution. The first contribution is to the ETO planning environment. Eleven areas of uncertainty were identified and related to customer orders and critical competences, as shown in figure 2.

The second contribution is to explore the role of S&OP in relation to the identified areas of uncertainty. To mitigate for these areas of uncertainty, we explore the role and maturity dimensions of S&OP. The S&OP organization needs to integrate an additional function concerned with engineering resource planning. Such growth of the S&OP organization calls for more coherent integration of S&OP sub-processes that enables to run S&OP within reasonable timeframes. Arguably, this is possible through the early involvement of engineering resource planning actors in that cross-functional teams dedicated to measure and follow up the performance of demand and supply planning. The engineering resource planners need to explicate the approaches they use to identify the required engineering workloads and corresponding competences needed as a first step towards learning about and standardizing relevant know-how knowledge and best practices. In this respect, the IT tools used in S&OP should at least intuitively support such knowledge elicitation from individuals on top of the need to support reliable scenario planning capitalizing on companywide data. That is, in ETO settings, the need for IT and information sharing is relatively high even at lower S&OP maturity levels

The study also identifies a need to continuously improve the short-term performance of S&OP through measuring the efficiency of the key events of the S&OP activities such

as important meetings. Within longer terms, the maturity assessments are suggested to identify the significant deficiencies and develop action plans accordingly.

The third contribution is related to the role of S&OP in other processes. The alignment of S&OP with the bidding process and organizational development seems to be highly important in ETO settings due to the recurring exchange of inputs and outcomes between these processes. Further, S&OP seems to have cross-hierarchical integrative potentials within large engineering organizations, which is manifested by improved information quality and constructive engagement and suggested for future research. Studying S&OP in other ETO settings with different complexity is also highly recommended to further explore, validate and generalize the findings of this study. Another trajectory is to more deeply study the requirements on and the potentials of one or more S&OP dimensions to manage one or more areas of uncertainty related to engineering resource planning.

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Why Sales and Operations Planning not is implemented: Empirical evidence

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Abstract

This paper is concerned with the reasons for not using and the perceived relevance of Sales & Operations Planning (S&OP) based on 156 full and useable answers to a questionnaire-survey distributed among Danish manufacturer. The more the respondents perceive the lack of knowledge S&OP the more they perceive the relevance of S&OP. Further, the more the respondents perceive unrecognized needs the less the perceived relevance of S&OP. Lack of implementation skills does not influence this S&OP relevance. The perceived relevance of S&OP influence only sales performance in terms of customer and delivery performance but neither operational nor financial performances.

Keywords: Questionnaire-survey, maturity, readiness, performance

Introduction

Sales & Operations Planning (S&OP) is a cross-functional process that aims to balance supply and demand typically with a tactical planning horizon from 3-24 months (Kristensen and Jonsson, 2018). Extant literature on S&OP is rich and is found in academic, grey and practitioner-oriented literature (Thomé et al., 2012; Tuomikangas and Kaipia, 2014). It contains a number of research contributions focusing on various maturity stages of S&OP (e.g. Danese et al., 2018; Grimson and Pyke, 2007; Wagner et al., 2014), technology implementation and outcome at the expense of drivers and antecedents that promote S&OP (Swaim et al., 2016; Qi and Ellinger, 2017). However, some literature has, in fact, focused on the antecedents for S&OP and success criteria for implementing S&OP (Boyer, 2009; Iyengar and Gupta, 2013; Lapide, 2014; Swaim et al., 2016) but are concerned with companies that already have decided to implement S&OP.

Literature focusing on the stages before implementation processes of S&OP is limited despite some practice-oriented literature (Tinker, 2017). Extant literature on S&OP is not

explicit about this pre-stage of S&OP but several sources justify this point of analysis (e.g. Stahl and Shedlawski (2012) on why companies do not choose to pursue S&OP due to catch-22) and Naslund and Williamson (2017) have investigated companies not operating with S&OP to identify the performance potential of such companies if implementing this tool. The S&OP maturity models by Danese et al. (2018) and Wagner et al. (2014) do contain a first step that equivalize with having no S&OP processes. However, this seems only to be mentioned and not further researched. It is interesting to analyze why S&OP not is implemented by companies since benefits apparently appeal to both sales, operations, and finance (Prokopets, 2012), and is a tool that can help tearing down the silos (Grimson and Pyke, 2007; Wagner et al., 2014), which may sustain dysfunctional organizations (Rangarajan et al., 2018). The S&OP literature also demands more empirical founded literature on S&OP issues (Ivert et al., 2015; Swaim et al., 2016; Pedroso et al., 2016; Thomé et al., 2012). A specific point of analysis is also to look at the firm size in the analyses. Further extant literature on S&OP is sparse on contributions having an explicit focus on small- and medium-sized enterprises (SMEs) (Kristensen and Jonsson, 2018; Stentoft et al., 2019).

Hence, the purpose of this paper is to advance the understanding and provide novel data of reasons for why companies are not using S&OP and what might be done to facilitate a better evaluation if the relevance of S&OP.

Conceptual frame of reference

This section argued for various reasons for not using S&OP. The section is based on inputs from literature (see Table 1) as well as from ten case studies concerning the whole process of initial clarification of what S&OP is through a decision to implement and develop the S&OP process to pilot and final operation (Stentoft et al., 2019) (see Appendix A). In the first meetings in these ten companies, discussed why S&OP was not part of their daily business and why they found it relevant for them to implement. Furthermore, this section also includes a brief sub-section about the performance outcome of S&OP.

Reasons for not using Sales & Operations Planning

Lack of knowledge about S&OP

Among possible reasons for not applying S&OP, the first plausible reasons are the lack of knowledge about S&OP. This knowledge-gap may take place both at the top management level as well among the organization in general. S&OP literature stresses the importance of top management support (Ivert and Jonsson; McLeod, 2012; Wallace and Stahl, 2008) when deciding and operating S&OP, which requires knowledge about it. Furthermore, it might be the case that top management or some from this group do know to S&OP, but that the organization does not. Literature, therefore also stress the importance to prepare the organization for the potential for such processes e.g. though training or other cross functional initiatives (Slone et al., 2010; Rangarajan et al., 2018). The lack of knowledge has also been discovered at the beginning of a large project following the decision-processes, planning, and implementation of S&OP in ten Danish manufacturers (Stentoft et al., 2019). In the first meeting with the companies, they were all asked about why they do not have a S&OP up running. In case 4, 9 and 10 it was experienced that no one in the top management knew about S&OP. However, in case 4 and 10 there was a S&OP knowledge among the middle managers who knew from past jobs and from their professional network. In case 3, 5, 8 and 9, we experienced a low S&OP knowledge level in the organizations, which all are SMEs.

Table 1 – Reasons for not using S&OP

Lack of knowledge about S&OP	**References**	**Case example(s)**
• Low level of S&OP knowledge in top management	Cecere (2015); Gray and Dougherty (2017); Ivert and Jonsson (2010); McLeod (2012); Milliken (2008); Rangarajan et al., 2018); Wallace and Stahl (2008, p. 76)	Case 4, case 9 and case 10 (see Appendix A)
• In general, too little S&OP knowledge in the company	Boyer (2009); Dougherty and Gray (2006, p. 127); Ivert and Jonsson (2010); Rangarajan et al., (2018); Slone et al. (2010, p. 117)	Case 3, case 5, case 8 and case 9 (see Appendix A)
Unrecognized need for S&OP	**References**	
• There is no need for a S&OP process	Muzumdar and Fontanella (2006)	Case 4 (see Appendix A)
• Lack of S&OP readiness	Ambrose et al. (2018); Grimson and Pyke (2007)); Stentoft et al. (2019); Tinker (2017); Vereecke et al. (2018)	Case 4, case 6 and case 10 (see Appendix A)
• Difficult to see the benefits/value are higher than the costs of implementing an operation S&OP	Chase Jr. (2013); McLeod (2012); Stahl and Shedlawski (2012)	Case 5 and case 8, case 9 (see Appendix A)
Lack of implementation skills	**References**	
• Lack of human resources to work with S&OP	Boyer (2009); Githens (2009); Dougherty and Gray (2006, p. 128); Milliken (2008); Pedroso et al. (2016)	Case 1 and case 5, case 9 and case 10 (see Appendix A)
• Have tried with S&OP in the past once or more times without success	Grimson and Pyke (2007); Iyengar and Gupta (2013); Lapide (2005); Moon and Alle (2015); Pedroso et al. (2016); Singh (2010); Slone et al. (2010, p. 118); Wagner et al. (2014); Wallace and Stahl (2008, pp. 76-77).	Case 2, Case 6 and Case 7 (see Appendix A)

Unrecognized need for S&OP

Another group of reasons for not using S&OP is concerned with an unrecognized need for S&OP. Muzumdar and Fontella (2006), for example, mentioned that many executives are unsure about S&OP and question why their company needs S&OP. This was experienced in case 4 (an SME) where the CEO expressed at the first meeting that S&OP was not needed because their business is so special. However, after some months, the COO and planning manager returned with an acceptance to be part of the overall project since they had convinced the CEO to start up the S&OP project. Another reason for not having implemented S&OP is a lack of S&OP readiness. In case 4, 6 and 10 such lack of readiness became visible in different ways. In case 4, the CEO's articulated resistance led to a lower S&OP awareness among the sales and finance staff. In case 6, which is a large company, there was in the beginning a lack of buy in to process by sales. In case 10, there was a lack of readiness by some members of top management and middle managers due to unsolved issues with prioritization of time between daily operation and the S&OP process development. The uncertainty of the division of this work created a lower readiness. The last reason identified in this group may also simply be that managers cannot see that the benefits are higher than the costs of implementing and operating S&OP (Chase Jr., 2013; McLeod, 2012; Stahl and Shedlawski, 2012). This reason was also found in case 5, 8 and 9. In case 5, the sales staff was not motivated for the S&OP project and questioned that the benefits did not defend the resources that should be used. A similar situation was present in case 8, where sale also had reservations towards S&OP due to the extra workload. In case 9, the skeptics towards S&OP came from finance that extended the company's decision process to join the project due to a perception that the outcome could not exceed the efforts put into the process.

Lack of implementation skills

The final group of possible reasons for not operating with a S&OP process is concerned with a lack of implementation skills. The first reason is here lack of resources. So, a company might have knowledge about S&OP and they have also recognized a need for S&OP but has not implemented it due to lack of resources. Having the resources necessary to first attend a S&OP project and afterward operate the process is crucial (Boyer, 2009; Dougherty and Gray, 2006); Pedroso et al., 2016). The resource issue also became visible in case 1, 5 and 9 and 10. In case 1, the top management and middle managers were aware of S&OP and its relevance for their company, and only two years before they decided to start up but did not start up due to lack of the right resources. In case 5, it became clear during the first meetings that the company had difficulties in initiating and implementing business projects due to a weak separation of operation and project work. Lack of resources to carry out S&OP projects was also mentioned in case 9 and 10. Finally, a reason for not operating with S&OP might be past negative experiences with unsuccessful implementations (Iyengar and Gupta, 2013; Lapide, 2005; Moon and Alle, 2015). Case 2, 6 and 7, which all are large companies, reported in the beginning that they had tried with S&OP before but failed with the implementation due to lack of top management support, lack of sales involvement and havening a too short-termed focus.

Accordingly, we hypothesize that:

H1: Reasons and Relevance toward S&OP

a) Lack of knowledge toward S&OP influence the perceived relevance of S&OP.
b) Unrecognized needs toward S&OP influence the perceived relevance of S&OP.
c) Lack of implementation skills toward S&OP influence the perceived relevance of S&OP.

Performance outcomes of S&OP

Extant literature on S&OP is also concerned about how performance might be affected by S&OP (Swaim et al., 2016; Prokopets, 2012; Thomé et al., 2014; Tuomikangas and Kaipia, 2014). In literature, the performance effect is divided into sales performance (Swaim et al., 2016; Wagner et al., 2014), operational performance (Boyer, 2009; Thomé et al., 2012) and financial performance (Prokopets, 2012; Thomé et al., 2012).

Accordingly, we hypothesize that:

H2: Relevance toward S&OP and Performance of the firm

a) Perceived relevance of S&OP influence firm's sales performance.
b) Perceived relevance of S&OP influence firm's operational performance.
c) Perceived relevance of S&OP influence firm's financial performance.

Method

This paper is based on the data from a questionnaire-survey carried out in the autumn 2018 in an investigation of reasons behind companies not applying S&OP. In total, 891 Danish manufacturing companies with 50 or more employees were contacted. 240 of the companies agreed to participate in the survey about reasons for not using S&OP. In total, 166 responded of which 156 respondents have provided full and useable answers leading to a response rate at 17.5 percent (138 SMEs and 18 large companies). The constructs that were chosen to measure the hypothetical model are built on extensive review of relevant literature. The construct reasons for not using sales and operations planning (S&OP) includes indicators like lack of knowledge, unrecognized needs, and lack of implementation skills. The construct relevance of S&OP is evaluated according to the answer provided by the respondents on a

5–point Likert Scale. The construct performance includes sales, operational and financial indicators (see Appendix B for the complete list of constructs and indicators). Sales performance includes customer, delivery, and sales performance. Operational performance includes operational cost, planning cost, and output cost. Financial performance includes net working capital and profitability.

Analysis

The analysis aimed at exploring the understanding of reasons for not using S&OP, the relevance of S&OP, and the performance implications. Exploratory factor analysis and linear regression were performed using SPSS 24 software. The validity and reliability of the measurement instrument were assessed. Tests for non-response bias (Li et al., 2016) and common method variance (Chang et al., 2010) were performed, and the results inform that it is not of major issue. The seven questions concerning the reasons for not using S&OP like lack of knowledge, unrecognized needs, and lack of implementation skills were built based on the existing literature and were sent to the respondents from three companies for validation. The respondents did authorize the appropriateness of the selected reasons for not using S&OP. Factor analysis was performed for the construct performance and the selected indicators for the projected factors were included for regression analysis.

Findings

Factor analysis was performed for the construct performance in terms of sales, operational, and financial. The result of the exploratory factor analysis (see Appendix B) indicated three indicators for customer performance (improved customer service level; improved customer satisfaction; and customer continued usage), three indicators for delivery performance (improved forecast accuracy; reduced stockouts; and improved time-to-market of new products / services), two indicators sales performance (improved earnings and growth in market shares), one indicator for operational cost performance (lower purchase costs), one indicator for planning cost performance (a more stable production (fewer re-scheduling)), one indicator for output performance (an improved capacity utilization), three indicators for net working capital performance (lower capital tied up in inventories; improved accounts payable - extended payment deadlines to vendors; and improved accounts receivable - shortened period for customer receivables), and three indicators for profitability performance (improved return on investment; improved product profitability; and improved customer profitability). The selected indicators for the projected factors were included for regression analyses to test the proposed theoretical model.

Linear regression was performed to check whether the chosen reasons for not using S&OP positively influence the relevance of S&OP. The results indicate that lack of knowledge positively influence the relevance of S&OP (statistically significant at 95% level; p-value = .020) and unrecognized needs negatively influence the relevance of S&OP (statistically significant at 99% level; p-value = .000). The result also indicates that lack of implementation skills does not influence the relevance of S&OP. Hence, H1a and H1b are supported. Next, linear regression was performed to check whether the relevance of S&OP influences the performance of the firm in terms of sales, operational, and financial. In general, the relevance of S&OP negatively influences the sales performance (statistically significant at 90% level; p-value = .067). However, the relevance of S&OP does not influence the operational and financial performances of the firm. With reference to sales performance, the relevance of S&OP negatively influences the customer performance (statistically significant at 95% level; p-value = .021) and delivery performance (statistically significant at 90% level; p-value = .097). Hence, only H2a is supported. In addition, secondary data was gathered and analyzed to check whether relevance of S&OP influence

last available three years income not influence income index and ROI performances. Since we believe that firm size plays a major role in S&OP implementation, the impact of firm size was investigated. The results indicate that firm size does not have a great impact (marginal impact 90%) on the relationship between reasons and relevance of S&OP.

Discussion

This research considers that lack of knowledge, unrecognized needs, and lack of implementation skills are the reasons for not using S&OP and perhaps about companies readiness for S&OP. The companies because of lack of knowledge toward S&OP are not able to realize the relevance of S&OP. Therefore, companies have to make a conscious effort in acquiring adequate knowledge to understand the relevance of S&OP and increase their readiness for using S&OP. Alike, companies should also begin acknowledging the unrecognized needs to realize the relevance of S&OP as well as to encourage the readiness for using S&OP. Further, the lack of implementation skills may not be important for perceiving the S&OP relevance and readiness. This research suggests companies to first unfold the appropriate knowledge through various internal and external sources. The acquired new knowledge will result in understanding the unrecognized needs to realize the relevance of S&OP and stimulating the companies readiness for S&OP. Undoubtedly, this will optimize the S&OP implementation skills. Regarding the performance, the less awareness of relevance toward S&OP results in more realization only toward sales performance. In particular, the relevance toward S&OP and companies readiness for using S&OP seems to be important for both customer and delivery performances. Whereas, the realization of relevance toward S&OP perhaps does not seems to be important for operational and financial performances.

This research increases firms' consciousness toward the reasons for not implementing S&OP as a tool or concept. Lack of knowledge can prevail among both top management and middle managers in a company. However, knowledge can be captured either by internal ambassadors or external consultants or professional organizations. These sources will help to improve the knowledge level in terms of articles, professional network facilitated by organizations, and conferences related to S&OP. Unrecognized needs happen both when a company lacks knowledge and has adequate knowledge concerning S&OP practice. Therefore, engaging both internal and external resources and capabilities can originate a thirst for new knowledge to identify the unrecognized needs. This will, in turn, bring much more visibility to the benefits of S&OP implementation. When a company has identified relevant knowledge and unrecognized needs they still lack implementation skills because of no human resources and has tried earlier without success. This research recommends companies to do a complete analysis of the internal employees and available external resources to make an overview of how well they are managing their current jobs using available resources. Besides, they can try to reorganize the existing human resources to work with the implementation of S&OP. If companies have tried in the past without success then they need to think about the requirement for change management, emphasize working with the burning platform, try to change their approach (mindset), and try to involve strong change agents. Altogether, understanding the reasons for not using S&OP and solving them will increase the readiness for S&OP implementation. Even though, the relevance of S&OP is not found to influence on operational and financial performances, it is found that the relevance of S&OP impacts negatively on sales performance. This seems to underpin a perception of that companies find that there is a trade-off between implementing S&OP and sales performance. Our study doesn't indicate the existence of such a trade-off, but may, in turn, be a reason why some companies see no need for S&OP and that lack of readiness exists in other companies.

Conclusion

This paper has set out to investigate possible reasons behind why companies have not implemented S&OP despite its accompanying benefits. Thus, we hypothesized that three groups of reasons for not have implemented S&OP affect the respondents' perception of S&OP. Furthermore, we hypothesized that the perception of relevance influence sales, operational and financial performance in the company. The analysis found statistical evidence for supporting H1a and H1b i.e. that the lack of knowledge of S&OP and an unrecognized need for S&OP influence the perception of the relevance of S&OP. The more the lack of knowledge the more the respondents find S&OP relevant and the more an unrecognized need for S&OP the less perceived relevance for S&OP. In contracts, data does not find support for H1c. Lack of implementation skills does not affect the respondents' perception of the relevance of S&OP. Regarding the relationship between perceived relevance and performance, we only found support for H2a i.e. the relevance of S&OP negatively influences the sales performance. Thus, the more perceived S&OP relevance the lesser the respondents perceive their sales performance which indicates that S&OP can be one among other factors that can help companies to improve their sales performance. Finally, the data did not find any support for a relationship between perceived S&OP relevance and operational and financial performance. Overall, the results seem not to differ with respect to firm size.

Implications for theory and practice

This paper has implications for both theory and practice. For theory, this study indicates a need for further practitioner-oriented research on antecedents for making decisions on S&OP. Is S&OP relevant to all business sectors? Such knowledge can be in the form of identifying contingencies and is as much important to know as it is to know drivers and barriers, performance outcome and success criteria and maturity models of S&OP. Next, future research can further explore the problem area with respect to firm size. Is S&OP, in fact, also relevant for SMEs? Recent research has found that S&OP is relevant for SMEs (Stentoft et al., 2019), but further research is needed. Finally, the focus on reasons for not operating with S&OP is closely related to readiness for S&OP, which is a topic that needs further exploration as a tool to be used in the decision- making process for initiating a S&OP project and thus is a preceding activity before the activation of S&OP maturity models. For practice, this study indicates a need to increase the knowledge level about S&OP among the top and middle managers. This can be done by professional organizations and/or management consultants. An increased awareness can help managers to make conscious decisions either to deselect of select S&OP as a mean to maintain or even enhance competitiveness.

Limitations and guidelines for future research

First, the questionnaire part is based on single respondents from each company. Future research can be strengthened by obtaining multiple respondents per company. Second, the qualitative part is limited to insights from 10 case studies. Future research can include more case studies to explore further reasons for not applying S&OP. Third, future studies should also include a more thorough theoretical underpinning of organizational readiness before implementation of S&OP. Fourth, this study did not focus on the various contingencies for companies being part of the research. Future, research can further investigate whether S&OP is deemed more relevant in some industries and/or with certain contingencies than others. Fifth, overall more research is needed into the limitation and the alternatives for implementing S&OP.

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Appendix A: 10 completed case studies from Stentoft et al. (2019)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10
Firm size	140 employees (SME)	450 employees (large)	28 employees (SME)	103 employees (SME)	100 employees (SME)	1.300 employees (large)	2.000 employees (large)	200 employees (SME)	100 employees (SME)	1.300 employees (large)
Industry	Tobacco	Foam	Sport cloth and accessories	Industrial lighting	Brewery	Automotive	Life-saving equipment	Logistics Equipment	Cowshed equipment	Exhaust pipes
Turnover in 2018	54,2 mill Euro	40 mill Euro	8,3 mill Euro	19,5 mill Euro	24,9 million Euro	0,22 billion Euro	0,25 billion Euro	40 million Euro	~ 15 million Euro	0,13 billion Euro
Low S&OP top management knowledge	—	—	—	✓	—	—	—	—	✓	✓
Low S&OP knowledge in the company	—	—	✓	—	✓	—	—	✓	✓	—
No need for S&OP	—	—	—	✓	—	—	—	—	—	—
Lack of readiness	—	—	—	✓	—	✓	—	—	—	✓
Can't see the benefit	—	—	—	—	✓	—	—	✓	✓	—
Lack of resources	✓	—	—	—	✓	—	—	—	✓	✓
Have tried with S&OP before	—	✓	—	—	—	✓	✓	—	—	—

Notation: — = Not practiced; ✓ = practiced

Appendix B: Principal Component Factor Analysis

Constructs and Indicators	Principal Component Factor Loading
Construct 1: Sales Performance	
Customer *(Eigen value = 2.147)*	
Improved customer service level	0.826
Improved customer satisfaction	0.835
customer continued usage	0.666
Obtaining new customers[a]	-
Delivery *(Eigen value = 1.939)*	
Improved on-time delivery[a]	-
Improved forecast accuracy	0.872
Reduced stockouts	0.769
Improved time-to-market of new products / services	0.652
Sales *(Eigen value = 1.429)*	
Improved earnings	0.705
Growth in market shares	0.847
Construct 1 – Cronbach's alpha	0.823
Construct 1 – % of variance explained	68.93
Construct 1 – KMO Measure of Sampling Adequacy	0.769
Construct 1 – Mean (std.)	3.07^{***} (0.57)
Construct 2: Operational Performance	
Operational cost *(Eigen value = 1)*	
A better balance between production and sourcing costs for transport and security inventory costs[a]	-
Lower manufacturing unit cost[a]	-
Lower purchase costs	0.999
Less overtime[a]	-
Less obsolescence[a]	-
Planning cost *(Eigen value = 1)*	
A more stable production (fewer re-scheduling)	0.978
A better human resource allocation[a]	-
Output cost *(Eigen value = 1)*	
Improved productivity[a]	-
An improved capacity utilization	0.977
Higher stock turnover[a]	-
Construct 2 – Cronbach's alpha	0.804
Construct 2 – % of variance explained	100
Construct 2 – KMO Measure of Sampling Adequacy	0.513
Construct 2 – Mean (std.)	2.94^{***} (0.57)
Construct 3: Financial Performance	
Net working capital *(Eigen value = 2.541)*	
Lower capital tied up in inventories	0.723
Improved Accounts Payable - extended payment deadlines to vendors	0.782
Improved Accounts Receivable - shortened period for customer receivables	0.731
Profitability *(Eigen value = 1.744)*	
Improved Return on Investment	0.888
Improved product profitability	0.935
Improved customer profitability	0.898
Construct 3 – Cronbach's alpha	0.766
Construct 3 – % of variance explained	71.42
Construct 3 – KMO Measure of Sampling Adequacy	0.723
Construct 3 – Mean (std.)	2.79^{***} (0.54)
[a] Items removed after EFA (Varimax rotated factor analysis) Statistical significance *** $p < 0.001$	

Service Operations Management

Blockchain effects on customer order management: programming and prototype

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Abstract

Blockchain is a novel technology that shows great promise to disrupt many aspects of society, industry and supply chain. Supply chain applications of Blockchain, however, have been rarely discussed in the academic literature. This study investigates the effects of Blockchain on the customer order management process and operations. A Blockchain is programmed in a Large International Firm in a prototype study. Results show reduction on order processing times and costs.

Keywords: Blockchain, supply chain, operational performance

Introduction

Blockchain offers four unique and powerful characteristics – transparency, traceability, resilience and safety that other digital systems lack (Palfreyman, 2016). This is a decentralized database that append records. There is great interest in Blockchain due to its architecture of anonymity, security, transparency and reliability without requiring neither trust between the participants nor a regulating intermediary (Yli-Huumo et al, 2016). The information track record is held in a tamper-proof database available to be inspected on demand by interested parties (Swan, 2015).
Supply chains are seen as one of the area most prone to disruption, due to its presently time-consuming and fragmented information tracking systems. Supply chain applications

of Blockchain, however, have been rarely discussed in the academic literature. To date there is not research on the effects of Blockchain in the customer order management process. This study investigates the effects of Blockchain on the customer order management process and operations. There is limited understanding on the use and benefits of Blockchain on supply chains, even less at processes level. The research question is What are the effects of the distributed ledger platform – Blockchain – on the operations of a supply-demand chain, particularly in customer order management?

Literature

A. Blockchain Technology: A Distributed Data Ledger

A Blockchain transaction generally starts when a party declares the transaction to the network, the receiving party broadcasts the acceptance of the transaction and the entire network participates in validating the transaction (Nakamoto, 2009). The transactions (or other pieces of information) are combined, recorded and cryptographically encoded into uniquely identifiable blocks, along with a pointer to the previous block and a timestamp. Many such blocks chronologically appended form a chain (Kruijff and Weigand, 2017). Each chain is initiated by a 'genesis block', hardcoded in the software, which is the only block that does not point to a previous block.

A block may contain a ruleset with additional conditions required to be fulfilled in order for the pieces of information be sent across the network (Kiviat, 2015). This functionality evolved into the concept of a smart contract, defined as executable code operating on the Blockchain to facilitate promises between untrusting parties (Alharby and van Moorsel, 2017).

B. Blockchain Applications

Blockchain is a revolutionary technology largely applied in finances, particularly in cryptocurrencies such as Bitcoin (Glaser and Bezzenberger, 2015; Holotiuk et al., 2017; Yermack, 2017) and smartcontracts (Alharby and van Moorsel, 2017). Outside cryptocurrencies, limited understanding on the uses of Blockchain is shown (Avital et al.2016; Risius and Spohrer, 2017).

Nowinski and Kozma (2017) foresee a trend that the research body on applications will explode in the following years. Applications could include services in supply chain management, insurance, digital knowledge management and e-commerce (Glaser, 2017).

The majority of the applications of this digital technology is at a nascent stage. Few cases demonstrate the use of Blockchain, nonetheless learning from these applications has changed the way companies operate. From a practical perspective, the majority of companies are cautious in investing in Blockchain, while still keen to learn from proof-of-concepts that demonstrate the feasibility and benefits of this digital technology (McLannahan, 2016). Hence, the impact of Blockchain on business models remains highly interesting to both industrialists and scholars (Risius and Spohrer, 2017).

Beyond the financial applications (Brown, 2018) , Blockchain is recently implemented and tested in few other contexts such as, health (Eklab et al, 2016), energy (Naudin, 2017), land registry (Landmateriet, 2017, (Vorick and Champine, 2014; Bocovich et al, 2017; Shieber, 2017), education (MIT, 2018), high-value assets (Everledger), data management (Zyskind et al, 2015), industriland administration, Conoscenti et al (2016), food (Steiner and Baker, 2015), and other market-place economic models (Sun et al, 2016, McConaghy and Holtzman, 2015). However, the majority of these implementations are reduced to early Blockchain implementation stages with little information disclosed about the effects

of Blockchain on their operations, performance and outcomes. Only few successful cases show the impact of the Blockchain technology on the business performance.

C. Blockchain in supply chains

Blockchain as an open platform that allows companies to build their own applications. Its versatility and vast array of applications inspires its use in the supply chain (Benkler, 2006). Companies are actively exploring how they can leverage Blockchain to innovate parts of their business operations under the form of 'private' Blockchains (Davidson et al., 2016), Private Blockchains do not require cryptographic incentives nor proof-of-work as public ones, but access is restricted to the chosen network and its information.

Reducing the complexity and lowering the technical barriers have contributed to the growing popularity of Blockchain. Thereby, it is foreseen that Blockchain will increasingly be in competition with existing organisations' systems and eventually could pose a threat to them due to its potential to perform their tasks more efficiently or reliably (Davidson et al., 2016).

As most companies build and maintain their own supply chain management software, it is difficult to have a global view of goods status in today's increasingly intricate supply chain networks(Gao et al, 2018).

It is hypothesized that the value-added from Blockchains resides on the companies' internal value chain (Science, 2016). Blockchain could revolutionise the way supply chain works (Dickinson, 2016). Kshetri (2018) claims that supply chain is believed to be one of the promising and transformative non-financial applications of Blockchain. Bunger (2017) supports that an industrial use-case in supply chains can provide an early return on investment for Blockchain applications.

Currently, the foods and goods supply chains are leading the implementation of the blockchains. Cases demonstrate the implementation of blockchain on the main stream supply chain of cotton, coffee and other goods. These use Blockchain from the growing, producing to the processing, distribution and retailing stages of the supply chain. Four out of eight applied cases reported in literature have been used in the foods and goods supply chains. The rest are applications on diverse sectors such as the health and safety compliance, high value assets and automotive. Their Blockchain applications are limited to front-end of the supply chains such as, in distribution and retailing.

With the exception of the Everledger case, the maturity level of these blockchain implementations are at the proof of concept stage. Most of these successful pilot cases are waiting to be scale up to understand and study the full potential of the blockchain in their industrial contexts. To date there not academic studies that demonstrate the effects of blockchain implementations on punctuated stages of the supply chain. In response to these research gaps, this study investigates the effects of Blockchain on the customer order management process and operations. The next chapter set the method for building and programing the Blockchain and the analysis of the results. This paper ends with some conclusions and future research.

Method

The emerging nature of research on Blockchains in supply chains is formalized not long after 2015, where few studies were conducted beyond smart contracts in a supplier-provider context (Dickinson, 2016; Gao et al, 2018; Miau and Yang, 2018).

Given the emerging knowledge in this topic, an exploratory research method is chosen as the right methodological fit to investigate our line of enquiry (Edmonson and

McManus, 2007). An in-depth case study method is selected as the foundational method for this exploratory research.

A Blockchain is first programmed from scratch. Our study (Yin 2009) is set in an international industrial manufacturing company specialized in heavy-assets equipment. For the purpose of this paper, the company is named as 'HAE" (disguised name for the company). At HAE, an Enterprise Resource Planning (ERP), an in-house collaboration tool, an Electronic Data Interchange (EDI), Excel sheets, customer portals, and some others are used to manage customer orders. Customer orders are presently highly manual and time-consuming, hence there is a high investment and operating cost aimed at human resources. Additionally, due to the laborious manual activities required for each order, processing and response times are long.

Unit of ananlysis. To add a precise understanding to the existing body of literature and to control our study, we decided to focus the implementation and use of Blockchain a particular stage of the supply chain – the Customer Order Management. Customer order management was chosen because it is often seen as the bottle neck to all the information flowing from the early processes of a supply chain stages.

Data collection. The triangulation of data and information strengthen the validity and reliability of this research.

The direct data collection process consisted of more than 36 hours of direct contact:

1. Interviews face-to-face, over phone and Skype. with four out of six Account Coordinators for the customer order management department of the company, the Head of Supply Chain and the Head of Digital Transformation.
2. Shadowing customer orders by direct observation.

HAE Case

Identified Problems in the Current Processes

Looking into the problem further, there are several key issues that are evident in mapping the scenario.

1. Amending orders can take many days to be approved. Inefficient communication lines and inadequate scenario handlers, result on long period of time before an amendment to an order is approved and modified.
2. Multiple communication channels to place or change an order. Lack of standardisation is risky and causes inefficiencies in the system such as discrepancies in the data collected and possibility of errors down the line. This substantially increases customer frustrations and likelihood of disputes between the customer and supplier. e.g. traceability and accuracy of modifications are highly unreliable.
3. Multiple rulesets for different orders/customers..
4. Extensive manual work. The situation becomes complicated as there are multiple customers and a lot of manual work involved.
5. Multiple external customers. External customers need to feel in control, which is not possible when using this current centralised trust model.
6. Prolonged Grief. Grief'' is the terminology used within the Order Management department to refer to the inability to process an order due to incomplete or incorrect information. It is the source of many discussions and is a significant drain of time for the Account Coordinators.

Blockchain Prototype Building

In programming the Blockchain for HAE, the selection of the technologies for the particular company & clients' needs is very important. This continues by building the architecture and the business network. Finally, developing the Blockchain Interactions for Placing and Amending Orders. To secure the programming quality, the 'Test Driven Development methodology' is followed.

A. Selecting of Technologies

- *Back-end Technology*

The back-end is the part of the system that stores and processes information. Also known as the data access layer of a piece of software or the "server side". It refers to everything that does not appear in front of the user.

The back-end for this study is the Blockchain (which acts as the database). It is accessed via CRUD calls from a RESTful api. This layer is concerned with security, content management and ensuring there is an established connection with the front-end. The content that the customer requests is dynamic. A closed network Blockchain – is selected on the basis of its perfect fit for the tasks' context and the simplicity of its use. After a long analysis of all options.

The Hyperledger Composer and Hyperledger Fabric combination is by far the most suitable choice for programming our Blockchain prototype. This combination is selected because (a) its ability to create neat private blockchain networks and (b) the low barrier to entry, unlike the alternatives.

- *Front-end Technology*

The front-end is the customer-facing interface (also called user interface), it is the one the customer uses to interact with the server. Also known as the presentation layer, this is concerned with usability, creative output and functional user experience. The user interface needs to ensuring that it is simple yet intuitive. The front-end communicates with the server by way of a RESTful api. Exposing a RESTful API on the back-end side is one of the most popular method for getting the front-end to communicate with the back-end. The back-end facilitate this communication by having a few endpoints that return responses as JSON objects.

There are several options for the front-end framework. Each choice has some benefits and constraints.

The Angular interface could be a great choice because due to the Open Source Yeoman code generator framework that allows the user to quickly create a skeleton; however, it is restrictive as it is not commonly used in industry. The Electron another fantastic open-source framework that can be used to create desktop GUI applications, but one of its main limitations is that user may prefer a more intuitive web interface. While HTML+CSS and Vue.js are both easy to pick up, however, the React is by far the most suitable interface because it is widely used in industry for rapidly prototyping web applications.

B. Building the Architecture

The system architecture has few components that must communicate seamlessly in order for the full-stack application to work. Figure 1 illustrates how a single client application is subscribed to the Fabric runtime. The full-stack Blockchain (mobile/ web/API) solution

contains the transaction logic that is executed on the Fabric runtime. Hyperledger Composer generates a business network archive. It runs on top of Fabric; i.e. the Composer SDK maps down to the underlying Fabric SDK.

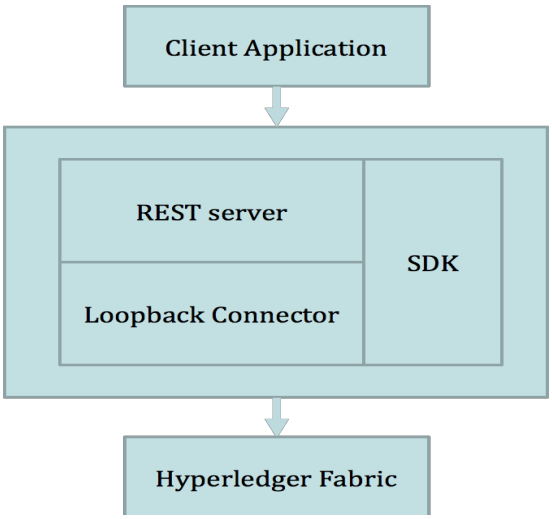

FIGURE 1: Customer-Blockchain Architecture

The Hyperledger Composer permits the ability to develop core components in a 'business network', generates RESTful APIs that interact with customers applications and deploys the network to a live instance of a Fabric runtime. This composer offers superior integration capabilities possible by a LoopBack connector that exposes endpoints to the running network as a RESTful API, which in turn can be consumed by a customer application.

C. Coding the Blockchain

In maximizing the accuracy and efficiency of coding, we used the 'Test Driven Development' methodology. By following a continuous cycle– coding, testing and refactoring – its unit testing verifies individual units of code to ensure they work as intended. Thus, this methodology allows external developers to easily understand the codebase (Dingsøyr et al 2012).

The final version Blockchain-enabled Customer Order Management System for HAE (back-end and front-end applications) has more than 5000 of line codes and took 15 iterations. Two programmers: one focused on programming the Blockchain (back-end) and the second one for the customer interface (front-end). Figure 2 shows the coding for the process of placing an order.

```
/**
 * Allow customer to place an order
 * @param {com.order.management.system.PlaceOrder} placeOrder
 * @transaction
 */
async function placeOrder(orderRequest) {

    const factory = getFactory();

    var order = factory.newResource(nameSpaceSystem, 'Order', orderRequest.productOrderNumber);
    order.quantities = [orderRequest.quantity];
    order.modificationStatuses = ['PENDING'];
    order.orderStatus = 'PENDING';
    order.shipmentDates = [orderRequest.shipmentDate];
    order.supplier = factory.newRelationship(nameSpaceParticipant, 'Supplier', orderRequest.supplier.getIdentifier());
    order.customer = factory.newRelationship(nameSpaceParticipant, 'Customer', orderRequest.customer.getIdentifier());
    order.part = factory.newRelationship(nameSpaceSystem, 'Part', orderRequest.part.getIdentifier());

    // save the order
    const orderAssetRegistry = await getAssetRegistry(order.getFullyQualifiedType());
    await orderAssetRegistry.add(order);

    // emit the event
    var placeOrderEvent = factory.newEvent(nameSpaceSystem, 'PlaceOrderEvent');
    placeOrderEvent.productOrderNumber = order.productOrderNumber;
    placeOrderEvent.quantity = order.quantities[0];
    placeOrderEvent.shipmentDate = order.shipmentDates[0];
    placeOrderEvent.supplier = order.supplier;
    placeOrderEvent.customer = order.customer;
    placeOrderEvent.part = order.part;
    emit(placeOrderEvent);
}
```

FIGURE 2. Blockchain Coding for Placing an Order

Results and Findings

First, the Blockchain was programmed following the following steps: we started by mapping the information flow and take the specifications and routines. Then the selection of the digital technologies made us to identify and evaluate various technologies, to inform our selection – Hyperledger Composer and fabric. We built the Blockchain architecture. We programmed the Blockchain app for customer order management. To connect the Blockchain with the user, built a user interface. We worked in continuous communication and synchronization with HAE company. Each step was validated with the company and customers.

The results were validated in a further workshop with more than dozen HAE employees.

Findings

The following early findings from the analyses of our study are summarized here: The Blockchain implementation:

(1) *Improve the efficiency* in the order management process. The Blockchain Solution considerably improved efficiency of the order management process at the HAE company. While normally it would take 2-4 days for an order or modification to be processed and approved, the Blockchain Solution leads to instantaneous, automatic approval times (including the verification time against set rules). Improved efficiency, from 2-4 days to less than 1 minute.

(2) *Improved Traceability* of order placed and modified. The Blockchain Solution improved the traceability of orders placed/amended at the HAE company. The company never had this open detail of traceability of transactions in the past. Therefore, transactions such as placing and amending orders are traceable back to participants, date/time and detailed modifications – quantities, specifications, approvals, confirmations, etc. Moreover, Blockchain provides a Dashboard with real-time traceable status of orders to customers and employees.

(3) *Improved the visibility* of the order management process. The visibility of data is increased and safely opened to employees and customers' employees in the supply chain

by predetermined access rights for writing, viewing and/or accessing information. Our very early simulation analyses show that Blockchain improve the efficiency of some operations. 65% reduction in the processing time for Placing Orders and a 60% reduction in the processing time for Amending Orders from the current state to the mature Blockchain state and reduction of account coordinators from 6 to 2.

Contributions, Limitation and Future Work

This is the first study that demonstrates with real data from an industrial firm the reduction of operations, efficiency gains and human processing input savings by using Blockchain in customer order management. Moreover, this study extends the supply chain theory by analyzing the granular effects Blockchain to process level i.e. customer order management.

The effects of Blockchain on the customer order management shows that Blockchain:

- Consolidates a single point of entry for placing and amending orders.
- Removes the multiple check points.
- Reduces manual input into the orders.

Limitations and Future Work

This research is based on a single in-depth case. However, this study sets the precedent on the benefits of the Blockchain and has the scope to be tested in other context in future.

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Quality Management for High-Contact Professional Service Firms: A Multiple-case Evidence from Indian Law firms

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Abstract

This paper presents an exploratory study to understand the distinctive quality dimensions of high-contact Professional Service Firms (PSFs). The paper is based on empirical evidences from multiple cases in leading Indian law firms. The paper adopted an exploratory, multiple, embedded and comparative case study design. The empirical evidence from multiple case studies in 10 law firms was used to explore the QM dimensions for PSFs. The results showed that QM in PSFs is a multifaceted and continuous process rather than a straightforward and episodic one. The findings reveal three distinctive dimensions of QM for PSFs

Keywords: professional service firms; quality management; service quality;

Introduction

Globally, the professional service firms (PSFs) are at an inflection point of growth, facing an ever more demanding clientele and ensuing pressures to cut prices and expand service value. For instance, the waxing client dissatisfaction with legal advisory services (or law firms) is evident from a worldwide stagnant growth in legal service demand (between negative 4% and positive 6%), declined lawyer productivity (from 134 to 122 billable hours) and reduced collection realization rates (from 94.6% to 89.1%) during the past decade (Georgetown Law & Thomson Reuters Legal Executive Institute, 2017). Yet, there is limited Service Operations Management (SOM) research to investigate what PSFs should do, and how they should be managed to achieve superior quality (Jayaram and Xu, 2016; Lewis and Brown, 2012; Goodale et al., 2008, Zhao et al. 2004; Harvey, 1990). The established service quality literature ascribed the inconsistencies in

PSFs' service outcome to their emblematic operational characteristics viz. knowledge intensiveness, professional autonomy, altruism, self-regulation and customization (Lovelock, 1983; Schmenner, 2004). However, lately, even the most autonomous services of medical practitioners (Sabella et al. 2014), accountants (Jeffords and Thibadoux, 1993) and engineering designers (Boone, & Ganeshan, 2001) have recognized the economic benefits of a systematic implementation of customer-focused quality management (QM) systems and practices (work measurement, coaching, employee training and reward system to name a few) that have paid manufacturing sector off in a big way in the past (Flynn et al., 1994).

Considering the academic research on QM in PSFs, the recent editorial note for the special issue of Journal of Operations Management (JOM) on "Professional Service Operations Management" (Harvey et al. 2016) emphasized the role of client awareness and precision in the recognition of relevant service quality attributes. The authors also highlighted the role of proxy indicators of quality (such as partnership-based organization structure) in the firm's service quality assessment. Additionally, the need for managing the network or interactive quality during the extended service delivery process typical to PSFs was also highlighted. A large part of service quality research on professional services is into modelling the client's expectation-perception gap (Parasuraman et al., 1988; Zeithaml, 1988). There has been little focus on how PSFs should be managed to achieve superior quality (Zhao et al. 2004). A process-focused research for exploring such service provider's activities, procedures and behaviours that drive the client's expectations and/or perceptions during the extended service delivery process in professional services is scant in the literature (Svensson, 2006). Therefore, this paper presented an exploratory study to understand the distinctive quality dimensions for professional services followed by the development of a conceptual model for QM in PSFs. The study used empirical evidences from multiple case studies in law firms to examine the QM practices in high-contact PSFs. The study was narrowed down to a specific professional service sector (legal advisory services) in line with the past research (Brandon-Jones et al. 2016; Lewis and Brown, 2012), which established that sector-specific insights played a crucial role in deriving competitive advantage in professional services. Given the exploratory nature of the research, the study adopted multiple, embedded (Yin, 2003), and comparative (Dul and Hak, 2008) case research design to achieve the research objectives. This

qualitative research design was suitable to gain a holistic (systematic, encompassing and integrated) view of the context of study.

Literature Review

Distinctive characteristics of PSFs and associated QM challenges

PSFs are conceptualized as one service category in generic service typologies in the service marketing literature (Silvestro et al., 1992; Schmenner, 2004). For PSFs, these typologies have emphasized some shared operational characteristics such as high level of customer contact and labour intensity (Lewis and Brown, 2012). However, these typologies fell short in recognizing the distinct QM and operational (control) challenges related to programmability of tasks and measurability of outcome faced by various professional service providers (Goodale et al., 2008). Harvey (1990) emphasized that unlike other service firms, the nature of operations management decisions in PSFs are driven by the relative power of the three stakeholders i.e. the professionals, the clients and the top management (firm). In a study based on the evidences from a specific PSF setting (law firms), Lewis and Brown (2012) emphasized that unlike other service categories, in PSFs the professional-client exchange is asymmetrical and required varying degree of customization in process design for different clients; there are less variables involved in the processes, creating an opportunity for commoditization; and the notion of professional identity greatly influences the efficiency of a PSF. Based on an empirical investigation in Management Consulting firms, Brandon-Jones et al. (2016) demonstrated the need for a contingent approach towards management of operational quality in PSFs. The authors showed that both the firm-level (scale of operations, degree of specialization) and individual-level (leverage, partnerships) characteristics impact the planning and control of the professional service quality.

Researchers have extensively discussed the QM challenges in PSFs using theoretical and conceptual research approaches (Fischer et al., 2014; Goodale et al., 2008). Some of these challenges are high process variability (due to high level of customer contact); limited scope for standardization and automation (due to high level of customization and knowledge intensity of the processes); input/output based operational planning and control measures (hours billed instead of process measures); and limited emphasis on the internal quality monitoring (due to strong

influences of explicit code of conduct and implicit norms). Further, defining the direct QM measures for PSFs can be tricky due to disparate quality evaluation criteria adopted by the service provider and receiver (Haywood-Farmer and Nollet, 1994; Lehtinen and Lehtinen, 1991). Therefore, it is important for the professional service providers to understand the direct and indirect QM indicators and manage them effectively to warrant a satisfying client experience.

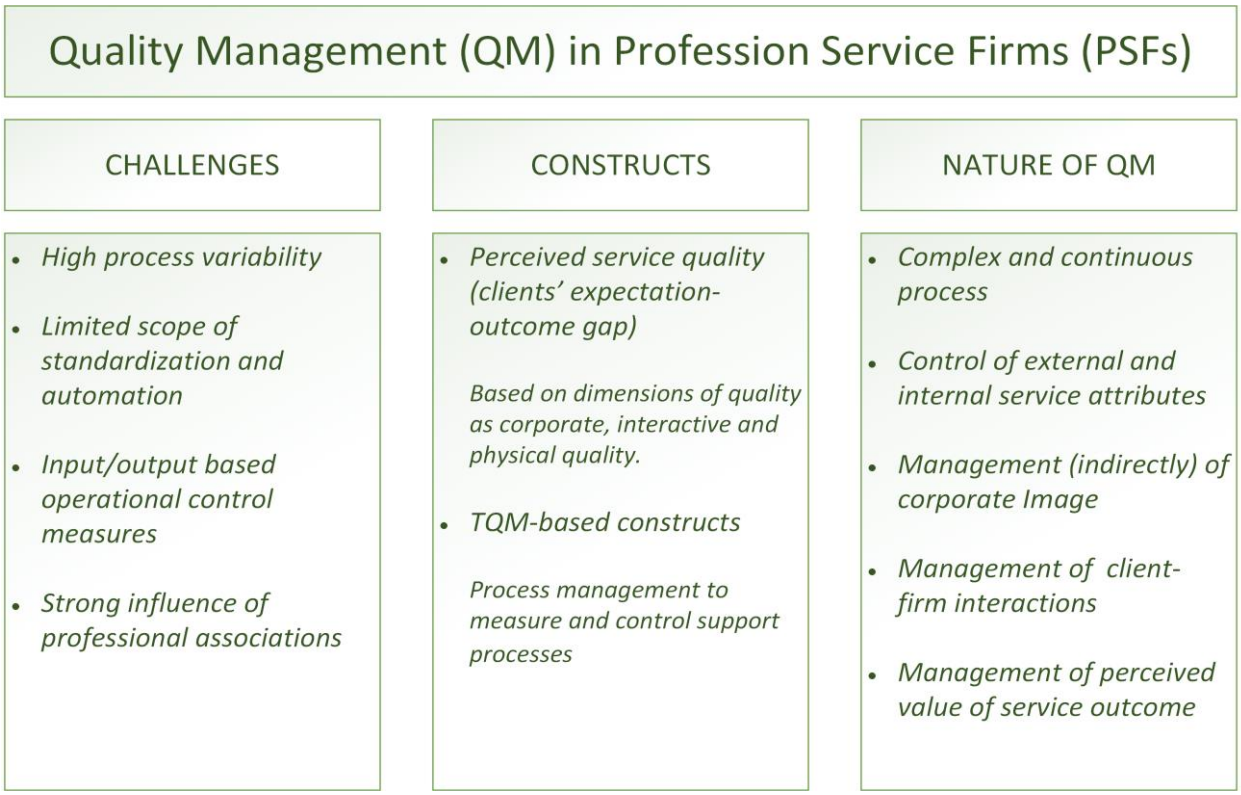

Figure 1: Preliminary research model for QM in PSFs

Research Methodology

The purpose of this exploratory study was to develop a conceptual model for QM in high-contact PSFs. Adoption of a qualitative research design was appropriate for the early stages of theory-building to achieve the research objective, considering the limited research done so far on the complex phenomena of QM in PSFs (Miles and Huberman; 1994; Siggelkow, 2007; Eisenhardt, 1989). The paper used multiple, embedded and comparative case-study research design (Yin, 2003; Dul and Hak, 2008; Silverman, 2002).

Case Selection

This study was conducted in the Indian legal service sector. The Indian legal advisory service sector is world's second largest legal market (in terms of number of lawyers with 1.3 million lawyers) and is currently preparing for opening-up to foreign legal professionals (INBA, 2017; Chinna, 2012). For the exploratory study, the Indian legal sector was represented by 10 leading law firms with leverage ratio (i.e number of non-partner lawyers to equity/salaried partners) of 8.5 to 3.3. All the selected firms were general partnership firms known for Corporate & Business Law advisory services (though these firms also offered advisory in mergers & acquisitions, insurance, tax, and capital markets) and were ranked in band 1 & 2 (law firm ranking from 1-6, 1 stands for best; ranking is based technical ability, professional conducted and other quality attributes) by Chambers and Partners (Chambers and Partners, 2017).

Data collection and analysis

The data was collected at multiple points in time in the selected case settings during the fall of 2017. The primary method of data collection was semi-structured or standardized open-ended interviews (Rubin and Rubin, 1995) using an interview protocol as the instrument. For a detailed description of case findings, multi-stage data processing and analysis process, suggested by Miles and Huberman (1994) was adopted.

Findings

The major findings regarding the design of QM activities in the case studies are summarized in Table I and Figure 2.

Table I: Design of QM activities in legal advisory services

Dimension of Quality	QM Objective	Design of QM activities	LF1	LF2	LF3	LF4	LF5	LF6	LF7	LF8	LF9	LF10
Corporate Quality	Firm's image	Partner-driven networking and referral generation	●		●				●	●		
		Policy (practice development) and internal team (partner and staff) driven						●			●	●
		External professionals (PR) driven		●		●	●					
Interactive Quality	Support process control	Controlling personnel recruitment and retention requirements	●					●		●	●	
		On-going monitoring of client feedback, process manuals along with controlling personnel recruitment and retention		●		●	●					●
		Merit-based compensation system together with other measures					●					●
		Use of statistical methods, which are not common for process management in law firms										
	Client-firm interaction management	Intangible signs of service quality (lawyer's technical competence and specialized expertise)	●		●		●		●	●		
		Building tangible evidence (office and staff appearance)									●	●
		Cautious blend of tangible and intangible cues of service quality at all touchpoints (SLAs, client testimonials)		●		●						
Physical quality	Perceived value delivered	Time-based billing supported by accurate/detailed timekeeping systems.	●		●			●	●	●		
		Customized billing structure (time-based and fixed fee).		●		●						
		Value-based alternative fees arrangements (AFAs)					●				●	●

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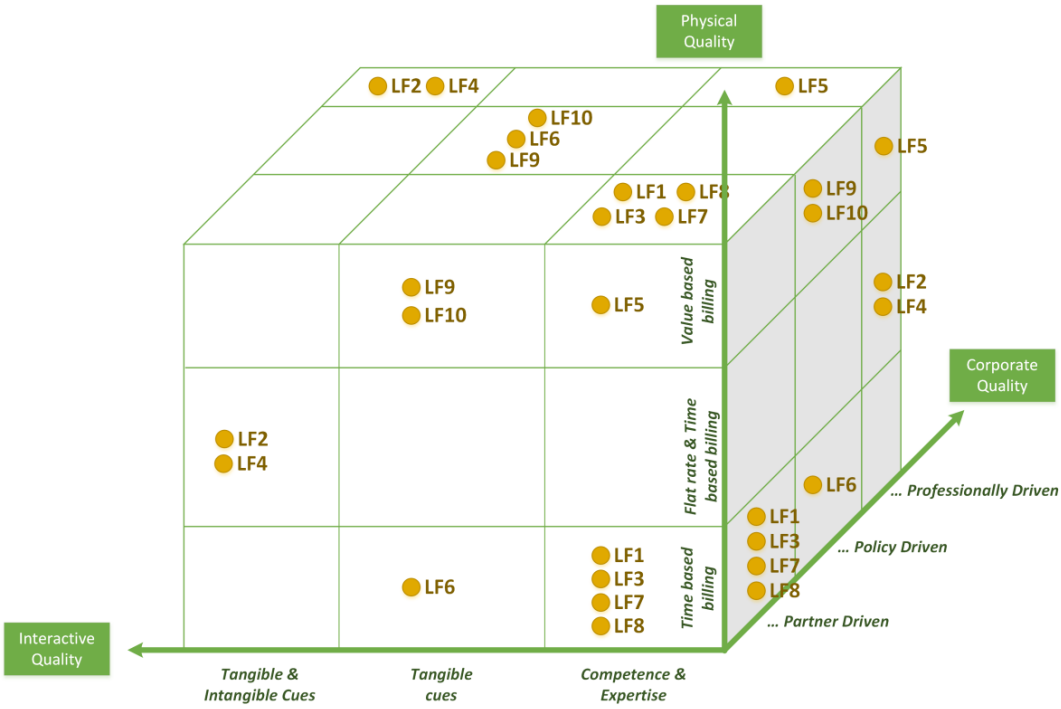

Figure 2: Dimensions of quality

Discussion and Conclusion

Broadly, the empirical findings showed that the unique personnel (lawyer) and organizational characteristics of law firms make QM a multi-dimension and continuous effort rather than a straightforward and episodic process. This observation is in line with (Ritsema et al. 1992) the definition of professional service quality as a process of continuously meeting the specification agreed by the client and the professional, considering the efforts and anticipated outcome, and incorporating all the self-evident needs of both the parties. Additionally, the findings also support the observation by Harte and Dale (2005) that it is difficult to define quality measures and controls in professional services because of their highly intangible, labour intensive and customer-centric nature. It was substantiated that external image/reputation (corporate quality), internal client interface & support process/procedures (interactive quality) and perceived value for monetary and non-monetary costs (physical quality) broadly cover the complete scope of quality management in PSFs (Lehtinen and Lehtinen, 1991). Further, for managing the corporate quality, the findings illustrated that projection of firm's 'corporate image' should be targeted especially at the client-market served (global and domestic corporate clients

in these cases) with thorough understanding of the competition. This observation is aligned with the argument by Jääskeläinen and Laihonen (2014) that lack of awareness about the alternative service providers makes the 'image and reputation' crucial in client's selection of professional services. In fact, managing partner in one of the firm with international reputation explicitly endorsed "the need to work on developing a brand identity" to attract corporate clients worldwide. Additionally, a great degree of creativity and diversity was observed in firm's choice of image-building solutions, owing to the regulatory restrictions on legal advertising (in India) (Figure 2). This observation is in line with Nachum's (1999) proposal that creativity and reputation are variables that drive a PSF's competitiveness. The observed solutions for image-building were not only driven by senior management (firm representation in prominent forums by partners) and dedicated internal teams (practice development team working on continuous personnel engagement) but also steered by specialized external professional (external PR arranges and realizes publicity opportunities for the firm). On the content of corporate image building activities, endorsement of firm's legal acumen (trainings/workshops on recent statute, representation in law conferences) emerged as the primary agenda followed by highlighting the social responsibility endeavours (pro-bono work in association with NGOs).

This paper contributes to the SOM theory by focusing on the operational quality aspects in PSFs from service provider’s perspective, which was mainly explored from customer’s perspective, so far. The paper contributes proven QM attributes and dimensions for PSFs to the existing knowledge base on operational control and QM issues unique to professional services (Brandon-Jones et al. 2016; Lewis and Brown, 2012; Holschbach and Hofmann, 2011, Goodale et al. 2008). An indirect control on firm’s image through a constant engagement of professionals (people outside the marketing function) emerged as the primary dimensions of QM in PSFs (Cameran et al. 2008). Further, the findings showed that an effective design of service encounters in PSFs is achieved through instilling tangible and intangible components in the client-interaction (including both front-end and backend aspects) (Ponsignon et al., 2011; Svensson, 2006). Finally, due to the ambiguity in the definition and scope of service outcome in PSFs, managing the perceived value of services vis-a-visa costs (and efforts) is crucial for these firms (Lapierre, 1997).

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Using customer journey mapping to improve industrial sales and customer experience

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Abstract

This paper describes how customer journey mapping can support the business-to-business (B2B) sales process over the operational life of equipment and examines both the products and the services offered throughout the entire lifecycle. Three cases from industrial firms are described and compared with the literature. The analysis of the results of this study shows that while the current customer journey mapping is useful in a complex B2B environment, it is sub-optimal and changes are therefore needed to provide a tool that is more suited to this context. The study identifies key areas where improvements could be made.

Keywords: Product service system; Customer Journey Mapping; B2B Marketing;

Introduction

The sales process of industrial product-service systems is often very complicated compared to the sale of stand-alone products (Kowalkowski & Ulaga, 2017), making it even more important to address stakeholder needs proactively (Anderson et al., 2006; Cohen et al., 2006). Additionally, the procurement/sales process has been getting more complex according to Nicholas et al., (2017), who stated that more than six stakeholders are now involved in a typical purchase process. Customer journey mapping has been used successfully in business-to-consumer (B2C) environments (in both sales and execution) to understand and map B2C customers' experience and to support the redesign of supplier processes (Lemon & Verhoef, 2016). As a Service Design method, it has been useful in these B2C markets; the methods help in understanding B2B environment although can lead to oversimplification . Complex B2B sales processes where the supplier is not directly selling to the 'end customer' can be very convoluted, with many layers and different roles and responsibilities (Anderson & Narus, 1999). For capital equipment with a long operational life, this process can be further complicated, while the introduction of digital solutions around the product-service system—to create more value for the customer—adds complexity to the sales process (Clarke, 2014).

Research question

The purpose of this paper, based on the problem described above, is to identify how customer journey mapping can be adapted to B2B businesses to support the sales and project execution

process over the operational life of the equipment. For business leaders who provide industrial product service systems this will offer tools that can support improved customer experience. The research question is:

- *How can the customer journey mapping process be adapted for use in complex B2B product service system environments?*

Literature review

The literature review describes the use of customer journey mapping and service blueprints, before moving to consider complex product-service systems (PSS) and servitization; it then moves to consider the marketing aspects of transactions between firms in a B2B environment.

Customer journey mapping and service blueprints

Customer journey mapping and service blueprints trace their history to 1984 when Shostack published the first scholarly article on the topic, describing a service blueprint as a tool to support service design and innovation. From this visual tool the customer journey mapping process has evolved (Stickdorn, 2011) providing two tools that complement each other for understanding and designing new services for individuals. The tools have been used in B2C environments and an example of a customer journey map is shown in Figure 1. An important prerequisite before starting any customer journey mapping process is to understand the transaction that is being investigated.

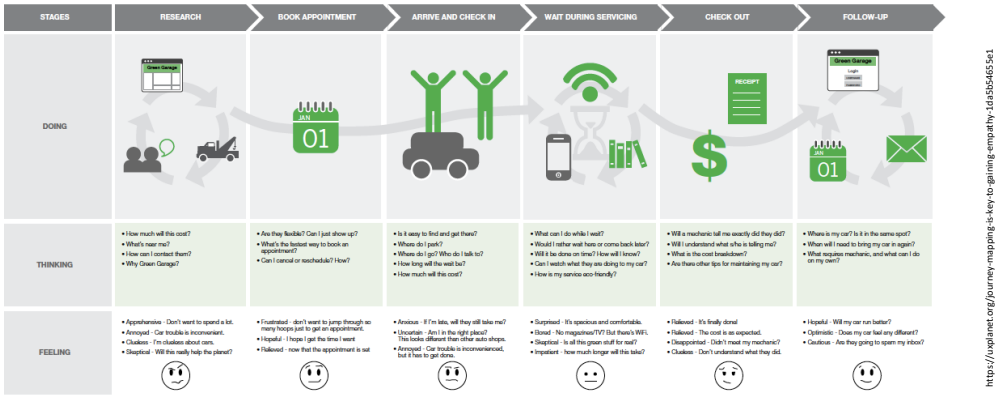

Figure 1: A customer journey map for a B2C environment

Richardson & Li (2010) looked at improving the customer experience by improving touchpoints. This approach was taken further by Kalbach & James (2016) who describe using personas and empathy cards in customer journey maps to provide more insights into service delivery, in particular what is and is not important for the customer. Davey (2018) described a practical way to create customer journey maps. The integration of these ideas helps to improve customer intimacy, which is needed for Design Thinking approaches to improving experience (Dalton & Kahute, 2018). The actor personas here provide the basis for the innovation process and the subsequent service blueprints that can then be created. The visual approach to the customer journey helps to provide deep understanding of the customer experience (Lemon & Verhoef, 2016) and can act as the basis for innovation that can improve that experience.

Complex product service systems and servitization

The contribution of services to the success of a manufacturer's business is frequently referred to as 'servitization' (e.g., Lightfoot et al., 2014). Kowalkowski et al. (2017) take this further by making it clear that servitization, including aftersales activities, is not a simple marketing approach but rather, fundamental to provide services that customers value, and support them (or the products they own) to achieve the outcomes that are important for them. All of these authors describe that much of the customer value from the service aspects accrues from intangible aspects, and that customer experience is one of the most crucial intangible aspects.

Understanding firms and their buying processes

Anderson & Narus (1999) highlight the importance of understanding firms, in particular: treating firms as individuals; the firm's value creation processes; understanding a firm's buying processes; and recognizing the roles of individuals within the firm in particular purchasing roles (e.g., initiator, influencers, gatekeepers, decider, purchaser and users). Within B2B marketing there is much discussion of "stakeholders" and maintaining relationships with them to improve sales effectiveness and relationships during project execution. Anderson et al. (2006) are also clear that value must be identified and developed for the customer in a B2B environment. Consideration of the stakeholders and the firm is discussed in the literature, as both influence each other and when providing a service or a sale the provider must understand both (Cohen et al., 2006). The importance of understanding the buying process (e.g., as a journey rather than a single event) is described by Viio & Grönroos (2016). The marketing literature goes further by stating that, in general, good customer experience and ongoing relationships between individuals in a supplier/buyer relationship increases the chance of repurchasing in the future. There are many differences between B2B and B2C marketing, but one of the starkest is that the number of stakeholders in a B2B transaction is significantly more complex than in a B2C transaction (Lilien, 2016). Nicholas et al. (2017) confirmed that the complexity of B2B transactions is increasing, with a growing number of stakeholders involved (+6.8) in the buying process; a number that rises with more expensive purchases. Sellers often come to the table late and do not take time to understand the buyer's procurement processes. The solution proposed by Nicholas et al. is to make the buying process easier by simplifying and improving the buyer's experience. This is achieved by matching the sales processes with the buyer's procurement processes and providing the information they need at a particular point in time, rather than overloading them, allowing the offer to be 'tweaked'.

Research framework

Individual case studies with reflections and cross-case analyses are an appropriate approach to qualitative research and are applicable to the development of a tool or integration of a new tool into an existing framework (Karlsson, 2009; Yin, 2009). Voss (2008) provides more guidance, with a cross-case analysis providing a valuable approach to study complex phenomena within their contexts (Baxter & Jack, 2008) to evaluate an existing process, to propose improvements based on the lessons learnt from the research, and then to build new theory. Effective dimensions are required for case analysis and cross-case analysis from the customer journey and marketing literature, along with a clear research question as an overall guide. In the case of customer journey mapping, the high-level dimensions identified from the literature are: context information; business process or transaction being mapped (Wellsandt et al., 2016); mapping process applied (Polaine et al., 2013); how were actors defined, personas developed, and company profiles created; insights into the customer's processes (Nicholas et al., 2017); and general reflections.

Methodology

A case study approach was applied (Karlsson, 2009; Yin, 2009), with three cases to explore two mapping processes and a cross-case analysis to compare the findings with the literature (see Figure 3). The industrial cases were developed from three different projects where the aim of the customer journey mapping could be clearly defined. The case studies were selected to have the following traits in common: complex engineered products and their associated services; a long operational lifetime; and set in a business-to-business (B2B) environment. Three of the authors were involved, and observed the mapping processes.

The application of a cross-case analysis provides a framework (i.e., dimensions: objective of the mapping; processes mapped; regions; equipment lifecycle; mapping process; effectiveness of actor identification; development of actor personas; development of company profile; insight into customer processes and post mapping reflections) for structured reflections that distill lessons learnt from the three cases and provide a definite structure with a list of factors to be investigated.

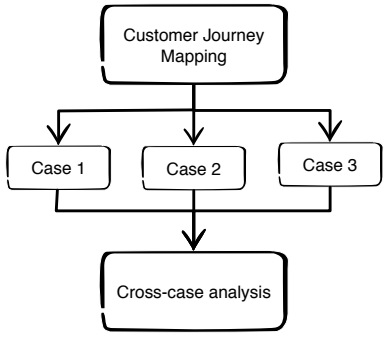

Figure 2: Schematic of the research methodology

From the results of the cross-case analysis, potential changes to the customer journey mapping process were identified to make it more applicable to complex B2B environments. The aim here was to extract the key lessons and points of difference to support customer journey mapping to be used in an industrial B2B environment.

Results and initial analysis

The cases examined in this paper come from capital equipment industries, providing product service systems as solutions over the whole operational life-cycle. All of the manufacturers in this study had direct access to the ultimate owner of the equipment. Two of the suppliers could be considered first-tier suppliers, whereas the OEM for the engine sub-system was a subcomponent supplier for the engine. In all three cases, the equipment was integrated into the customer's process plant or a ship alongside equipment from other manufacturers. Typically, system integration was undertaken by an EPC contractor or shipbuilder who developed the whole system for the 'end customer' as a project. In each of the cases, given the long operational life of the equipment, there was a complicated cycle of 'repair, refurbish, replace' depending on the equipment upgrade cycle. The results of the study will now be described in three sections covering the work that was undertaken for each case, following with a cross-case analysis.

<u>OEM for glass manufacturing equipment</u>

Here two different journeys were created, one for the sales process of the original capital equipment, the other for sales of refurbishment services. Based on the two different customer journeys, a sales support handbook was developed.

Early in the mapping process, it became clear that the sales team did not fully understand the customer's buying process. Although the sales process (both BOL and MOL) could be generically described, it was apparent that different firms had different approaches to the procurement process. At least five stakeholder groups were identified, with another 20 different individuals involved in the decision-making process. This complexity had not been seen clearly within the firm before mapping. The combined mapping of new equipment sales, aftersales and equipment refurbishment provided clear links between the three main sources of sales for the firm. In this case the sale of spares was not a major part of the revenue model. What became clear were the 'trigger' points for the initiation of refurbishment process – there was an agreement that this typically took place after six years of operation and that the sales process started informally after three to four years of operation. The mapping provided deeper insights into the customer's two crucial buying processes: new equipment and refurbishment. The firm proposed adjusting their sales process to match the 'generic' buying process and improve the information flows to the customer with the aim of improving the sales hit rate. Figure 3 shows the high-level generic customer journey map for the sales process of new equipment. A detailed playbook for sales was one of the case's outcomes.

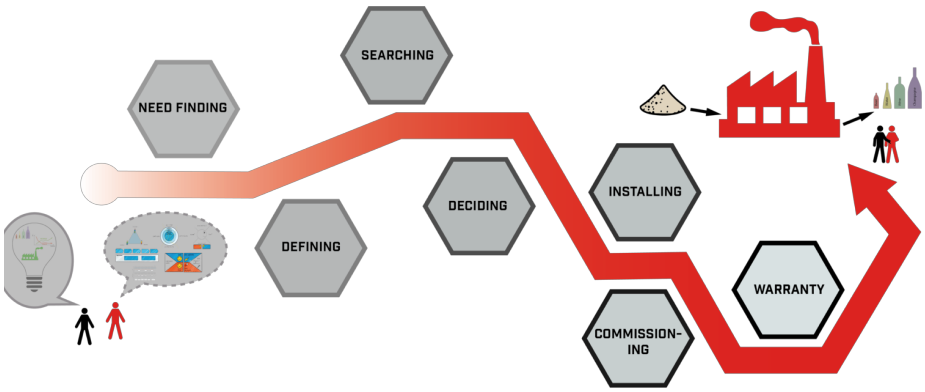

Figure 3: Generic model of the new equipment journey map extracted from the sales playbook

OEM for paper manufacturing equipment

Customer journey mapping was developed for both the sales and the project execution process in Europe and in China. The lifecycle of a paper mill is typically over 30 years, based on continued equipment repair, refurbishment and upgrades to support market demands and safety requirements.

The mapping process defined descriptions of the role and responsibilities for each of the actors in a clearer form than previously, where the term "end user" was used to described many different actors involved in the process. A redacted extract from one map developed is given in Figure 5. Customer 'trigger points' for sales were identified more clearly with the mapping process than before. The complexity of the customer side of the process showed itself in this mapping, giving insights into which actors on the buyer's side were leading the process, and at what point in the process they handed over responsibility to another actor. In this mapping process personas for individual actors as well as the company were developed, as it was considered that the cultural aspects of the firm affected the behaviors of the actors within the firm. Extending the mapping process into project execution provided insights to improve information flows and communication with the customers. Feedback from management stated clearly that matching the sales process to the buying process was important for them and that they expected sales performance to improve.

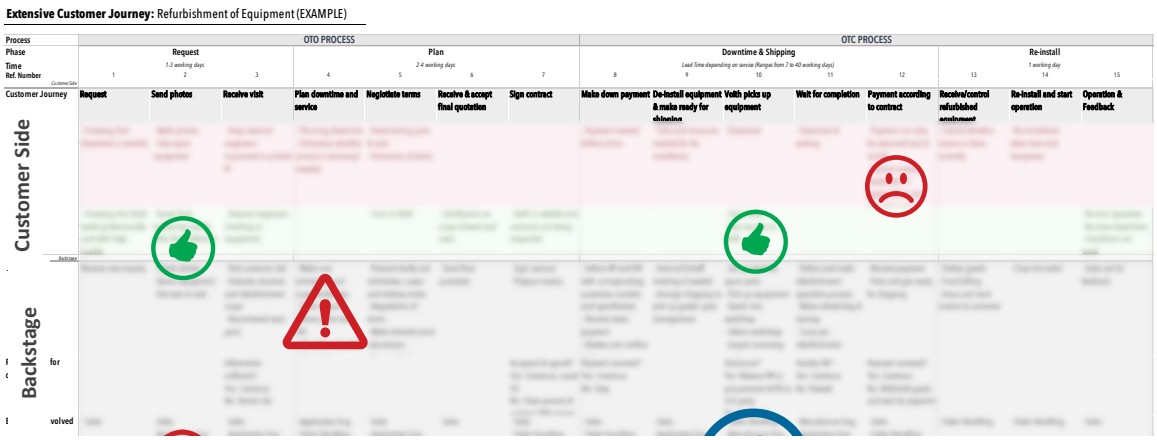

Figure 4. Example of a journey map created for equipment refurbishment

OEM for engine sub-system

The workshop was a one-day event with the aim of supporting the development of a web portal for customer and supplier use. Part of the output generated at the workshop is shown in Figure 6. The sales and the execution journey were mapped for both new equipment sales and equipment repair in the MOL. Personas were created for all key actors (buyer/user side and supplier side). Initially personas were created only for the buyer/user side, however having personas for all actors gave better definition to the journey map. Even simple personas were found to support discussions and helped to challenge assumptions. Much of the service delivery in this case

depended on third-party actors, and for the first time the firm created personas for these key third-party actors (e.g., freight forwarders). The most challenging aspect of the mapping was the buyer side processes, where there is limited understanding of all actors and their individual roles and responsibilities.

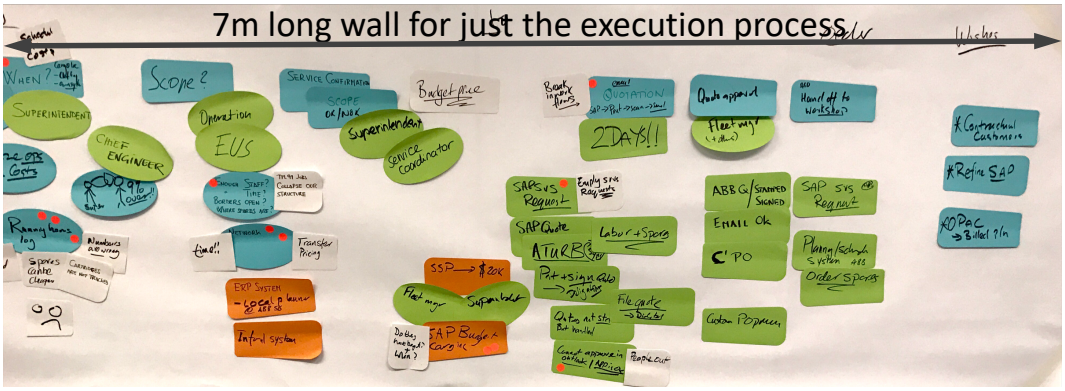

Figure 5. Photograph of the customer journey map from the workshop

Cross-case analysis

In this section a cross-case analysis of the three cases provides reflections to support the development of a generic customer journey map more suited to application in complex product service systems. Table 1, provides an overview of the three cases considering: Objective of the mapping, Processes mapped, Regions, Equipment lifecycle, Mapping process, Actor personas, and Company profiles. The four key reflections from the three cases are also described in the table.

Table 1. Cross case analysis using the analysis dimensions based on the literature

Dimension	**OEM for glass manufacturing equipment**	**OEM for paper manufacturing equipment**	**OEM for engine sub-system**
Objective of the mapping	To develop a sales tool	To improve communications with customers	To help to develop a web-based customer portal
Processes mapped	Order acquisition process	Order acquisition process Order execution process	To understand the sales process and project execution process
Regions	Europe	Europe and Asia	Global
Lifecycle	MOL	BOL & MOL	MOL
Mapping process	Interviews with 'customer support' staff	Interviews with sales and execution teams	Workshop with corporate sales and execution teams
Actor identification	New "hidden" actors identified, limited contact with some actors	New "hidden" actors identified, limited contact with some actors	New "hidden" actors identified, limited contact with some actors
Actor personas	Defined and individual roles clarified The critical actors were defined in detail	Defined and individual roles clarified Some (key) actors defined in detail others less defined	Defined and individual roles clarified. Critical actors defined in more detail than secondary actors
Company profiles	Templates created	Defined in detail and supported an understanding of both the culture and behavior of the firms	Existing segmentation used, this was well defined on company behavior and is a basic company profile
Customer processes	The customer's buying process was clarified	Clarified customer's buying and operational processes	Clearly described complex interactions on buyer side
Reflections	Sales did not understand the customer's buying process: 5+ stakeholder groups with 20+ stakeholders deciding. Complex product and service system evaluation and long product life Triggers identified for new equipment and refurbishment	Identification of customer 'trigger points' for purchase Clear identification of roles and responsibilities actors Mapping of sales and execution processes Firms treated as individual actors with individual needs	Mapped the journey for both new equipment and repairs Created personas for all key actors (buyer/user side and supplier side) Created personas for key third-party actors Mapped out the buyer/user side processes

Discussion

The discussion will first consider four critical aspects (i.e., actor identification, actor personas and firm profiles, customer process understanding, mapping process) and the points of clarification will provide the basis for the discussion. It will close with a proposal for a rebuilt customer journey mapping process for application in complex B2B environments.

Actor identification

It is important to recognize that some actors were very hard to pinpoint, yet their roles became clear during the mapping process. This stakeholder analysis, according to Anderson & Narus (1999), is one of the most crucial activities in developing insights into a firm and its decision-making processes. Appropriate communication with the different actors leads to improved relationships and has a positive impact on customer experience. In many B2B decision-making processes (Nicholas et al., 2017) there are key decision makers that need to be appropriately influenced. Here it is necessary to identify all the actors in the journey, on the supplier and on the customer side, since in B2B environments some of the key actors may be in third-party firms, making identification more difficult and requiring input from multiple sources for cooperation. However, identifying actors does not provide insight into their importance, and this should be considered in the building of personas.

Actor personas and firm profiles

In the B2B environment it was seen in the results that personas were needed for both internal and external actors and for every transition. The level of detail in each persona was a function of that actor's role and their importance at a particular instance/situation. However, without profiles for the firms, development of actor personas and/or empathy maps was unsatisfactory. Profiles of the firms supported better customer understanding and even basic segmentation supported the development of more insightful personas; this could be from the fact that the firm's culture plays a role in the behaviors of individual actors. Many different sources of information were used to create the firm's persona, however group work with different people in a workshop environment was the most effective method for the development of personas, and this is in line with the literature (Lemon & Verhoef, 2016); Polaine et al., (2013); Richardson & Li, 2010). Having basic data in one place helps to ensure that everyone has a similar understanding of the customer firm.

Customer process understanding

This activity makes it possible to better match supplier interventions with buying activities and customer execution processes. The literature suggests that this improved understanding of customer processes is important both in the sales process and to improve the general effectiveness of communications. Often the term 'fog' was used to describe the customer's process and through the identification of the actors and personas it is possible to 'lift' the fog and to make connections between different actors on the customer's side in what are the customer's backstage activities. It also provides insights where new (third-party) services are critical to a customer. The process of identifying and making the connections came from the initial front-line customer touchpoints where both the supplier and customer actors were first identified. From these touchpoints, using input from different people and assumptions, it is possible to build a picture of the customer's backstage processes, albeit an estimated understanding. This imperfect view of the customer's processes provided input into discussions that supported the further development of a deeper understanding; an approach that supported the breaking down of assumptions. Viio & Grönroos (2016) confirm the importance of repeating this to build a fuller shared understanding of the customer's processes.

Mapping process

The mapping process was very complex when the whole equipment operational life cycle was considered (often over 25 years in duration). Development of some aspects (e.g., profiles of the firms) was more effective when started independently before returning to individuals for review, with the inputs then being synthesized into a coherent profile. The journey mapping process was

most effective when there was input from many people, and when it was coupled with iterations and reviews by the team who provided the input; this is in agreement with many scholars (e.g., Polaine, Løvlie, & Reason, 2013; Clarke, 2014; Kalbach, & James, 2016). The mapping helps to identify critical third-party actors as well as direct actors. Workshops were used to give a clear focus, with facilitation to ensure the quality of the output that could then be re-drawn into a more useable form. Interviews and drawing the map without iterations and input from others provided a woefully incomplete view of the journey. The use of templates helped with the mapping process to capture the appropriate information from the participants, although there is an associated risk of a desire to complete the template before moving to the next step. With effective iterations in place it was found to be more efficient to partially complete the template and to return later.

Suitability of customer journey mapping for application in complex B2B environments

The evidence from the cases and the cross-case analyses confirms that the B2B customer journey mapping process is far more complex than for B2C customer journey mapping. This has been shown to come from customers' firms being more complex, with many different actors involved in the buying process. This is not new and has been seen in the literature (Anderson & Narus, 1999; Bitner et al., 2008; Kalbach & James, 2016), which says clearly that it is important to understand both the customer's process and the 'customer' themselves. The mapping process is able to support this by providing a framework that allows the supplier to see through the 'fog' of the customer's organization. This paper adopts the underlying assumption that understanding your customer and their processes and improving touchpoints (and hence communication) will lead to improved customer experience, and that this translates to improved revenues and lower costs associated with a particular customer. The research question asked what changes needed to be made to the CJM process to improve its applicability for use in B2B environments and the cases here shed light on the difference and propose a modified process, drawing on the existing customer journey mapping process, that has increased applicability to complex product service systems. A modified process is needed for the application of customer journey mapping in B2B environments and the three cases here provide some evidence that could underpin a reforming of the process for this purpose. A proposal for the process is given in Figure 6 which shows that the actors and their roles should be identified irrespective of the firm they are active in; then business profiles and actor personas should be created, and finally the customer journey map can be developed, showing the backstage/hidden actions as well as the visible actions and touchpoints.

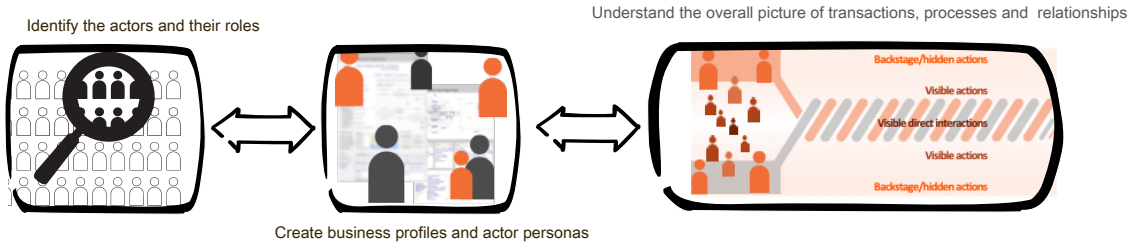

Figure 6. Proposed framework for industrial B2B customer journey mapping process

Conclusion

The cases confirmed that customer journey mapping in a B2B environment is more complicated than in a typical B2C environment. However, customer journey maps (and the associated personas and business profiles) could be used for the new equipment sales process, service sales processes, and execution activities. This is mapping more than just the initial product sales but rather, all of the relationships and transactions along the operational life of the equipment. Doing this would provide a detailed understanding of the information flows required to support a proactive rather than a reactive sales process. The mapping creates deep insights into customers and how sales, products, and services are delivered to customers. According to the literature, this should improve customer retention, and sales volume and margins. When developing a customer journey map, the following tasks were found important to consider:

- identification of the journey (including any triggers for new journeys, such as upgrades);
- identification of the actors and the key actors;
- creating business profiles and actor personas;
- co-creation of the customer journey and iterations to provide additional insights and to share lessons.

The limitations to this study are that a new proposed framework was not tested from the research. The framework should be tested thoroughly in different B2B environments to understand how it performs relative to the traditional customer journey mapping process. It is suggested that it should not diverge too far from that of the traditional B2C customer journey mapping process as this is well documented in the practitioners' world.

Recommendations

It is recommended that a generic framework is developed and tested for this complex PSS environment in much the same way as for B2C environments. In practice, the framework could then be tailored for each firm, to support their processes. The framework could be integrated into sales support tools, such as customer relationship management. Additional testing of such a framework would be required, to understand its full applicability. Specific industrial recommendations are:

- integration of both sales and operation to improve customer experience;
- integration with marketing theory to support customer experience.
- the equipment's operational lifecycle should be integrated to support trigger points.

Further research needs to be undertaken to understand the applicability of this work in different industrial environments, this should include:

- testing of the proposed framework for industrial B2B customer journey mapping;
- further integration of B2B marketing theory into the B2B customer relationships;
- further work on the trigger points that equipment can provide to reinforce customer experience.

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Improving professional service operations using action research: The case of legal services

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Abstract

This paper reports on a longitudinal action research project conducted over three years within a medium-sized law firm. The focus is on high volume/low variety service processes which are considered a breakaway from the widely agreed typology of professional service generally characterised by high degrees of customer contact, labour intensity and customisation. Using customer contact as the central theme, this paper explains how a particular high volume/low variety legal service has been redesigned using a novel soft systems based intervention embedded into action research methodology. This research led to identification of key success factors and delivered improvements to service.

Keywords: Professional Service, Soft Systems Methodology, Action Research

Introduction

Professional services sector accounts for a significant portion of the UK's economy and employment, and is one of the fastest growing sectors. Professional services such as law, accounting, medicine, management consulting, investment banking, advertising, engineering, architecture etc., are also considered to be knowledge-intensive and often presented as models of good practice for an increasingly knowledge-based economy.

Within professional services, legal services are considered as an exemplar (Nordenflycht, 2010), but even so are often criticised for being inefficient, ineffective and uneconomical in an increasingly competitive UK legal market (Falconer, 2005). Several studies indicate that little research has gone into development and application of Operations Management (OM) theory in the context of professional services, especially

law firms (Lewis & Brown, 2012; Sampson, 2012; Kaiser and Ringlstetter, 2011; Machuca et al., 2007). A vast majority of literature surrounding law firms, focuses on change at an institutional level (Cooper et al., 1996; Sherer & Lee, 2002; and Pinnington & Morris, 2003). Based on these works and a wider literature review, there is little empirical research to draw conclusions about the operations management practices and challenges existing at the field level in law firms.

For example a recent in-depth case study conducted in a law firm explained how the firm adapted to endogenous and exogenous forces by embarking on an action research project (Clegg *et al.*, 2019). The present paper aims to extend the research in this domain by exploring one particular service line within the high volume and low variety service range, the Wills and Estate planning service. High volume, low variety service processes are considered a breakaway from the typical notion of professional service that is generally characterised by high degrees of labour intensity, customer interaction and customisation (Schmenner, 1986; Lewis & Brown, 2012).

Professional service operations management

OM theory informs that professional service is one of the purest forms of service (Schmenner, 1986; Goodale, *et al.*, 2008) and characterised by extensive customer contact, process customization, complexity and throughput variability. According to the taxonomy proposed by Nordenflycht (2010), delivering legal services is marked by the highest degree of professional service intensity compared to other professional services and is characterised by a set of three distinct features that include knowledge intensity, low capital intensity and professionalised workforce. Each of these characteristic features corresponds to different challenges and managerial implications. For example high knowledge intensity corresponds to challenges of directing, supervising and retaining employees. Other challenges such as inefficient processes are inherent to professional services in particular and services in general due to their distinct characteristics of customer contact, intangibility, inseparability of production and consumption, heterogeneity, and perishability (IHIP).

Yet, how these challenges manifest in practice at the operational level is a topic that has not been discussed widely, at least not in the legal services sphere. This paper aims to articulate some of the challenges inherent within High volume/low variety services within a law firm and presents how these have been addressed using a robust methodology rooted in systems thinking.

Volume and variety at Lawyers Co.

Lawyers Co. (LC) is a long established law firm in business for over 140 years and currently employing over 250 staff. LC is considered a full service law firm providing a variety of legal services grouped into 8 departments.

The volume and variety framework proposed by Hayes and Wheelwright's (1979a, 1979b) along with Silvestro' *et al's'* (1992) adaptions for services was used to categorise various services provided by the law firm to into two distinct groups as suggested in the framework (a) High Volume/Low Variety, (b) Low Volume/High Variety, as shown in Table 1.

Table 1: Volume-Variety mix for five departments at LC

Service Line	**Volume**	**Variety**
Road Traffic Accident Claims	High	Low
Wills and Estate Planning	High	Low
Commercial Property	High	High
Dispute Resolution	Low	High
Corporate Services	Low	High

High volume/low variety services can be organised and operationalised as service factories akin to what was proposed by Schmenner (1986, 2004). But there is no evidence on how and to what extent these service lines within a law firm can be redesigned into a service factory model of operations. In the following sections, a Will writing service which is part of the Private Client department at LC is analysed using a Service Blueprint (Shostack, 1984) to understand the existing service design and mainly to analyse the *customer contact* involved in this operation so that it can be redesigned for the better. Also, Harvey *et al.,* (2016) argue that the presence of significant amounts of standard work inside the professional service space suggests an opportunity for deploying classic process analysis and improvement interventions from the OM literature.

Customer contact in high volume/low variety services

Customer contact (also termed customer involvement and customer interaction in OM literature) in the service delivery process is a source of complexity which negatively impacts on efficiency. Research informs that high contact processes are inherently inefficient and influence the outcome of that service, a feature that prominently distinguishes services from manufacturing (Chase, 1978; Shostack, 1984; Chase and Tansik, 1983). Similarly, Sampson and Froehle (2006) state that "with service processes, the customer provides significant inputs into the production process", making this central to their unified services theory which proposes that the presence of customer inputs is a necessary and sufficient condition to define a production process as a service process. In understanding legal service processes, this definition is even more contextual and pertinent due to the high *customer contact* present at every step of the service delivery process. For example in a typical legal matter, from providing matter details to offering input at key stages and through to negotiating the settlement or alternatively appearing in the court, client is heavily involved in the service delivery process and accordingly shapes its output and outcome. Yet high client contact is mainly characteristic of only few service lines within LC and law firms in general, such as Dispute Resolution and Corporate Services which are marked by high complexity involving multiple stakeholders, information feedback loops and a variety of systemic success factors (Clegg *et al.,* 2019).

In high volume/low variety service lines such as Wills and Estate Planning, Road Traffic Accident Claims, and to some extent in Commercial Property services and Family services, client involvement although present, is relatively low and punctuated throughout the service process rarely affecting the outcome of service.

For example in a typical matter involving Will writing service, client contact occurs in three to four instances – once at the beginning when making an enquiry, once in the middle when providing the personal details, also there can be a second contact here for

providing further details and once in the end for signing the will in the presence of a witness which is often done at the law firm offices.

An investigation into understanding the customer involvement in Will writing service at LC using the Service Blueprint has revealed two major fail points which needed to be addressed. Figure 1 provides a Service Blueprint that takes into account major activities in the process of delivering a Will writing service.

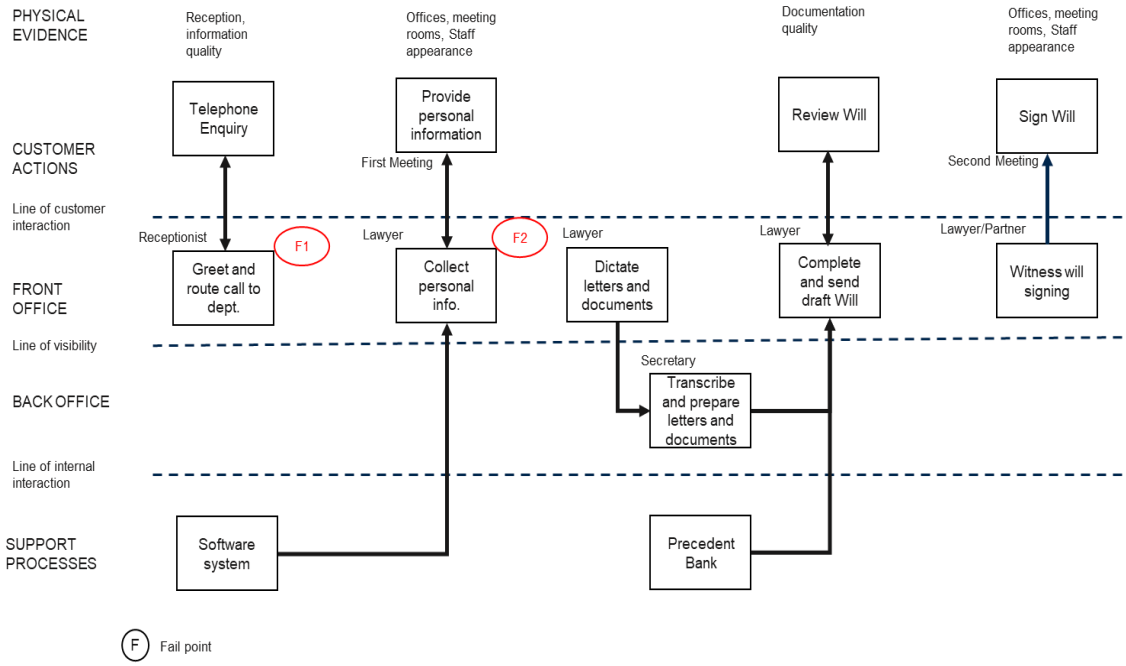

Figure 1: Service Blueprint of Will writing service

Fail points

As shown in the Service Blueprint in Figure 1, the two fail points occur at the stage of receptionist responding to initial enquiry by potential client (F1) and at the first client-lawyer meeting (F2). F1 denotes the wastage of opportunity for capturing client details by the receptionist and the lack of empowerment and training to carry out initial screening of the enquiry (for example finding out whether the client is ready to instruct the firm, or needs additional information before instructing the firm, or is simply shopping around for the lowest quote). Also F1 indicates that every enquiry that is routed to the lawyer in Private Client department is a potential waste or ineffective use of lawyer time – lawyer having to collect the personal details over the phone spending time which cannot be billed or recovered is a waste that can be eliminated. F2 indicates another redundant step in the process, collecting personal and case details at the first meeting, which can be altogether avoided if the client is willing to provide required details over the phone and submit documents over email – a waste that can be eliminated by providing alternative options to direct meeting. Besides these fail points, there can be several other systemic success factors that need to be understood before taking action for redressal.

Using PrOH modelling methodology as an intervention for change

To understand legal service operations and then enable improvements, systems thinking is used as a methodology, the principles of which have been widely applied to solve

complex real life problems in management, and to facilitate organisational change (Ackoff, 2006; Jackson, 2006). Within systems thinking a novel methodology known as the Process Oriented Holonic (PrOH) Modelling (Clegg, 2007) is used, which was developed from the principles of soft systems methodology (SSM).

The overall methodology aligns with that of the basic principles of SSM (Checkland and Poulter, 2006 pp. 11) as described in the following steps:

- identifying perceived *problematic real-world situation calling for action to improve it* – for instance legal service operations within the context of recent deregulation and the need for delivering services that are more efficient, effective and economical.
- building *models of purposeful activity relevant to this situation* using PrOH modelling
- employing a *process of using the models as devices to explore the situation* through PrOH Storyboarding workshops
- conducting a *structured debate about desirable and feasible change* using action research team meetings.

This research extensively used PrOH modelling methodology for modelling service operations within LC. It has been used to build models of legal processes in order to visualise the interactions between people, systems and other tangible and intangible entities involved in legal service delivery. Making use of the abstraction and enrichment principles laid out in the PrOH modelling methodology (Clegg, 2007), both high level and granular level models have been built and used in the process of making operational and cultural changes at LC.

PrOH enabled the modellers to engage with professionals in a knowledge-intensive environment through a structured process of enquiry which involved initial data gathering to build the model, a story boarding workshop to elicit ideas for improvement and change, leading to formation of action teams that were deployed in the process of *developing solutions* and *implementing changes* to process and practice. PrOH facilitated conceptualising, visualising, analysing and improving professional service operations that are inherently complex due to the factors detailed earlier in the paper such as client contact, labour intensity, customisation etc. A more detailed explanation of this methodology and the subsequent transformation similar to the one at LC has been explained in the recent paper by Clegg *et al.* (2019). In the present context of high volume/low variety services, an example PrOH model of the Will writing service is presented in Figure 2.

It might be argued why Service Blueprint alone was not sufficient for the purpose of analysing and redesigning the service operations at LC. It is very essential to understand that conventional process mapping tools would fail to model and elicit the intangible factors in the process such as success factors and also the multiple feedback loops as shown in Figure 2. Sampson (2012) argues that Service Operations Management (SOM) has not sufficiently contributed to research and practice. In spite of a plethora of ‘process mapping’ and ‘flow charting’ tools currently in use by both service and production operations professionals across the globe, Sampson advocates that there is an imminent need for new tools that help conceptualise, visualise and analyse service operations.

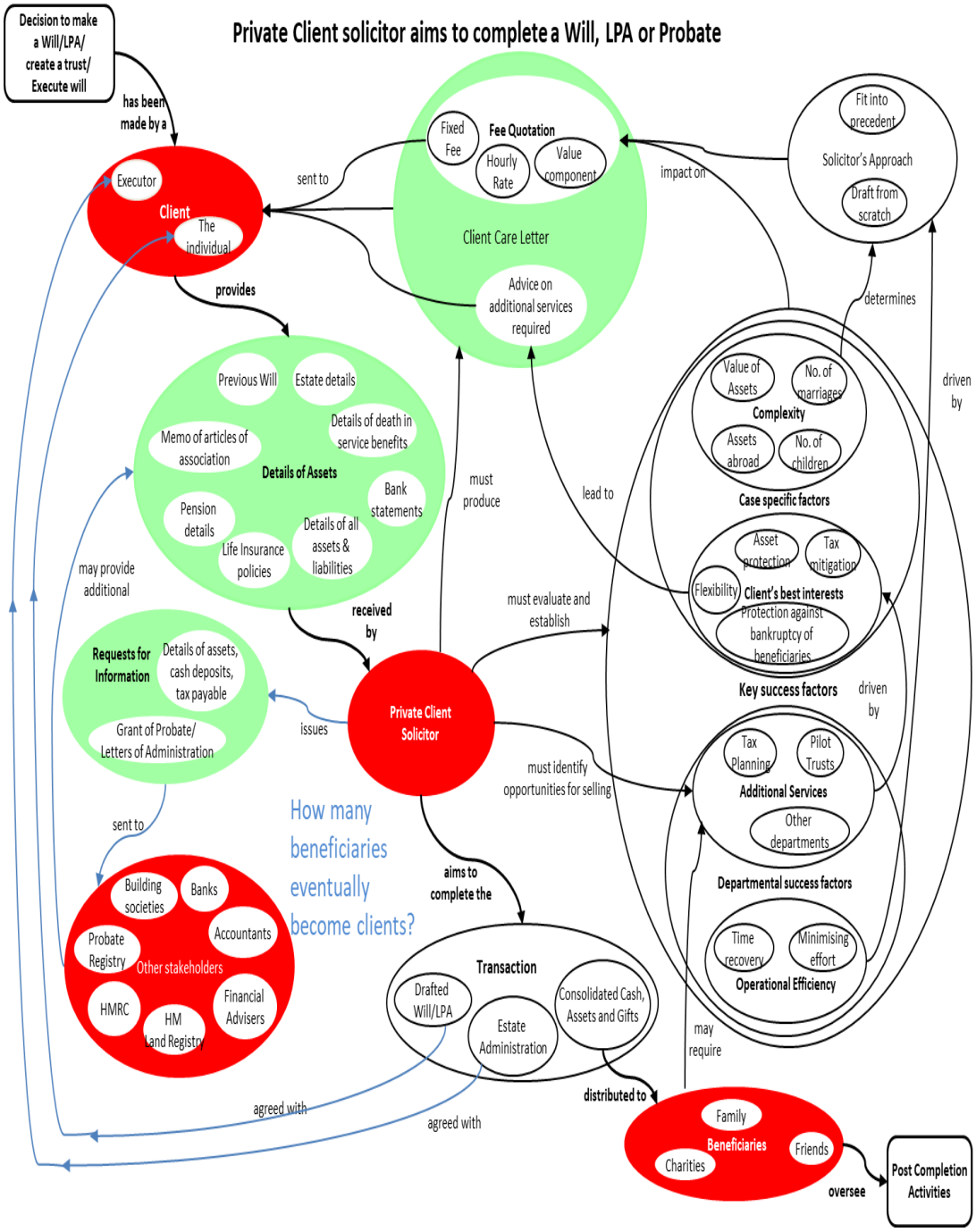

Figure 2: PrOH model narrating the high level view of delivering Will, Lasting Powers of Attorney (LPA) and Probate in the Private Client department at Lawyers Co.

Also process mapping techniques are criticised for being overly reductionist and reductionism is not appropriate for modelling human activity systems (HASs) (Checkland, 1981, p.52) such as legal services because hidden and emergent properties of systems and knowledge, their sub-systems and meta-systems, and respective knowledge, can be lost. Therefore PrOH model use can be thoroughly justified as the Systemic Success Factors of this operation have been captured in the model through consultation and workshop sessions based on the information provided by staff as well as

from the financial data provided by the firm's Finance department. The success factors are considered for each element of the professional service triad, the Professionals (lawyers), Clients and the Firm as shown in Table 2.

Table 2: Systemic success factors and challenges for private client department at Lawyers Co.

Systemic Success Factors			**Operational Challenges**
For Lawyer	**For Client**	**For Firm**	Improving client engagement whilst maintaining compliance. Improving time recovery. Document reusability and effective case management. Administrative routines to be standardised. Pricing and scoping complex probate matters. Work division and creation of new roles Training and upskilling paralegals and lawyers
Case complexity – value of assets, assets abroad, number of children etc. Information provision at the outset.	Flexibility, Asset protection, Tax mitigation. Speed of delivery	Profitability Utilisation = (actual hours billed/Total hours available) Value = realised fee per hour(Fees/Hours) Productivity = (Value)x(Utilisation) Selling additional services to clients	

Source: Adapted from Clegg et al. (2019)

Changes implemented in the Private Client department

As a result of the investigation and in conjunction with lawyers and support staff, various improvements have been made to the current process with the aim of eliminating fail points, improving utilization, productivity and also enriching the client's experience of receiving the service, as presented in the systemic success factors table above. Improvements and changes implemented to the process also reflect the addressing of challenges presented in Table 2. The changes implemented in Private Client department can be categorised under three broad headings – *process improvement*, *knowledge management* and *client service*.

Process improvement

- The redesigned Will writing service as shown in Figure 3 clearly indicates the changes proposed to the process. The receptionist will make use of the newly created diary allocation system to route the call to the available case manager or schedule a telephone meeting with the client at a later date which imparts more certainty and speed to the process. At this stage, the receptionist can also collect personal information and input to the central client data base which has proved cost effective as billable lawyer time is not spent on this administrative task. This is similar to the Mid Office concept discussed by Silvestro and Lustrato (2015) who argue that 'if the mid office can facilitate high volume processing and scale economies in the back office, while also enabling service customization in the front office, then the mid office may offer a service configuration which supports mass customisation. In the case of LC the mid office is the case manager (paralegal) sandwiched between Reception (front

office) and the Lawyer (back office) who is now consigned to only review the draft will and not directly face the client in a Will writing service.

- New roles have been created not by adding members to the team but by effectively dividing work between the existing team. For example two administrative roles have been created by assigning one existing paralegal (legal executive) and upskilling one existing secretary to take on the roles of *case managers* as shown in the revised Service Blueprint in Figure 3. The designated case manager will be responsible for making contact with client, sending letters, drafting the will and ensuring matter closure. According to Bordoloi et al. (2019, pp. 262) a dedicated non-billable (or low charging) manager assigned to a group of professionals might bring down the utilization but will increase the efficiency and competitiveness of the group in the long run. The role of the highly-skilled lawyer has been limited to only reviewing the Draft Will thus spending less time in the process which leads to more profitability. Will writing is a fixed fee service and thereby benefits from reducing the cost, as the lawyer can focus on more complex, customisation-intense matters in Private Client department such as probate and estates planning which do not operate on a fixed fee.
- Customer contact has been decreased by reducing the number of face to face meetings which results in time savings (realised as lower cost) as well as improving efficiency.

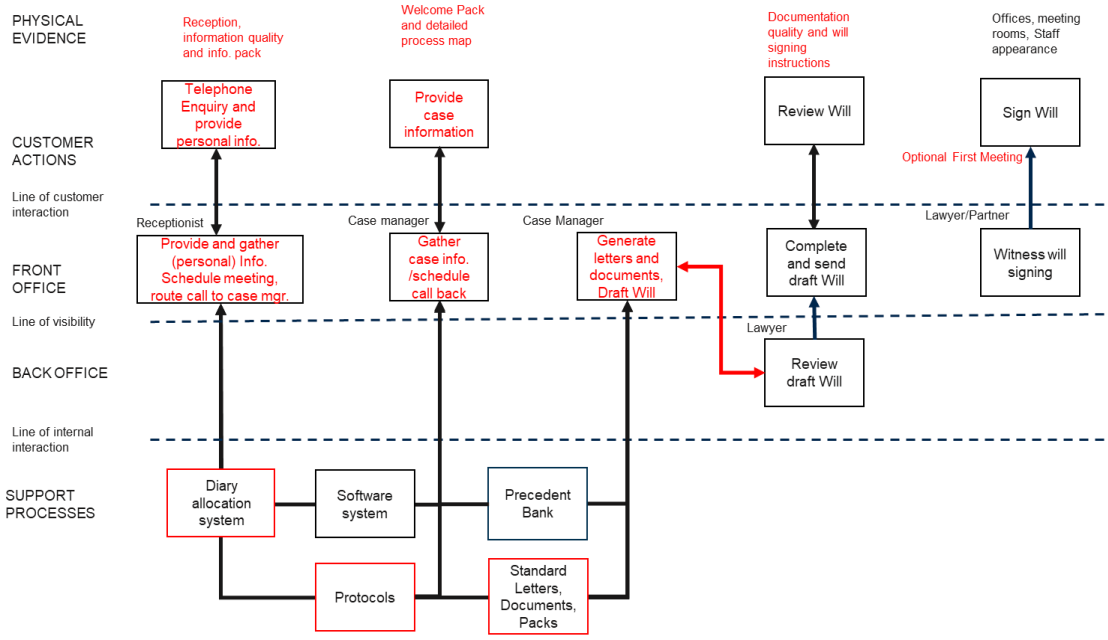

Figure 3: Service Blueprint of the revised Will writing service at Lawyers Co. (all changes highlighted in red colour).

Knowledge management

- Information packs have been created which detailed the flow of events and processing involved in each service line within the department including the indicative prices. For example a standard information pack comprising of different services within Wills and Estates planning has been created which will be emailed or posted to clients according to their preference based on the telephone enquiry. New forms have been created such as the initial enquiry form which will directly feed into the firm's central client data base.
- 12 standard letters have been drafted and made available to staff in the departmental folders electronically. These letters include follow up communication after the initial

enquiry, reminders for payment, reminders for information provision, instructions for will signing etc.

- 11 standard documents have been drafted and made available to staff in the departmental folders electronically. These documents include draft Will templates, Will explanation letter templates, instructions to execute Will and codicil etc. Notably, the newly created payment authorisation form eliminates *idle time* lost in waiting for the client's payment before the lawyer/case manager begins to draft the Will. A checklist has been created which comprises of the list of various details regarding client's personal wealth, family information etc. which allows the case manager to obtain all the evidence required to draft a Will at once.

Client Service

- Various client service protocols have been created such as the one for receptionist and case manager to deal with clients based on the initial enquiry type – those ready to make a Will, those requiring additional information before instructing the firm and those simply shopping around for the lowest quote. A diary allocation system has been proposed which allows the receptionist to schedule meetings in the diaries of the available case manager at the time of enquiry based on a distributed work load management system, which results in prompt service to clients whilst improving the utilisation rate.
- Training has been provided to these case managers using a robust manual newly created based on a typology of clients drawn by consulting senior lawyers in the team and corroborating with historic data on fee billed on a range of matters with differing complexity. In order to equip lawyers dealing with Probate matters where the relatives of deceased clients approach the firm for executing the will, bereavement training is provided to all lawyers in the department.

The Service Blueprints presented in this paper are only a high level representation of the process indicating major activities. Whereas detailed activities and steps in the process are mapped separately using Microsoft Visio, which are not presented here for reasons of brevity.

Conclusion

Although marked with several customer contact instances throughout the matter progression, drafting a legal will in most cases is a less complex operation compared to other legal services, and therefore can be potentially standardised. Also the need for standardising or productising this service is driven by the competitive market forces due to the threat from semi-qualified specialist will writers and 'supermarket law shops'. The major challenges faced by Private Client department at LC have been understood and addressed using this action oriented research engagement.

This research highlights the merits of applying a soft systems based approach in a complex organisational setting which led to the elicitation of operational issues, followed by implementation of practical changes. By working closely with lawyers and support staff, several innovative solutions were designed, some of which have also been fully implemented.

This action research project indicates that despite high labour intensity and customer contact involved in delivering high volume legal services, there is considerable potential

for rationalising processes and improving efficiencies without disturbing but in fact improving the lawyer-client relationship, the *sine qua non* of a law firm.

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The differential effect of service transition on the job satisfaction of salespeople and front-line service employees

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Abstract
This study investigates the effect of service transition within traditional manufacturing companies on the job satisfaction of two functional groups of workers: salespeople and front-line service (FLS) employees. Although there is a growing body of work on the implications of service transition strategies for manufacturers performance, yet only limited attention has been given to how employees perceive of, and react to, such an important strategic redirection. We examine the effect of service infusion on the overall job satisfaction of sales staff and FLS personnel using data from an employee ratings company, with results showing differential effects.

Keywords: service operations, servitization, job satisfaction

Introduction
Over the last decade increasing attention has been devoted to manufacturing firms transitioning towards services – a phenomenon that is commonly known as 'servitization' (Baines et al., 2009; Vandermerwe & Rada, 1988). It entails manufacturing companies seeking to enhance their product portfolio by offering services and combining their products with services to create new offerings (Vandermerwe & Rada, 1988). Implementing a servitization strategy does not necessarily guarantee better performance (Gebauer et al., 2005). Recent studies suggest that significant initial investment is required (Visnjic Kastalli & Van Looy, 2013), that organizations need to reach a 'critical mass' for profitability from services (Fang et al., 2008), and that adding services does not linearly increase performance (Fang et al., 2008; Suarez et al., 2013; Visnjic et al., 2016). Although this is highly relevant, there is a need to take a step back and examine the implications of the transition upon the job satisfaction of employees. This aspect to date has been neglected in the extant literature. This is surprising as the performance of a firm will be in large part contingent on employee job satisfaction. So, whilst we have witnessed an ever-burgeoning literature on servitization, scant attention has been provided to how

service provision is actually impacting those that need to deliver it and their job satisfaction.

In this paper, we examine the service transition and its implications upon employees. In particular, there is a need to examine the implications of a transition towards services upon frontline staff (FLS) that are responsible for day-to-day service related activities, and, in most cases, at the coalface with the customer. Of interest are also sales employees who traditionally in manufacturing firms are responsible for the sale of products, with the sale of support services that help with the functioning of the product (Gebauer et al., 2010). Changing the business strategy towards services entails changes to the 'dominant mindset', which means changes to the psychological contract (Rousseau, 1995). Routines and practices for selling products tend to have become embedded and are difficult to adjust, especially given sales are incentivized in a way that potentially privileges product sales. Change is difficult. Hence, asking sales to now promote and sell services, which in the past may have given away for free (Witell & Löfgren, 2013), is no simple task; such changes rarely play out smoothly.

Most studies tend to rely on primary datasets based on surveys administered to evaluate employee satisfaction. In recent times, with the onslaught of new platforms to voice their views (via ratings and/or qualitative responses), employees - and former employees - freely provide their input when it comes to job satisfaction (Conway, forthcoming; Stamolampros et al., forthcoming; Huang et al., 2015). Such data offers potentially novel insights that would not have been captured via in-company surveys. In this study, we draw upon a novel dataset of online ratings provided by current and former employees to the job listings website, Glassdoor Inc., to examine the impact of service transition on employee job satisfaction. In so doing, we aim to address the following research question:

1. What is the impact of service transition on employee job satisfaction?
    i. What is the impact of service transition on salespeople's job satisfaction?
    ii. What is the impact of service transition on frontline service employee job satisfaction?

We thus contribute to the servitization discussion by, firstly, providing evidence of the impact of service transition on employee job satisfaction and, secondly, by identifying and discussing the differential effect of service infusion on sales and FLS personnel.

The remainder of the paper is structured as follows: next, the theoretical background is presented, followed by our hypothesis development. After which we present our research methodology, followed by the results of the study. Lastly, we discuss our findings provide some tentative concluding thoughts.

Theoretical background and hypotheses development

Job satisfaction is a heavily researched domain by organizational scholars. It is argued that job satisfaction is influenced by numerous factors (Lawler 1973; Ilies et al., 2009; Judge et al., 2017). Numerous studies have been undertaken with different theoretical underpinnings when it comes to job satisfaction. There exist a plethora of definitions, models and theories that attempt to explain job satisfaction. One of the most commonly used definitions in organizational research defines job satisfaction as "a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences' (Locke, 1976, p. 1304). We will discuss some of the most prominent theories and models briefly below.

Arguably one of the best-known studies that explains job satisfaction being an outcome of the difference between expected and perceived rewards received in one's place of work

(Lawler, 1973). In other words, it is rewards that meet expectations that drive job satisfaction, whereas rewards that do not meet expectations lead to dissatisfaction.

Hackman and Oldham (1976) proposed their job characteristics model. In this, they argue that core job characteristics seen as inherent in all jobs include skill variety, task identity, task significance, autonomy, and feedback which motivate employees towards desirable outcomes. When employees are able to use their many skills (i.e. *skill variety*) in order to complete a particular product (or service) (i.e. *task significance*), an employee will be able to attribute meaning and value to their work. When individuals have freedom (i.e. *autonomy*) to determine when and how they work, then they have a sense of responsibility and of being accountable for what they are trying to achieve because they have control of their job. When other organizational members – be they senior managers, supervisors, fellow employees, team members – provide input (i.e. *feedback*) on the (in)effectiveness it enables employees to improve. The model of Hackman and Oldham (1976) proposes that the strength of these relationships is moderated by an individual's desire to derive satisfaction and personal growth and development, known as '*growth needs strength*' (see also McClelland, 1987).

Herzberg (1966) proposed the two-factor theory to understanding the causes of individuals' satisfaction. In this theory, job satisfaction and dissatisfaction are not considered to be two polar opposites on a single dimension nor an outcome of the same factors. Different factors thus are said to account for satisfaction and dissatisfaction. Job satisfaction is said to be an outcome of drivers known as motivators that result from the conditions of the job itself. Examples of motivators include things such as responsibility, advancement growth and recognition. The drivers of dissatisfaction are known as hygiene factors and are needed to ensure workers are content with their work.

Other notable work includes Karasek's (1979) three-dimension *demand-control-support* (JDCS) model that explains the stress an employee encounters at work, emphasizing the situational predictors of job satisfaction (Karasek, 1979; Karasek and Theorell, 1990). In more recent times, Judge et al. (2001a; 2001b; 2017) consider the following to be important features of job satisfaction: promotions, pay, supervision, recognition, working conditions, the organization, management and coworkers.

Overall, it is fair to say there is no clear agreement as to what accounts for job satisfaction. Although there are some common drivers for job satisfaction, there are also different drivers and factors identified in the extant literature. This shows that there are a number of ways of understanding job satisfaction.

Next, we discuss service transition and its implication for job satisfaction for sales staff and FLS employees.

Service transition and job satisfaction

An extensive body of research claims that manufacturers are increasingly transitioning towards services and solutions as part of their offerings (Neu and Brown, 2005; Fang et al. 2008; Kowalkowski et al., 2012; Wise and Baumgartner, 1999; Storbacka, 2011). For example, the construction equipment company Caterpillar has increasingly infused services into its product offering - such as spare parts support, maintenance, "negative downtime" concept where customer only learns of an issue with equipment once it has been repaired – to meet customer needs. To date, much of the literature has focused on the strategic aspects of transitioning to service (Gebauer et al., 2010; Josephson et a., 2016; Patel et al., 2019), design considerations for firms (Foote et al., 2001; Davies et al., 2006; Raja et al., 2018), and financial performance (Eggert et al., 2014; Fang et al., 2008; Visnjic and van Looy, 2013; Visnjic et al. 2016; Visnjic et al., 2019).

Although the transition to services is an area that is receiving increasing attention, the pursuit of a service strategy and the implications this has upon employees has largely been neglected. It goes without saying that service transition is likely to have implications on the role of staff inside organizations. For example, salespeople who are accustomed to selling products will also be expected to promote and sell services. Although this may seem straightforward, it is anything but. Changing the routines that sales staff become accustomed to, measured upon are fraught with difficulties. In some cases, this has led to some arguing that firms are better off creating new service organizations with sales staff purely dedicated to selling service, or at least so that they are service-savvy (Reinartz and Ulaga, 2008; Ulaga and Loveland, 2014). Similarly, delivering service requires customer-facing FLS personnel. For many companies, they may already possess a field service workforce, though infusing greater service will mean expanding the demands that are placed upon the staff. In other cases, it will be a case or recruiting anew FLS personnel to meet customer needs and realize the service strategy. Of particular interest here is what such changes mean for employees in terms of their roles and resultant effect on job satisfaction for sales and FLS personnel.

We therefore examine the following hypothesis:

Hypothesis 1: *As the level of service infusion increases, there will be a decrease in the job satisfaction of the non-customer facing employees*

Hypothesis 2: *There will be a U-shaped relationship between the level of service infusion and the satisfaction of salespeople*

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Methodology

Sample and data collection

The focus of this study is on manufacturing firms with primary 3-digit North American Industry Classification System (NAICS) codes between 333 and 336. These include manufacturers of machinery (333), computer and electronic products (334), electrical equipment, appliances and components (335) and transportation equipment (336). These are the industries in which servitization has been most prevalent according to the literature, seemingly due the properties of the manufactured products (relatively long-life and complex). The strict focus on manufacturing industries that are clearly conducive to servitization excludes companies that are practically unlikely to sell product-service offerings due to the nature of their products (e.g. paper product manufacturers), while it indirectly controls for industry-level factors that could confound the relationship between the extent of servitization and satisfaction with one's employer.

Following prior research (e.g. Fang et al. 2008; Visnjic et al. 2019), as a proxy for the level of service transition of a manufacturer at any point in time, we compute their 'service ratio' (Fang et al. 2008). This is the proportion of a manufacturer's total revenues in a year that comes from service activities. To obtain the required data, we use COMPUSTAT Business Segments because it provides time series of firm revenues from different business operating segments. For any given firm, the definition of the operating segments and the allocation of revenues between them is self-reported by the management team. Despite this disadvantage, this is the most common (and possibly, only) way to track a firm's service transition over time. From the description of the operating segments and their associated NAICS code, we categorize them into service and nonservice, following the procedures specified in Visnjic et al. (2019). For a given firm in a given

year, the service ratio is the quotient of the division of the sales revenues from all service business segments by the total revenues.

To obtain measures of an employee's satisfaction with their employer, we match our dataset with data supplied by Glassdoor, a job search engine and review website. We specifically utilize the 'overall satisfaction' rating, as well as satisfaction with four employment aspects: 'compensation and benefits', 'career opportunities', 'work-life balance' and 'senior leadership'. All ratings range from 1 to 5, and we extract only those that come from employees (both former and current) of the manufacturers in our sample. Employee reviews begin in 2008, so this comprises the first period in our timeframe. We use the aggregate role categories, as specified by Glassdoor, to identify sales and front-line service employees, with all the rest being classified as 'all other' non-customer facing employees. Accordingly, roles such as 'sales representative' and 'field sales manager' are classified as salespeople, while 'customer service' and 'field services' are classified as front-line service employees.

Several variables that could affect both the extent of servitization of the company and the satisfaction of its employees, are included in the models as controls. These include firm size (total sales and number of employees), profitability (ROA), R&D expenditure, overall performance (Tobin's Q), as well as industry (primary 3-digit NAICS code) and a linear time trend. Crucially, some manufacturers have begun their servitization 'journey' long before 2008, while others start reporting revenues from services only after 2008. We control for this using a dummy variable, as one could expect that the accumulated experience of providing product-service offerings (prior to the year we first start observing) may have helped senior management teams to implement policies and measures to address issues faced by their sales and service employees.

Analysis

As our dependent variables are naturally ordinal, the appropriate econometric models are the ordered logit and ordered probit. In the five models (one for overall satisfaction and one for each of the four separate aspects), the minimum number of observations (i.e. employee ratings) is 39822 (from 586 firms), and the maximum 41301 (from 595 firms). The 3-level categorical variable of job function enters our models as a set of two dummy variables, with the 'all other' category being the reference level. Crucially, to test our hypotheses, we interact these two dummies with the service ratio (and its quadratic term).

Results

Table 1 contains the main results of this work. The dependent variables in the five presented models are the ordinal scales of overall satisfaction (model 1) and the four separate aspects captured by Glassdoor: employee satisfaction with their compensation and benefits; the senior leadership in the organization; the career opportunities provided; and their work-life balance (models 2-5).

Table 1 – Results of the ordered probit regression models

	(1) Overall	(2) Compensation	(3) Leadership	(4) Career Ops	(5) Work-life
Service ratio	-0.300	-0.634**	-0.466*	-0.0535	-0.0907
	(0.262)	(0.305)	(0.243)	(0.233)	(0.318)
Service ratio^2	0.209	0.455	0.439*	-0.0542	0.113
	(0.262)	(0.296)	(0.250)	(0.239)	(0.314)
Employee role (base = 'all other')					
Salespeople	0.158***	0.0883	0.163***	0.141***	-0.0354
	(0.0560)	(0.0570)	(0.0484)	(0.0447)	(0.0604)
FL service people	-0.129*	-0.0836	-0.145**	-0.254***	-0.275***
	(0.0662)	(0.0696)	(0.0730)	(0.0781)	(0.0675)
Time trend	0.0409***	0.0231***	0.0188**	0.0294***	-0.023***
	(0.00661)	(0.00625)	(0.00786)	(0.00570)	(0.006)
Total sales (natural logarithm)	0.00629	0.0836	-0.0121	-0.0391	-0.0151
	(0.0692)	(0.0772)	(0.0692)	(0.0633)	(0.0569)
ROA	0.920***	0.522***	1.110***	0.631***	0.186
	(0.180)	(0.179)	(0.210)	(0.174)	(0.156)
No. of employees (natural logarithm)	-0.102	-0.148**	-0.0771	-0.0456	0.00518
	(0.0654)	(0.0751)	(0.0641)	(0.0608)	(0.0529)
R&D expenditure (natural logarithm)	0.0888***	0.0783***	0.0599**	0.0876***	0.0193
	(0.0246)	(0.0284)	(0.0250)	(0.0212)	(0.0268)
Already servitized in 2008? (Yes = 1)	0.0797	0.169***	0.00314	0.0552	0.106*
	(0.0536)	(0.0512)	(0.0558)	(0.0550)	(0.0596)
Interaction terms					
Service ratio * sales	-0.679*	-0.755*	-0.968***	-0.848**	-0.643
	(0.360)	(0.387)	(0.361)	(0.370)	(0.422)
Service ratio * services	0.143	0.192	0.286	0.462	0.0744
	(0.417)	(0.368)	(0.419)	(0.477)	(0.447)
Service ratio^2 * sales	0.651*	0.876**	0.981***	0.924**	0.684
	(0.343)	(0.360)	(0.354)	(0.361)	(0.418)
Service ratio^2 * services	-0.240	-0.425	-0.260	-0.368	-0.257
	(0.527)	(0.468)	(0.456)	(0.550)	(0.535)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
N (employees)	41301	40011	39822	39988	40028
n (firm)	595	587	586	587	586
R^2	0.013	0.012	0.008	0.007	0.004
AIC	121286.0	134649.8	138384.0	138792.5	136738.4

Clustered (by firm) standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The results can be summarized as follows:

- As service infusion increases, non-customer facing employees become increasingly unlikely to report a higher level of satisfaction with their compensation and benefits. There is no statistically significant effect of service infusion on the likelihood of higher overall satisfaction (or any other aspect).
- Compared to non-customer facing employees (the reference level), the likelihood that salespeople will report a higher level of overall satisfaction (and satisfaction with any other employment aspect) exhibits a (steeper) U-shaped relationship as service infusion increases. This is illustrated graphically in Figure 1, which presents the predicted probabilities of reporting a '5' (the highest level) for the different aspects of employee satisfaction when the service ratio increases by 10% at a time. An interesting additional finding is that salespeople seem to be more likely to feel very satisfied when their employer is a pure product provider (service ratio = 0%) or fully 'servitized'; namely, when the firm is 100% focused in either of side of the product-service continuum.
- The form of the relationship between service infusion employee satisfaction FLS personnel with their employer is not significantly different compared to the base-level. However, they remain the most unlikely to report higher levels of satisfaction as service transition progresses (Figure 1) and seem to feel less satisfied with all aspects related to their employment. In addition, one can notice that for a fully servitized firm (service ratio = 100%), the predicted probability that a sales person will report a high level of satisfaction with any aspect of employment is about double compared to a FLS employee.

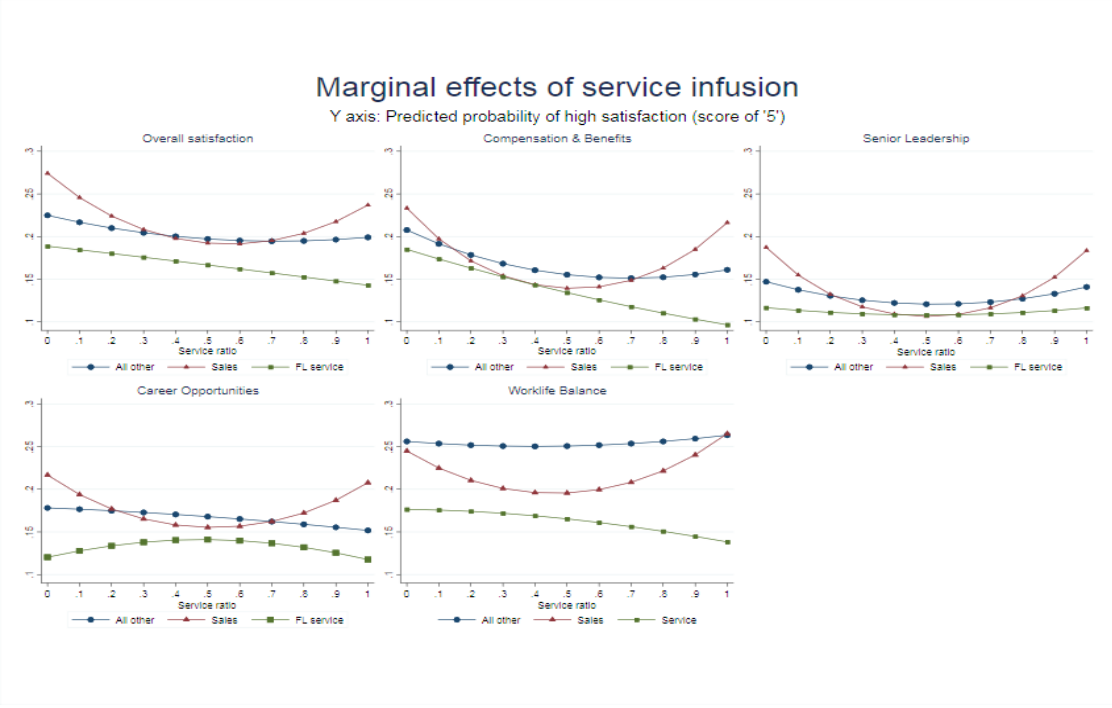

Figure 1 – Marginal effects of service infusion

Discussion and contribution

This study contributes to the emerging body of work examining the implications of service transition upon employees. Specifically, this work has implications for the design of sales and FLS roles, and how to manage these individuals during service transition. The results suggest a differential effect of service transition for sales and FLS personnel. It is noteworthy that for the sales personnel role, the firms have managed to, over time, address the initial drop in satisfaction. In contrast, the situation for FLS personnel roles is bleaker; especially when it comes to 'compensation and benefits' the results indicate that these employees are increasingly dissatisfied, with little sign of recovery. As such, we raise important questions for addressing the job satisfaction levels of all staff, but specifically those in FLS positions. We argue that low job satisfaction may explain the high propensity for those firms transitioning to services to experience difficulties or, in some cases, bankruptcy (cf. Benedettini et al. 2015).

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A staged performance model for service innovation

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Abstract

This research attempts to identify key staged-performance indicators from new service development stages and tie them to modes of innovation and performance. The empirical results indicate that three modes of innovation coexist in IT service innovation. The relationship between business model innovation and financial/non-financial performance is mediated by development and deployment performance. While development and deployment performance can mediate the relationship between process innovation and non-financial performance, they exert no mediation effect on the relationship between process innovation and financial performance. None mediation effect of development and deployment performance is found between product innovation and either financial or non-financial performance.

Keywords: modes of service innovation; service innovation stage; cost/time; functionality/service experience; financial/non-financial performance

Instruction

After decades of development, services have become the dominant sector and the most effective engine of the world economy, as evidenced by its 65.08% share of the world's gross domestic product (The World Bank Data, 2017). Under this trend, numerous service firms emerge and manufacturing firms that historically focused on providing products begin to add accompanying services to their products for higher profit margins (Visnjic, Wiengarten, and Neely, 2016). Due to the unique characteristics of intangibility, heterogeneity, perishability, and inseparability of services, service demands are highly diversified, personalized, unstable, and unpredictable. Being continuously innovative is imperative for service firms to attract customers, gain competitiveness, and remain in business. However, from the back end, the outcome of service innovation is not that satisfactory as we anticipated. The success rate of service innovation is not high, and firms' performance is not necessarily guaranteed by service innovation. The reasons for this tension between service innovation and its outcome may lie in the way of innovation performance measurement.

Firstly, after three decades of development, the studies of service innovation have expanded from broad in scope to specific in detail to bring about several key antecedents of service innovation performance (Storey and Perks, 2015). While those antecedents already cover multifaceted factors related to organization structure, organization strategy, innovation strategy, innovation efficiency, internal communication, external partnerships, and etc. (Storey et al., 2016), systematic examination between innovation success and modes of service innovation is less well understood (Wang et al., 2015). Since different modes of innovation have different objectives, appear in different domains, exhibit diverse innovativeness, require heterogeneous resources, involve distinct external partners, and are launched in different environments (Voss and Zomerdijk, 2007), the development patterns and performance outcomes derived from different types of service innovation are likely to be different (Avlonitis et al., 2001).

More importantly, although researches have already recognized that service innovation performance is a multidimensional concept (Cheng and Huizingh, 2014), historically, the majority of performance-related studies only focused on different dimensions of the final performance (either commercial success or strategic competitive advantage), ignoring important intermediate performance dimensions and their associations with final performance in the service innovation process (Storey et al., 2016).

Against this background, the purpose of this study is to answer the research question: "What is the staged performance model for different modes of service innovation?" That is, this research attempts to identify key staged-performance indicators derived from new service development stages and tie them to modes of innovation and final performance for the first time. More specifically, this study focuses on two staged performance from the development stage (development performance) and deployment stage (deployment performance) of the service innovation process. The development stage has two dual objectives: efficiency (time/cost) and effectiveness (functionality/experience), the development performance has two dimensions (Carbonell et al., 2009) (see Figure 1).

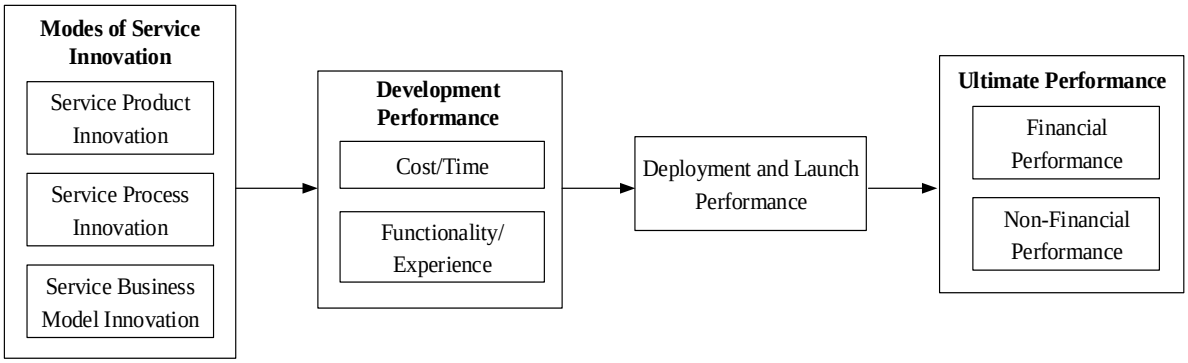

Figure 1. Conceptual model

Theoretical development and hypotheses

Modes of Service Innovation

In this study, we employ Voss and Zomerdijk's (2007) typology because it clearly distinguishes service innovations occurred in different levels and domains of an organization which is most applicable to our research design. Service product innovation involves the introduction of new service products, which could be one of the following: new to the market, new to the providing firm, new to customers, service product line extensions, bundling or unbundling of existing service products, modifications or repositioning of an existing service product (Voss and Zomerdijk, 2007; Wang et al., 2015). Process innovation focuses on changes in the internal organizational processes to increase firms' efficiency and effectiveness to produce and deliver products or services (Piening and Salge, 2015). Service process innovation primarily takes place in the operational areas of the service system, including significant changes in the way of information exchange or interface between the service provider and its customers, and the back-office processes or internal organizational structure that can increase the efficiency to develop and deliver innovative services (Zomerdijk and Voss, 2011). A business model outlines the technologies and features in a firm's product/service, the architecture of revenues, costs and profits associated with the firm developing it, and the mechanism of how the firm delivers the value of the product/service to customers (Teece, 2010). Compared with product and process, the design of business model is more fundamental to a firm's competitiveness since it not only defines a firm's product and operation process, but also how to allocate a firm's asset or resource to fulfill customer needs and convert payments received into profits (Teece, 2010). Thus, the innovation of business model involves both a significant or even complete change in the way firms earn their revenues and the corresponding product and organizational arrangements made to accompany with the change (Voss and Zomerdijk, 2007).

A Staged Performance Perspective towards New Service Innovation

Johnson et al. (2000) capture the basic shared steps in previous service innovation process literature and propose four general stages of service innovation: design, analysis, development and full launch. Every firm begins its new service development process from the design stage and puts a great effort to it. The aim of this stage is to generate an idea with the greatest potential and design corresponding strategies and objectives. Then, in the analysis stage, any idea that can eventually be commercialized into a service product is perceived to have potential in

profitability in these two stages according to the specific evaluation system of an organization.

The tasks at the development stage are to allocate resources to develop and test the functionality of the core service, associated delivery system, and marketing program; train operation and delivery personnel, and get internal and external feedbacks to refine the offering (Melton and Hartline, 2010). Naturally, the more resources and efforts put into the development process, the better the functionality or customer experience of the service. Thus, firms need to achieve a tradeoff between efficiency (cost/time) and effectiveness (functionality/experience) at this stage based on their own capability and market competitiveness. Similarly, proficiency in the deployment and launch stage increases the efficiency of adoption and delivery of the innovation both within the firm and outside to customers which are conductive to assess internal and external reactions (Wang, Voss, and Zhao, 2018).

Hypotheses

For incremental service product innovations in the case of improvements, modifications, repositioning, or line extensions, firms are familiar with the original service, its technology, design, pricing and marketing programs (de Brentani, 2001). This can significantly reduce the difficult, effort, and cycle time needed for the project in the development stage and facilitate firms to develop comparatively advantageous services in a timely manner (Song and Montoya-Weiss, 2001). By contrast, when undertaking service product innovations with dramatic departure from current services, more trial, time, resources, learning, breakthrough technology, employee training, internal synergy, and external partner collaborations are needed to solve design and develop problems (Wang et al., 2015).

By significantly changing the back-office processes and organizational structures supporting the front-end processes, process innovation increases the efficiency of inter-functional communication and coordination between different departments within the firm (Wang et al., 2015). Business model innovation is the most disruptive innovation in organizations and involves substantial or even complete changes in the way firms convert revenues into profits (Markides, 2006; Voss and Zomerdijk, 2007). Thus, business model innovation typically leads to a better performance on the functionality of a firm's service, but may not do good on the cost and time efficiency of the service. Here, we predict:

H1a: Incremental service product innovation is positively associated with the efficiency dimension (cost/time) of development performance.

H1b: Radical service product innovation is negatively associated with the efficiency dimension (cost/time) of development performance.

H1c: Service process innovation is positively associated with the efficiency dimension (cost/time) of development performance.

H1d: Service business model innovation is negatively associated with the efficiency dimension (cost/time) of development performance.

Incremental service product innovations are typically improvements or modifications which gradually remedy service insufficiency, recover customer complaints, and repair technology bugs and ultimately contribute to a continuous slight improvement of the functionality/experience of the service product. On the contrary, radical service product innovations are typically supposed to either meet customers' specific requirements that can't be met previously due to technology or resource constraints or create a totally new type of

service due to technology breakthroughs (Lovelock and Yip, 1996).

Through efficient customer communication enabled by process innovation, firms can also get valuable feedbacks about their defects in the after-sale service and service remedy policies of existing services and use these to increase customer service in future service develop (Chen and Tsou, 2012). Regarding business model innovation, since it can thoroughly change both the service and the way customers consume the service, it will bring customers a novel service experience that they have never experienced before (Amit and Zott, 2001). Based on all this, we posit:

H2a: Incremental service product innovation is positively associated with the effectiveness dimension (functionality/experience) of development performance.

H2b: Radical service product innovation is positively associated with the effectiveness dimension (functionality/experience) of development performance.

H2c: Service process innovation is positively associated with the effectiveness dimension (functionality/experience) of development performance.

H2d: Service business model innovation is positively associated with the effectiveness dimension (functionality/experience) of development performance.

As the world economy becomes more service oriented, firms compete fiercely on new service offerings (Bitnet, Brown, and Meuter, 2000). If a firm can develop a new service faster and with less costs than competitors, it will have enough time and resources to transfer the service across all appropriate intrafirm departments and external lead customers in the deployment and launch stage. In a similar vein, when a new service has preeminent functionality, it must be designed and developed properly based on in-depth market research, superior organization resources, and state-of-the-art technologies (Song, Song, and Di Benedetto, 2009). Careful development of the value proposition ensures that the service can deliver value correctly to both internal and external target users (Crawford and Di Benedetto, 2006). It is easily for the service innovation both to be deployed and diffused inside the firm to synergetic supports from different departments and get feedbacks from external users to refine the new offering. As a result, we postulate:

H3a: The efficiency dimension (cost/time) of development performance is positively associated with deployment and launch performance.

H3b: The effectiveness dimension (functionality/experience) of development performance is positively associated with deployment and launch performance.

Better intrafirm deployment enables different departments within the firm have an adequate understanding of the service innovation, reducing the difficulties in justifying the necessity to allocate managerial resources and exert synergetic efforts to support the launch and after-launch activities of the new service (Wang, Voss, and Zhao, 2018). Externally, early delivery to lead and other potential customers provides the firm an opportunity to collect initial market reactions to the proposed service and make sufficient adjustments to ensure the service addresses customer needs correctly at full launch (Song, Song, and Di Benedetto, 2009). Early delivery to market and sufficient managerial support facilitate the firm to grab market share and achieve superior benefits ahead of competitors. Accurate service proposition and perfect after-sales service also improve customer satisfaction and loyalty toward the service provider.

Moreover, the more proficiently the intrafirm deployment and refining is undertaken, the better the value proposition of the new service will be (Wang, Voss, and Zhao, 2018).

Subsequently, superior value proposition of the new service increases the target market's acceptance to the service and gradually locks customers in the service. Due to the high searching costs and switching costs for customers to switch to another service provider, the firm can charge a relatively high price for premier benefits which ultimately lead to a better financial performance. Moreover, comfortable service experience derived from the superior functionality of the service that cannot be provided by other service providers increases customers' satisfaction and commitment to the certain provider as well. Thus, we suggest:

H4a: Deployment and launch performance is positively associated with financial performance.

H4b: Deployment and launch performance is positively associated with non-financial performance.

Method

To design the measurement items, we invited three operations management professors and one marketing professor, all of whom were actively involved in teaching and research in Chinese and Western universities. 60 managers of service innovation projects were invited to pilot-test the questionnaire, and face-to-face interviews were conducted with them. 1000 companies were randomly selected from the four first-tier cities in China, namely Beijing, Shanghai, Shenzhen and Guangzhou. The sampling pool consisted of the service firms listed in the database of National Bureau of Statistics and headquartered in any of the four cities. In total, the data collection efforts resulted in usable responses of 200 service innovation project from 141 companies for a response rate of 14.1%.

We used the bootstrapping-based partial least squares (PLS) approach to structural equation modeling (SEM) to test the overall model and relevant hypotheses. PLS simultaneously assesses the quality of research constructs and the proposed relationships between constructs, and has been widely adopted in business research fields such as operations management, information systems, and marketing.

Results show that incremental service product innovation exerted a significant positive effect on development efficiency ($\beta = 0.196$, $p < 0.01$). Radical service product innovation, service process innovation and service business model innovation exerted a nonsignificant positive effect on development efficiency respectively ($\beta = 0.088$, $p = 0.381$; $\beta = 0.111$, $p = 0.261$; $\beta = 0.139$, $p = 0.238$). As such, H1a was supported while H1b, H1c, H1d were not supported.

Incremental service product innovation and service process innovation exerted a nonsignificant effect on development effectiveness respectively ($\beta = 0.075$, $p = 0.345$; $\beta = 0.098$, $p = 0.267$). Radical service product innovation and service business model innovation exerted a significant positive effect on development effectiveness respectively ($\beta = 0.163$, $p < 0.10$; $\beta = 0.173$, $p < 0.05$). As such, H2b and H2d were supported while H2a and H2c were not supported.

Further, both development efficiency and development effectiveness exerted a significant positive effect on deployment and launch performance ($\beta = 0.251$, $p < 0.001$; $\beta = 0.356$, $p < 0.001$ respectively). H3a and H3b were thus supported.

Finally, deployment and launch performance exerted significant positive effects on both financial performance and non-financial performance ($\beta = 0.569$, $p < 0.001$; $\beta = 0.441$, $p < 0.001$ respectively), supporting H4a and H4b.

Conclusion and Discussion

In recent years, the service sector has become dominant in economy and service firms compete fiercely in new offerings (The World Bank Data, 2017). Given the growing popularity of new service innovation activities and the complex outcomes of service innovation, this study attempts to build a staged-performance model for service innovation. The main objectives of this study were to identify key staged performance indicators derived from the new service development process, tie them to modes of innovation and final performance (financial and non-financial), and explore the mediating effects of those staged performance indicators between modes of service innovation and final performance.

Theoretical implications

To start with, this study highlights the importance to see service innovation performance in a staged model. Our study, by providing a staged model with multiple performance indicators, points out the need to assess innovation performance from an overall staged perspective since service innovation performance not only contains different dimensions, but also presents in a sequential way. The empirical results of our results suggest that different modes of service innovation first impact development performance, then deployment and launch performance, and ultimately financial and non-financial performance.

Further, we enrich the extant research on service innovation by showing that different modes of innovation have different staged performance model. Although previous study has already pointed out that different types of innovation may be associated with different development patterns and performance outcomes, relevant framework concerning such associations is still lacking (e.g., Avlonitis et al., 2001). Our study, by providing non-significant empirical evidence, points out that process innovation cannot improve development performance directly. Lastly, service business model innovation was found to be significantly associated with effectiveness (functionality) but not with efficiency (cost/time) of development performance.

Third, this study also explored the mediation effects of development performance and deployment and launch performance between modes of service innovation and final performance. Regarding development performance, its efficiency (cost/time) dimension fully mediates the relationship between incremental service product innovation and deployment and launch performance. And its effectiveness (functionality/experience) dimension fully mediates the relationship between service business model innovation and deployment and launch performance. These results provide favorable evidence for the argument in existing literature about the importance of the proficiency in development stage of service innovation (e.g., Song, Song, and Benedetto, 2009), especially for incremental service product innovation and service business model innovation.

Managerial implications

First, managers frequently confront a question: whether a new service idea can bring benefits to a firm after launched to the market? The findings of this study suggest that they should evaluate service innovation performance in a staged way. For instance, a poor final financial performance or non-financial performance do not necessarily mean that the service idea does not meet market demands. It is likely due to the poor execution and performance in the

development and deployment and launch of the service innovation.

Second, managers should pay attention to the modes of service innovation when assessing the intermediary performance indicators in the staged model because different modes of service innovation impact these indicators differently. The most challenging job for managers is the performance evaluation of service process innovation due to its insignificant direct effects on both efficiency and effectiveness of development performance. A possible solution is to indirectly examine process innovation's ability in helping firms to acquire, integrate, and disseminate knowledge and resources.

Finally, this study is the first to identify the mediating effects of development performance and deployment and launch performance between modes of service innovation and final performance. This inspires managers that for a better final performance (both financial and non-financial), resources and attentions should be made to achieve high-quality development activities and deployment and launch activities in service innovation since only through well development activities can service innovation ideas be deployed and launched to both internal users and external customers, and only through well execution of deployment and launch activities can efforts made into development activities be transferred into final financial and non-financial performance.

Limitations and Future Research

First, this study used data from IT-related service industries only. Therefore, the results found in this research are tentative and subjective to characteristics of IT services. Further replications efforts are needed to test the conceptual model and relevant hypotheses in other service settings, such as personal services, professional services, or tangible products related services to advance the literature. Likewise, the cross-sectional nature of the data may cause biased results. Longitudinal data, multiple informant data, or data from multiple sources are therefore required in future studies to verify the results of this study. Third, our sample is constrained to the Chinese firms. Thus, the generalization of the results in other areas beyond China should be made with caution.

Lastly, in the empirical analysis of this study, we captured modes of service innovation from 170 innovation projects from IT-related service industries and then explored the individual effect of each mode on different staged performance indicators. However, as suggested by existing literature, different modes of innovation can coexist in a same innovation project (Wang et al., 2015) and exert synergetic effects on innovation performance (Visnjic, Wiengarten, and Neely, 2016). Considering the sample size and the complexity of the conceptual model, we neither proposed nor tested the interaction effects of different modes of innovation this time.

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Servitization

Organisational transition from products to engineering services: An employee perspective

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Abstract

The organisational transition from products to engineering services requires manufacturers to enable various changes at the organisational and individual level. The purpose of this paper is to investigate the individual level of servitization starting from understanding different strategic stages of transition. Based on an initial theoretical review of the literature on servitization, service operations and organisational psychology, we propose a conceptual framework that details organisational transition stages and the employee-related aspects. Providing an employee perspective of the transition could facilitate the overall transition by enabling managers to identify those aspects that require their attention and develop suitable strategies.

Keywords: organisational transition, engineering services, employees.

Introduction

Many manufacturers face organizational transitions to becoming increasingly service-focused (Vandermerwe and Rada, 1988) and customer-focused (Ahamed et al., 2013). This organizational transition has often been described under the keyword servitization. Organizational transitions require attention to the organizational level changes and the individual employee-level changes (Rese and Maiwald 2013).

Current research provides extended insights into the organizational level of servitization as the company strategy (Rabetino et al., 2017) and the organisational culture (Nuutinen and Lappalainen, 2012). The "organisational transformation" (Bustinza et al., 2017) or the "service journey" (Martinez et al., 2017) has been discussed as a process of integrating products and services in the business model of the company rather than a specific transition from offering products to offering services (Peillon et al., 2015). In this way, manufacturers that started adding basic services to their business models, later on,

based on their resources, could enlarge their offerings with advanced services in a process of integrating basic and advanced services in the portfolio (Benedettini and Neely, 2018). For the purpose of this paper, we decided to label the servitization process as the "organisational transition from products to engineering services" because we are interested in exploring and explaining different characteristics of the process as well as enabling managers to identify and use what is relevant for their specific transition (Bustinza et al., 2017; Lütjen et al., 2017). The label "engineering services" is used to describe both basic and advanced services due to their industrial approach and their common use in the manufacturing sector (Steinmann et al., 2014).

What is missing in the current literature are explanations of the individual level of servitization, with a focus on the employees implication (Rese and Maiwald, 2013). For a service integration, relevant support from individual employees that are expected to engage in the process is one of the key points (Bel et al., 2018). For example, the selling of services depends on people in relevant positions and, having the focus on employees' skills and motivations is another key point for the transition (Kanninen et al., 2017). Moreover, authors have called for research to investigate the individual aspects that lead people to a specific behaviour in different stages of servitization (Lenka et al., 2018). In order to further the research interested in the individual level of transition we investigate the following research question:

What are the employee-related aspects that need to be considered in different stages of the transition towards engineering services provision?

This research proposes a conceptual framework that is aimed at providing guidance for further empirical investigations. We present an initial literature review to develop this conceptual framework.

Research method

In order to investigate the relevant stages of the transition towards the servitization and the employee-related aspects specific for each stage, we conducted an unsystematic theoretical review that enabled us to combine insights from theoretical and empirical studies (Paré et al., 2015). Considering the organisational transition as being specific for each organisation, we investigated strategic stages that could be relevant for different manufacturers due to their general approach. Starting from investigating the servitization literature and understanding the specific of the transition stages we linked, in an iterative process, two of the stages of servitization identified by Vandermerwe and Rada (1988) with three of the most frequent strategic stages identified in a review conducted by Martinez et al. (2017). For providing the employee perspective, we investigated the case studies concerning the servitization process, empirical studies that researched the employees as the operational resource of the company and a theoretical paper that proposed an orientation towards the individual level of servitization. Based on the specific of the change, we linked those specific employee-related aspects to each stage. Furthermore, general aspects that support the transition as different types of commitment and the individual change experience have been investigated in empirical and theoretical papers.

In the following sections of the paper, the stages of transition identified in the literature are described and insights into the employee-related aspects are provided.

Organisational transitions towards engineering services

The integration of services into the company portfolio is a long term process that involves different stages (Peillon et al., 2015) and consists of different models of change (Martinez et al., 2017). Vandermerwe and Rada (1988) explained the companies' patterns as starting with a focus on only one of the offerings, products or services, which is followed by integrating those offerings in a package, and finally offering packages of services that cover the customer needs.

Following these descriptions, research papers offered a large overview of transition stages. Martinez et al. (2017) reviewed several examples and defined the servitization as happening in strategic and operational steps. The authors concluded that most of the companies' strategic stages started with adding services related to their products. In this stage, companies are introducing into their portfolio, operational services that usually help the customer process of installing and maintaining the products (Salonen, 2011). For some companies, the services related to products, as delivery, are not creating revenue due to the lack of value awareness (Reinartz and Ulaga, 2008). In order to, build an image as provider of both products and services, the company undergoes the second most discussed strategic stage identified by Martinez et al. (2017), the development of a service culture. For manufacturers, this stage implies changing the mindset of stakeholders from offering products to providing solutions as a result of a long-term process of including the service values alongside to their core values (Gebauer et al., 2006). The following stage concerns the preparation of the product-services that should be included into the company's portfolio (Martinez et al., 2017). The main focus here is on understanding the customer activities and needs (Lim et al., 2012) and could be similar to the last stage explained by Vandermerwe and Rada (1988). The last strategic stage describes the process of testing the design of the services (Martinez et al., 2017) and is not described in this paper as is more related to the service than the organisational transition. The operational level of transition includes mainly aspects related to internal level of the company as employees (Martinez et al., 2017).

Based on these investigations, the organisational transition of servitization can be conceptualised in three stages as depicted in Figure 1.

Figure 1 - Strategic stages of the organisational transition towards servitization

The first stage focuses on offering engineering services as a distinct business opportunity. In the process of adding engineering services to the main offerings of the company, the specific of the company - customer interaction shifts from "product provision – payment received" to developing continuous engagement around the service provision. The specific of the engineering services within this stage is related to the core product (Gebauer et al., 2006) hence the relationship between company and customers requires a low level of interaction (Salonen, 2011). In order to provide this type of engineering services, organisational capabilities that support the mutual engagement are required (Oliva and Kallenberg, 2003; Davies, 2004). This often involves the creation of a new service department including own performance metrics, local service culture and separate value stream with employees who specialise on the provision of engineering services and (Oliva and Kallenberg, 2003). The process of evaluating the company's

offerings requires new performance metrics suitable for both products and services (Martinez et al., 2010) and performance indicators for employees (Gebauer et al., 2006).

The second stage focuses on building a service culture. Evaluating the organisational culture provides evidence for the overall image of the company (Nuutinen and Lappalainen, 2012) and the specific view of manufacturers as product providers is one of the main challenges in the transition process (Martinez et al., 2010; Dubruc et al., 2014). This includes internal standardisation and optimisation of service-related processes, including service provision, service development and sales. The aim is to have a standardised service portfolio that reflects organisational standards and image.

The third stage focuses on building a customer culture where customer needs are the basis for the provided and new service offerings (Marques et al., 2013). This requires manufacturers to restructure their value stream around the provided customer value rather than internal capabilities and processes (Martinez et al., 2017). Long-term and deep customer relationships are required to access the information needed for this purpose (Kreye et al., 2015).

Employee-related aspects in the service transition

The employee related aspects distil down to aspects that are specific to the transition stage, i.e. which one of the three transition stages described above the organisation is in, and general aspects that apply to any organisational change or transition. This section describes these elements in two separate sub-sections.

Transition-stage specific employee aspects

In the first transition stage (offering engineering services), the differences between production and service provision affect the employee-related aspects. The quality of services helps companies to build their external image as a trustworthy service company (Oliva and Kallenberg, 2003). As far as the employees are concerned, having the necessary knowledge and the required skills, among other aspects, helps their individual readiness for organisational change (Hanpachern et al., 1998). Baines et al. (2013) noted six sets of skills relevant for employees involved in advanced services, which cover activities related to the customer interaction or the technical aspects, depending on their role. These skills include employees' soft skills and improve the way services are delivered (Antioco et al., 2008). In addition to having the necessary skills for services, employees need an appropriate motivation that supports the service provision (Kreye, 2016). This implies that, with the new requirement, rewards systems should support the service provision and motivate people involvement.

In the second transition stage (building a service culture) where the service strategy is integrated within the wider organisation, a wider circle of employees is affected by the organisational transition. This includes employees that affect the service value stream including otherwise product-focused departments such as planning, IT, logistics and marketing departments. Employees in these areas are expected to adapt their mindset to services as one of the offerings of the company (Martinez et al., 2010). Difficulties arise because the required mindset is related to the role of the employee and being involved in the product-related unit of the organization could hinder the collaboration with employees that are involved in the services (Rese and Maiwald, 2013). Organisational identity consisting of sharing the same purpose and standards as well as the shared identity with the subunit expressed as feeling a collective effort and responsibilities (van Dick et al., 2018) is an aspect that should be considered in this stage. Organisational identity may still consist of a product-focused mind-set and integrating a service-related identity can cause resistance and tensions (Huy, 1999).

In the third transition stage (establishing a customer focus), front-line employees are the starting point for organisational innovation of the service business and are, thus, not only an operant resource (Kreye, 2016; Martinez et al., 2017), but also a creative resource (Laperche and Picard, 2013). This means that front-line employees such as sales staff and service engineers have to not only adjust their behaviour according to the individual customer (Bowen and Ford, 2002), but also function as a source of information and inspiration for internal service innovation activities. This requires internal information processing to identify new value potential through tracking and understanding changing customer requirements as well as translating these into offerings. The type of relationship between customer and employees, could constitute the premise for increasing employees motivation through feedback from the customer (He et al., 2015).

General aspects involved in the transition

General aspects involved in organisational transformations are commitment and experience with changes, either influencing people support or resistance towards the change.

In general, commitment is explained as a force "experienced as a mind-set (i.e., a frame of mind or psychological state that compels an individual toward a course of action)" (Meyer and Herscovitch, 2001, p.303). Meyer and Allen (1991) model of organisational commitment explained three dimensions of commitment based on their specific triggers. This model includes, the affective commitment of individuals presented as the emotional investment and willingness to be part of the organisation, the continuance commitment associated to the cost felt by people for the turnover behaviour and the normative commitment driven by rewards in advance or investments that lead to the feeling of duty. Herscovitch and Meyer (2002) found out that the supportive behaviour towards the change could be explained by people organisational commitment towards the change rather than by their general commitment to the organisation. The authors explain that people's emotional implication in the change process (affective commitment), their sense of duty and responsibility towards the change (normative commitment) the lack of choice and the pressure associated with resistance (continuance commitment) determines them to approve the transformation. However, only the first two dimensions influence people effort in supporting the changes, implying that not having an alternative will not make them supportive.

Furthermore, people experience in terms of their expectations and openness to change. The negative valence of personal experience related to changes in the organisation can cause doubt about the organisational success to implement change due to the inability of managers (organisational cynicism) and a diminished level of openness to change (Bordia et al., 2011). In other words, previous failures of organisational changes influence employees' opinion about the management capabilities and motivations for change. Bordia et al., (2011) concluded that, this lack of trust in the change efforts, increases to the negative feelings and diminishes the willingness to support the process of change. In addition to the negative personal experience, people assumptions could influence their behaviour. Ford et al. (2002) noted different types of conversations about changes that shape people expectation and lead to different type of resistance. In this context, authors explained that the background conversation about the company traditional way of succeeding (complacent background) increases people expectations to success in the same way and not interfere with the routine. As far as the conversation about the failures of previous changes are concerned, attributing this lack of success to internal (resigned background) or external aspects (cynical background) leads to specific negative expectation about the people or company resources for succeeding (resigned

background) or about the possibility of anyone to succeed with this change (cynical background). As a result, people resistance is driven by the specific nature of each employee's background.

The proposed conceptual framework

Based on the above considerations, we propose a conceptual framework of the employee-related aspects of the organisational transition towards engineering services in three stages: offering engineering services, building a service culture and establishing a customer focus. For each stage, we propose employee-related aspects that could facilitate the understanding of the individual level of servitization. Figure 2 summarises the proposed framework with concepts explained above.

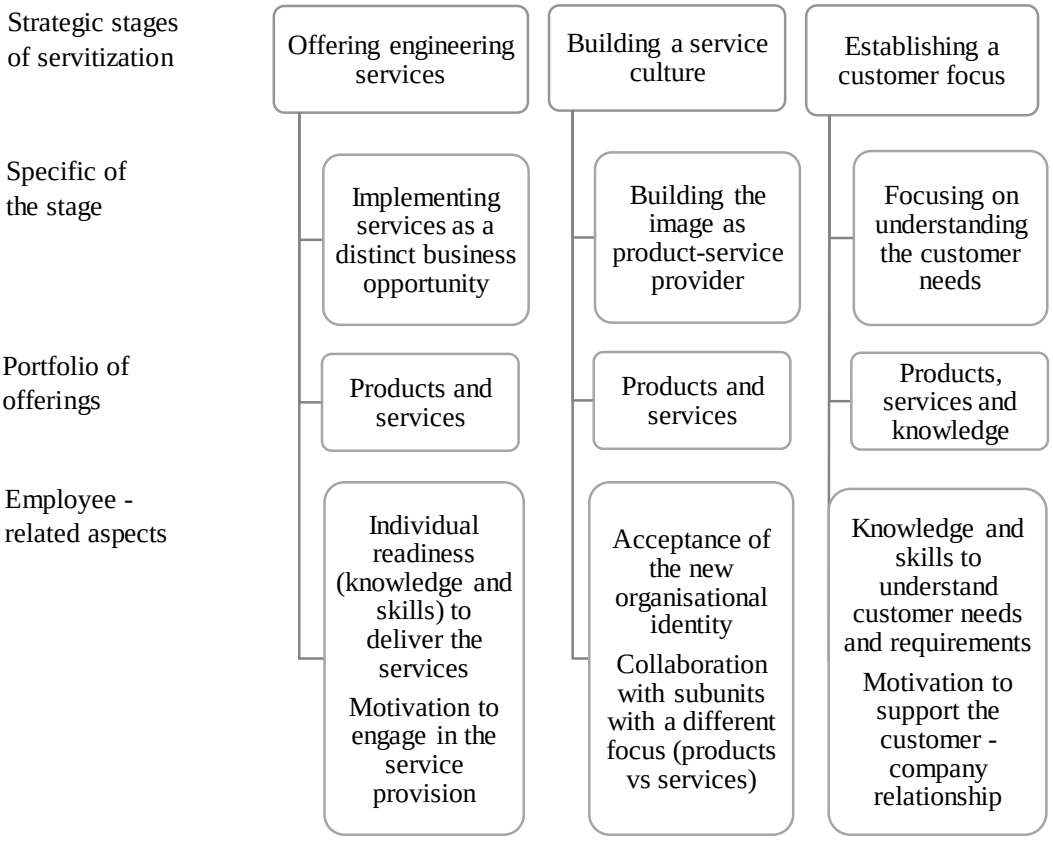

Figure 2 - The conceptual framework of the organisational transition towards servitization

Conclusion and further directions

The aim of this paper was to identify those employee-related aspects relevant in the manufacturers' transition towards providing services. In order to enable the research of those specific aspects, we proposed the following research question: *What are the employee-related aspects that need to be considered depending on the stage of the transition towards engineering services provision?* Theoretical and empirical papers provided us insights and concepts that facilitate the development of a conceptual framework of the employees' side of the organisational transition towards the services provision.

The proposed conceptual framework represents a starting point for investigating the individual level of servitization in a structured process. Due to the theoretical approach,

the employee-related aspects could be considered only as preliminary outcomes that need further investigation. Further research consists on exploring the requirements from different types of stages of the transition and their impact on the employees' level. Understanding individual aspects that influence people behaviour during the transition offers the possibility to predict and overcome internal resistances with specific strategies.

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Servitization and differentiation advantage: An empirical investigation

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Abstract

This study theoretically articulates and empirically tests a model of the role played by advanced services (ADS) in supporting a business strategy based on product and service differentiation, taking into consideration the complexity of the business environment. Based on survey data from 931 manufacturers, we find that: i) environmental complexity has a positive impact on strategic focus on product and service differentiation; ii) strategic focus on product and service differentiation, but not environmental complexity, have a positive impact on ADS; iii) ADS have a positive impact on service differentiation advantage, but not product differentiation advantage.

Keywords: servitization, advanced services, competitive advantage.

Introduction

Manufacturing firms increasingly realize the strategic importance of service in achieving competitive advantage based on differentiation (Baines et al., 2017). Despite this, our understanding of the strategic and competitive role played by servitization is still incomplete (Bustinza et al., 2015). A telling manifestation of this is that research on the impacts of servitization on firm performance remains inconclusive, with several studies having revealed that these impacts are more complex and fine-grained than originally envisaged (Kastalli and van Looy, 2013; Eggert et al., 2014; Forkmann et al., 2017; Sousa and da Silveira, 2017). Specifically, we lack a more comprehensive theoretical articulation of how servitization can support a differentiation strategy in manufacturing firms. Ascertaining whether and under which conditions servitization supports differentiation advantage is essential for justifying such strategies' effectiveness (Sousa and da Silveira, 2018; Voss et al, 2016).

To address this research gap, our study theoretically articulates and empirically tests a model of the role played by servitization in supporting a business strategy based on product and service differentiation. In doing so, we focus on the offering of Advanced Services (ADS), because the potential for differentiation lies with this type of services, rather than with Basic Services (Sousa and da Silveira, 2018).

Theoretical background

Advanced services and differentiation

ADS support the customer's actions in relation to the product and the adaptation of the product use to the customer's unique needs, usage situations, and behaviors (Eggert at al., 2014; Smith et al., 2014). Examples include training in using the product, product upgrades (to fit customer needs), consulting, and product rental. ADS are relational-oriented, involve significant co-creation of value with customers (influencing and sometimes managing their processes of value creation), intense interactions with the customers, and are often complex and customized (Sousa and da Silveira, 2017).

Differentiation in the marketplace can be achieved by a distinctive product and/or service offering (Porter, 1980). Hence, competing based on differentiation involves emphasizing the competitive priorities of product and service differentiation; differentiation advantage is achieved by excelling in the corresponding performance dimensions relative to the competition.

We develop a theoretical model to examine the role of ADS in supporting a business strategy based on product and service differentiation (Figure 1). The model integrates the two theoretical lenses that are most commonly employed in the servitization literature to understand its competitive role: market forces and capabilities (Eloranta and Turunen, 2015).

The market forces lens is rooted on Porter's (1980) paradigm of competitive market forces, which advocates that service offerings need to fit the firm's external environment and competitive strategy. In this context, servitization is often portrayed as a means to achieve differentiation in complex environments (Neu and Brown, 2005). The literature supports a two-pronged effect of external environment on servitization: a direct effect, by which service offerings need to be aligned with the environment (Gebauer, 2008); and an indirect (mediated) effect through competitive strategy, by which certain environments favor a differentiation strategy, which in turn can be adequately supported by servitization (Matthyssens and Vandenbempt, 2008). Based on this literature, we posit that ADS are appropriate to support differentiation strategies in complex environments.

The capabilities lens focuses on the resource-based view of the firm (Barney, 1991). It advocates that service offerings are associated with the development of valuable and difficult to imitate resources and capabilities that create competitive advantage (Ulaga and Reinartz, 2011). Based on the processes of value co-creation between manufacturers and customers during service encounters (Payne et al., 2008), we posit that ADS lead to differentiation advantage through the development of deep customer knowledge as a capability.

Research hypotheses

Market forces and advanced services

To examine the market forces perspective, we draw on the seminal dimensions of organizational task environment of Dess and Beard (1984), adapted to the study of servitization by Neu and Brown (2005): *munificence* (tame-hostile), *complexity* (simple-complex) and *dynamism* (stable-dynamic).

Munificence pertains to the availability of resources that allow an organization to survive and grow. In the servitization literature, the provision of services is seen as a way for firms to create additional value in highly competitive environments (Baines et al., 2017). ADS support this goal, since their high-value, differentiated nature leads to increased revenue and profitability (Eggert et al., 2014; Sousa and da Silveira, 2017).

Complexity pertains to the heterogeneity and range of factors that affect an organization's activities. In the servitization literature, this dimension is related to market

complexity, involving the existence of different customer segments with different needs and a variety of contextual use scenarios (Neu and Brown, 2005). Such markets provide more opportunities to adopt differentiation strategies, as well as to offer new, customized services (ADS) targeting customer needs that are often not met by existing market offers (Neu and Brown, 2005).

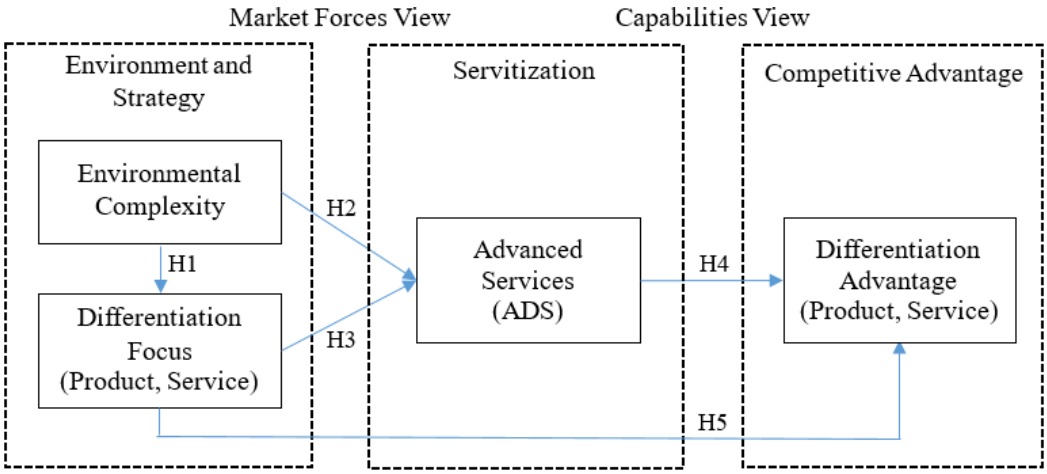

Figure 1. Theoretical model.

Dynamism refers to the degree and nature of change in factors that are relevant to an organization's activities. In servitization, this dimension is most often associated with the degree of technological change (Neu and Bown, 2005). Environments with a high degree of technological change provide opportunities for differentiation strategies (Ward and Duray, 2000). In addition, they are associated with high levels of technology-based product innovation. Such products lend themselves to value-added service provision (ADS) to help customers exploit the full potential of the innovations (Visnjic et al., 2016).

Neu and Brown (2005) propose that these three dimensions give rise to "complex markets", driving servitization initiatives. Thus, we aggregate munificence, complexity and dynamism under a single construct of "environmental complexity". Overall, the above arguments point to complex environments having both an indirect (mediated) effect on ADS through strategic focus on differentiation, but also a direct effect that goes beyond business strategy. Thus:

H1a/H1b. Environmental complexity is positively associated with strategic focus on product/service differentiation.

H2. Environmental complexity is positively associated with the offering of ADS.

Manufacturers compete based on differentiation by building non-price-based value offerings, comprising differentiated products and services (Matthyssens and Vandenbempt, 2008; Kastalli and van Looy, 2013). The customized, often complex nature of ADS is a core element of differentiated customer solutions (Sousa and da Silveira, 2017; Eggert et al., 2014). Thus:

H3a/H3b. Strategic focus on product/service differentiation is positively associated with the offering of ADS.

Advanced services and differentiation advantage

The servitization literature highlights customer knowledge as a key capability (e.g. Gebauer et al., 2011). In order for this knowledge to be a sustainable source of advantage, it should not be based solely on hard data such as customer satisfaction measures but should incorporate a deep understanding of customer experiences and processes (Payne et al., 2008), becoming a valuable and difficult to imitate capability. We argue that ADS lead to deep customer knowledge and differentiation advantage, as follows.

ADS involve understanding how customers use products in their specific context (e.g., equipment use physical environment) (Smith et al., 2014). This provides valuable information for designing new products or modifying/upgrading existing products to fit unique customer needs and use contexts (product differentiation advantage) (Visjnic et al., 2017). It also allows for the provision of higher quality service (e.g., customer support, customer training) by considering the product's specific use context (service differentiation advantage) and allowing the manufacturer to actively influence customer processes (Payne et al., 2008). Thus:

H4a/H4b. The offering of ADS is positively associated with product/service differentiation advantage.

Following strategic management theories, strategic focus on differentiation leads to suitable resource allocation and configuration policies that promote differentiation advantage (Porter, 1980). This logic applies to service offers (e.g., Neu and Brown, 2005), as well as to goods offers (e.g., Hill, 1989). Thus:

H5a/H5b Strategic focus on product/service differentiation is positively associated with product/service differentiation advantage.

Our research model includes two relationships (H3b, H4b) which have been empirically examined using the same dataset by Szász and Seer (2018) as part of a model looking only at the service business of manufacturing firms. Our study re-examines these relationships in a broader, more comprehensive model, adding key constructs related to environmental complexity and the product business (product differentiation focus, product differentiation advantage).

Methods

Data and measures

We tested our model with data from the 2013/2014 International Manufacturing Strategy Survey (IMSS-VI). The following information about the survey was available from the network (IMSS, 2015) and appeared in previous IMSS studies. The survey was carried out in 22 countries by local researchers. It assessed the strategies, practices, and performances of manufacturing business units from ISIC sectors 25-30, which includes manufacturers of fabricated metal products, instruments, equipment, and machinery. The researchers initially contacted 7167 units and received 931 complete responses (13%).

The model included four sets of variables, namely environmental complexity, product and service differentiation focus, ADS, and product and service differentiation advantage. Based on the theoretical background, we developed environmental complexity as formative and the remaining variables as reflective (Diamantopoulos and Siguaw, 2006).

Environmental complexity was given by three formative indicators measuring the munificence, market complexity and dynamism faced by business units (Dess and Beard, 1984; Neu and Brown, 2005). Respondents were asked, "how do you perceive the

following characteristics of the environment in which your business unit operates?" Responses were given on five-point scales for "competitive rivalry within industry" ("Very low" = 1, "Very high" = 5) (munificence), "market span" ("Few segments" = 1, "Many segments" = 5) (market complexity), and "rate of technological change" ("Very low" = 1, "Very high" = 5) (dynamism), (IMSS, 2015). The scale was successfully validated through a MIMIC model (Diamantopoulos and Winklhofer, 2001; Diamantopoulos and Siguaw, 2006). The reflective indicators measured the perceived threats (*i*) that new players could enter the market ("market entry") and (*ii*) that products made by the business unit were replaceable ("products will become substituted").

Focus on product and service differentiation were operationalized by "order-winner" (Hill, 2000) indicators at the business unit level. Respondents were asked to "consider the importance of the following attributes to win orders from your major customers". Responses were given in a five-point scale of "importance in the last three years" with endpoints "Not important" (1) and "Very important" (5) (IMSS, 2015). The indicators were product customization (modification), product range (mix), frequent new products (changeover) and innovative products (changeover).

Focus on service differentiation indicators included product support (including after sales and technical) and customer service (including training, information, and help-desk) (IMSS, 2015). They matched closely the two most commonly found strategic types ("after-sales service provider" and "customer support service provider") in Gebauer's (2008) services configurations framework.

ADS was operationalized as in Sousa and da Silveira (2017), who also used indicators from IMSS-VI. The scale measured the extent of offering of ADS ("advanced services"), namely, rental/lease of products, product upgrades, help desk, user training, and consultancy (IMSS, 2015). Answers were given on a five-point scale with endpoints "None" (1) and "High (5).

Product and service differentiation advantage were measured by performance relative to main competitors. Respondents were asked, "How does your current performance compare with that of your main competitor(s)". Responses were given on a five-point scale with endpoints "much lower" (1) and "much higher" (5) (IMSS, 2015). Both scales should be symmetric in content with the product and service differentiation "focus" scales. Thus, service differentiation advantage included the two indicators of product assistance and customer service quality, and product differentiation advantage had three indicators including mix flexibility (ability to provide a wide product range), customization ability and new product introduction ability.

All models controlled for the ln-transformed number of employees in the business unit.

Measurement validation

Table 1 presents the means, standard deviations, and case numbers of all observed indicators. The maximum variance inflation factor was 2.22, indicating that multicollinearity was not problematic.

We carried out analyses in R version 3.4.3 (R Core Team, 2017) using Rstudio desktop version 1.1.419 (RStudio Team, 2015) in a GNU/Linux system. We tested measurement and structural equation models with the lavaan package (Rosseel, 2012) using maximum likelihood estimates. We tested the unidimensionality, validity, and reliability of scales with confirmatory factor analysis (CFA) of the complete measurement model. Initial fit statistics were satisfactory (χ^2/df = 3.587, CFI = 0.929, NFI = 0.905, TLI = 0.906, RMSEA = 0.058 [0.052; 0.065]) but some standardized loadings λ were low. We refined the model by dropping three indicators including product customization (product differentiation

focus), rental/lease of products (ADS) and mix flexibility (product differentiation advantage).

The refined model had satisfactory fit (χ^2/df = 2.412, CFI = 0.971, NFI = 0.953, TLI = 0.958, RMSEA = 0.043 [0.035; 0.051]) (Bagozzi and Yi, 1988), Convergent validity was supported as λ values were significant ($p < 0.001$) and average variance extracted (AVE) values were near to or greater than 0.50 (Fornell and Larcker, 1981; Bagozzi and Yi, 1988). The product differentiation advantage scale was somewhat below the convergence threshold (AVE = 0.49). However, we maintained that scale because overall model fit was satisfactory, and it had good conceptual symmetry with the product differentiation focus scale. Scales reliability was supported as all composite reliability (CR) values were greater than 0.60 (Bagozzi and Yi, 1988).

Discriminant validity is supported when pairwise correlations between latent variables are lower than the squared root of their respective AVEs (Fornell and Larcker, 1981). This was observed in all cases except in the correlation between service differentiation advantage and product differentiation advantage. So, we carried a nested models comparison test (Anderson and Gerbing, 1988). The constrained model had significantly worse fit than the constrained model (χ^2 difference = 47.06, df = 1, $p < 0.001$), which is evidence to discriminant validity (Anderson and Gerbing, 1988).

Results

We developed a structural model to test hypotheses H1 to H5. Table 2 presents the path estimates and overall model fit. Fit statistics were all satisfactory (Bagozzi and Yi, 1988). Environmental complexity was positively associated with product differentiation and service differentiation focus, supporting H1a and H1b. However, it was not significantly related with ADS ($p = 0.056$), failing to provide support to H2. Both product differentiation and service differentiation focus were positively associated with ADS, supporting H3a and H3b. The differentiation focus variables also related positively with their performance advantage correspondents, supporting H5a and H5b. Finally, ADS was positively associated with service differentiation advantage but not with product differentiation advantage ($p = 0.076$), supporting H4b but not H4a.

Discussion

Concerning market forces, we found that complex market environments lead to the adoption of business strategies based on product and service differentiation (H1a, H1b) and these in turn drive the offering of ADS (H3a, H3b). However, our results raise doubts as to the direct influence of environmental complexity on ADS (H2). The absence of such direct effect would suggest that these traits only indirectly affect servitization, via the mediating effect of business strategy. Thus, the offering of ADS seems to by primarily driven by business strategy, confirming that ADS indeed have a key strategic nature and are integral to the manufacturing firm's business model (Sousa and da Silveira 2017).

As anticipated, strategic focus on product/service differentiation per se led to increased product/service differentiation advantage (H5a, H5b). This reinforces the need for a clear strategic orientation towards differentiation of the product and service functions in the manufacturing firm. In examining the market forces view, we found that the offering of ADS is significantly influenced by contextual conditions, namely business strategy and (indirectly) environmental complexity. This encourages a more widespread usage of contingency approaches in the study of servitization (Forkmann et al., 2017).

Our study also supports the capabilities view, according to which service offerings are associated with the development of valuable capabilities that provide competitive advantage. We found that ADS have a positive impact on competitive advantage via

service differentiation (H4b), even after accounting for the positive effects of strategic focus on service differentiation (e.g., via suitable resource allocation and configuration). In addition, after accounting for the positive effects of strategic focus on product differentiation, there was no evidence that the offering of ADS affected product differentiation advantage (H4a).

A possible explanation for these results may be that servitization effects on product and service advantage work through different organizational mechanisms and time scales. Because of the intangible nature of services, customer knowledge accrued via ADS can be quickly absorbed by the service provision function in the manufacturing firm and used to improve services and achieve service differentiation advantage. However, for product differentiation advantage, customer knowledge needs to be fed back to the design, engineering and manufacturing functions to redesign products and manufacturing processes. This process takes longer and may be affected by organizational context traits, such as the degree of cross-functional collaboration and knowledge integrating mechanisms among the firm's service and manufacturing functions (Schaarschmidt et al., 2018). So, the relationship between ADS and product differentiation advantage may be more complex.

Conclusions

Theoretical contributions

Our study advances the theoretical understanding of the competitive role of ADS, by integrating the market forces and capabilities perspectives on servitization and addressing both the product and service businesses inside the manufacturing firm. We complement prior research which has primarily addressed either product- or service- related outcomes, but rarely both simultaneously (Shaarschmidt et al., 2018). The study answers calls for developing stronger and more holistic theoretical foundations for ADS (Baines et al., 2017), increased understanding of the contextual conditions that influence the adoption of servitization (Baines et al., 2017; Forkmann et al., 2017), as well as to perform theory validation in the servitization field employing large scale empirical studies (Kowalkowski et al., 2017).

Managerial implications

Firms operating in complex environments could be tempted to offer ADS in a reactive response to the environment. Our study highlights the need for manufacturing firms to consider servitization as a strategic move integrated in an overall differentiation strategy – involving an explicit focus on product and service differentiation – rather than a piecemeal program. While the offering of ADS generates service differentiation advantage, it does not seem to have an impact on product-differentiation advantage. This allays managerial concerns that servitization could disrupt strategic focus in the manufacturing function and hurt product differentiation advantage (Josephson et al., 2016). Thus, managers pursuing product and service differentiation strategies should strive to incorporate ADS in their core corporate offerings. In doing so, they are able acquire a deep understanding of customer experiences and processes that can become a source of differentiation advantage.

Limitations and future research

We were not able to measure the deep customer knowledge capability. This was because of the complex and tacit nature of this construct, as well as because of limitations of our data. Future studies should develop scales to measure this construct and incorporate it in appropriate research models.

Our findings suggest future research avenues. Although we found that both product and service differentiation focus drive the offering of ADS, the impact of ADS on product and service differentiation advantage is distinct. This reinforces the need for servitization research to jointly address the product and service businesses in the manufacturing firm, as well as their interplay. Thus, future research should examine the role of integration mechanisms inside the firm (Schaarschmidt et al., 2018). Future studies should also examine the detailed mechanisms by which ADS affect product and service differentiation advantage. Of interest would be to conduct longitudinal case studies looking at the dynamics between customers and servitized manufacturers and the processes by which deep customer knowledge accrued by the offering of ADS is co-created, absorbed and leveraged by the manufacturer over time to produce differentiation advantage.

Table 1. Descriptive Statistics

Indicators/Variables	*N*	Mean	S.D.	Min	Max
Service differentiation focus ($N = 908$; $\alpha = 0.82$)					
Product support	913	3.88	0.95	1	5
Customer service	922	3.63	1.07	1	5
Product differentiation focus ($N = 902$; $\alpha = 0.75$)					
Product customization	922	3.68	1.04	1	5
Product range	924	3.51	0.99	1	5
Frequent new products	918	3.25	1.09	1	5
Innovative products	921	3.61	1.05	1	5
Advanced services (ADS) ($N = 893$; $\alpha = 0.81$)					
Consultancy	908	2.73	1.29	1	5
User training	920	2.87	1.35	1	5
Help desk	914	3.00	1.35	1	5
Product upgrades	914	2.59	1.36	1	5
Rental/lease of products	903	1.87	1.17	1	5
Service differentiation advantage ($N = 842$; $\alpha = 0.73$)					
Product assistance	852	3.36	0.78	1	5
Customer service quality	852	3.36	0.85	1	5
Product differentiation advantage ($N = 842$; $\alpha = 0.74$)					
Mix flexibility	863	3.43	0.80	1	5
Product customization ability	862	3.52	0.85	1	5
New product introduction ability	869	3.45	0.93	1	5
Environmental complexity	917	3.51	0.66	1.67	5
Firm size (LN)	929	6.02	1.72	1.10	11.92

Valid sample size (*N*) and Cronbach's alpha (α) in parenthesis next to each variable.

Table 2. Direct Path Estimates

(Hypothesis) Path	Std. Est.	SE	*p*-value
(H1a) Environmental complexity → Product diff. focus	0.442	0.034	< 0.001***
(H1b) Environmental complexity → Service diff. focus	0.239	0.038	< 0.001***
(H2) Environmental complexity → ADS	0.078	0.041	0.056
(H3a) Product differentiation focus → ADS	0.247	0.054	< 0.001***
(H3b) Service differentiation focus → ADS	0.354	0.047	< 0.001***
(H4a) ADS → Product diff. advantage	0.096	0.054	0.076
(H4b) ADS → Service diff. advantage	0.173	0.052	0.001**
(H5a) Product diff. focus → Product diff. advantage	0.297	0.049	< 0.001***
(H5b) Service diff. focus→ Service diff. advantage	0.238	0.048	< 0.001***
Firm size → Product differentiation focus	0.001	0.038	0.985
Firm size → Service differentiation focus	0.054	0.039	0.167
Firm size → ADS	0.037	0.036	0.294
Firm size → Product differentiation advantage	0.004	0.042	0.932
Firm size → Service differentiation advantage	0.003	0.040	0.947
χ^2 /df	2.445		
CFI	0.969	RMSEA	0.043
NFI	0.949	CI upper	0.035
TLI	0.957	CI lower	0.051

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

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Are practitioners and literature aligned about digital twin?

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Abstract
The attention of practitioner and research on the concept digital twin is constantly growing: many companies have already in their offer a so-called digital twin and literature have seen in the recent years a strong increase of contributions on the topic, nevertheless, none of them ever stated if it is the same thing to which the professionals are referring to. For this reason, the purpose of this paper is to understand whether literature and practitioners are aligned about the digital twin paradigm, eventually identifying which are the differences and so define what are the possible developments for future research.

Keywords: Digital twin, servitization, literature review

Introduction
Worldwide, the new national development strategies for the industry – such as Industrie 4.0 in Germany, Industria 4.0 in Italia , Made in China 2025 in China and Smart Manufacturing in the USA – have the common goal of smart manufacturing (Kang et al., 2016), an emerging form of production integrating manufacturing assets of today and tomorrow with sensors, computing platforms, communication technology, control, simulation, data intensive modelling and predictive engineering (Kusiak, 2018). Based on that, an intensive and articulated application of networked information-based technologies throughout the manufacturing and supply chain enterprise is needed (Davis et al., 2012). Such technologies, such as sensors, cloud computing, augmented/virtual reality, additive manufacturing, machine learning, artificial intelligence, robots etc. produce, share and use big amounts of data that manufacturing companies and organizations need to transform in useful informations with the help of gaining richer and deeper insights and getting an advantage over the competition (Sagiroglu and Sinanc, 2013). One way to seize such opportunities is the concept of digital twin.

The concept of digital twin is born in order to add value and efficiency of both the data collected from the physical manufacturing sites and the data generated or existing in these deployed information systems (Cheng et al., 2018). It has found increasing attention by both industry and academic as the number of applications, on one hand, and contributions, on the other, has strongly

increased in the recent years: in the industry, numerous companies offer a so-called digital twin to their customers; in the literature, the number of contributions on the topic has greatly increased since 2017 (as the following literature review demonstrates). To this high number of contributions correspond a similarly high variety of definitions and interpretations of digital twin, depending on the type of industry involved and the field in which is implemented (Tao, Sui, et al., 2018).

Considering such a high number of applications, it is evident that the possibilities in business terms need to be addressed, not just from a technical point of view, but also from a business model point of view, in particular the integration of the digital twin and service represents a promising research direction which should be addressed in future paradigms (Tao, 2018): servitization, the concept that refers to the transformation in which manufacturers are increasingly offering services that are directly coupled to their products (Baines and W. Lightfoot, 2013), is a topic for which there is a growing interest among academia, business and government because it is thought that a move towards servitization is a mean to create additional value adding capabilities for traditional anufacturers (Baines et al., 2009).

There is the need for studies in such direction but in order to seize such opportunities, it is fundamental that literature and practitioners are aligned about the digital twin concept; this is the reason why this paper aims to answer the following research question (RQ): *are the practitoners and the literature aligned about the concept of digital twin?*

In order to give an answer to this question, the definitions of digital twins that can be distinctly obtained analyzing the literature and the results coming off the combination of a survey with the interviews done with the practitioners, are compare.

The paper is structured as follow: first the method and results of the analysis of the literature review made on the Scopus database are presented, to which the genesis of the concept and its definition are deduced; then the results of a systematic combining of the results of the survey made on a sample of about 60 professionals, with in-depth interviews carried out on 15% of the same sample and therefore, are presented with its correspondent definition. Then the findings are discussed and so conclusions are made, The paper finishes with the definition of possible future works and the limitations of the research are pointed out.

Literature review

Approach

A literature review was conducted on the Scopus database searching for the “digital twin” term in the keywords: it resulted in 255 results of different types (articles, conference papers, etc.), distribuited from 1993 (Koren et al., 1993) to March 2019 (Figure 1) and mainly focused in subject areas of *computer science* and *engineering*.

Based on a cross-referenced analysis of the results, 4 more papers have been added to the selection and included to point out the following definition of digital twin, for a total of 259 papers.

The analysis and the selection of the papers that have been considered the most relevant for the purpose to address the RQ, have been done reading in order the title, abstract and finally the entire paper; then, the selected ones (21 in total) have been used to obtain a general and common definition of digital twin.

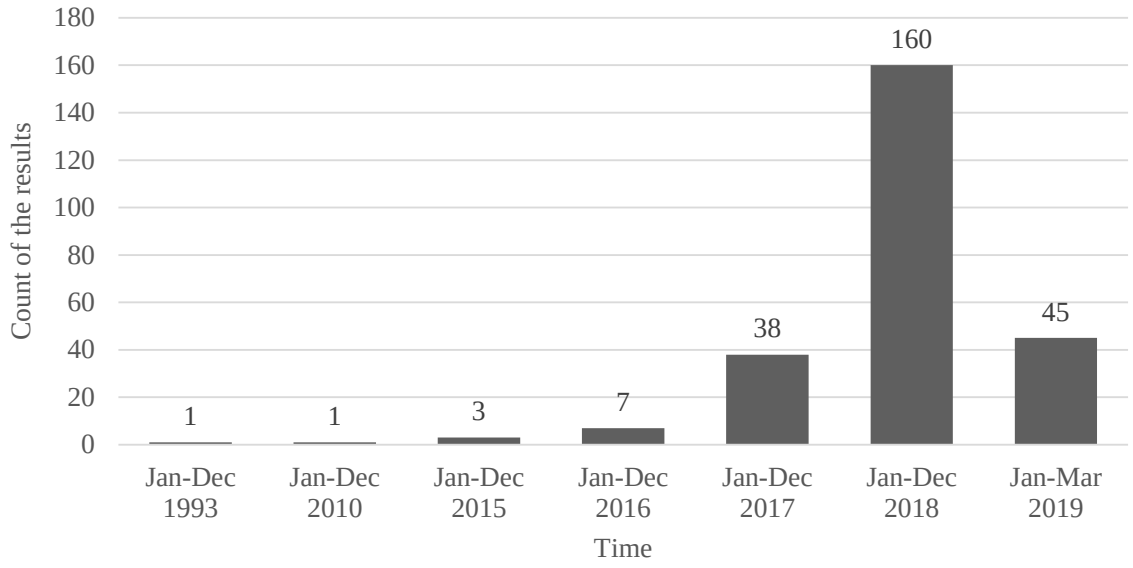

Figure 1:Histogram representing the count of contributions found in the Scopus database from January 1993 to March 2019.

Evolution of the digital twin concept

A first intuitive digital twin concept was introduced for the NASA's Apollo project in the late 1960s, when NASA created two identical space vehicles where the ones left on earth was called "the twin" and was used to mirror the condition of the space vehicle that performed the mission, so a prototype that mirrored the real operating condition for the simulation of real-time behaviour; the NASA then evolved its concept of digital twin as an integrated multiphysics, multiscale simulation of a vehicle or system that uses the best available physicals models, sensor updates, fleet history, etc., to mirror the life of its corresponding flying twin (Glaessgen and Stargel, 2012). By the way, it is generally accepted (Cheng et al., 2018; Glaessgen and Stargel, 2012; Haag and Anderl, 2018; Padovano et al., 2018; Tao, Cheng, et al., 2018; Tao, Sui, et al., 2018; Zheng et al., 2018a, 2019) that the concept of digital twin was firstly presented by Grieves in a conference about PLM in 2003 as made of three parts, i.e. physical product in real space, virtual product in virtual space and the connection of data and information that ties two spaces together (Grieves, 2014). From Grieves, the concept of digital twin evolved in the years: until 2014, the different definitions given referred to the aeronautical field, with the digital twin concept that maintains the characteristic bi-part composition (i.e. virtual and physical) and integration (i.e. with data) but the concept of simulation is introduced (Glaessgen and Stargel, 2012; Hochhalter et al., 2014; Reifsnider and Majumdar, 2013); then, with the introduction of the Industrie 4.0 plan in Germany (Rosen et al., 2015), the concept of digital twin becomes broader, moving from products to processes (Rosen et al., 2015); from real-time representation to optimization and prediction (Tao and Zhang, 2017; Zhuang et al., 2018); from simulation to real-time and continuous evolution (Haag and Anderl, 2018; Tao, Cheng, et al., 2018; Tao, Sui, et al., 2018; Tao and Zhang, 2017).

The definition of digital twin from the literature

Based on the results of the research, literature defines the digital twin as a *way* to combine (Tao and Zhang, 2017), integrate and realize the interaction (Cheng et al., 2018; Shubenkova et al., 2018) between physical and virtual worlds. It can have different granularity since the physical object can be a system (Tao and Zhang, 2017) or a sub-system (Glaessgen and Stargel, 2012; Zhuang et al., 2018) and can be a product (Grieves, 2014) or a process (Rosen et al., 2015).The integration and interaction between physical and virtual worlds means that there is a bi-directional connection between the two parts: on one direction, various types of data are collected from the physical world and elaborated in the virtual world (Cheng et al., 2018; Shubenkova et al., 2018;

Zhuang et al., 2018); then, the results are fed back to the physical part for its management and optimization (Zhuang et al., 2018). The connection is in real-time and enables the co-evolution of the virtual part with its physical *twin* (Haag and Anderl, 2018; Tao, Cheng, et al., 2018), since it is not only the representation of the current and past status of the physical part but of all its entire lifecycle (Cheng et al., 2018; Tao, Cheng, et al., 2018). In addition to this, the digital twin is not only a tool to manage, control and monitor the physical object but also to support the decisional making process as it can perform optimization and predictions of its future status (Cheng et al., 2018; Shubenkova et al., 2018).

Digital twin possible uses

The research gave also several results in term of possible uses of the digital twin as a base or enabler for different purposes: in (Rosen et al., 2015), the authors consider the digital twin as a key enabler for the *autonomous systems*, i.e. intelligent machines that execute high-level tasks without detailed programming and without human control; for (Zhuang et al., 2018), the digital twin provides a new solution to data management, acting as a single data source throughout the product lifecycle: first, the manufacturing connected resources generate real-time data; then, the data are real-time processed in order to guide the managers to dynamically optimize the production activity plans; finally, the newly production activity plan is fed back to the physical assembly shop-floor and guides the production second round.

In terms of service proposition, for (Padovano et al., 2018), the digital twin can be used as a based service oriented application for a 4.0 knowledgement navigation in the smart factory (a *KaaS*, Knowledge as a Service model), as an holistic software platform that works as a service-oriented knowledge-aware expert system that offers a full set of services (diagnostics and condition monitoring service, prognostics and decision support service,…) designed as a separately-maintained and deployed apps accessible over standard internet protocols; (Tao, Cheng, et al., 2018) specify nine categories of services that can be develop thanks to the digital twin: service of real-time state monitoring, service of energy consumption analysis and forecast, service of user management and behavior analysis, service of user operation guide, service of intelligent optimization and update, service of product failure analysis and prediction, service of product maintenance strategy, service of product virtual maintenance, service of product virtual operation.

Practitioners analysis

Approach

In order to extract a general definition of digital twin from the practitioner perspective, the following approach was applied: a survey to different company managers and practioners have been launched based on three core questions (what is a digital twin, what could be its purposes and which are its potential benefits); then, a semi-structured interviews to provide deeper insights into the digital twin; finally, a systematic combining of the results to provide a framework that describes the expectations of the community of the digital twin and to link the digital twin back to the literature.

Based on the research question detailed before, this was considered to be the most effective approach to gain insights from practitioners as it was conceived that the data (both ranking and open questions were used) from the survey results would help to show the gap between theory and practice with digital twins. This is confirmed by (Forza, 2002), who states that surveys are an effective tool to poll a population, which was from our own lists plus a self-selecting population from social media. The screening of the results was undertaken to ensure that industrial inputs were assessed.

The use of semi-structured interview is often used to provide deeper insights than from simple surveys, their applicability has been confirmed by (Barriball et al., 1994). The interview script -

focused on questions of the survey plus one open question - was built up based on the initial analysis of the survey results and made to 15% of the survey respondents.

We adopted systematic combining, in line with (Dubois and Gadde, 2002), in order to elaborate the framework that is presented in Table 1. In doing this, we moved back and forth between the empirical data and the extant literature, following a nonlinear analysis process (Eisenhardt, 1989): the open answers collected with the survey were transcribed, and enriched with the information coming from the interviews; we analysed the data qualitatively and the complexity was reduced through successive categorization of primary data (Bryman, 2004), in particular the content analysis was conducted by using ad hoc codes (manifestation of the findings recovered from the literature, around the conceptual definition of what a digital twin is, why a digital twin exist, how and what a digital twin does) that were converted into more meaningful "in vivo" codes, that were foundational to the development of the first-order categories; then, we moved back and forth to examine, compare, group, and find in-depth relationships among first-order categories and codes; doing this way, we reduced first-order categories to the most salient categories; finally, we established the 2nd order themes, that constitutes the pillars of the working definition of the digital twin.

During the mentioned stages we always referred to the literature to verify the explicative power of the working definition of the digital twin, to check for missing concepts, contradictions, and to improve the overall quality and internal consistency. We extensively used memos and affinity diagrams. We also shared the findings between the paper's authors that initially had worked independently. Any discrepancy was analysed until we mutually agreed upon general and common definition of digital twin.

Results

Based on the 53 answers of the survey and the 9 interviews conducted, the results of the approach previously explained are shown in Table 1.

Table 1: The results of the systematic combining analysis applied on the answers of the survey and the interviews.

Second-order theme	First-order category	Representative code	Representative quote
A digital twin can collect – even in real time – field data of different kinds coming from the object it represents, to integrate them and show the object status (e.g. the contextual or environmental conditions, the operational conditions, the service activity) in a more meaningful way; the data trol and change it\s current status.	Data integration	Operational/ process data	*Digital twin collects real-time data coming from the product or process.*
		Service/ maintenance data	*What service life it has, what work has been done to it, what new parts have been fitted, etc..*
		Contextual/enviro -nmental data	*The usage is rated as well as the environmental conditions.*
		Semantic integration	*A digital twin is a representation of all characteristics of a physical asset in the digital world.*
	Data communication and remote control	Real time feedback	*A digital twin is a virtual representation of a real environment […] that provides real-time feedback.*
		Bidirectional communication	*The flow of data can be bi-directional since they are not just only to represent the reality but also to manipulate it.*

Second-order theme	First-order category	Representative code	Representative quote
A digital twin can be used to track the life cycle status of an object, make simulation and scenario analysis (what-if?) that are feed by real data (data driven analysis), to predict and simulate events, to show opportunity for improvement, to take decision and optimize. The environment for analysis and simulation is created through Industrial Internet platforms, that integrate applications, resources and skills coming from different fields and actors of the ecosystem.	Life cycle analysis, condition monitoring and resource integration	Aging, wear, degradation	*A computational model that simulates aging at the same rate as a physical part.*
		Resource integration	*Promoting a product lifecycle analysis by enriching the combination of different engineering expertise.*
	Decisional support and optimisation	Simulation models	*A dynamic system, comprising of physical, operational and simulation data.*
		Predictive models	*On this platform analytics solutions are deployed to monitor, predict and optimize physical assets.*
The digital twin is a virtual model of a real system or process, that can have different granularity.	Digital model of a real physical asset, product, component or system	System	*A virtual representation of a real environment (for example, a production system).*
		Sub-system	*A digital representation of a physical asset, such as an installation, equipment, or subcomponent.*
	Digital model of a process, a service, a maintenance activity	Process	*A digital twin is the digital mirror of a real process.*
		Maintenance	*Maintenance will be done on the real system but is virtually also "added" to the virtual simulation environment.*
The digital twin uses I4.0 techniques and technologies (i.e. VR, AR, 3D modeling, cloud, ML, IoT, numerical methods (CFD, FEA), etc.) to collect and elaborate data and acts on the physical counterpart thanks to the use of actuators.	Data transfer and elaboration tools	Transfer data	*IoT based platforms enable the data transfer.*
		Data collection/elaboration	*ML, AR, VR, discrete event modeling, CAD, CFD, Cloud,… enable the data collection and elaboration.*
	Cyber remote control	Remote control and manipulation	*Digital twin can act as a remote controller of actuators placed on the product or on the objects etc of the process.*

The definition of digital twin given by the practitioners

Summarizing the results previously showed, we can say that for the practitioners a digital twin is a virtual model of a real system or process, that can have different granularity; it can collect – even in real time and thanks to I4.0 techniques and technologies (i.e. VR, AR, 3D modeling, cloud, ML, ioT, numerical methods (CFD, FEA), etc.) - field data of different kinds coming from the object it represents, in order to integrate them and show the object status during its entire lifecycle (e.g. the contextual or environmental conditions, the operational conditions, the service activity) in a more meaningful way; the data are used not only to represent the status of the object but also to predict and optimize – thanks to simulation and scenario analysis (what-if?) that are feed by real data (data driven analysis) coming from Industrial Internet platforms, that integrate applications, resources and skills coming from different fields and actors of the ecosystem – the decision-making process. A digital twin can also send data to the real object, to control and change its current status.

Discussion

With the support of Table 2, we discuss the differences between the literature and practitioner definition of digital twin.

Table 2. Comparison between the literature and practioner definition of digital twin.

Characteristic	Literature	Practitioner	Different
What is	A "way"	Virtual model	•
Different realities	Real and virtual	Real and virtual	
Digital twin object	Product or process	Product or process	
Granularity	System or sub-system	System or sub-system	
Communication between the realities	Bidirectional	Bidirectional	
Type of communication	Real-time integration and interaction	Real-time integration and interaction	
Actions on data	Collection and elaboration	Collection and elaboration	
Types of data	Various	Various	
Data time horizon	Past, present and future (lifecycle)	Past, present and future (lifecycle)	
Data enables	Management, control, optimization, prediction	Management, control, optimization, prediction	
Relationship between physical and virtual world	Co-evolutionary and the virtual con act & control the physical	Virtual con act& control the physical	•
Tools used	I4.0 techniques and technologies	I4.0 techniques and technologies	

Starting from what is a digital twin, literature does not specify which kind of element (i.e. model, object, etc.) it is, and uses a more general term ("way"), instead practitioners specify that it is a model of a product or process with different granularity (system, sub-system); as previously described within the results of the literature review, in different use-cases and other papers we found instead a direct reference to simulation and/or modeling of products and/or processes.

In terms of what the digital twin does, it is commonly recognized that it realizes the interaction and integration between physical and virtual world in a real-time manner, along all of the lifecyle of the physical part, by a bidirectional flow of data: the data coming from the physical object are first collected in the virtual world; then, they are elaborated in order to predict and optimize its behaviour and to define a plan (Zhuang et al., 2018) that finally guides the user or the the virtual part on how to act on the physical part. The main difference to highlight is that if the practitioners intend the digital twin as a model/simulation of the reality and so something that simulates it, literature explicitly states that both worlds co-evolve together, just like they would be two "twins".

About how the digital twin does that, even if in the definition of the literature there is not an explicit reference to how the interaction and integration between the two worlds is done – also because, we assume, of the more general definition of what is a digital twin (a "way") –, we found many different use-cases in literature that refer to the same technologies and techniques specified by the practitioners .

Conclusions

Based on the previous discussion of the results, we can conclude that literature and practitioners seem to be generally aligned on the digital twin paradigm; nevertheless, even if the practitioners are aware of the possibility to develop customized, punctual and fast services based on the actual status of product/process thanks to the digital twin, literature rather neglect – considering the total 255 results of the literature review – its plausible key role in the service strategy of product-based companies, claiming only that it can enable the development of new and smart product-service solutions (Tao, Cheng, et al., 2018; Zheng et al., 2018b) or making manufacturing as on-demand cloud services (Lu and Xu, 2019; Padovano et al., 2018). In particular, (Tao, Cheng, et al., 2018) specify nine categories of services that can be provided to product users and manufaturers but still state as a possibile future work the development of smart service analysis method based on digital.

Considering that servitization is a data-intensive process and effective approaches should be adopted to exploit data for new revenue stream in manufacturing companies (Opresnik and Taisch, 2015); that massive user/product generated data serves as the key for value creation, while effective data analytics tools enable its success (Rymaszewska et al., 2017); that adopting a platform approach with modular architecture is very effective for overcoming the servitization paradox (Cenamor et al., 2017), as the general definition of digital twin highlights how much effective it should be to bring the data into action, we can conclude that apart the obvious need for future research works on relevant industrial applications (Negri et al., 2017; Tao, Cheng, et al., 2018) to develop the *how-to* part of the definition (considering also what has been done so far from a regulatoryaspect), particular attention should be given to investigate how the digital twin enables the service growth of manufacturing firms and to demonstrate how much they would benefit from them.

The limitations of this research can be found both in the literature and practitioners analysis: the literature review was done based only on the Scopus database and does not consider papers that could use different terms of digital twin (i.e. digital shadow); instead, the survey and the interviews could be conducted in a more structured way (i.e. carefully planning the selection of the respondents) and it lacks of a deep analysis of the documents, magazine articles, etc. where is the explained the digital twin concept for manufacturing – but not only – companies.

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The differential effect of service transition on the job satisfaction of salespeople and front-line service employees

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Abstract
This study investigates the effect of service transition within traditional manufacturing companies on the job satisfaction of two functional groups of workers: salespeople and front-line service (FLS) employees. Although there is a growing body of work on the implications of service transition strategies for manufacturers performance, yet only limited attention has been given to how employees perceive of, and react to, such an important strategic redirection. We examine the effect of service infusion on the overall job satisfaction of sales staff and FLS personnel using data from an employee ratings company, with results showing differential effects.

Keywords: service operations, servitization, job satisfaction

Introduction
Over the last decade increasing attention has been devoted to manufacturing firms transitioning towards services – a phenomenon that is commonly known as 'servitization' (Baines et al., 2009; Vandermerwe & Rada, 1988). It entails manufacturing companies seeking to enhance their product portfolio by offering services and combining their products with services to create new offerings (Vandermerwe & Rada, 1988). Implementing a servitization strategy does not necessarily guarantee better performance (Gebauer et al., 2005). Recent studies suggest that significant initial investment is required (Visnjic Kastalli & Van Looy, 2013), that organizations need to reach a 'critical mass' for profitability from services (Fang et al., 2008), and that adding services does not linearly increase performance (Fang et al., 2008; Suarez et al., 2013; Visnjic et al., 2016). Although this is highly relevant, there is a need to take a step back and examine the implications of the transition upon the job satisfaction of employees. This aspect to date has been neglected in the extant literature. This is surprising as the performance of a firm will be in large part contingent on employee job satisfaction. So, whilst we have witnessed an ever-burgeoning literature on servitization, scant attention has been provided to how

service provision is actually impacting those that need to deliver it and their job satisfaction.

In this paper, we examine the service transition and its implications upon employees. In particular, there is a need to examine the implications of a transition towards services upon frontline staff (FLS) that are responsible for day-to-day service related activities, and, in most cases, at the coalface with the customer. Of interest are also sales employees who traditionally in manufacturing firms are responsible for the sale of products, with the sale of support services that help with the functioning of the product (Gebauer et al., 2010). Changing the business strategy towards services entails changes to the 'dominant mindset', which means changes to the psychological contract (Rousseau, 1995). Routines and practices for selling products tend to have become embedded and are difficult to adjust, especially given sales are incentivized in a way that potentially privileges product sales. Change is difficult. Hence, asking sales to now promote and sell services, which in the past may have given away for free (Witell & Löfgren, 2013), is no simple task; such changes rarely play out smoothly.

Most studies tend to rely on primary datasets based on surveys administered to evaluate employee satisfaction. In recent times, with the onslaught of new platforms to voice their views (via ratings and/or qualitative responses), employees - and former employees - freely provide their input when it comes to job satisfaction (Conway, forthcoming; Stamolampros et al., forthcoming; Huang et al., 2015). Such data offers potentially novel insights that would not have been captured via in-company surveys. In this study, we draw upon a novel dataset of online ratings provided by current and former employees to the job listings website, Glassdoor Inc., to examine the impact of service transition on employee job satisfaction. In so doing, we aim to address the following research question:

1. What is the impact of service transition on employee job satisfaction?
    i. What is the impact of service transition on salespeople's job satisfaction?
    ii. What is the impact of service transition on frontline service employee job satisfaction?

We thus contribute to the servitization discussion by, firstly, providing evidence of the impact of service transition on employee job satisfaction and, secondly, by identifying and discussing the differential effect of service infusion on sales and FLS personnel.

The remainder of the paper is structured as follows: next, the theoretical background is presented, followed by our hypothesis development. After which we present our research methodology, followed by the results of the study. Lastly, we discuss our findings provide some tentative concluding thoughts.

Theoretical background and hypotheses development

Job satisfaction is a heavily researched domain by organizational scholars. It is argued that job satisfaction is influenced by numerous factors (Lawler 1973; Ilies et al., 2009; Judge et al., 2017). Numerous studies have been undertaken with different theoretical underpinnings when it comes to job satisfaction. There exist a plethora of definitions, models and theories that attempt to explain job satisfaction. One of the most commonly used definitions in organizational research defines job satisfaction as "a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences' (Locke, 1976, p. 1304). We will discuss some of the most prominent theories and models briefly below.

Arguably one of the best-known studies that explains job satisfaction being an outcome of the difference between expected and perceived rewards received in one's place of work

(Lawler, 1973). In other words, it is rewards that meet expectations that drive job satisfaction, whereas rewards that do not meet expectations lead to dissatisfaction.

Hackman and Oldham (1976) proposed their job characteristics model. In this, they argue that core job characteristics seen as inherent in all jobs include skill variety, task identity, task significance, autonomy, and feedback which motivate employees towards desirable outcomes. When employees are able to use their many skills (i.e. *skill variety*) in order to complete a particular product (or service) (i.e. *task significance*), an employee will be able to attribute meaning and value to their work. When individuals have freedom (i.e. *autonomy*) to determine when and how they work, then they have a sense of responsibility and of being accountable for what they are trying to achieve because they have control of their job. When other organizational members – be they senior managers, supervisors, fellow employees, team members – provide input (i.e. *feedback*) on the (in)effectiveness it enables employees to improve. The model of Hackman and Oldham (1976) proposes that the strength of these relationships is moderated by an individual's desire to derive satisfaction and personal growth and development, known as '*growth needs strength*' (see also McClelland, 1987).

Herzberg (1966) proposed the two-factor theory to understanding the causes of individuals' satisfaction. In this theory, job satisfaction and dissatisfaction are not considered to be two polar opposites on a single dimension nor an outcome of the same factors. Different factors thus are said to account for satisfaction and dissatisfaction. Job satisfaction is said to be an outcome of drivers known as motivators that result from the conditions of the job itself. Examples of motivators include things such as responsibility, advancement growth and recognition. The drivers of dissatisfaction are known as hygiene factors and are needed to ensure workers are content with their work.

Other notable work includes Karasek's (1979) three-dimension *demand-control-support* (JDCS) model that explains the stress an employee encounters at work, emphasizing the situational predictors of job satisfaction (Karasek, 1979; Karasek and Theorell, 1990). In more recent times, Judge et al. (2001a; 2001b; 2017) consider the following to be important features of job satisfaction: promotions, pay, supervision, recognition, working conditions, the organization, management and coworkers.

Overall, it is fair to say there is no clear agreement as to what accounts for job satisfaction. Although there are some common drivers for job satisfaction, there are also different drivers and factors identified in the extant literature. This shows that there are a number of ways of understanding job satisfaction.

Next, we discuss service transition and its implication for job satisfaction for sales staff and FLS employees.

Service transition and job satisfaction

An extensive body of research claims that manufacturers are increasingly transitioning towards services and solutions as part of their offerings (Neu and Brown, 2005; Fang et al. 2008; Kowalkowski et al., 2012; Wise and Baumgartner, 1999; Storbacka, 2011). For example, the construction equipment company Caterpillar has increasingly infused services into its product offering - such as spare parts support, maintenance, "negative downtime" concept where customer only learns of an issue with equipment once it has been repaired – to meet customer needs. To date, much of the literature has focused on the strategic aspects of transitioning to service (Gebauer et al., 2010; Josephson et a., 2016; Patel et al., 2019), design considerations for firms (Foote et al., 2001; Davies et al., 2006; Raja et al., 2018), and financial performance (Eggert et al., 2014; Fang et al., 2008; Visnjic and van Looy, 2013; Visnjic et al. 2016; Visnjic et al., 2019).

Although the transition to services is an area that is receiving increasing attention, the pursuit of a service strategy and the implications this has upon employees has largely been neglected. It goes without saying that service transition is likely to have implications on the role of staff inside organizations. For example, salespeople who are accustomed to selling products will also be expected to promote and sell services. Although this may seem straightforward, it is anything but. Changing the routines that sales staff become accustomed to, measured upon are fraught with difficulties. In some cases, this has led to some arguing that firms are better off creating new service organizations with sales staff purely dedicated to selling service, or at least so that they are service-savvy (Reinartz and Ulaga, 2008; Ulaga and Loveland, 2014). Similarly, delivering service requires customer-facing FLS personnel. For many companies, they may already possess a field service workforce, though infusing greater service will mean expanding the demands that are placed upon the staff. In other cases, it will be a case or recruiting anew FLS personnel to meet customer needs and realize the service strategy. Of particular interest here is what such changes mean for employees in terms of their roles and resultant effect on job satisfaction for sales and FLS personnel.

We therefore examine the following hypothesis:

Hypothesis 1: *As the level of service infusion increases, there will be a decrease in the job satisfaction of the non-customer facing employees*

Hypothesis 2: *There will be a U-shaped relationship between the level of service infusion and the satisfaction of salespeople*

Hypothesis 2: *There will be a U-shaped relationship between the level of service infusion and the satisfaction of salespeople*

Methodology

Sample and data collection

The focus of this study is on manufacturing firms with primary 3-digit North American Industry Classification System (NAICS) codes between 333 and 336. These include manufacturers of machinery (333), computer and electronic products (334), electrical equipment, appliances and components (335) and transportation equipment (336). These are the industries in which servitization has been most prevalent according to the literature, seemingly due the properties of the manufactured products (relatively long-life and complex). The strict focus on manufacturing industries that are clearly conducive to servitization excludes companies that are practically unlikely to sell product-service offerings due to the nature of their products (e.g. paper product manufacturers), while it indirectly controls for industry-level factors that could confound the relationship between the extent of servitization and satisfaction with one's employer.

Following prior research (e.g. Fang et al. 2008; Visnjic et al. 2019), as a proxy for the level of service transition of a manufacturer at any point in time, we compute their 'service ratio' (Fang et al. 2008). This is the proportion of a manufacturer's total revenues in a year that comes from service activities. To obtain the required data, we use COMPUSTAT Business Segments because it provides time series of firm revenues from different business operating segments. For any given firm, the definition of the operating segments and the allocation of revenues between them is self-reported by the management team. Despite this disadvantage, this is the most common (and possibly, only) way to track a firm's service transition over time. From the description of the operating segments and their associated NAICS code, we categorize them into service and nonservice, following the procedures specified in Visnjic et al. (2019). For a given firm in a given

year, the service ratio is the quotient of the division of the sales revenues from all service business segments by the total revenues.

To obtain measures of an employee's satisfaction with their employer, we match our dataset with data supplied by Glassdoor, a job search engine and review website. We specifically utilize the 'overall satisfaction' rating, as well as satisfaction with four employment aspects: 'compensation and benefits', 'career opportunities', 'work-life balance' and 'senior leadership'. All ratings range from 1 to 5, and we extract only those that come from employees (both former and current) of the manufacturers in our sample. Employee reviews begin in 2008, so this comprises the first period in our timeframe. We use the aggregate role categories, as specified by Glassdoor, to identify sales and front-line service employees, with all the rest being classified as 'all other' non-customer facing employees. Accordingly, roles such as 'sales representative' and 'field sales manager' are classified as salespeople, while 'customer service' and 'field services' are classified as front-line service employees.

Several variables that could affect both the extent of servitization of the company and the satisfaction of its employees, are included in the models as controls. These include firm size (total sales and number of employees), profitability (ROA), R&D expenditure, overall performance (Tobin's Q), as well as industry (primary 3-digit NAICS code) and a linear time trend. Crucially, some manufacturers have begun their servitization 'journey' long before 2008, while others start reporting revenues from services only after 2008. We control for this using a dummy variable, as one could expect that the accumulated experience of providing product-service offerings (prior to the year we first start observing) may have helped senior management teams to implement policies and measures to address issues faced by their sales and service employees.

Analysis

As our dependent variables are naturally ordinal, the appropriate econometric models are the ordered logit and ordered probit. In the five models (one for overall satisfaction and one for each of the four separate aspects), the minimum number of observations (i.e. employee ratings) is 39822 (from 586 firms), and the maximum 41301 (from 595 firms). The 3-level categorical variable of job function enters our models as a set of two dummy variables, with the 'all other' category being the reference level. Crucially, to test our hypotheses, we interact these two dummies with the service ratio (and its quadratic term).

Results

Table 1 contains the main results of this work. The dependent variables in the five presented models are the ordinal scales of overall satisfaction (model 1) and the four separate aspects captured by Glassdoor: employee satisfaction with their compensation and benefits; the senior leadership in the organization; the career opportunities provided; and their work-life balance (models 2-5).

Table 1 – Results of the ordered probit regression models

	(1) Overall	(2) Compensation	(3) Leadership	(4) Career Ops	(5) Work-life
Service ratio	-0.300	-0.634**	-0.466*	-0.0535	-0.0907
	(0.262)	(0.305)	(0.243)	(0.233)	(0.318)
Service ratio^2	0.209	0.455	0.439*	-0.0542	0.113
	(0.262)	(0.296)	(0.250)	(0.239)	(0.314)
Employee role (base = 'all other')					
Salespeople	0.158***	0.0883	0.163***	0.141***	-0.0354
	(0.0560)	(0.0570)	(0.0484)	(0.0447)	(0.0604)
FL service people	-0.129*	-0.0836	-0.145**	-0.254***	-0.275***
	(0.0662)	(0.0696)	(0.0730)	(0.0781)	(0.0675)
Time trend	0.0409***	0.0231***	0.0188**	0.0294***	-0.023***
	(0.00661)	(0.00625)	(0.00786)	(0.00570)	(0.006)
Total sales (natural logarithm)	0.00629	0.0836	-0.0121	-0.0391	-0.0151
	(0.0692)	(0.0772)	(0.0692)	(0.0633)	(0.0569)
ROA	0.920***	0.522***	1.110***	0.631***	0.186
	(0.180)	(0.179)	(0.210)	(0.174)	(0.156)
No. of employees (natural logarithm)	-0.102	-0.148**	-0.0771	-0.0456	0.00518
	(0.0654)	(0.0751)	(0.0641)	(0.0608)	(0.0529)
R&D expenditure (natural logarithm)	0.0888***	0.0783***	0.0599**	0.0876***	0.0193
	(0.0246)	(0.0284)	(0.0250)	(0.0212)	(0.0268)
Already servitized in 2008? (Yes = 1)	0.0797	0.169***	0.00314	0.0552	0.106*
	(0.0536)	(0.0512)	(0.0558)	(0.0550)	(0.0596)
Interaction terms					
Service ratio * sales	-0.679*	-0.755*	-0.968***	-0.848**	-0.643
	(0.360)	(0.387)	(0.361)	(0.370)	(0.422)
Service ratio * services	0.143	0.192	0.286	0.462	0.0744
	(0.417)	(0.368)	(0.419)	(0.477)	(0.447)
Service ratio^2 * sales	0.651*	0.876**	0.981***	0.924**	0.684
	(0.343)	(0.360)	(0.354)	(0.361)	(0.418)
Service ratio^2 * services	-0.240	-0.425	-0.260	-0.368	-0.257
	(0.527)	(0.468)	(0.456)	(0.550)	(0.535)
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
N (employees)	41301	40011	39822	39988	40028
n (firm)	595	587	586	587	586
R^2	0.013	0.012	0.008	0.007	0.004
AIC	121286.0	134649.8	138384.0	138792.5	136738.4

Clustered (by firm) standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

The results can be summarized as follows:

- As service infusion increases, non-customer facing employees become increasingly unlikely to report a higher level of satisfaction with their compensation and benefits. There is no statistically significant effect of service infusion on the likelihood of higher overall satisfaction (or any other aspect).
- Compared to non-customer facing employees (the reference level), the likelihood that salespeople will report a higher level of overall satisfaction (and satisfaction with any other employment aspect) exhibits a (steeper) U-shaped relationship as service infusion increases. This is illustrated graphically in Figure 1, which presents the predicted probabilities of reporting a '5' (the highest level) for the different aspects of employee satisfaction when the service ratio increases by 10% at a time. An interesting additional finding is that salespeople seem to be more likely to feel very satisfied when their employer is a pure product provider (service ratio = 0%) or fully 'servitized'; namely, when the firm is 100% focused in either of side of the product-service continuum.
- The form of the relationship between service infusion employee satisfaction FLS personnel with their employer is not significantly different compared to the base-level. However, they remain the most unlikely to report higher levels of satisfaction as service transition progresses (Figure 1) and seem to feel less satisfied with all aspects related to their employment. In addition, one can notice that for a fully servitized firm (service ratio = 100%), the predicted probability that a sales person will report a high level of satisfaction with any aspect of employment is about double compared to a FLS employee.

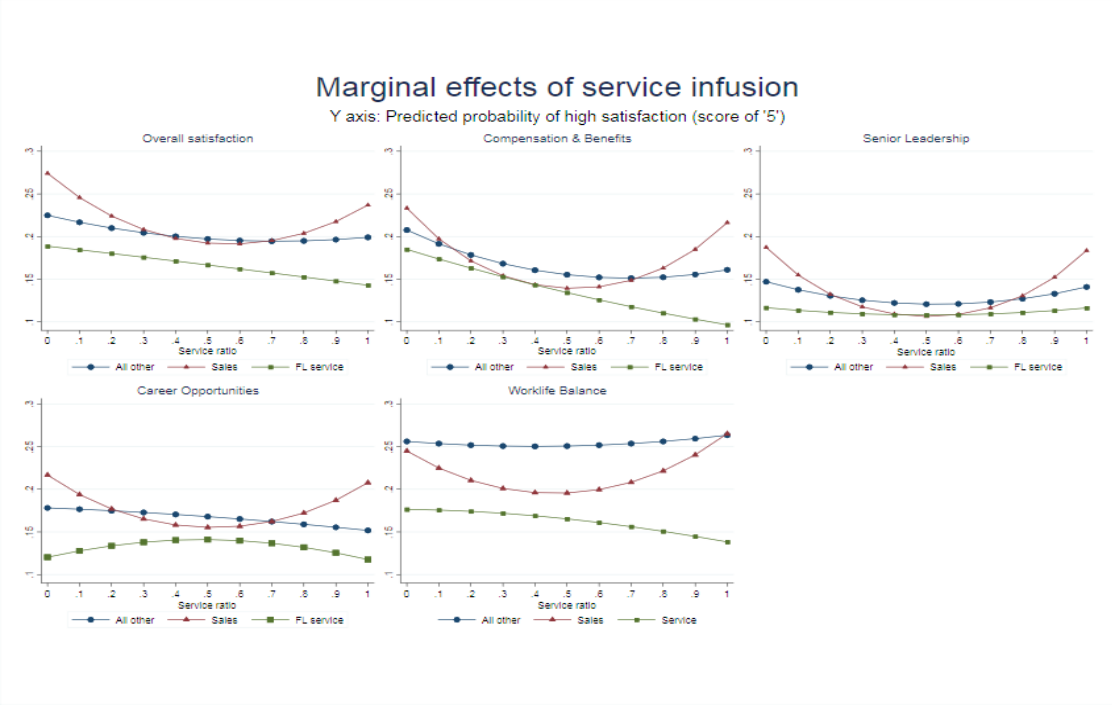

Figure 1 – Marginal effects of service infusion

Discussion and contribution

This study contributes to the emerging body of work examining the implications of service transition upon employees. Specifically, this work has implications for the design of sales and FLS roles, and how to manage these individuals during service transition. The results suggest a differential effect of service transition for sales and FLS personnel. It is noteworthy that for the sales personnel role, the firms have managed to, over time, address the initial drop in satisfaction. In contrast, the situation for FLS personnel roles is bleaker; especially when it comes to 'compensation and benefits' the results indicate that these employees are increasingly dissatisfied, with little sign of recovery. As such, we raise important questions for addressing the job satisfaction levels of all staff, but specifically those in FLS positions. We argue that low job satisfaction may explain the high propensity for those firms transitioning to services to experience difficulties or, in some cases, bankruptcy (cf. Benedettini et al. 2015).

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The impact of servitization on firm performance: moderating role of digital solutions

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Abstract

Digital transformation of the manufacturing industry has been one of the dominant topics in recent years. Prior research investigated the impact of servitization on firm performance in terms of growth and stability. However, the moderating role of digital solutions was neglected. The aim of this study is to evaluate digital solutions in manufacturing firms and their impact on firm performance. Our analysis used a Serbian and Lithuanian dataset of 143 manufacturing firms from the European Manufacturing Survey conducted in 2018. The empirical results revealed that in manufacturing firms, product-related services, along with digital solutions, can significantly increase share of revenue.

Keywords: Servitization, Digital solutions, Social Network Analysis

Introduction

Servitization, the transformation of product-oriented companies towards service-oriented businesses, has flourished in recent years (Marjanovic, Lalic, Majstorovic, Medic, Prester and Palcic, 2018). The servitization trend was first mentioned by Vandermerwe and Rada (1988) to depict the relationship between product, service, knowledge, support and self-service, in order to offer fuller market packages and create added value for customers. An early study showed that the relationship between servitization and product innovation should be a central concern of the manufacturer both in the short and in the long run

(Visnjic, Wiengarten and Neely, 2016). Product–service system (PSS) represents a tie between tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific customer needs (Tukker, 2004). PSS provides more specific PSS types, one of which is product-related service (Tukker, 2004). This type of provider not only sells a product, but also offers services that are needed during the use phase of the product (Tukker, 2004). A prior study makes recommendations for service-oriented manufacturing firms: "the adoption of an integrated product-service business model as a way of creating reciprocal spill overs between products and services" (Visnjic Kastalli and Van Looy, 2013, p.178). Moreover, evidence from other authors shows that servitization has a positive impact on the creation of added value in manufacturing firms (Eggert *et al.*, 2014). The adoption of a gradual strategic change by manufacturers moving to product-related services and to customer support represents a growing trend in aspiring to offer an "integrated solutions" business by manufacturing firms (Baines, Lightfoot and Benedettini, 2009). To improve the business model, manufacturing firms are in constant struggle for application of digital solutions. Two thirds of manufacturing firms worldwide say that digital solutions in manufacturing are one of their highest priorities (Behrendt *et al.*, 2018). The high complexity of production, services and external drivers clearly present the challenges of digital transformation (Liere-Netheler, Packmohr and Vogelsang, 2018). The share of a company's sales that comes from exports seems to be another driver of service digitalization which provides transformation from PPS to digital PPS (Lerch and Gotsch, 2015). There is a real need for research on manufacturing transformation when a firm chooses to move from its traditional manufacturing focus towards servitization (Benedettini, Neely and Swink, 2015). Furthermore, the role of digital solutions in transformation of manufacturing is not sufficiently investigated (Ardolino *et al.*, 2018). This paper investigates and offers an understanding of the impact of product-related services and digital solutions on the performance of manufacturing firms.

The remainder of the paper is structured as follows: Section 2 presents the literature review and describes the proposed model that has been used in this paper. In Section 3, we present data and research methodology. Section 4 provides the research results and discussion. Finally, Section 5 shows the conclusion of this paper with identified limitations of the study and suggestions for further research.

Literature review

The process of creating value by adding services to product offerings is known as servitization (Vandermerwe and Rada, 1988). Increasingly, durable goods manufacturers choose to innovate their offerings by providing services to accompany their existing products throughout the life cycle (Visnjic Kastalli and Van Looy, 2013). A prior research provides the evidence base underpinning servitization adoption. This research shows that diversification impacts between revenues from products and revenue from services are typically split 50/50 and enables overall business growth (Baines and Shi, 2015). In developed countries there is a considerable debate about the terminology, ideas and concepts which describe and differentiate products and services in manufacturing firms (Baines, Lightfoot and Benedettini, 2009). In the PSS communities, the core theme addresses potential commercial benefits to a manufacturer that provides service with or instead of a physical product (Baines, Lightfoot and Benedettini, 2009). Furthermore, another study shows that product-related services have a positive impact on a company's turnover (Lalic *et al.*, 2018; Marjanovic, Lalic, Majstorovic, Medic, Prester and Palcic, 2018). Moreover, some of the observed types of product-related services show the highest positive impact on the turnover of companies when directly invoiced (i.e. maintenance

and repair; design, consulting, project planning; software development; revamping and modernization and end of life services) and indirectly invoiced (i.e. maintenance and repair and design, consulting, project planning) (Lalic *et al.*, 2018; Marjanovic, Lalic, Majstorovic, Medic, Prester and Palcic, 2018). It could be argued that round the world, high-quality product-related services are significantly related to customer satisfaction and loyalty (Zahringer*et al.*, 2011).

The field of digital servitization is differentiated from mainstream servitization in different aspects: the marginal cost of digital services is lower than with traditional services; traditional services are usually complementary to a product offering, while digital services are often substituted for traditional products, and finally, digital technologies open new business opportunities, especially the application of information technology in the manufacturing sector (Vendrell-herrero *et al.*, 2017). Furthermore, a study from the German Manufacturing Survey in 2012 shows that digitalization is positively associated with manufacturing companies' share of turnover with new products (Kroll, Horvat and Jäger, 2018). Lerch and Gotchs argue that as the final step of the transition to a services focus, digitalized PSSs move firms beyond traditional service offerings in their high degree of automation and in their ability to act independently and forecast product-service requirements and failure modes (Lerch and Gotsch, 2015). Cambridge Service Alliance identified top five service technologies and all of them are digital services: predictive analysis, remote communications, consumption monitoring, and two aspects of mobile communication platforms (Dinges *et al.*, 2018). Moreover, these digital services are in line with digital solutions which were identified by the European Manufacturing Survey (EMS)(Fraunhofer Institute, 2018). Prior research has pointed out the importance of digital solutions; thus, this represents a fruitful area for further examination. To shed more light on this important area of production research, the authors investigate which digital solutions have a dominant place in manufacturing firms.

The product-related services and digital solutions presented in the model (Figure 1) were identified based on exploratory interviews with practitioners and group discussions with experts in the field. All EMS consortium members were involved in the process of identification, which resulted in a universal list of digital solutions (e.g web-based services for customized product configuration or product design, web-based offers for product utilization, mobile devices for diagnosis, repair or consultancy, digital (remote) monitoring of operating status, data-based services based on big data analysis). Based on the literature review of digital solutions in manufacturing, the following research question was posed:

- *RQ1: Which digital solution has a dominant place in manufacturing firms?*

Previous research has already demonstrated the move from product-related services to digital services through phases: manufacturer, IT-based services, pure digital services and digitalized PSSs (Lerch and Gotsch, 2015). Digitalized PSSs incorporate digital solutions as a novel component besides the product-related service in the PSS, creating intelligent, independent operating systems (Lerch and Gotsch, 2015). Moreover, Carlos Gonçalves dos Reis *et al.* (2018) argued that managers should adapt their business strategy to the digital reality by integrating new technologies in their business models, if they want to have better results on the market. Furthermore, researchers presented drivers for digital transformation in two groups, namely: organizational (e.g. process improvement, workplace improvement, vertical integration, management support, horizontal integration and cost reduction) and external (e.g. customer demands, supply chain, innovation push,

market pressure and laws/government) (Liere-Netheler, Packmohr and Vogelsang, 2018). From this point of view, it is possible to pose the following research question.

- *RQ2: How do product-related services, along with a digital solution, affect firm performance?*

To address RQ1 and RQ2, the following model is proposed in Figure 1.

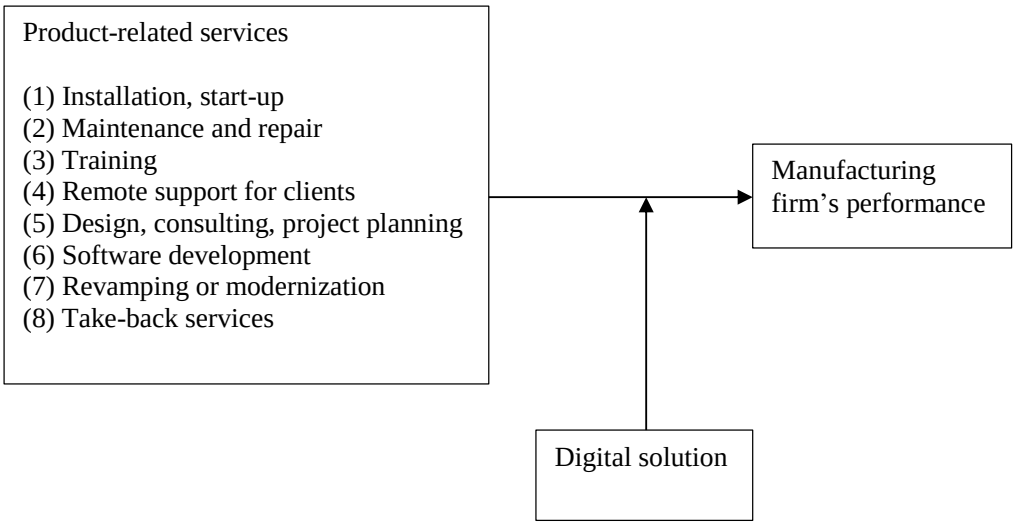

Figure 1 – Proposed research model

Data and methodology

The survey was conducted under the international project EMS which was coordinated by Fraunhofer ISI Institute from Germany. The dataset used in this paper was built from 2018 data collection. Manufacturing companies (NACE Rev 2 codes from 10 to 33) having at least 20 employees in Serbia and Lithuania were considered, taking into account 143 responses in total. Each survey was carried out based on a proportionally size- and industry-based stratified random sample. Cochran's (1977) method was used as the sampling technique. Moreover, the data collection procedure was in line with Dillman's (1977) method. The comparison of data regarding firm size distribution between Serbian and Lithuanian subsamples, and those of other EMS countries (e.g. Croatia, Germany, Slovakia, Slovenia) shows no significant size bias. Table 1 and Table 2 show that both samples of EMS have reasonable representation for all firm sizes and fair coverage of all manufacturing industries.

Table 1 – EMS database - distribution of firms by country and size

	Country sample		Firm size		
			20 to 49 employees	50 to 249 employees	250 and more employees
	%	n	n (%)	n (%)	n (%)
Lithuania	21.7	31	16 (52.5)	13 (41.5)	2 (6)
Serbia	78.3	112	51 (45.8)	48 (42.9)	13 (11.3)
	100	143			

Table 2 – Classification of manufacturing sectors according to share in total sample

NACE Rev. 2	Manufacturing industry	Share in total sample (%)
10	Manufacture of food products	15.55
25	Manufacture of fabricated metal products, except machinery and equipment	11.83
14	Manufacture of wearing apparel	8.58
31	Manufacture of furniture	8.58
16	Manufacture of wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	8.35
22	Manufacture of rubber and plastic products	6.26
28	Manufacture of machinery and equipment n.e.c.	6.03
27	Manufacture of electrical equipment	4.41
23	Manufacture of other non-metallic mineral products	4.18
26	Manufacture of computer, electronic and optical products	3.48
	Other industries	22.75

Social Network Analysis (SNA) was used for data analysis. SNA method is widely used in the social sciences (Wasserman and Faust, 1994). Moreover, SNA is used in economics, marketing, and industrial engineering (Wasserman and Faust, 1994). According to (Goes *et al.*, 2017; Leng and Jiang, 2018; Li, Jiang and Zuo, 2018; Omar, Minoufekr and Plapper, 2018), SNA should be used as a research method in the manufacturing context. Early studies applied SNA in Industry 4.0 (Omar, Minoufekr and Plapper, 2018), creation of personalized manufacturing service (Zhang *et al.*, 2013), rural manufacturing (Molano, Polo and López, 2015), etc. This paper applies two-mode networks in manufacturing. One group of nodes represents firms, and the other group of nodes represents services (i.e. product-related services and digital solutions). An earlier research has proposed eigenvector centrality, which computes the importance or dominance of a node in the network (Wasserman and Faust, 1994). For example, if firm 1 (F1) is connected with resource 1 (R1) and firm 2 (F2) is connected with resource 1, then F1 and F2 are connected. Two-mode data offer some interesting possibilities for gaining insights into macro-micro or node-structure relations (de Laat *et al.*, 2007; Rakic *et al.*, 2018). With two-mode data, researchers can examine how macro-structures (e.g. manufacturing sector) affect interactions between product-related services and digital solutions. In this paper, a dataset of firm by firm ties was created, measuring the strength of the tie between each pair of firms by the frequency of use of the same resources. The digital solution which has the highest eigenvector centrality is the dominant node in the network, and it was included in the regression model. To identify a relevant effect of product-related services on firm performance (i.e. share of revenue), we tested two node-level regression models: (1) with the application of the dominant digital solution and (2) without the application of the dominant digital solution. The regression model is presented in Figure 1. Both research questions were analysed using UCINET (Borgatti, Everett and Freeman, 2002) to examine the data and generate the graph.

Results and discussion

The results of the present study will be analysed as follows: RQ1 based on Figure 2 and Table 3, and RQ2 based on the regression model. For RQ1 (*Which digital solution has a dominant place in manufacturing firms?*), the use of digital solutions in manufacturing firms was evaluated based on the data analysis. In order to answer RQ1, digital solutions are ranked based on eigenvector centrality in the network. Figure 2 depicts the network between firms and services. In Figure 2, red circles represent firms, and blue squares represent services.

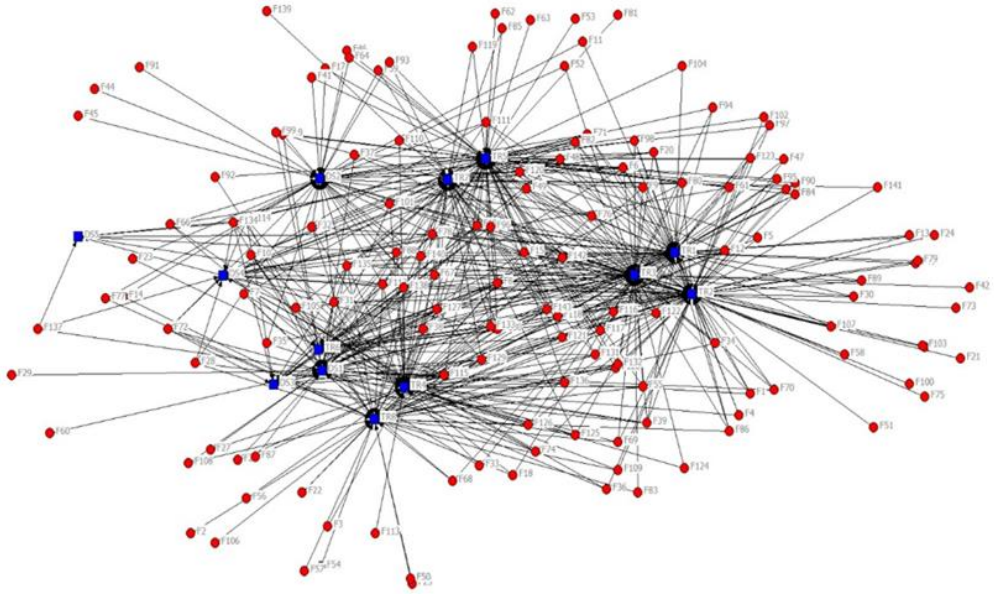

Figure 2 - Graph illustrating network between manufacturing firms and services (product-related service and digital solutions)

Table 3 shows the results of eigenvector centrality between digital solutions in the two-mode networks. A very common and a very useful approach to two-mode data is to convert it into two one-mode datasets, and examine relations within each mode separately (Hanneman and Riddle, 2005). The authors applied this approach to discuss the results and they evaluated the relations between digital solutions which are presented in Table 3/

Table 3 – Evaluation of digital solutions using eigenvector centrality based on SNA method

Digital solutions	Eigenvector	Rank
Web-based services for customized product configuration or product design	0.643	1
Web-based offers for product utilization	0.546	2
Mobile devices for diagnosis, repair or consultancy	0.376	3
Digital (remote) monitoring of operating status	0.355	4
Data-based services based on big data analysis	0.143	5

Web-based services for customized product configuration or product design have the highest rank because they have the highest eigenvector centrality (0.643). Furthermore, this digital solution was included in the regression model so that the authors could investigate the moderating role of the digital solution on firm performance. For RQ2 (*How do product-related services, along with a digital solution, affect firm*

performance?), two regression models were tested. In the model that estimates the effect of product-related services on firm performance without the application of digital solutions, it is shown that the impact is significant and positive. Introduction of the best ranked digital solution (i.e. web-based services for customized product configuration or product design) into the model increases the positive effect on firm performance, providing support to RQ2. The R^2 changes from **0.22** (without application of digital solution; **B = .473, p < .001**) to **0.25** (with the application of digital solution; **B = .496, p < .001**). In terms of profitability, our findings support the earlier research, which presented a positive effect of product-related service on firm performance (Gebauer *et al.*, 2008; Lalic *et al.*, 2018; Marjanovic, Lalic, Majstorovic, Medic, Prester and Palcic, 2018). Moreover, at the same time, we presented that the moderating role of digital solutions increases the positive effect on firm performance.

Conclusion

This paper evaluates the use of digital solutions in manufacturing firms. Furthermore, it contributes to the existing literature by presenting the position of digital solutions in manufacturing firms. The research was conducted under the international project EMS. The dataset used in this paper was built from 2018 data collection. The results showed that web-based services for customized product configuration or product design are the best-ranked digital solution. Moreover, the results for the model with the application of web-based services for customized product configuration or product design show a higher positive effect on the share of revenue than the model without it. It could be concluded that manufacturing firms, in order to achieve better performance, need to integrate business processes with digital solutions.

This approach could be helpful to managers of manufacturing firms. With this information, managers can better shape the package for their customers when offering products. Furthermore, they could put emphasis on things that add value to firm performance. Production managers could introduce corrective actions in order to increase the effectiveness of production, develop strategies to address problems, provide better services for their customers, and create a more efficient business.

This research is limited only to the impact of one digital solution on the manufacturing firms' performance. There are other digital solutions which are important for manufacturing firms that could be included in future research. Also, this research considers only a dataset from Lithuania and Serbia. Future research should take into consideration different challenges in measuring the impact of other digital solutions provided by manufacturing firms from different countries.

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Preparing for PSS: an investigation in the Daimler Group

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Abstract

A challenge for manufacturers is the constant pursuit of improving their economic efficiency and profitability. With the increase in the use of ICT, Internet of Things and Big Data, the integration of produtcs and services is reshaping the business models. This paper aims to to investigate the main factors to advance with the integration of products and services in Mercedes-Benz and other business units of Daimler Group. The findings suggest that several interviewees mentioned the necessity of technical improvement of current products to meet the needs of the market, confirming the internal culture focused on product.

Keywords: PSS, Servitization, Business Model, Operations Strategy.

Introduction

In recent years, several factors have led to changes in customer-business relationships, from the growth of the world population and the consequent increase in consumption and demand to new consumer behavior and lifestyle (KÖLSCH et al., 2017). With globalization, new competitors unexpectedly emerged threating traditional businesses' profitability and economic efficiency. In pursuit of profitability or even for the sake of survival and maintenance of their business, we note the growth of the integration of products and services, especially in globally active companies (Reim et al., 2015).

Neely (2008) has compared data between 2004 and 2007 of a sample of more than twelve thousand companies in several countries. The author reveals that the percentage of companies with services in the descriptive memorial of its social name in the United States is 59% while in Finland it was (53%). Singapore (49%), Malaysia (46%) and the Netherlands (40%) were also highlighted with large percentages of services in the total number of businsses. More recently, Santamaría et al. (2011) reported that one out of five companies surveyed reported introducing integration of PSS products and services. In China, this percentage increased from 1% in 2002 to almost 20% in 2011 (Neely et al., 2011).

In addition, with the increase in the use of IT services, Big Data, IoT and the consequent development of smart products, it is expected to reach the level around 212 billion of product until the end of 2020 (Manyika et al, 2013; Seregni et al, 2016). Therefore, a new strategy is increasingly being considered by organisations. There is an opportunity to take advantage of the concepts of the industry 4.0, IoT, and sustainability to meet the new reality of the consumer market (Al-Fuqaha et al., 2015).

The benefits to compete by introducing advanced services include revenue growth and greater economic profitability (Eggert et al, 2014), improved product innovation, quick response to customers, creating new possibilities for revenue (Baines and Lightfoot, 2013), increase customer loyalty (Saccani et al, 2016) and support to exceed barriers toward the competitive advantage (Oliva; Kallenberg, 2003). However, how to provide such services has challenged many companies (Baines et al., 2017).

One of the biggest challenges to change the business model of a typical manufacturing company towards servitization is how to transform the organization for this purpose. What is known is its business model must be adapted or transformed (Weeks; Plessis, 2011).

The literature has shown that the fundamental concepts of servitization are well established on contrast to the necessary practices to promote this change (Baines et al., 2017). Thus, understand how the companies move from a product-oriented for a result-oriented perspective through a PSS business model is still an open topic.

This paper aims to answer the question on how and to what extent product and services are being integrated in an automotive company. A case study in the Daimler group was developed with predominant focus on the Brazilian truck unit of Mercedes-Benz.

New PSS Business Model Development

Reim et al. (2015) defined business model as being the design or architecture of the mechanisms of creation, capture, and supply of value. They conducted a systematic literature review of 67 articles to understand how companies adopt and implement PSS, using the former classification from Tukker (2004): product-oriented (PO), use-oriented (UO) and result-oriented (RO). By analyzing the content of the articles, it was found that scholars tend to discuss PSS business models and implications for implementation using five distinct sets of tactics: contracts, marketing, work network, product and service design and sustainability strategy.

Contracts refer to how rights and duties are distributed between supplier and customer. A PSS contract must be developed addressing all aspects of the service provided very clearly, involving the obligations, any failures and all legal considerations involved. These contracts have a complexity far beyond the simple sale of a product and the terms and agreements must be adapted according to the negotiated context of PSS (Reim et al., 2015).

The second set of tactics describes how PSS providers interact, communicate and use customer and market insights to implement their business model in PSS. The extent of customer interaction increases when the company shifts to a service-oriented business model. Communicating the value of the service with transparency and unambiguity, as well as showing how it differentiates from the competitors and seeking to gain a new segment of customers. Finally, use the customer and market insights, considering the collection of product data or service in use through interaction with them.

The third set of tactics describes how PSS providers use their networks and relationships with partners to ensure that the PSS business model is successfully implemented. This strategy refers not only to whom to make partnerships, but also to

what type of partnership, shaping the sharing and coordination of the activities (Reim et al., 2015).

Product and service design tactics describe how PSS providers structure their products and services to meet the needs of customers and thus achieve success in implementing the PSS business model. To meet the new design requirements of products and services, it is needed to give emphasis on the alignment of the physical characteristics of the product with the characteristics of the service offered and vice versa (Reim et al., 2015). A closer and long-term relationship requires a product and service design perfectly adapted to the needs of the customer.

Most of the studies show that PSS implementation results in sustainability benefits and avoid rebound effects. PSS business model may facilitate the extension of product life cycle, collection of end-of-life products, as well as remanufacturing, recycling, as appropriate disposal of parts and components.

The tactics presented by Reim et al. (2015) although involve several aspects for the implementation of a new business model. However, they leave out the human aspect approach. In this sense, Weeks and Plessis (2011) emphasized the importance of organizational culture and human resources policies in the implementation of PSS. They observed that organizational culture and shared business values, from executives to the employees, demonstrate the importance of unique identity, common understanding and shared company-wide attitude in the development of a new business model. Other characteristics such as individual autonomy and support in decision making, risk tolerance, high performance to the form of conflict management are determinants for the implementation of the new PSS business model (Weeks; Plessis, 2011).

Similarly, in a systematic review of literature, Brax and Visintin (2017) found eight stages to move forward a PSS model: production, business analysis, solution design, supply network design, implementation, operation, support and disposal, not necessarily all of them being used sequentially. In addition, these stages, also three value elements are identified: financing of the capital good investment, system ownership and payment model. System ownership and payment model are considered as revenue models elements, while financing is considered a supplementary value element.

Ulaga (2013) argues the need of a transition planning to a PSS business model. The involvement of the company's board of directors is crucial. Many companies due to the complexity of the change, decided to split the business and creating separated business unit, or even create a new company to quickly develop the new PSS business model (Ulaga, 2013; Baines et al., 2017).

Reinartz and Ulaga (2008) highlight the need to develop ways of service charging (pay-for-use, pay-per-hour). In the customer service, the back-office processes should be monitored and the processes not necessary should be eliminated. Instead, create an experienced sales force services for the complex services solutions requires long sales cycles and decisions are made by high-ranking customers, which demand experienced and prepared team for such negotiations.

Foote et al. (2001) state that in terms of reorganization it will be important to hire trained and specialized technicians in working with ICT as well as in performing new services such as consultant and customer training. Moreover, it is needed a definition of an organizational structure to meet this new demand (Baines et al., 2017).

An analysis of the economic feasibility, considering the servitization paradox and the U-Curve effect may be necessary, since the investments for such implementation may have their return in a period such that the levels of risk can hinder this process (Eggert et al., 2014; Kwak; Kim, 2016). Regardless of complex economic analysis, companies

should recognize the importance of integrating services as a proactive and conscious strategy that enables its growth and increase profitability (Kwak; Kim, 2016).

The studies have reinforced the importance of the current organizational structure and the adaptations needed for the implementation of PSS, in addition to the human management and internal behaviors of the company. Individual autonomy, structure, support, identity, performance, conflict tolerance and risk tolerance. These characteristics of the organizational culture and its attributes, added to the internal behaviors, are also determinants for the implementation of the new business model PSS (Weeks; Plessis, 2011).

Gebauer et al. (2005) argue the main aspects concerning to the organizational culture were the necessary motivation of the managers and the opposition behavior limiting the business model change.

Methodology is presented in the sext section.

Methodology

Changes in strategy and business model, especially those regarding the inclusion of services into products can be very complex to be understood. Thus, conventional data gathered techniques, in which respondents complete questionnaires remote does not seem enough to secure and generate practical insights (Baines; Shi, 2015). Based on the characteristics of the subject, this study can be considered qualitative empirical research involving a single case. The case study seeks to show a reality that is not enough known not trying to establish cause-and-effect relations (Yin, 2017). Therefore, this research is characterized as ‘exploratory’ in the specific context of a Brazilian subsidiary of a multinational car manufacturer located in Sao Paulo.

Despite its limited use for theory-testing, case study research has been used in the field of operations management to test complex issues such as business strategy implementation (Voss et al., 2002, Yin, 2017).

Respondents and data sources

One of the most important aspects in the definition of the respondent is the level of knowledge about the subject being investigated (Baines; Shi, 2015). In order to reduce this vulnerability and the risk of repetitive responses in this study, due to the company's internal culture, it was decided to expand the research not only by focusing on Mercedes-Benz but also on other Daimler companies. The research was therefore extended to companies Daimler AG (Germany), Detroit Diesel Corporation (DDC), Daimler Trucks North America (DTNA), Mitsubishi Fuso Truck and Bus Corporation (Japan) and Daimler India Commercial Vehicles - DICV (India).

The respondent’ profile was firstly a person is part of the organization of one of the companies of the Daimler group, be it in the supply or consumption of services, be personally involved in the provision of services or related activities, have knowledge and experience in the function, and preferably have some authority on the subject. In addition, to avoid the risk of inhibitory factor by the function performed by the respondents, only those with executive positions of different levels of hierarchy (sequentially in ascending hierarchical order, Managers, Senior Managers, Director, COO and CFO) and of several areas of responsibility: Operations, Sales, After Sales, Human Resources, Quality, Controlling, Industrial Planning, Purchasing and Information Systems IT.

Furthermore, the research also count on a participant observation since one of the researcher has been working for 35 years in the Daimler Group, currently at the Global Procurement department of the Brazilian subsidiary of Mercedes Benz but already had in

the Cost and Value Engineering, Truck Product Planning, Product Cost Calculation & Investment Analysis departments

Participant observation is commonly linked with the data collection phase, but it cannot be resumed on this. The participant observation can be defined as an observation process of a community or social group where the researcher has a role in this unit of analysis in order to share experiences (Bernard, 2017). According to Jorgesen (2015), the researcher interacts with people in everyday life while collecting information. It is a single method for investigating the richness, complexity, even conflictual and diverse experiences and thoughts.

Results

Current PSS context in the company

Prior to officially interviews get started, some meetings with the sales department of Mercedes-Benz were carried out and it was realized that to some extent a PSS model is currently been in deployed since a newly data equipment has been offered, called *Fleetboard*. This equipment is one of the most advanced telematics systems, that uses the computer integration facilities with the resources of the internet and mobile network with the intelligent processing of truck data. For the carrier and those responsible for fleet management, it provides important data on the use of their vehicles. For example, an analysis of driving by the driver (driving style), checking habits and vices in the steering wheel, or monitoring of routes with verification of stopped time and in movement. The diagnosis allows an evaluation of the operation of the engine and equipment in general, including digital map, geographical position, check driving conditions in different types and different road conditions and prognostics maintenance, based on forecasting and use.

The Fleetboard is currently offered only as a product supporting the management of the fleet. However, there is a way to obtain all information pertaining to the use of the product, from the availability on the Internet, of a source of data that must be stored and analyzed and can become an important source of information for an adding value. The question is: *how data can be exploited and made available and how to add value and increase the profitability of the company with the use of this data*?

In this paper, the sale of data will not be our focus since the proposal is to use these data to generate a form of different product sales embedded services, advancing with the use of IoT and Big Data.

Insights from interviews

To facilitate the organization of the data ~~obtained in the research including both, the interviews and documents,~~ it was elaborated some figures summarizing the main aspects related to each constructs and dimensions as well as the actions of PSS. The changes in the business model was discussed as an open topic regarding the importance of the PSS business model for the company, the integration of services to the truck product and the business vision for the company's future business model.

All respondents agreed on the need for a change to improve the company's profitability, but it is interesting to note that several of them mentioned the necessity of technical improvement of current products to meet the needs of the market, confirming the internal culture focused on product (PO), according to Tukker' typology (2004).

Specifically on the topic of integration of services to trucks, the respondents agreed that it should improve profitability, but they advocate the integration of lower grade. The director supports the truck rentals, sales manager cited the sale of maintenance services and sales senior manager the extended warranty and driver training sold jointly to the

product. On the other hand, the respondents agreed that the integration of product services should be a matter of survival, which reinforces the findings of Reim et al. (2015).

Most of the respondents considered very difficult for the company to reach the new business model due to cultural issues. However, these cultural issues should be managed by the company executives, corroborating with the findings of Weeks and Plessis (2011). Training of employees is also vital, particularly technical staff such as product engineers, as the company is totally dedicated to the development of new products instead of service-oriented solutions.

Fourteen respondents stated that creating a business unit separate from the current company to foster the development of the new PSS business model may be the most viable alternative, reinforcing the studies of Ulaga (2013) and Baines et al. (2017) which argue that the only way to speed up and facilitate the development of the new business model for PSS.

Four respondents also cited the use of startups and one cited the company's current project, called Leadership 2020, which uses ideas incubators, especially for the lower investment needed.

We evaluated several currently sorts of contracts, from those related to the purchase of material to those referring to purchases of machines and equipment. Our findings suggest that no partnership was observed. People from procurement area presented the parts and tools contracts used in the company and reinforced that they are always related to the supply of a physical product and not services. In the case of services, the scope is usually defined as the payment with a fixed amount according to a worksheet accompanying the tasks, as highlighted by purchase director, with a form of turnkey payment, that is, full payment when the task is executed and final delivery.

Long-term contracts cover a maximum of 5 years, but most of the contracts analyzed has 1 year as duration. According to Baines and Shi (2015), companies with a PSS model must have long-term contracts and managed risks. All the contracts examined were standardized and any change should be approved through the legal department, having developed an internal system for this purpose.

The contracts are managed and monitored by the contract manager and no risk management instruments have been observed. Controlling director clarified that it will be used investment analysis spreadsheets on the acquisition of capital goods, given by the controlling department of the company, being considered viable the investments that generate returns in a maximum of two years. This is in line with one of the important aspects cited by Brax and Visintin (2017) for the implementation of a new PSS business model.

According to the experience of companies with PSS business model, we tried to understand some services that the company already provides, but by the current PO business characteristic are not charged. People form sales and strategy have argued that the sales area has a software to calculate the Total Cost of ownership (TCO) as recommended by Roda and Garetti (2014). This software is used by technical sales assistants to suggest, according to the customer needs, the most viable products from the point of view of total cost. We found that this same worksheet is used by the post-sales staff as a guidance tool for large fleet owners to optimize costs and this service is offered but not charged (Reinartz and Ulaga, 2008).

The ~~interaction~~ relationship of the sales staff with the dealers of trucks is very close, including using sales performance indicators and basis for comparison of them and, even, for the best awards. People from strategic area reinforced that, however, there is small interaction with final customers, for example, with logistics companies that are large

consumers of trucks. With this, the development and preparation of the employees do not focus on serving the public directly, but only to the dealers.

The company uses the concept of indicators of the balanced-score card, with annual definition of goals, being cascaded and monitored monthly. The business strategy area, directly linked to the CEO, is responsible for the control and monthly reporting of the results of the indicators. The main performance indicator used by the company is return on sales (ROS), not only by the Brazilian subsidiary but by all Daimler group.

It was also noticed a difficulty in reflecting on possible future clients in the PSS model, due to the culture of products and the current relationship through dealers.

In general, the managers understand that this topic is a huge challenge, because the company does not present a culture of partnerships and networking.

According to interviews with the controlling area, Mercedes-Benz has never used the concept, for example, of open-book, open structure and shared costs with its business partners. Neither it has any kind of sharing of internal information since it is characterized as confidential information, which makes it difficult to use the PSS business model as discussed by Foote et al. (2001).

Respondents generally considered that a large majority of internal processes being bureaucratic and non-agile, especially due to the rigid compliance rules, with regulatory standards followed by all the employees. According to the procurement manager, this directly influences even the training and skills required for purchasing personnel who end up following the standards and do not develop in commercial and non-technical aspects for a business partnership. In managers' views, it should be developed the new business model PSS in a separated organization, or it could be a business unit or even a startup. Human resources director considers that several factors make it difficult to change the business model for PSS, but in particular by the very closed corporate culture also in the upgrade process, not based on partnership and trust, essential as pointed by Baines and Shi (2015), but in rigid contracts and communication in the majority of official character, through letters and controlled emails.

Some previous attempts of internal changes were carried out without agility and were very difficult to involve all the executives, probably because the size of the company and problems related to internal communication or even motivational reasons. It has also been pointed out that the several years of crisis and the constant reduction of personnel generate a certain pessimism and lack of motivation in the case of need for change.

The product development department appears to be focused on the technology of new products, with little customization. Customization is carried out especially by companies that complement the trucks with items to meet the specific use of the products. Most of the product developments are carried out in the headquarter, which in turns bring low flexibility and would be a major disadvantage for the implementation of the PSS business model (Baines et al., 2007).

We tried to deep in the characteristics and information provided by the Fleetboard with the sales area. They mentioned the difficulty in use it as a new service.

Regarding the concepts of Big Data, people from IT area cited the implementation of the concepts of industry 4.0 in production but regarding the use of Big Data in products is still outside the current reality of the company in Brazil.

Managers have shown great concern with sustainability. Chief of operations mentioned the sustainability in the production processes by reusing material such as waste, burrs, lost parts used in production. In relation to sustainable products, the use of alternative materials, such as the development of trucks using coconut fiber instead of foams.

Mercedes-Benz has developed an area for motor reconditioning and resale of used products, but without yet worrying about the final disposal of the end-of-life product.

The company controls the conservation of environment and natural resources of their direct and indirect suppliers, including having an annual award for the different actions on the environment.

Organizational and human management was stressed as a crucial issue by all respondents. A common agreement was regarding the need to hire qualified personnel for the new PSS business. A sample of this was that few respondents demonstrated knowledge of PSS and constantly returned to product focus. Specially, Mercedes-Benz Chief Operating Officer believes it is complicated to achieve full executive motivation and an awareness of the need for change. The respondents also considered that internal motivational campaigns would not have positive effects nowadays because of the negative market situation and ongoing staff reductions leading to a non-positive climate to a campaign of this type.

Another finding is that interviewees of the quality department did not agree that the personal of this area should to add a capacity of services. Likewise, the services director considered that both the technical training and the psychological profile of the staff are focused on technology and new products, not services. However, senior manager of DICV stated that since the company is relatively new, the staff personal was prior recruited prioritizing qualifications for the service area.

Conclusion

Transforming a product-oriented organization to compete through services is a challenge for practitioners. So it is for researchers to understand and facilitate the transformation towards service-orientation. In general, the academic research is fragmented and no frameworks explains how to the shift towards the integration of products and services. Thus, this is inevitably a barrier to the adoption of servitization (Baines et al., 2017).

Our findings indicate that PSS consider manufacturing companies as a service provider, instead of being considered as customers. Many manufacturing companies are now customers of advanced services, through partnerships and the acquisition of complex manufacturing technologies such as machining, extrusion, forging and casting. This topic raises questions about the relevance of manufacturing servicing and requires further studies.

For reasons of scope definition, this paper focused on the strategic and behavioral actions of change of the PSS business model in a manufacturing company. Internal issues of logistics or production processes were not taken into account. This is certainly an area that should be considered for future research.

A limitation of this paper is that it is based on a single segment (loads) and a specific product (trucks). However, it was minimized using multiple respondents from various companies of the Daimler group from different countries and with access to different sources and internal documentation. Moreover, expanding the research to other Daimler companies reduced the risk concerning the repetitive responses in the Brazilian subsidiary.

In terms of managerial implications, Mercedes-Benz should use the information provided by Fleetboard to infer the use of product data and change the current business model, to supply not only a truck, but a complete transport solution, adding new services to the currently product.

To take advantage of Big Data can, for example, with accurate information conductivity style's designated driver, the company should propose exchanges drivers to

more appropriate routes or more appropriate costs (for the driver who can have good savings fuel and consumption in general, the same must be placed in routes of great consumption). Another possibility is, from the data of duration and movement in a certain route, the causes of loss of time and efficiency can be determined. From that alternative routes (that bring better yield) can be proposed or an integrated mesh of transport of load can be redesigned. With tele-diagnosis data, a predictive maintenance can be proposed, or even negotiated with a supplier. For example, tire wear and tear information directly to producers, following the model of the Michelin implanted concept.

It is also possible to provide service training, whether it is for drivers, fleet operators or even the maintenance companies. Also propose the sale of a powertrain (engine, transmission and drive axle) suitable for general use of the product, in order to generate a total cost optimized for fleet owners, through better efficiency and adequate consumption, form pay-per-use. Or a partnership with a specialized company in logistics and transport, offering not only a truck but a complete integrated transport solution that meets the needs of the customer.

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The transition to the supply of Product-Service Systems (PSS) in suppliers in the primary sector

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Abstract

Product-service systems (PSS) are presented in various sectors, yet most of the theoretical framework of servitization is based on manufacturing firms. The primary sector diverges from manufacturing in many aspects, despite highly representative economically, introduces particularities intrinsic to the primary activities. Thus, this article performs a critical analysis of the main model of PSS transition process, Oliva and Kallenberg's model (2003), and propose a comprehensive framework validated through an exploratory analysis in coffee production's suppliers. The findings provide evidence that servitization differs from the manufacturing PSS transition, and serve as a guide for provisioning of services at the primary sector.

Keywords: Product-Service Systems, Servitization, Primary Sector.

Introduction

Vandermerwe & Rada (1988) evidence of the importance of supply a bundle of goods and services to customers, showing that this was a recurring practice in organisations seeking superior performance. However, although widespread, diversification by services would not per se guarantee this result (Brax, 2005; Hou and Neely, 2013). For this purpose, the innovation movement with services should be progressive, from a restructuring of the business model, migrating from product orientation to service orientation (Kastalli and Van Looy, 2013). In this process, called Servitization, products and services would find the necessary structure for the formation of a single intricate unit, a product-service system (PSS) (Mont, 2002).

Several authors (Dimache and Roche, 2013; Reim et al., 2015) advocate that the transition from a product-centric firm to a "servitized" enterprise can be envisaged in a continuum of PSS supply possibilities. In this continuum would be several combinations of PSS from the less advanced (with greater appeal for products and services as coadjutants), to those more advanced (with greater importance of the services, including with the possibility to suppress the possession of the physical product by the client).

However, for this offer to occur, an intrinsic service issue cannot be neglected: the need for a more in-depth relationship, since the value created emerges precisely from the interactions between customers and sellers, which boosts earnings for both (Gronroos, 2015).

In the primary sector, the inter-firm trade model prevails, or business-to-business (b2b), whose relational aspects and network structures are superior, allowing the creation of closer ties, of longer duration, and with greater intensity for the expected return (Ford, 1980; Saccani et al., 2014). Also, there is concern about the performance of the business on both sides of the negotiation (Cannon & Perreault, 1988), which enhances the environment for the most exclusive and innovative service offerings (Bastl et al., 2012).

Despite this favourable profile for servitization, we find a gap in studies that contemplate this type of transaction. For the author, this gap would mainly come from the lack of available data and the lack of knowledge and mastery of the theme by the researchers. This reflects a significant number of research papers in servitization that is based mainly: a) in cases of companies operating in the business-to-consumer type of market; b) in case studies dealing with particular sectors; and c) studies encompassing a group of manufacturing firms. As a result, the main advances and frameworks on the subject follow the particularities of direct contact with the final consumer in the delivery of the service.

The present article brings a critical re-reading and adaptation of the servitization model by Oliva & Kallenberg (2003) to encompass the characteristics peculiar to services in the primary sector and the lack of understanding in the literature of servitization beyond manufacturing.

Methodological aspects

In order to attend the goal of this article, the first step was a qualitative work, with the literature review subdivided into two complementary phases: a) search of the main works on the measurement of servitization in manufacturing; and the second, b) search for studies on the subject for the interfirm sector. In these stages, the main databases of journals accessed were EBSCO, Jstor, Emerald, Elsevier (Science Direct), Web of Science and Google Scholar.

As a result of this qualitative research, the article “Managing the transition from products to services” from Olivia & Kallenberg (2003) was recognized as one of the most significant impact in the literature about servitization, having been cited as a reference by at least 800 articles since its publication (data from Emerald Insight, 2017). Thus, we chose to use the framework proposed by the authors as the initial parameter of classification of the services identified in the evaluated companies, aiming to verify the applicability of the conceptual framework for the interfirm sector.

Subsequently, we make a critical analysis of this model, with the proposal of a new conceptual framework (Convergent Typology) aggregating the proposals of classification of the services considering its complexity, orientation, and the possibilities of supply. In this direction, the text proposes a new more comprehensive framework based on the literature review of the theme (Baines and W. Lightfoot, 2013; Dimache and Roche, 2013; Gebauer, 2008; Mathieu, 2001; Parida et al., 2014; Reim et al., 2015; Saccani et al., 2014; Ulaga and Reinartz, 2011).

The second part was to validate the new model through an exploratory analysis of the intensity and occurrence of supply of PSS in seven firms: four companies that supply agricultural machinery and implements with a recognized investment in the portfolio of services (Identified as A1, A2, A3 and A4); and three companies that supply agricultural inputs which offer differentiated services to customers (Identified as B1, B2 and B3).

The focus on primary sector firms is based on two main factors: a) academic research that encompasses the development of services for the interfirm sector, and b) high potential for servitization in primary sector firms. Neely (2013) states that companies of farm machinery and implements (in particular the production of grains) can be considered as one of the most servitized in the world. In general, in the primary sector, the servitization strategy has been used as an exit to solve intrinsic issues, such as product technologies become increasingly mature making it more difficult to achieve technological superiority through the actual product, and, with it, the difficulty of standing out in the competitive market. Thus, we can see a demand for studies that contemplate this transition of products for services also in this market.

We chose to research companies that work in coffee production because of its cultural and economic importance for the country (Brazil is considered the world's largest producer and exporter of coffee, commercializing 30% of the volume of grain sold in the international market, according to data from the Ministry of Agriculture, Livestock and Supply.

The data collection took place in two relevant coffee production areas in Brazil, representing together almost a third part of the total production of the country and a large number of specialised suppliers. The interviews were conducted with the managers responsible for the service area in each of the companies and had an average duration of half an hour. During the collection of data with the questionnaire, the collection of printed data also took place: event folders, field work day worksheets, user manuals, technical delivery procedures, sale catalogues, among others accessed through electronic means in the institutional sites. Additionally, as a way to ensure the understanding of the types of services available to clients, interviews were also conducted with Technical experts and managers from three Cooperative of Coffee Growers (COOCAFÉ, EXPOCACCER and ACARPA).

The conceptual framework of reference

Oliva & Kallenberg (2003) evaluated 11 manufacturing companies in the process of servitization to describe how the process of organisational transition occurs for the provision of services. The authors use the concept of a product's installed base (IB) as a parameter of the measurement of services offered jointly to existing assets. Thus, the product's installed base (IB) "is the total number of products currently under use", and in this context, IB "is the range of product-services or process related services required by an end-user over the useful life of a product in order to run it effectively in the context of its operating process".

This transitional process would consist of a four-step evolution: 1) Consolidate the product-service systems, combining the offer of services with the supply of goods to the end user; 2) Enter the market for the provision of installed base services, which implies identifying a profit opportunity with the services and creating the necessary structures and processes to exploit it commercially; 3) Expand the service offered through two transformations - a) migrating focus from transactional to relational; and b) changing the focus of the value proposition solely based on the effectiveness of the product for its effectiveness and efficiency in the process for the end user; and 4) Assume the operations of the end user, entering the field of operational services (no company surveyed had reached this level). The services fall into four categories: basic installed base services, maintenance services, professional services and operational services.

Thus, walking on the continuum for more advanced supply, the assets would become supporting elements of the offer, making their possession less important, and the impact

of services increasingly prevails on the results of the supplying organisation. In short, in the transition model proposed by Oliva & Kallenberg (2003) has some assumptions:

- Although not considered mandatory, the maintenance services were identified as necessary for the company to be prepared structurally for the evolution of service;
- Basic services (IB) are product oriented, with the identification of basic services directed to the process of the end user not being adequate;
- The most advanced services are called operational, process-oriented. Both descriptions of the service assume that the moment of the offer of the service is after the purchase, that is when one already has some level of relationship in progress with the client;
- The most successful companies in the provision of services are those that maintain specific organisational separation for the operation with products and services.

The Convergent Model: A new proposal to re-read the reference framework

As evidenced, Oliva & Kallenberg (2003) identified four types of service, limited to two types of orientation: to the product and end-user (Figure 1). However, more recent studies to measure servitization (Dimache & Roche, 2013; Reim, Parida & Örtqvist, 2015; Gebauer, 2008; Saccani, Visintin & Rapaccini, 2014) classify services in PSS into three forms of orientation, which are superimposed on the model by Oliva & Kallenberg (2003). It occurs that, each of these three forms of orientation has specific characteristics, with its separation being necessary to compose the continuum of PSS: a) services oriented to the physical product; b) services oriented to the use of this service; and c) service oriented to the results of the service. Saccani et al. (2014) did a complete bibliographic review of the PSS offerings summarising how services can be categorised not only between their orientation towards product or use but also to results. The authors identify the characteristics related to the recipient of the PSS such as their intensity of relationship and level of customisation. In this sense, as the PSS changes from product-oriented to use-oriented and subsequently to result-oriented, the level of customisation becomes greater, and the need and intensity of the relationship increases. Besides, Reim et al. (2015) identified that results-oriented services are those that demand greater responsibility and attention from suppliers because they are the riskiest. This is evidenced by the high possibility of customisation, the innovation required in the processes, the need for constant communication and interaction based on trust, and the high formalisation of activities. The counterpart of this initial cost would be the highest returns to the business, promoting the joint creation of value and being able to reach the competitive advantage more easily (Vandermerwe & Rada, 1988; Reim et al., 2015).

This interaction should, therefore, be based on greater trust among those involved, increasing the necessary degree of contact with the client and the focus on the joint creation of solutions. With this, and for greater freedom to provide the result, the PSS supplier can offer greater possibilities of customisation, with more significant opportunities for innovation and greater flexibility in both the production of the PSS and the established routine. Despite the advantages, it poses a higher risk to the PSS, if an internal restructuring does not support the path through the PSS continuum, the chance of failure before reaching this orientation is high (Reim et al., 2015).

In addition to the result orientation, which would represent the most advanced services in the continuum, there would still be two types covered by Oliva & Kallenberg (2003): the most basic, or least advanced, characterised as well-oriented; and the intermediate, denominated due to its use-orientation. In the first type, services are directly related to the good offered, requiring less interaction with the user and/or involvement of the provider

and lower investments. Consequently, it has a lower risk of execution and little or no possibility of customisation. In the second type, there are those services rendered for the use of that good, involving the user more directly, and becoming less tangible.

Given this differentiation, we sought to verify the compatibility of the reference framework cited with the reality of the primary sector in particular four main points:

- Oliva & Kallenberg (2003) argue that the evolution of service supply would be required to reach higher levels of servitization. Given that the more service-oriented companies need to compose a range of comprehensive services, it is expected that the most service-oriented firms will be those with a more significant number of linked services. Therefore, it is expected that the company will first offer basic installed based services or maintenance services, and subsequently, began offering professional and operational services;
- Basic services would only be those focused on products, and it is not appropriate to identify basic services for the end-user process. Therefore, it is expected that all services falling within this category will be product-orientated;
- The most advanced services are termed as operational, process-oriented. Both descriptions of the service assume that the moment of the offer of the service is after the purchase, that is when they already have some level of relationship in progress with the client. Thus, it is expected that the most advanced services will be identified in the post-sale;
- The most service-oriented firms are expected to show an organisational separation between operations for integrated products and services (PSS).

All the assumptions are based on the classification of the service as a starting point for the identification of the service level. The new Convergent Typology is represented in Figure 1, which brings a comparative representation between the classification of services in both typologies.

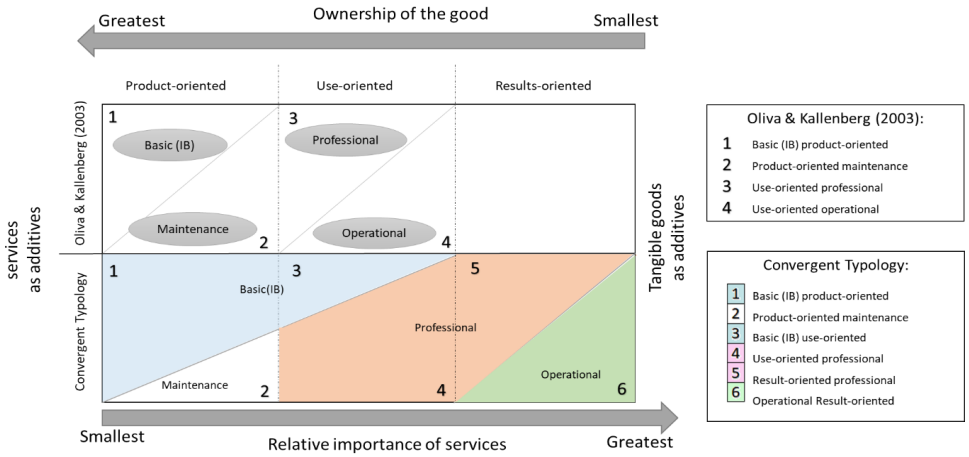

Figure 1 – Comparative representation between the reference framework and the new proposal.

In the new classification we have the dimension of the importance of services and the need for product ownership, as evidenced by Saccani, et al. (2014), among other authors who classify services through their orientation (Dimache & Roche, 2013; Reim et al., 2015; Mont, 2002; Gebauer, 2008). Thus, for services classified as product-oriented (basic and maintenance), the importance of services would be lower, with a greater need for ownership of the product, which is the main purpose of support. Three key points should be highlighted in this new classification:

- The division of services considered as basic (IB), between product-oriented and use-oriented. This was a demand evidenced by the theory and confirmed in the data collection, since the effort necessary to supply use-oriented services is greater, although they are considered basic. As such, basic use-oriented services are more advanced than product-oriented services but less advanced than services identified as user-oriented professionals.
- The professional services were subdivided according to their orientation, which may be less advanced (use-oriented), or result-oriented. This differentiation was also corroborated by the research findings since the efforts for sale (still in pre-purchase) signalled the assistance of consultancies, experiments, and advice with a focus on the performance of purchased products and how to improve production management.
- Services considered as operational, contrary to what it is signalled by Oliva & Kallenberg (2003), were reclassified as result-oriented (for the authors, these were user-oriented services and with high a demand of relationship). This new categorisation reinforces the great need of relationship evidenced by the authors, keeping the service receiver as a process manager and with a high possibility of customisation.

The new table shows nuances of the evolution of the servitization in a given company, stratifying levels of evolution that were previously not perceived in the classifications surveyed. Also, it is perceived that there is no need to overlap less advanced services so that more advanced services can be offered. Therefore, we seek to identify the main services with this format mentioned in the literature, not limited to those in manufacturing. Thus, we recognize during literature review 24 types of service identified in the companies in the process of servitization (code and type of service): (S1) Maintenance (various); (S2) Deliveries and logistics; (S3) Troubleshooting and problem-solving; (S4) Training/ seminars/lectures; (S5) Consulting, auditing and customer service; (S6) Inspection/ Monitoring / Diagnosis; (S7) Replacement management; (S8) Customer support; (S9) Updates and Upgrades; (S10) Documentation / information material; (S11) Help Desk; (S12) R&D; (S13) Installation / Commissioning; (S14) Demonstration; (S15) Supply of utility items/ consumption items; (S16) Technical assistance; (S17) Recruitment of staff; (S18) Revenues; (S19) Warranties ; (S20) Lease of goods; (S21) Orders; (S22) Cost-benefit calculation; (S23) Analysis of manufacturability and viability of goods; (S24) Client Process Operation.

In addition, Figure 2 shows the representation of the services found in firms served by the framework of reference and the new Convergent Typology.

Presentation and discussion of results to validate the new model

The initial analysis starts with the identification of the types of services found in the sample, characterising them according to the classifications proposed in the reference framework - Oliva & Kallenberg (2003). It was to be expected that most services would be concentrated on those basic products, but product-oriented. This is because, according to Parida et al. (2014), for manufacturing, this is the main frame, whose services are based mostly on maintenance services. For the primary sector, this is most relevant, because, in a commercial interfirm relationship, the aspects related to the product are usually overcome by those related to the relationship between the parties (Bastl et al., 2012).

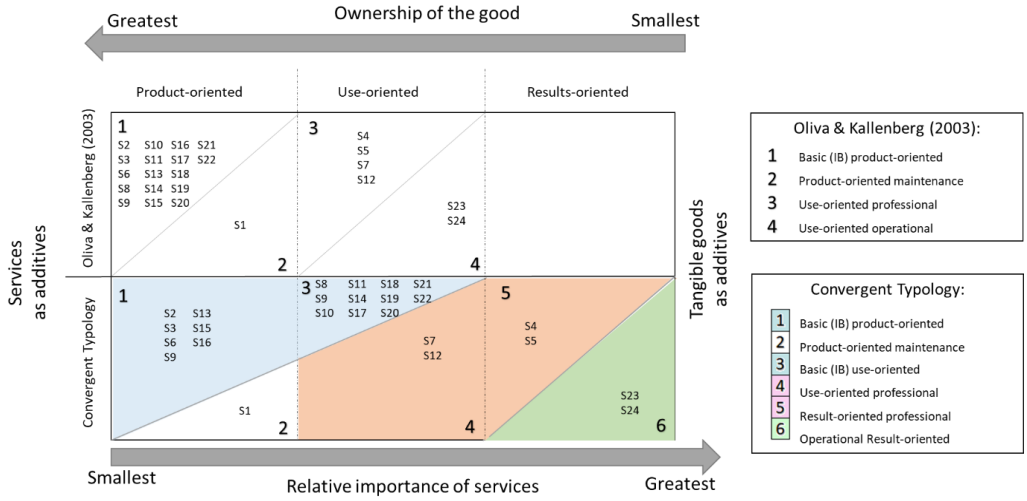

Figure 2 – Classification of the 24 types of service according to the two conceptual frameworks considered.

We can verify that the differentiation between service supply was identified for the companies of the two surveyed sectors. Industry A offered 12 basic services (product-oriented), while only one service of this type was identified by industry B (deliveries and logistics). On the other hand, basic services, but use-oriented are proportionally more used by companies in Industry B, which is justified given the intrinsic characteristics of the goods traded (low differentiation, low technological input, single use). This differentiation can be seen in other well-oriented services, such as maintenance, which was found only in industry A.

Professional services could be found in companies of both industry A and industry B, practically in the same proportion. These services, which are not directly related to the product marketed, but to customer service through the sale, shows that both companies can offer it, being able to be an even more significant differential for those of industry B, given their limited offer possibilities. Although no company presented results-oriented services (according to the reference classification), we can verify that company A2 was the one that presented the most significant amount of services (15) and a larger number of more advanced offerings and can be classified as the most servitized in the evaluation. The most advanced services fall into the category of professional services since no services of the "operational" types were identified. In the last ranking, however, there is company B2 that has a lower number of more complex supplies, being also between the last two in quantity of services made available to the client.

The company categorised as more servitized (A2) was also the one with a more significant amount of services; however, it can not be said that the number of services offered is decisive for a higher service level. This is confirmed by evaluating the B2, B3, and A4 service supplies. As shown in Figure 3, companies B2 and B3 have the same amount of services offered (5); however, company B1 offers two professional services, while the others offer only one. Thus, it is possible to highlight at least three points that are discordant to the framework created by Oliva & Kallenberg (2003):

- The findings show that the provision of less advanced services in the PSS continuum is not a necessary condition for the firm to be more servitized. That is, the company can offer more advanced services without necessarily offering also less advanced services. This is evident when observing that all the companies

surveyed offered at least one professional service, including B2 and B3, which did not offer maintenance services.

- The number of services, per se, is not a determining factor for servitization. What adds greater weight is the number of services in more advanced categories, including a necessary separation between the services considered basic by their orientation (whether by product or by use). For the authors, this distinction does not exist, since all services considered to be basic would necessarily be product-oriented. However, in the practice of the companies surveyed, we can verify that there are two types of basic services: those product-oriented (services that support the commercialised item) and use-oriented (services that support the use of the commercialised item).
- Another relevant issue concerns the fact that there were no services that fit into the classification of result-oriented services (as can be seen in Figure 3). In using the criteria by Oliva & Kallenberg (2003) would be only those focused on the transaction with the client and the process management. That is, assume that the services in question are valid for the post-purchase and that consulting, training and other services would not be in this category. However, the findings of this research show that, specifically for the field of agricultural inputs, this categorisation does not contemplate the reality of the sector. The results of the research showed that some of the services categorised by Oliva & Kallenberg (2003), as professionals and use-oriented, are result-oriented services to the result of the business being able to occur, including in steps before purchase. Thus, these services would be at another point on the PSS continuum, more to the right, that is, they would be more advanced. In the companies surveyed these services were found in the three companies in the field of agricultural inputs (B1, B2, and B3).

The possibilities of supplying services serve as a guide for managers to highlight opportunities that were not contemplated. In addition, we can see that some services are not offered due to the incompatibility of the commercialised product. The classification proposed by Oliva & Kallenberg (2003) allows to identify that the majority of the services offered by servitized firms are characterized as basic, that is, they are still on the left side of the PSS supply continuum, indicating that ownership of the item is still very relevant, contributing to a relative importance of goods significantly higher than the importance given to services. According to the authors, the organisations that only maintain services that fall into this category are more likely to face problems to have the expected return with servitization.

Although there is a greater possibility of offering services at the time of purchase, the types of services supplied are considered as basic, that is to say, as those services additional to the supply of goods, characterised by a low level of customisation and value perceived by the customer. The only two services characterized as operational, that is, those in which there is the greater relative importance of services and which are located to the right in the continuum of PSS are in pre-purchase possibilities, as a way to assist the operation of the customer's processes and in the improvement and updating of the items. It should be emphasised that there be a concentration of services of a higher degree of servitization for when improvement and update are performed on the items, with two services known as professionals, R&D and Consulting, auditing and customer advice for business, in addition to the service listed as operational.

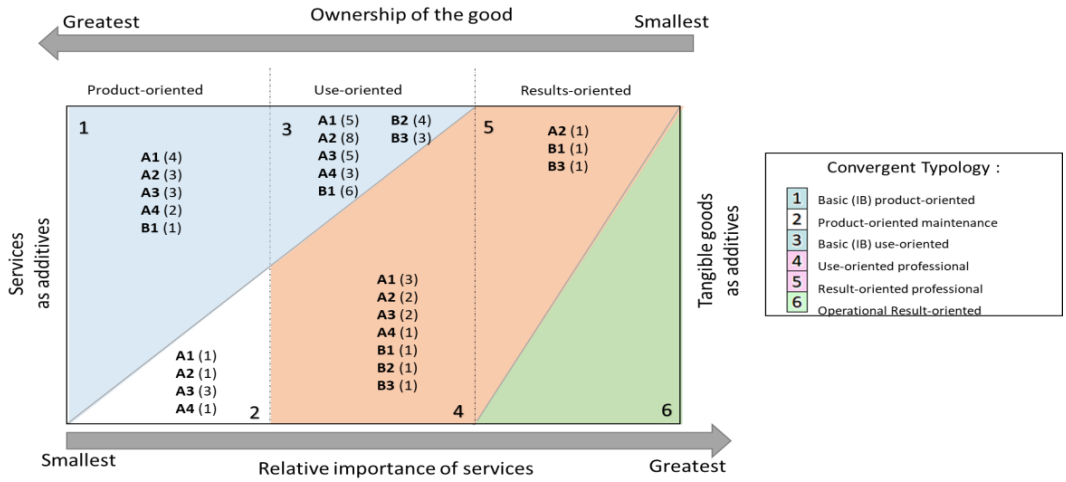

Figure 3 – Identification of the number of services identified in the evaluated companies.

In this analysis, two companies of agricultural inputs (B1 and B3) proved to be more serviceable than machines and implements (A1 and A3), by offering professional services that are use-oriented. This verification contradicts the profile found for manufacturing firms, according to the classification by Oliva & Kallenberg (2003), insofar as for Industry B companies, they are not based on maintenance services (pointed by the authors of the reference framework as relevant for more advanced firms in the servitization process).

Conclusion

The present study brings contributions to the theoretical framework involving the service and its form of measurement in the PSS continuum. Therefore, we propose the Convergent Typology between two approaches of classification of services with distinct and complementary approaches, namely: a model based on the complexity of the PSS supply, starting with the model by Oliva & Kallenberg (2003). This new typology has allowed the classification of services into more categories within a continuum that varies between basic service-oriented good and operational service-oriented result.

The field research findings reinforce the inconsistency of the framework proposed by Oliva & Kallenberg (2003) to classify the identified services, making it necessary to adapt them to the reality of the interfirm sector. This issue was evidenced in four aspects: a) when reclassifying the services and identifying the most service-oriented company; b) when dividing services from the basic type into product-oriented and use-oriented; c) when going from the professional services division into use-oriented and result-oriented; and d) when it is perceived that it is not necessary to offer less advanced services, in order for one to be, necessarily, more servitized (including the number of services was not relevant for the companies evaluated).

Thus, in addition to the theoretical discussion provided by the new typology of services classification and the identification of the supply through opportunities in the pre-sale moments, sales and after-sales, it can be seen that most of the service offerings are concentrated as basic, which also occurs for manufacturing companies (Parida et al., 2014). However, we realise that there is a higher incidence in those considered as use-oriented. The latter requires the supplier to be more prepared, especially concerning the customer, being more complex than the basic services oriented to the product. We did not identify a service considered as more complex, neither (operational results-oriented services). In addition to the higher supply of basic services mentioned above for

companies that supply agricultural machinery, equipment and implements, the possibilities of offering services and the way in which the deal with the customer exists resemble the manufacture since it allows the provision of product-oriented services. These, such as maintenance services, are gaining strategic importance and differentiation for customer choice in becoming loyal. However, the differentiation between service offerings concerning those identified in manufacturing is undeniable, especially in the field of agricultural inputs. We expect this new framework to be a driver for the manager to invest in services that bring a higher return, given the existing structure.

The primary objective of the research was to foster the discussion about the servitization in a format and sector not explored in the literature of the area.

We recommend the replication of the new framework to other sectors in the interfirm sector and manufacturing so that the results can be compared directly.

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A Grounded Theory Analysis of Complex Service Networks

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Abstract
This study explores the complexities faced by organisations operating in service networks, using grounded theory. In total, 68 interviews were conducted with experts employed in servitized manufacturers from various sectors. This led to the development of the 'CAGE' framework and revealed safety as a recurring theme from the discussions. Overall, this study contributes to knowledge by examining, the complexities of service networks, complexities that can impact service provision both from an operational and a safety perspective, and the manner in which servitized manufacturers can manage them. Thus, in addition to the academic contribution, the results also have significant practical implications.

Keywords: Servitization, Complex Service Networks, Safety

Introduction
Rapid economic growth during the Golden Age of Industrialisation, led to a shift in demand from quantity to the quality of "*manufacturing consumption*" (Versen and Wren, 1998, p. 510). This situation, combined with rapid technological advancements (Ostrom et al., 2010), increased automation and decreased cost of manufactured goods (Johnston, 1994), has resulted in the rapid development of the service sector (Memedovic & Lapadre, 2009; Ostrom et al., 2010). As a result, the world is becoming dominated by services (Memedovic and Lapadre, 2009) with developed economies generating more than 70% of their Gross Domestic Product (GDP) from the service sector (Johnston, 1994; Ostrom et al., 2010).

This shift towards providing more services, also called "*tertiarization*" (Memedovic and Lapadre, 2009), or for manufacturers specifically, the "*servitization of manufacturing*" (Vandermerwe and Rada, 1988), requires significant organisational changes, and involves the creation of new capabilities and processes in order to support the relational nature of services (e.g., Oliva and Kallenberg, 2003; Gebauer et al., 2005; Baines et al., 2009a). According to (McKinsey, 2012, p. 103), successful organisations of the future will also need to be able to work in large networks effectively, in order to build new knowledge and capabilities and "*sell products and services to diverse customer bases*". Due to the complexity of these networks, and the costs of gathering information, this can be rather challenging; the information is dispersed across various different locations and parties, and thus, an individual or an organisation can only hold partial or misinterpreted information (Pidgeon and O'Leary, 2000).

For organisations to operate successfully in networks and perform every day operations, each organisation will also need to have a clear understanding of where their

accountabilities lie throughout the whole lifecycle of a product and/or a service (Fielder et al., 2014). Fuse (2013) identifies this process as Through-Life Accountability (TLA) and defines it as "…*the duty to inform, justify and accept the consequences of decisions and actions taken during the entire lifecycle of assets and associated services. Critically it involves understanding the boundaries of and responsibilities for safe and consistent outcome delivery over an extended service contract involving multiple organisations*". However, this is far from straightforward, since the complexity of service networks does not always allow control of all the elements involved (Fielder et al., 2014). While the understanding of TLA is important for organisations operating in complex service networks, more research is needed from the academic community in order to understand more about the different dimensions of accountability, and the risks that a lack of its understanding may entail (Fielder et al., 2014).

When considering manufacturers who diversify into services, the challenges of operating in service networks can be even greater. For example, it has been argued that by taking over the customers' operations, servitized manufacturers have to deal with greater responsibilities than before, and for long periods of time, and assume risks that were previously the concern of the customer (Oliva and Kallenberg, 2003; Tukker, 2004; Neely, 2008; Nordin et al., 2011). In order to be able to produce their products and function in today's global supply chains, despite the challenges, manufacturers also have to depend on a large number of service providers (McKinsey, 2012). However, the extant literature tends to focus on the positive consequences of servitization and disregard any relevant risks (Nordin et al., 2011; Benedettini et al., 2015; Durugbo and Erkoyuncu, 2016). Thus, more research is needed in order to understand what the implications for these organisations working together are (Ostrom et al., 2010; Valtakoski, 2017).

Theoretical Background

Due to the nascent nature of this research, the literature review includes a range of different research fields. There are three main streams of literature that are relevant to this research: TLA, accountability and servitization of manufacturing.

Through-Life Accountability

The concept of TLA was first introduced by Fuse (2013). In their follow up study, Fielder et al. (2014) emphasise the importance of TLA by describing the HMNB (Her Majesty's Naval Base) Portsmouth business model, an example from BAE Systems Maritime Services, where the company has a contract to maintain maritime vessels. As part of their role, BAE has also been tasked not only to maintain it, but also to run the Naval Base. This includes providing catering, accommodation and social facilities for many employees including sailors. Since BAE do not have the expertise in all of these areas (e.g., catering) they outsource parts of the contract to external contractors, but the company is still responsible in case the agreed standards are not met by any of the partners.

A thorough understanding of TLA, therefore, provides servitised organisations with better control over their networks. What is more, such an understanding can shield them against potential risks. Interestingly, however, relevant academic research on TLA is sparse at best. For example, when using "Through-Life Accountability" as the search term in online research databases (e.g., Scopus® and ScienceDirect®) returned zero results. This motivated an expanded search of the term "accountability" separately.

Two distinct streams were identified in this literature. In the first, authors argue that accountability has different forms and attempt to identify them. In more detail, accountability is differentiated between individualising (internal or personal) and socialising (external or structural) forms (e.g., Roberts, 1991; Sinclair, 1995). According

to these studies, accountability can be further broken down into hierarchical and professional forms, as part of the personal accountabilities, and into legal, public and political forms, as part of the external accountabilities.

For organisations, firms and the society as a whole to secure their prosperity, they need to find a balance between the different forms of accountability and align the pursuit of their economic goals with a wider "*ethical discourse*" (Shearer, 2002, p. 570). However, finding the balance between the different forms of accountability can only be achieved under ideal conditions (e.g., Sinclair, 1995). This leads to the second stream of the literature, in which researchers argue that the multiple forms of accountability can lead to conflicting situations – a Multiple Accountabilities Disorder (MAD) (Koppell, 2005) or an "*accountability bias*" (Behn, 2001, p. 12) – since actors and organisations may be accountable for more than one dimension (e.g., Sinclair, 1995).

The complex meaning of accountability and its multiple forms, therefore, can lead to conflicting situations, since actors are often required to give account to a variety of different stakeholders against a broad range of criteria. Thus, it is far from straightforward for organisations to understand and deal with their accountabilities, especially in the case of servitized manufacturers where the product may be provided by one organisation and the support services by a large network of partners. However, while numerous studies discuss the complexity of accountability, there is a paucity of research on the guidance or tools that can be used by organisations for identifying and managing accountabilities.

Servitization

Nowadays, the provision of services is a key aspect of a manufacturer's business. An increasing number of – previously – traditional manufacturing organisations in developed economies will need to adopt this strategy in order to remain competitive in the current globalised economic environments (e.g. Mont, 2002; Neely, 2008).

Despite the various benefits of servitization, as several authors point out (e.g., Oliva and Kallenberg, 2003; Martinez et al., 2010), the transition to services involves significant challenges that render the success of the servitization strategy far from being certain. Indeed, the review of the literature of servitization reveals that there are a number of different risks/challenges related to the servitization of manufacturing. These include: operational risks (e.g., Nordin et al., 2011; Durugbo and Erkoyuncu, 2016); risks for specific functions of the organisation (e.g., Erkoyuncu et al., 2013); risks for customers (Holmbom et al., 2014); a transfer of risk from the customer to the manufacturer (e.g., Tukker, 2004); challenges in successfully diversifying into a service provider (e.g., Mont, 2002; Martinez et al., 2010); challenges in successfully delivering value to the customer (e.g., Neely, 2008; Holmbom et al., 2014); cultural challenges and challenges related to the complexity of service networks (e.g., Neely, 2008; Martinez et al., 2010; Holmbom et al., 2014; Durugbo and Erkoyuncu, 2016) and financial risks (e.g., Neely, 2008; Visnjic and Looy, 2013; Benedettini et al., 2015).

In fact, according to evidence provided in a number of empirical studies (e.g., Neely, 2008; Visnjic and Looy, 2013; Benedettini et al., 2015), it seems that manufacturers are not generally able to achieve the financial benefits of servitization that they might have expected, a finding that is widely known as the "*service paradox*" (Gebauer et al., 2005, p. 14). Due to the "*service paradox*", however, most studies focus on the impact of these on the delivery of the service to the customer, or on the failure of manufacturers to create value and/or profit from service provision, rather than the challenges of a fully and successfully servitized organisation. What is more, relevant studies, examine these issues either in dyadic or triadic relationships (e.g., Raddats et al., 2017; Finne and Holmström, 2013, respectively) within service networks. However, operating in today's highly dynamic service environments requires a broader understanding of the interactions

between the different actors (Li et al., 2017), and is more complex than simply understanding interactions between dyadic relationships (Banoun et al., 2016).

While identifying and understanding any potential risks and challenges that arise when operating in complex service networks is important for servitized manufacturers, extant research is limited and unstructured. All the identified challenges, however, have a common element: in order to successfully deliver the service to the customers, manufacturers need to form, operate in, and manage large and complex networks of partners and customers. To achieve this, the use of effective communication and information exchange is important, but not always easy. Indeed, a number of studies highlight the importance of being able to operate in networks and build close relationships with suppliers and customers. A number of studies also recognise these as a challenge. The required capabilities needed in order to be able to create, manage and operate these networks (as identified in the relevant literature) are: establishing and managing networks (e.g., Baines and Lightfoot, 2013); building and maintaining relationships with suppliers and customers (e.g., Baines and Lightfoot, 2013; Kreye, 2017); effective communication and information sharing (e.g., Baines et al., 2009b; Raddats et al., 2017) and sharing intentions and aligning goals (e.g., Jacobsson and Roth, 2014).

However, there is currently limited research regarding the challenges and risks involved after these networks are formed. For example, what are the specific elements that make managing these networks challenging? Why is this challenging? What type of information does the organisation need to ensure is shared? Put differently, what are the common sources of complexities in service networks that arise from the involvement of multiple organisations?

Research Design and Methodology

This study is addressing a nascent research problem (Edmondson and McManus, 2007), that is, a topic for which there is no previous theory within the context of complex services that could be used to support its methodology. Thus, it is an exploratory study that aims to "*seek new insights*" and "*assess phenomena in new light*" (Saunders et al., 2009, p. 139). For exploratory studies that aim to build theory, Glaser (1998), recommends the use of Grounded Theory (GT) as it has the ability to introduce new concepts, as these emerge directly from the data without forcing any leads.

Data Collection and Analysis

The sampling process for this study involved theoretical sampling and the recruitment of organisations and participants that are experts in the subject matter, or directly involved in the research problem (e.g., Glaser, 1998; Edmondson and McManus, 2007; Saunders et al., 2009) and both primary and secondary data can be used to address the research problem of a study (Glaser, 1998).

Due to the grounded nature of this study, it should be noted that, while the paper follows a more traditional structure where data and findings follow the initial theoretical overview, it is important to keep in mind that the actual process was far less linear. The research process, therefore, is presented in two different phases. Phase 1 represents the initial review of the literature that motivated this research, the narrative literature review of accountability and the systematic literature review of servitization. Phase 1 also represents the preliminary study conducted in order to narrow down the scope of the research. The analysis from Phase 1 has resulted in the creation of the CAGE framework that can help organisations identify the common sources of complexities within a service network. Phase 2 represents the main data collection and analysis stage of this study that collected data from three different ServManufacturerPro sites. The purpose of Phase 2

was to validate the CAGE framework that emerged from the analysis of Phase 1. An overview of the data is presented in
Table 1.

Table 1. Data Overview

		Industry	Country	interviews	Timeline
	Preliminary Study of TLA	Defence, Safety, Consulting, Transport, IT, Energy	UK	18 Secondary	June-Aug 2013
	Site 0 (So)	Defence	UK	5 Exploratory	May 2015
	Site 1 (S1)	Defence	UK	9 Semi-structured	July 2016
	Site 2 (S2)	Defence	Overseas	18 Semi-structured	June 2017
	Site 3 (S3)	Defence	UK	18 Semi-structured	July 2017

As GT requires, data analysis for this research begun soon after the first data were available by looking at the interview transcripts for emerging themes, and constantly comparing them and updating them (Glaser, 1998). Although the NVivo® software was used to assist initial coding, the process was supplemented by what Glaser (1998, p. 184) calls "*memoing*" in order to ensure that the relationship between the categories was identified for theory to be generated. The final framework is presented in the following section and summarised in Figure 1.

Results - The Cage Framework

Competencies

Manufacturers need to consider the competency of employees along with the assessment and training that partners provide for them, as competent people are required for the successful and safe delivery of the service. What is more, employees need to be continually assessed and developed in order to have a clear understanding of their accountabilities. Furthermore, even if all accountabilities are clearly explained and presented in the service contract, they will need to be reviewed constantly and understood on a case by case basis. This requires genuine knowledge and employees who are not hiding behind their organisation, but are willing to take on personal accountabilities. Last but not least, the technology and systems available within every partner organisation need to be considered. While some interviewees linked complex technology with increased risk, it was also recognised that technology can be used as a tool to clarify accountabilities, drive behaviours, and improve everyday communication, and, as a result, maintain a high level of safety. Therefore, further than individual competencies, the training provided to employees, and their continuous assessment, along with the technology and systems available are of key importance.

Attitudes

Organisations will also need to consider the individual people involved within their service network, as their personal attitudes and values can affect the way everyday processes are performed. Servitized manufacturers not only need to understand these, but also find a way to drive the right behaviours. This would require a better understanding of the personal cultures of the individuals involved. While this is not an issue unique to large networks, more differences are expected to arise within complex service networks. These differences could arise from an individual's country of origin, religious beliefs and professional background. Therefore, it is important for servitized manufacturers to be able to distinguish between these different attitudes and behaviours in order to be able to deal

with them efficiently and promote a safe and just culture across the whole service network. The next theme related with this characteristic highlights the importance of a joint and aligned incentives' system across the whole network. Incentives drive behaviours and need to be linked with a just culture or they can bring the opposite results. What is more, safety targets are harder to measure, and, as a result, "*the safety message tends to get watered-down, because it is not what pays people's wages*." This brings back the issue of finding the right balance between cost and safety, and the last theme that highlights the constant tensions between commercial and operational functions of organisations. For instance, as one of the interviewees points out, product-based organisations have far less things to consider compared to service-based organisations, since the latter need to consider the support of a product for the next 10 to 20 years. Even the shift from maintenance contracts to through-life support contracts can lead to changes in culture. In maintenance contracts the supplier benefits from replacing as many parts as possible, whereas in through-life support contracts the service provider prefers to re-use as many parts as possible. Similarly, even differences between departments need to be considered. Therefore, organisations need to understand the individuals' attitudes; the tensions between commercial and operations; and the incentives that exist within the service network, since these drive behaviours.

Governance

Another common concern is related to a general lack of control to take proper actions. According to the interviewees' responses, a lot of these issues can arise from the large number of parties involved in service networks, and depends on which entity has the right to govern or take decisions at each point in time. To this end, it is important to have clear governance with well-defined accountabilities, and a unified incident reporting system that promotes a culture of continuous learning. Two main themes were identified: procedures and regulations and structures and hierarchies. The first theme refers to the procedures that exist within the partners. According to the interviewees, procedures determine the way things are done and also drive behaviours. The second one refers to the general structures and hierarchies that exist within the network. In more detail, organisations should seek partners who have designated safety managers and safety management systems independent from commercial departments. This is critically important, since safety managers need to be able to put the delivery of a project on hold if they think something is not right. As mentioned previously, the categories presented here are closely linked. The tension between commercial and operations for instance, explains why safety managers should be independent to the commercial managers in order to be able to take proper actions when required.

Environment

Servitized manufacturers need to clearly understand the environment in which their partners and customers operate in. This involves understanding more about the sector and relevant legislation. While the environment is not something that can be affected, it provides crucial information for setting up the processes and communication paths between the partners. In more detail, each sector can have different approaches to safety and acceptable levels of risk. For example, the acceptable level of risk in military environments is different than civil ones. As one of the interviewees explains, in the former case, "*the trade of safety versus performance is absolutely part of the trading space, because it is a weapon.*" Finally, legislation is important as it determines the acceptable levels of risk (per country or per sector), the requirements for both safety management and incident reporting systems and any ISO and HSE requirements.

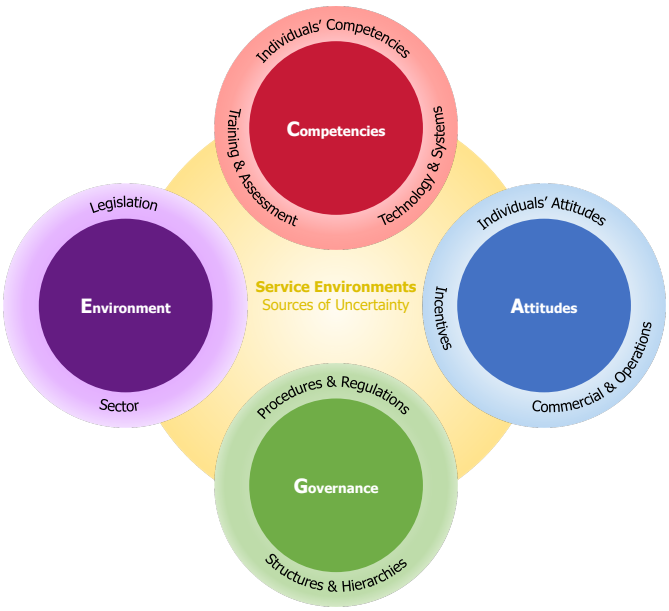

Figure 1. The CAGE Framework

Conclusion and Implications

The analysis of the preliminary study revealed four main sources of complexities: competencies, attitudes, governance, and the environment in which the partners operate, all of which are also closely interrelated. However, the main purpose of this preliminary study was not only to understand more about the common sources of complexities in service networks, but also to identify the main concern of the participants and proceed to the next round of data collection with a more focused approach and generate theory (e.g., Glaser, 1998). Despite the various challenges that the participants identified, a common issue was present in all four dimensions.

For instance, one of the main concerns in the competencies dimension was related to having both competent people and systems, so as to ensure that the whole network can sustain a high level of safety. Considering the second dimension, attitudes, one of the main concerns was related to having a unified incentives system and specifically one that does not compromise safety. One of the main concerns in the governance dimension was to have a clear separation between safety managers and operation managers. This would ensure that the organisation will not compromise safety in order to secure revenues. Finally, with regards to the fourth dimension, environment, the main concern was that the different environments that partners operate in can have an effect on acceptable levels of risk, and therefore, safety. Thus, it is clear that across the different themes and participants, potential safety risks seem to be a common concern.

In order to further support this finding, the researcher run a frequency word search in the transcripts with the help of the NVivo® software. In more detail, the frequency query looked into the forty most mentioned words in the transcripts, excluding any words with less than three characters. From the initial list of forty words, twenty-three words, such as 'yes', 'got', 'example', or 'back', among others, were excluded, since they offered no further insights. The researcher then looked into the remaining seventeen words in order to verify or refute the previous finding. The detailed list of the final seventeen words is presented in Table 2.

Table 2. Most frequently used words during interviews

Word	Frequency	Word	Frequency
accountability	721	**accountable**	208
service	441	**responsibility**	200
people	425	**something**	198
contract	317	**culture**	185
organisation	285	**systems**	184
safety	275	**contracts**	180
things	270	**time**	180
different	263	**governance**	179

Not surprisingly, the most frequently used word was accountability. This finding supports the previous argument that most of the challenges identified were related to a confusion of accountabilities or conflicting accountabilities. Even after excluding any references, where the word was used as part of the main theme of the interviews, that is, "through-life accountability" or "accountability through-life", the word was still mentioned 648 times (or 856 times including the word "accountable"), a lot more than the next most frequently used word, "service". The frequent use of the latter was also to be expected since the discussions were related to complex services. Two more of the most frequently used words were "people" and "organisation" showing that service networks are dynamic and largely depend on the people and organisations involved. The fourth most mentioned word was "contract", most often used referring to a service contract. The sixth most mentioned word was the word "safety". What is more, "safety" was mentioned by 91% of the respondents, supporting the argument that safety was a common concern between the majority of the participants.

Contributions and Implications

The main contribution of this study is in the field of servitization. More specifically, this study addresses an under-researched part of servitization: the sources of complexities associated with service networks characterising service provision, and the impact that these complex service networks can have on safety.

This research addresses an important issue for practitioners. With services becoming increasingly important, organisations need to be able to work in large networks effectively. The research revealed the common sources of complexities within a service network that organisations need to be aware of. Servitized manufacturers first need to address these elements within their own organisations. Then, identify any misalignments within the service network and address them externally as well. By identifying any misalignments within their service networks, organisations can identify the specific areas that need improvement. The framework, therefore, can be used in a number of different ways by servitized manufacturers, such as for understanding complexities/ risks within their networks, for planning purposes or for selecting suppliers/customers and for audit/mentoring purposes.

It is also found that complex service networks can expose the organisation to increased risks that can impact safety. The dimensions of the CAGE framework can help the organisation understand the areas that need to be improved. The recommended framework represents a novel approach for managing complex service networks, and also demonstrates that the different risks must not be treated as stand-alone or static elements but rather as a holistic framework. Managing complex service networks is an ongoing process that involves multiple organisations and people.

Limitations and suggestions for further research

As an exploratory research, this study presents a number of limitations that serve as promising avenues for future research. Particularly, although the selected methodology was justified, the research was qualitative and exploratory and therefore, does not provide statistical but only theoretical generalisation (Yin, 2003). Furthermore, the study focuses on 68 interviews from experts in the service field, and from a small number of different organisations. Using a sample from additional sectors might provide new insights. What is more, since the majority of the interviews involved participants from the main 'contractor', further research could focus on involving a larger sample of participants from the customer of these contracts and sub-suppliers of the service network. To this end, further research from a series of quantitative studies, such as anonymous surveys, that can include a large number of both organisations and participants and various sectors, can help weigh, assess and rank the different dimensions in terms of importance and criticality. The main purpose of this study was to examine the sources of complexities within a service network. But most importantly, since the findings from the preliminary study show that despite the various challenges that organisations operating in complex service networks face, a recurring theme revolved around how these can potentially impact safety, future research should focus more on understanding the impact that these complex service networks can have on safety.

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Servitization in the renewable energy supply chain – Explorative analysis in the Finnish energy sector

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Abstract

This explorative study investigates the actors and services in the renewable energy supply chain in Finland. A data set of 86 companies is developed, consisting of 1116 documents describing the service portfolio of the companies and their business activities. These are analysed to characterize the companies and examine the scope of their service activities. Specialized services and actors are identified for each type of renewable energy, and further research avenues for servitization scholars are proposed.

Keywords: Servitization, Renewable energy, Supply networks

Introduction

The adoption of renewable energy (RE) production technologies increases the number of actors and geographical decentralization in the energy supply network. Large installations are developed by energy companies especially for wind power, but the number of small, distributed installations also increases. The growth of distributed renewable energy forms depends on new actors taking the role of producer in the RE supply. These actors can be local 'prosumers' and energy production may not be their core activity (Child et al., 2017). Renewable and carbon-free energy necessitates the use of energy reserves, smart grids and local micro-grids to balancing of the production and consumption (Camarinha-Matos, 2016). These developments introduce market needs for advanced and supporting industrial services in the energy sector supply chain.

This research project explores services supporting and enabling *renewable energy supply chains* (RESC, for short) in the Finnish energy sector. The research aims to identify and categorize actors and service activities associated with the different forms of energy production in the RESC. The study uses the structural meta-model of servitization (Brax & Visintin 2017) to compare the service activities and map the range of services across the life-cycle of the renewable energy product-service systems.

Research methods

Explorative and theory building mode is used due to the novelty of the research topic. As explorative research requires boundaries to control the amount of data, the current analysis focuses on the Finnish energy sector which was selected as the case market for several reasons. Finnish industries are known to have high levels of servitization, and

several OEMs providing technology products and services for energy production are located in Finland. Furthermore, the regulations for operations and safety are strict, the renewable energy sector is growing, and trading surplus energy to the grid has become available to small-scale producers relatively recently.

The study aimed at forming a representative dataset of companies operating in the renewable energy supply chain in Finland. While the electricity producers, distributors and trade companies are easily identifiable from business information databases, industry classifications are less specific in identifying suppliers to renewable energy production. Therefore, the strategy to identify companies combines online searches on various websites and company lists based on industry classifications from statistical database (Amadeus from Bureau van Dijk).

The final sample of the current analysis, 86 firms, was searched as follows. Amadeus database was searched for active companies in focal industries. NAICS industry codes were used as selection criteria as, in comparison to NACE, NAICS enables a more fine-tuned sorting of industry activities in the sub-industry level. The researchers first identified the focal subindustries:

- 221111 - Hydroelectric Power Generation
- 221114 - Solar Electric Power Generation
- 221115 - Wind Electric Power Generation
- 221116 - Geothermal Electric Power Generation
- 221117 - Biomass Electric Power Generation
- 221118 - Other Electric Power Generation
- 237130 - Power and Communication Line and Related Structures Construction
- 237990 - Other Heavy and Civil Engineering Construction
- 238210 - Electrical Contractors and Other Wiring Installation Contractors
- 333611 - Turbine and Turbine Generator Set Units Manufacturing
- 334413 - Semiconductor and Related Device Manufacturing
- 335311 - Power, Distribution, and Specialty Transformer Manufacturing
- 423690 - Other Electronic Parts and Equipment Merchant Wholesalers
- 926130 - Regulation and Administration of Communications, Electric, Gas, and Other Utilities.

This search identified 5419 active firms in Finland (out of 447 916 firms in the database gobally). Next, to scope the search on companies operating in the renewable energy supply chain, a set of textual search terms were used in three descriptive felds (trade description, national activity labels, and overview), to identify any of the following terms: "hydro", "solar", "wind", "geothermal", "biomass", "alternative energy", and "ocean wave". The list of search terms was developed based on an examination of the descriptions of the NAICS codes in the abovementioned industries. This search resulted in a list of 337 companies in Finland (out of the global 32 951 such companies in the database). Statistics and background information for the companies in these lists was downloaded from Amadeus.

The list of 337 companies was manually examined and implemented in the data collection process which resulted in the final sample consisting of 86 companies. For each of the 337 companies, the researcher first examined the company records in the Amadeus database, to determine whether it was an independent company or a subsidiary. Next, the researcher examined whether the company had a website that describes their business activities and offerings. Then, the researcher downloaded the descriptive web pages, recorded them and saved as PDF files. The researcher sought information about the firm’s business, products and services, and about the company itself. The highest amount of

documents was 128 for Fortum Oyj which is also the largest company in the sample, and 46 documents for the next one, Prokon Oy. Excluding Fortum as an outlier, the sample has 11.6 documents per firm on average. Companies without a web site were excluded from the data in the preliminary analysis which is reported in this study. Companies without web sites appeared to be typically either 1) very small and temporary developers for wind park permissions, as described below, 2) privately owned small wind turbine installations, or 3) active water plants producing electricity to institutional customers.

The data was collected in the level of independent, operating companies. For subsidiaries, the researcher thus identified their parent company. If the company had several companies as owners, none of them to the extent of a parent company (i.e., owning shares exceeding 50%), the firm was considered independent. The global ultimate owner indicated by the database was used, if it was a company, not a private person or a municipality. For giant multinational companies the direct foreign parent of the Finnish subsidiary was used. These steps were necessary as the energy sector is highly networked, apparently more so than in manufacturing companies. This is because the companies producing or consuming large quantities of energy secure the supply by distributing production and ownership to several forms of energy production, on multiple locations, and in several companies. In this industry, all production units are typically subsidiaries, not branches. Thus, smallest firms are the size of a single windmill. Moreover, since the process to gain permissions for a wind park is risky and challenging, small private startups exist only to develop permissions for a specific location, and sell the plans to larger firms if they succeed in the process, thus being somewhat temporary arrangements in the supply chain.

The data was then thematically analyzed using the meta-model of servitization (Brax & Visintin, 2017) as a reference structure, using the Atlas.TI software for coding. Due to the complicated procedures in the sampling stage, the data collection was much more laborious than expected. Thus the current paper reports preliminary findings from this data set.

Findings

The preliminary findings indicate that advanced services are provided for wind energy installations and hydropower plants across their lifecycle, and for solar power installations in the early phases of the lifecycle. The service profile for different forms of RE vary; solar energy requires very little maintenance, whereas windmills require regular highly specialized maintenance. Wind farms is a growth market, whereas the hydropower market (about 250 plants) is not likely to grow.

Finnish RE technology providers are OEMs that provide services for the entire lifecycle of the installations. These include VEO, Moventas and Naps Solar. VEO provides installations combining multiple renewable energy sources (thermal, wind, hydro) and hybrid-engine power. In addition to providing gearboxes and basic maintenance services, Moventas provides refurbishing services with preowned gearboxes. In addition to OEMs, some project integrators are found in the market. For instance, SavoSolar develops photovoltaic power plants and exports them.

Specialized firms provide technical consultancy and inspection over the life-cycle of windmills, and legal services for new wind farm projects. Services are provided especially in the planning phase, and some companies such as JBE Services provide continuous monitoring, maintenance and dismantling services. Companies with Finnish origin serving the wind farms include JBE Services, Moventas and Suomen Hyötytuuli, a company owned by major Finnish city energy companies that operates several offshore wind farms. Maintpartner operates and maintains six hydropower plants for UPM, a large

paper mill company. Naps Solar combines business intelligence with solar power systems, providing turnkey on-grid photovoltaic systems, remote monitoring and maintenance, consulting and 'solar power as a service'. Nocart provides integrated product-service-systems for power plants combining multiple technologies to produce renewable energy, including biogas, thermal, solar, wind and hydropower.

The data set includes two particularly innovative startups. The technology provider Wello is a startup OEM developing and manufacturing boat-like small power plants to generate electricity from waves. The other interesting startup is Soletair. This firm develops carbon recycling processes based on air-capture technologies. In the Soletair concept, carbon is captured from air to be combined with hydrogen to produce hydrocarbons that can replace fossil based hydrocarbons and, when made into long-lasting products, form artificial carbon sinks. As the name of the company suggests, the carbon recycling processes are operated using solar energy.

Foreign RE companies with customer base in Finland belong to the OEM category, including Vestas, Siemens Gamesa, The Switch, Nordex, Rexel and Areva Solar. Areva Solar provides solar panel installations based on a product-focused business model. Rexel combines photovoltaic systems with industrial data centers and smart home solutions, including lighting, vehicle charging and data cabling. Vestas has provided over 350 wind turbines to Finnish wind farms and provides maintenance and operations services to them, as well a fleet optimization and, partnering with Utopus Insights, digitalization for renewable energy assets.

In addition to OEMs, a growing number of foreign investor-developers develop, build and own wind parks in Finland: ABO Wind, CPC Germania, Enefit, Entelios, Etha Wind, Intercon Energy, OX2, Sauria, Svevind, Vindin, and WPD. These companies typically enter the market by buying projects from small entrepreneurs who initiate the project and sell the plans if permissions are granted.

In contrast, Finnish developer companies carry out the risky planning and permission process themselves, and also offer development services for private investors and land owners. These companies are Allwinds, Hyötytuuli, Ilmatar, Lestijärvi Windpower, Lumituuli, Lähituuli, Puhuri, Rajakiiri, Smart Windpower, Suomen Merituuli, Suomen Tuulivoima, Services provided by these companies fall into two main categories, these consist of project management services focusing on the development and building of wind parks, or cover the entire lifecycle of the wind park from initial business screening to demolition. Because many of these companies are relatively young in the Finnish market, in-depth comparisons of their economic success are not worthwhile at the moment. Acquiring of permissions for wind parks is risky and can be extended due to complaints and appeals, and the proceedings required by authorities – these are assessed individually for each case.

Conclusion and discussion

Servitization scholars in the operations management community can contribute to sustainability in the energy sector by focusing on the service operations that support the renewable energy supply chain. The exploratory study indicates that Finnish technology companies exhibit advanced capabilities in servitization especially in the area of wind power and mixed power systems, and successfully export their services.

Service requirements for solar power are less complex and therefore represent the product-centric end of the servitization meta-model. However, the data shows that companies that develop and operate large installations can develop successful business models in the solar power sector as well. The competitive elements in such succeeding

business models are in the service aspects of an end-to-end solution, as price competition for the solar power panels is tough, and the panels in the market are substitutable.

Servitization research has mostly focused on OEMs in various technology intensive manufacturing industries, without particular interest on the renewable energy supply chain. The current analysis shows that the renewable energy supply chain is an important area for servitization scholars to explore further as the supply of renewable energy is critically dependent on several types of services. Since activities in the renewable energy production are rapidly increasing, as fossil-based energy production and peat are replaced with more sustainable energy forms, development of the services in these supply chains can contribute to improved efficiency and green sustainability.

In addition, servitization research in the past has focused on the transition of industrial companies towards more service-dominant business models. The energy sector is facing a transition as established companies are changing their power plants and production facilities to enable the use of renewable sources of energy. In addition, this disruption requires advancing digitalization across the RE supply chain, as other forms of biofuels need to be readily available and used to balance the fluctuation in wind and solar power.

The current study is a brief outlook on the developing renewable energy supply chain in the Finnish market and thus is a subject to major limitations. In its current form, the sample is neither fully representative nor random. This is because not all companies provide information about their offerings online - this is especially common for small companies, as well as for companies that are specialized contractors for other firms and do not market their services. The aim is to develop a dataset representative of the large and midsize companies in the market. Large and midsize companies extensively document their service portfolio in the publicly available material. The collected data allows a detailed analysis of the business activities of the firms in the sample. Further and more detailed analysis are to be carried out, aiming at quantitative analysis across the different types of services.

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Servitization of maintenance. A roadmap approach in the context of asset management

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Abstract

This paper aims at smoothing the servitization process for capital asset OEMs. To such purpose, the paper provides a map that links a wide range of services with the maintenance technologies which capacitate the manufacturers to deliver the service in a cost-effective way. The process of shifting towards a business model of servitizied maintenance is supported by considering the characteristics of operations management to take into account in this new scenario. The consideration of the operational aspects is proposed by means of Technology Roadmap tool with a new extra layer considering structural and infrastructural operational characteristics.

Keywords: Servitization, Maintenance technologies, Operations characteristics

Introduction, motivation and related works

Original Equipment Manufacturers (OEMs) have been challenged by the increasing presence in the market of new producers able to offer acceptable quality standards at a low-cost labour base (Baines, et al., 2007). This change of paradigm has encouraged their transition from selling products to selling services, seeking high returns and additional growth opportunities (Kohtamäki, et al., 2018). The transition process, known as servitization, transforms the strategic and operational business logic from product-oriented to service-oriented by placing increasing emphasis on customers and relationships (Baines, et al., 2009a; Rabetino, et al., 2017). In this context, the offer based

in the pure product is shifting towards an offer in which the product and the services are bundled to provide higher value to the user (Lightfoot, et al., 2013; Baines & Lightfoot, 2013). The conjoint offer of product and services is known as Product-Service-System (PSS) and it is of special interest for the scope of the paper - in spite of the several streams of their study (Kohtamäki, et al., 2018) - the body of research that understand them as technical services to be included in the life-cycle of the OEMs' installed base of capital assets (e.g. Aurich, et al., 2004; Nordin & Kowalkowski, 2010).

The adoption of PSS is expected to bring additional value not only for the asset manufacturer but for the customers as well (Cohen & Whang, 1997). Therefore, the conjoint offer of services and knowledge-intensive products may stand as a competitive advantage (Baines, et al., 2007; Banks, 2003). However, the technical complexities regarding the asset make the definition and implementation of PSS rather challenging (Teixeira, et al., 2012). In such context, the asset management discipline stands as a key pillar to capacitate the transition from a product-based offer to PSS whilst properly addressing the assets' technical challenges. As a matter of fact, most of the PSS offers found in the literature for capital assets include a considerable amount of maintenance related services (Gaiardelli, et al., 2014), and maintenance management has been considered a fundamental process of asset management indeed (Hastings, 2010; Crespo, et al., 2009). Therefore, if OEMs are willing to offer maintenance services for their installed base, one way to do so is by using their technological competences (Gremyr, et al., 2010; Exner, et al., 2017).

The benefits of the synergy among PSS and operational excellence has already been stated (e.g. Exner, et al., 2017; Goncalves & Kokkolaras, 2017). The idea considering the servitization of maintenance is not new in the literature (Lee, et al., 2014a) and it is expected to bring benefits in terms of service quality, downtimes reduction, product reliability or trustworthy relationships among others (Mourtzis, et al., 2017; Exner, et al., 2017; Gaiardelli, et al., 2014). However, manufacturers usually face technical challenges associated with the management of the PSS and the absorption of risks related to the service. In spite of the extensive research existent for both, maintenance management and servitization, to the best of authors' knowledge, it is difficult to find information regarding the technological capacitation requisites in order to offer certain maintenance-related PSS ensuring the profitability of the business.

Hence, this paper aims at smoothing the servitization process of OEMs willing to offer maintenance-related services for their installed base. To such aim, the PSS classifications proposed by Gaiardelli et al. (Gaiardelli, et al., 2014) and by Rabetino et al. (Rabetino, et al., 2015) are adapted. In the research, the classification is made according to three main types of PSS: (i) Product-oriented, (ii) Use-oriented and (iii) Result-oriented (Tukker, 2004).

- *Product-oriented:* the owner of the product is the customer and the business model is still focused on the product. The manufacturer provides additional services included in the sale (Aurich, et al., 2010).
- *Use-oriented:* the ownership of the product remains in the manufacturer and the business model is to sell its use, therefore it is the manufacturer the responsible of the services (Aurich, et al., 2010; Kang & Wimmer, 2008).
- *Result-oriented:* the business model shift to a scenario in which it is the outcome or capability of the product what it is sold. The manufacturer owns the product and the customer pays its performance (Tukker, 2004).

The work here presented relates the services with the maintenance technologies to develop if the services were to be implemented in the PSS portfolio of the OEMs. Here the term *technology* is defined as "the knowledge for solving technical problems"

(Schenkl, et al., 2014). Accordingly, the maintenance technologies are also conceived regarding whether they enable the transaction of the asset or the relationship with the customer, a perspective also found in the literature (Rabetino, et al., 2015). The linkage between the services and key-resource maintenance technologies is considered within the wide context of asset management. Hence, other fundamental aspects of asset management are considered as supporting processes for achieving servitization whilst thriving at maintenance.

Among the fundamental aspects of asset management, special emphasis is made on the operations strategy of the OEMs in order to implement the maintenance-related services. Applying traditional operations concepts to the management of service operations may limit the success of the service implementation (Davis & Heineke, 2004), given that service operations tend to focus more on relationship development whereas product centred operations tend to be more transactional-oriented (Baines, et al., 2009b). According to Baines et al. (Baines, et al., 2009a), the different operations strategy aspects are classified as structural or infrastructural. Besides, it is essential that the operations are considered from a product-centric services perspective.

In order to provide with a comprehensive and practical approach to consider all the aspects related to maintenance and asset management, a roadmap template is proposed as a tool intended to facilitate the implementation of the maintenance-related services and their associated technologies. Technology Roadmap (TRM) has position itself as one of the most well-known methods for aligning strategy and management of technology (Phaal, et al., 2004; Lee & Park, 2005; Amadi-Echendu, et al., 2011). Its popularity is due to the capability of providing a graphic representation to explore and communicate relationships among markets, products/services and technologies over time (Geum, et al., 2013). Although there are many variations for the representation of a TRM, it usually includes a connected multilayer perspective with a time-oriented distribution (Probert, et al., 2003; Wells, et al., 2004). In Table 1, the layers considered by Carvalho et al. (Carvalho, et al., 2013) are presented. In the literature a variety of roadmaps applications can be found but, given the introduced shift to servitization, the research direction should be headed to the co-evolutionary and integrative planning of PSS (Geum, et al., 2011). The proposal here presented, links the services associated with the installed base of OEMs with the maintenance technologies needed for proper service delivery. The literature has shown that roadmaps are a useful tool not only for the implementation of PSS (Geum, et al., 2011; Geum & Park, 2010) but for achieving maintenance excellence (Mostafa, et al., 2015; Hauge & Mercier, 2003).

Table 1 – Generalized TRM architecture according to Carvalho et al. (Carvalho2013)

Layer	Content	Description
1 (Upper)	Business or market goals	In this layer the goals are associated with the purposes of the items in the lower layers. They are considered the *know-why*.
2 (Middle)	Products, services, capabilities or systems.	This layer contains the items to deliver in order to fulfil the purposes, they are considered the *know-what.*
3 (Lower)	Technology, skills, competences or resources	The resources needed to deliver the items in layer 2. They are considered the *know-how*.

Research methodology

The research here presented is the output the interplay between two literature reviews regarding (i) servitization and PSS definition and (ii) maintenance within asset management discipline. The linkage among these two topics is what will contribute to the servitization of maintenance and it is based on the extensive literature review and the authors' experience with industrial applications.

On the one hand, the PSS offerings have been adapted from the research conducted by Gaiardelli et al. (Gaiardelli, et al., 2014) in which the offering is classified according to the dimensions defined by Tukker (Tukker, 2004) and explained in the previous section. The selected PSS offerings have been represented in blue circles codified by a reference number, the correspondence among the codification number and PSS can be seen in Table 2.

Table 2 – List of PSS offerings (Adapted from Gaiardelli et al., 2014)

Ref	PSS Offering	Ref	PSS Offering	Ref	PSS Offering
1	Home delivery	13	Off-site repairs	25	New products-oriented training
2	Installation, start-up and commissioning	14	Extended warranty	26	Product oriented consultancy
3	Standard spare parts delivery	15	Preventive maintenance	27	Process oriented consultancy
4	Ad-hoc spare parts delivery	16	Full maintenance	28	New products consultancy
5	Cleaning	17	Predictive maintenance	29	Leasing
6	Updates	18	Overhaul	30	Short term renting
7	Upgrading	19	Documentation	31	Long term renting
8	Refurbishment	20	Hotline for product support	32	Sharing
9	Recycling and take back	21	Hotline for process support	33	Pooling
10	Financial services	22	Hotline for new products	34	Pay per use
11	Inspection and diagnosis	23	Product-oriented training	35	Outsourcing
12	On-site repairs	24	Process-oriented training	36	Functional-based pay-per result

On the other hand, the research conducted for the different maintenance technologies and their relationship with the several PSS offerings can be seen in Table 3. In the table, each one of the technologies is briefly explained from the service-related perspective, given the scope of the paper. Besides, for the readers interested in further information, key references on each technology are presented also in Table 3. The maintenance technologies have been arranged according to whether they enable the transaction of the asset or they tend to promote a relationship with the customer. The potential of advanced maintenance technologies as enablers of service-oriented business model has been stated in the literature (Arnaiz, et al., 2016) and the transactional-relational perspective can be seen in previously mentioned related works (Gaiardelli, et al., 2014; Rabetino, et al., 2015).

Table 3 – Maintenance Technologies (Adapted from Gaiardelli et al., 2014)

Maintenance Technology	Description	Key reference
Fault Tree Analysis	It is a deductive and structured methodology to determine the potential causes of an undesired event by decomposing it into minor events combined by logical operators.	(Khakzad, et al., 2011)
Criticality Analysis	Process with a systematic basis for deciding what assets and failure modes should have priority within a maintenance management program aligning it with the business goals.	(Crespo, et al., 2016)
Failure Mode, Effects and Criticality Analysis (FMECA)	Tool for identifying all the failure modes of an asset. Also the effects of that failure in terms of human safety, environmental consequences and business impact.	(Carmignani, 2009)
Root Cause Analysis (RCA)	Systematic process to breakdown the failure into its causes identifying the principal one in order to prevent it from happening.	(Rooney & Vanden Hauvel, 2004)
Inspection & remote maintenance support	Set of technologies that enable to provide remote support in maintenance tasks. It comprehends work instructions, information, description of procedures, etc. It may be aided by Virtual Reality or Augmented Reality.	(Masoni, et al., 2017)
Reliability Centred Maintenance (RCM)	Methodology to identify the main maintenance needs in order to preserve system functionality and ensure its reliability.	(Rausand, 1998)
Diagnosis technologies	Set of technologies used for mapping the symptoms of failure with the equipment problems in order to identify the cause. The state of the art technologies consider system's health and operational environment.	(Galar, et al., 2015)
Predictive analytics	Technology focused on predicting the failure event in the equipment by continuously monitoring it in order to dispatch the maintenance activities just before the event.	(Van Horenbeek & Pintelon, 2013)
Prognostic and Health Management (PHM) Technologies	Technologies oriented to assess the health state of the assets and to determine the adequate maintenance actions to minimize de degradation (diagnostics are a part of PHM).	(Lee, et al., 2014b)
Digital Twin for Maintenance	Virtual Representation of the physical asset to simulate its performance and state. It is focused on representing the health state and the effect of maintenance actions.	(Qi & Tao, 2018)
Basic Reliability, Availability and Maintainability (RAM) Modelling	Technology oriented to describe the failure occurrence and estimate its impact on the availability of the asset. It is oriented to estimate the lifecycle costs and therefore it implies business considerations.	(Peng, et al., 2011)
Asset customized RAM	Technologies with the same purpose of basic RAM modelling but taking into account the operational environment of the asset so the analysis and lifecycle cost can be customized.	(Barabadi, et al., 2014)
Dynamic and customized RAM	Customized RAM analysis which not only consider operational environment but changing working condition as well, and their impact on lifecycle costs.	(Izquierdo, et al., 2019)

Contribution. Services and maintenance technologies map

According to the research supported by the related works and the authors' experience in several industrial applications, the map of Figure 1 has been created. In the figure, the different services to offer in order to achieve the servitization of maintenance are mapped with the several maintenance technologies which play a key role in maintenance management excellence.

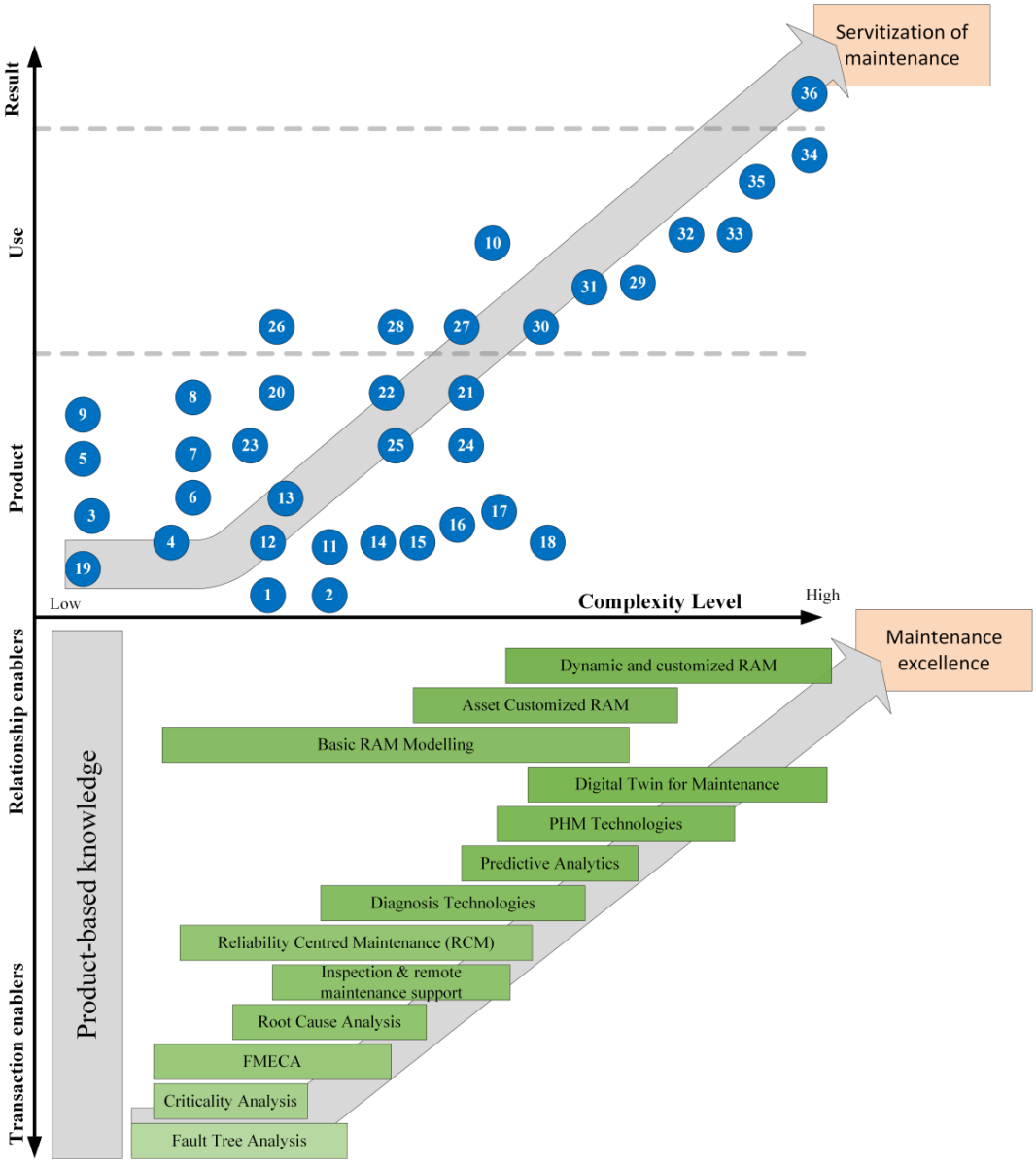

Figure 1 – Services and maintenance technologies map

In the map of the figure, the y-axis for the services has been defined according to the characteristics stated in previous sections: product, use, and result oriented. However, the maintenance technologies have been sorted attending to their potential to make more appealing the pure purchase of the asset (transactions enablers) or their potential to foster loyalty and a long-term relationship with the customer.

As it can be seen in the map, by scaling up the top part, where the services are located, the OEMs achieve the servitization of maintenance and their offers based on PSS become more attractive for the customers. Besides, if whilst scaling up in the services offer, they increasingly adopt the maintenance technologies, not only do they reap the benefits of a more attractive offer, but increase the margins of the offer as well by achieving excellence in maintenance.

Nevertheless, the implementation of the services and the adoption of maintenance technologies aiming at servitization and excellence of maintenance it is not an easy task. A systematic approach is a must to consider the implementation of the targeted service

and the adoption of the technology needed to deliver the service in an efficient and sustainable way. This paper provides a proposition of a roadmap as a tool to ensure that the services and associated technologies, which can be identified in the map in figure 1, are properly considered within the perspective of operations management and thus, ensuring they are cost effective.

The classification of the operations characteristics into structural and infrastructural has been adopted from the literature research, more precisely the operations characteristics proposed in the paper are the product-centric servitizied operations deeply explained in (Baines, et al., 2009a). The aspects covered by both types of operations characteristics are:

- **Structural characteristics of operations.** Include the specific technologies needed in the operations, it is necessary to consider if they are the same for delivering the services. The contemplated aspects regard capacity and facilities needs in case the demand is changing when the services are deployed. Also the positioning in the supply chain in terms of vertical integration and partnerships. Finally, it is also considered here that the planning and control should have the focus on fulfilling the objectives defined by the service contract.
- **Infrastructural characteristics of operations.** It is considered **t**he capacitation of human resources in terms of high product knowledge and relationship development. The quality assurance is controlled according to customer satisfaction assessment and the performance and availability of the product. The portfolio of PSS offers needs to be defined and the launch of new offers should be co-created with the customer and build quality relationships. It is also considered the nature of relationships with the suppliers, they should focus on integration to achieve cost-effective supplies for the PSS.

The consideration of operation management in the roadmap is integrated by means of adding a supporting layer to two bottom layers of the generalized TRM architecture previously described in Table 1. In this supporting layer, the operational aspects are decomposed into two categories according to the previously presented classification of structural and infrastructural aspects from a servitization point of view. A graphical representation of the new TRM proposal which integrates the operations layer can be seen in figure 2. By integrating this extra layer in the roadmap the considerations regarding the operational aspects are taken into account therefore further ensuring the proper implementation and profitability of the services to-be-delivered.

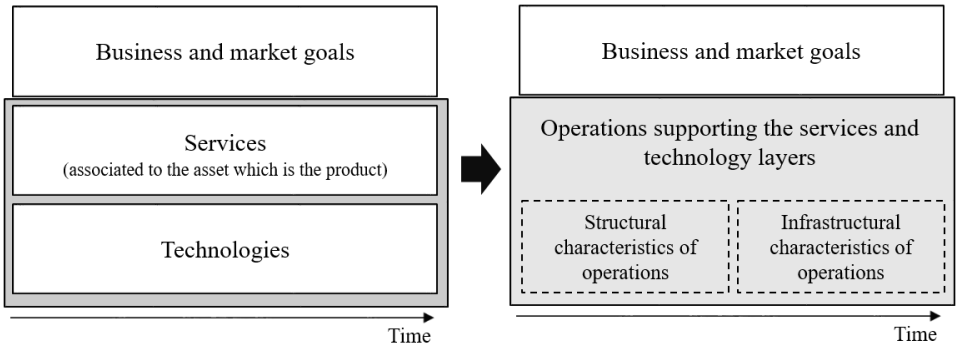

Figure 2 – Proposal of roadmap with operations layer

If the OEMs are willing to deploy certain services by using the proposed roadmap, the design of the two bottom layers is facilitated with the proposal of the services and maintenance technologies map of figure 1. Besides, in order to fully achieve the business

and market goals, the changes in the operations management are considered with the new supporting layer. With this comprehensive proposal, the maintenance technologies, the services, and the operational needs are aligned to the strategic objectives and it is presented in a time-oriented distribution.

Concluding remarks

This paper proposes a research work in the servitization of maintenance for capital assets OEMs. The approach presented comprehensively considers the servitization process within the asset management discipline, especially in terms of its relationship with operations management. It is explored within a roadmap proposal for implementing the services and developing the proper technological capabilities whilst taking into account the characteristics of servitizied operations. However, in spite of the novelty of the presented approach, further research is encouraged to explore the wide applications and implications of the ideas here presented. The authors identify future research lines that cover the development of how the operations should be adapted if the OEMs thrive for the servitization of maintenance. Besides the applicability of the research here presented is also worth of validation and test via case studies given the increasing interests of OEMs in profiting from maintenance as a service.

The literature shows that there is an increasing number of capital assets OEMs willing to undergo the servitization process seeking recurrent income through servitizied maintenance. Therefore the maintenance technologies and services map here presented has the potential of easing their transition, not only in technology capacitation but in operational readiness to support the deployment of maintenance services.

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Towards a seamless supply chain: A systematic literature review of influencing factors

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Abstract

The core rationale of supply chain management envisages an integrated supply chain as key to enhanced performance. However, this "end-to-end" approach has not been fully realized. The aim of this paper is to provide a comprehensive review and analysis of factors influencing integration in the supply chain. This is achieved through an exhaustive systematic literature review. From the analysis of 74 articles, a three-path influencing factors model is identified at internal, supplier and customer scopes. Subsequently, influencing factors are categorized into enablers, inhibitors, and dual according to behavioural patterns. The proposed framework provides an all-encompassing overview of factors influencing integration.

Keywords: supply chain integration, enablers, inhibitors

Introduction

Integration is the underlying perquisite to effective supply chain management (SCM). Hence, the study of supply chain integration (SCI) is central to SCM. Approaches to SCI suggest an emphasis in collaboration, coordination and integration in the flow of materials, services, processes and information through the entire SC with the ultimate objective of achieving an end-to-end supply chain (Chang et al. 2016; Childerhouse and Towill, 2003; Flynn et al.2010). Despite the large number of publications exploring SCI, very few firms have yet materialized the *seamless* supply chain (Towill, 1997). In this view, the industrial challenge of planning integration processes among SC partners is still a major source of poor performance (Richey et al. 2009). Thus, there is a need to identify a novel approach for improving performance across the entire SC beyond the realm of the individual firm.

The present paper focus on the first part of this challenge. Accordingly, the purpose of this paper is to investigate and explain both, sources of poor integration and opportunities to enhance SCI. The aim of this paper is to identify the corresponding roles of different influencing factors in enabling and/or inhibiting SCI. This is achieved through an exhaustive and inclusive systematic literature review (SLR).

Methodology

This paper adopted a five-step improve methodology prescribed by Denyer and Tranfield (2009) to systematically reviewing papers in the field of SCI. This methodology encompasses the five-steps of question formulation, location of studies, selection and evaluation, analysis-synthesis, and report of results. The present research design aims to provide rigor and transparency while minimizing bias. In addition, it benefits from enabling replicability.

Formulation of over-arching research question followed a process of setting the scope of the study, identifying emerging literature and further discussions with members of the review panel. The review question is derived as:

- What are the factors that influence the performance of SCI?

The over-arching question suggested the following sub-research questions:

- What are the sources that lead to poor integration?
- What are the sources that provide an opportunity to improve integration?

Two types of keywords relating to the concept of supply chain and integration were used in developing search strings with Boolean operators. Construct search strings are shown in Table 1:

Table 1: Specification of key words used as search strings

Supply Chain		Integration
("Supply chain" OR "Supply network" OR "Value chain" OR "Value network" OR "Logistics" OR Logistic*)	AND	("Integration" OR Integrat* OR "Alignment" OR align*)

In order to allow access to all relevant literature search strings were applied across four databases: Emerald, ScienceDirect, Scopus and Web of Science. These were screened for title and abstract publications in English language, including academic journals, chapters of edited books, and reports published between 2000 and 2018. From initial search, 23.940 papers were retrieved. Following elimination of duplicates, title and abstract of remaining papers were screened against inclusion and exclusion criteria.

Subsequently, the remaining papers were read in full. In order to identify most relevant publications studies were evaluated against a set of specific quality criteria based on subject matter and quality assessment. These included papers providing a comprehensive understanding of the research are of SCI. Then, studies that contributed to the increasing knowledge of factors influencing the performance of SCI were selected. As a result, 66 papers from the original search were identified as relevant for this research. In addition, 8 publications were included from cross-referencing that were not originally identified in the primary search. In all, 74 papers were analyzed for descriptive and thematic findings. Full selection process is detailed in Figure 1:

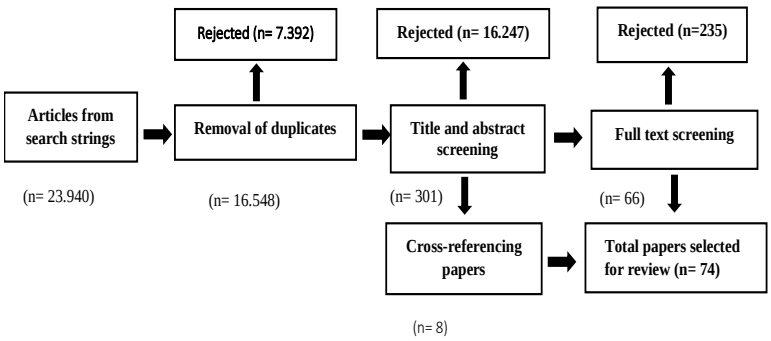

Figure 1. Summary diagram of systematic selection process

Descriptive Findings

The 74 papers selected for review are descriptively analysed in this section in respect of year of publication, research methodology, journal, field of study and industry. The aim of the descriptive analysis is to identify the research trends in the field of SCI.

Figure 2 indicates a gradual interest over the years, with a dramatic increase between 2009 and 2017. During this time 55 papers were published, which amounts to 75% of papers included in this study. A surge in recent publications clearly indicates an increased interest of academics in SCI within the operations management field.

Accordingly, 88% of studies were empirical of which 57 (87%) employed survey and fewer 8 (12%) a case-study method. This confirms the advance mature stage of SCI field, emphasizing a high degree of theoretical development through validation.

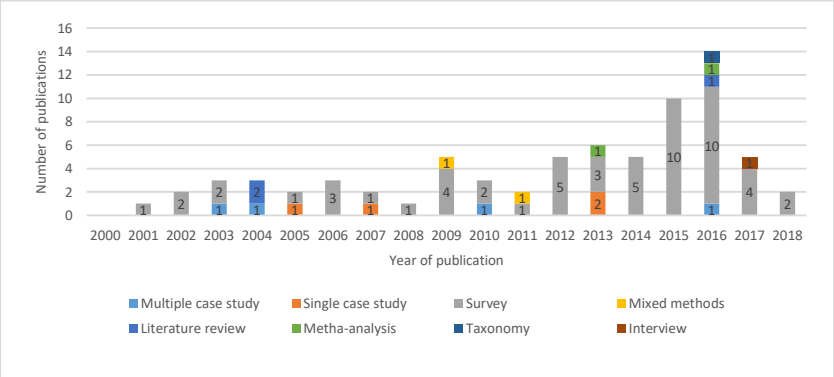

Figure 2. Publications according to year and research methodology

The studies selected for this review were exclusively published in academic journals. Once again, this illustrates the mature stage of this area of research. Likewise, most papers were published in operations management and technology journals (82%), operations research & management science (7%), information management (7%), marketing (1%) and social sciences (1%). This indicates the predominance of studies in operations and technology with little interest from other fields of research.

Finally, the presence of industry sectors is fairly represented across SCI studies. Manufacturing/Machinery (23%), consumer products (19%) and electrical/electronic are predominantly the most discussed industries.

Thematic Findings

This section identify and explain a three-path influencing factors model at three different scopes including internal, supplier and customer.

Types of influencing factors to SCI

Factors are classified as inhibiting, enabling and dual. Inhibiting factors have an exclusive inhibiting influence to a particular scope. Enabling factors have an exclusive enabling influence to a given scope. In contrast, dual factors may act as both enablers and inhibitors at any scope.

At internal scope financial and risk are classified as inhibiting factors. Technology, human intervention, communication, alignment, culture, uncertainty, strategy and

organizational are dual factors, while commitment is a single inhibiting factor. At supplier scope, financial is classified as single inhibiting factor. Correspondingly, technology, human intervention, communication, alignment, culture, uncertainty, strategy, organizational, trust, commitment and risk are dual factors. Dependence and power are single enabling factors. In addition, financial and risk are inhibiting factors to customer integration. Technology, human intervention, communication, alignment, culture, uncertainty, strategy, organizational, trust and commitment are categorized as dual factors. In contrast, dependence and power are classified as enabling factors. The following section identifies influencing factors across different scopes. Figure 3 depicts SCI influencing factors model.

Influencing factors: inhibiting forms

Common across all scopes (internal, supplier and customer)

Influencing factors inhibiting integrative practices across all dimensions include lack of access to high-class technology (Leuschner et al. 2013); lack of a supporting platform/and or practices for technology (Cousins and Menguc 2006); management resistance to change(Bernon et al.,2013; Frohlich, 2002); lack of management support to assist SCI practices (Zhao et al, 2015); management minimizing sharing of sensible strategic information (Trkman et al. 2007; Wang et al., 2014) ; management lack of understanding of SCI; poor SCI- Issue fit Strategic Alignment (Flynn et al. 2016); lack of communication (Forslund and Jonsson, 2009; Pagell, 2004) ; low levels of environmental uncertainty (Wong et al., 2011) ; high levels of market, demand and supply uncertainty (Childerhouse and Towill, 2003; Lu et al. 2018); financial and supply risk (Leuschner et al. 2013; Zhao et al. 2013); independent functionality (Richey et al. 2009) ; lack of technical and business skills, and fragmented planning system (Frohlich, 2002); poor strategic alignment (Flynn et al. 2016); time constrains (Alfalla-Luque et al. 2013); lack of external perspective (Richey et al. 2009); and increased cost associated with acquisition of supporting infrastructure for SCI (Terjesen et al. 2012)

Specific to external scope (supplier and customer)

Influencing factors specific to the external scope include continued use of low performance logistic tools that are outdated and/or incompatible and management "know-best" decision-making (Forslund and Jonsson, 2009); Management hindering integration practices to avoid personal risk (Villena et al., 2009); lack of trust (Revilla and Knoppen, 2015); absence/poor commitment (Yuen, 2016); partners lack of alignment (Das et al., 2006); deviation from the "optimum level" of integration (Swierczek, 2014); restricted share of knowledge or information sharing (Zhu e al., 2018); formal communication channels encouraging transmission but not proximity (Alfalla-Luque et al., 2013); SC partners organizational culture differences (Trkman et al., 2007); lack of governance structure to handle integration (Cousins and Menguc, 2006); centralised hierarchical structures that minimize employees involvement (Flynn et al., 2016); poor understanding of SCI (Leuschner et al., 2013); complexity of processes and materials requirements (Lockström et al., 2010); use of indiscriminate integration practices (Das et al., 2006; Gimenez et al., 2012); shared resources (Van Donk and Van Der Vaart, 2005) ; excessive intensity of SCI (Swierczek, 2014) ;and cost focused firms (Van Der Vaart and Van Donk, 2004)

Specific to internal scope

Influencing factors specific to the internal scope include employee use of soft skills to avoid undesirable jobs (Wang et al., 2014); poor functional, departmental and systems

alignment; poor quality of information hierarchical cultures that promote distance and remove power (Pagell, 2004); internal politics that are not inclusive of SCM practices (Zsidisin et al., 2015); and organizational resistance to change (Gimenez and Ventura, 2005).

Specific to supplier scope
Inhibiting forms include management cultural differences and a lack of cultural understanding (Lockström et al., 2010); and poor quality of information (Alfalla-Luque et al., 2013)

Specific to customer scope
Influencing factors specific to customer scope include instrumental commitment (Zhao et al., 2008); hierarchical cultures (Cao et al., 2015); high levels of demand risk (Zhao et al., 2013); and partners use of coercive power in the relationship (Zhao et al., 2008).

Influencing factors: enabling forms
Common across all scopes (internal, supplier and customer)
Influencing factors enabling integrative practices across all dimensions include logistic tools (Alfalla-Luque et al., 2013); processes supporting its functioning (Arun et al., 2006); top management support (Zhao et al, 2015); human capital (Huo et al.,2016a); high levels of communication (Bernon et al.,2013); supporting communication structure (Kim and Narasimhan, 2002); information and knowledge sharing, and knowledge capability supporting structure (Prajogo, and Olhager, 2012; Richey et al., 2009; Turkulainen et al., 2017a; Zhu e al., 2018); commitment to the relationship and identification with the firms' common norms and values (Huo et al.,2016a); alignment of SCI to the type of performance indicator aimed to improve and alignment of enabler and degree of SCI (Wong et al., 2011); development and group cultures (Cao et al., 2015); high environmental uncertainty (Terjesen et al., 2012); an external strategic orientation (Yunus and Tadisina, 2016) ; pursue of both internal and external integration jointly as they beneficially influence one another (Gimenez and Ventura, 2005); strategic processes and practices that support SCI (Terjesen et al., 2012); closer location to the customer order decoupling point (CODP) (Van Donk and Van Doorne, 2016); supporting management and information processing infrastructure (Srinivasan and Swink, 2015); and use of common platforms (Ralston et al. 2015).

Specific to external scope (supplier and customer)
Enabling forms of factors specific to the external scope include the use of inter-personal relationships (Wang et al., 2016); information integration (Prajogo, and Olhager, 2012); equal levels of dependence among SC partners (Zhang and Huo, 2013) ; trust (Chang et al., 2016); a reliable and genuine interest in the relationship (Vijayasarathy, 2010) ; desire to move from traditional to strategic collaboration (Yuen, 2016); open-minded and honesty (Zhang and Huo, 2013); appropriate use of power (Wang et al., 2016); partners alignment (Li et al., 2009); externally focused culture (Yunus and Tadisina, 2016); high Specification and volume uncertainty (Van Donk and Van Der Vaart, 2005); internal integration approach as key to achieve further integration (Gu et al., 2017); an evolutionary process approach to integration (II->SI->CI) (Chen, 2016); strategic collaborative practices (Frohlich, 2002); information integration strategy (Prajogo, and Olhager, 2012); pursue of coordinative practices (Wiengarten and Longoni, 2015); a simplification approach (Childerhouse and Towill, 2003); use of intangible/inimitable resources (Xu et al., 2014); a low "proactive" strategic orientation (Stonebraker and Liao,

2004) ; an “inside-out" removal of integration obstacles strategy (Frohlich, 2002); a socialization strategy (Cousins and Menguc, 2006); a continuous improvement approach to integration “not a one-time thing” (Trkman et al., 2007); joint influence of both interpersonal relationships and inter- organizational relationships (Wang et al., 2016); and a long-term relationship approach (Yuen, 2016).

Specific to internal scope

Enabling forms of factors at the internal scope include an open communication climate (Zsidisin et al., 2015); real time cross-functional communication that is informal (Arun et al., 2006); employee commitment (Alfalla-Luque et al, 2015); goal alignment (Turkulainen et al., 2017a); inter-departmental alignment (Alfalla-Luque et al., 2013); cultures that promote collaboration (Pagell, 2004); an innovative orientation (Lii and Kuo, 2016); the “optimal timing" of Integration efforts must precede the practice intended to improve or being applied at a nascent stage (Narasimhan and Das, 2001); flatter/ de-centralized organizational structures (Flynn et al., 2016); and inter-functional and Inter-departmental integration (Moyano-Fuentes et al., 2016).

Specific to supplier scope

Enabling forms specific at supplier scope include alignment of SCI efforts-environment (He et al., 2017); collectivism Culture (Chang et al., 2016); risk management practices (Villena et al., 2009); technological uncertainty (Huang et al., 2014); joint decision-making (He et al., 2017); and imitation of peers (Turkulainen et al., 2017b)

Specific to customer scope

Specific enabling forms at customer scope include high quality and consistent information (Chavez et al., 2015); and planning systems integration (Bernon et al.,2013).

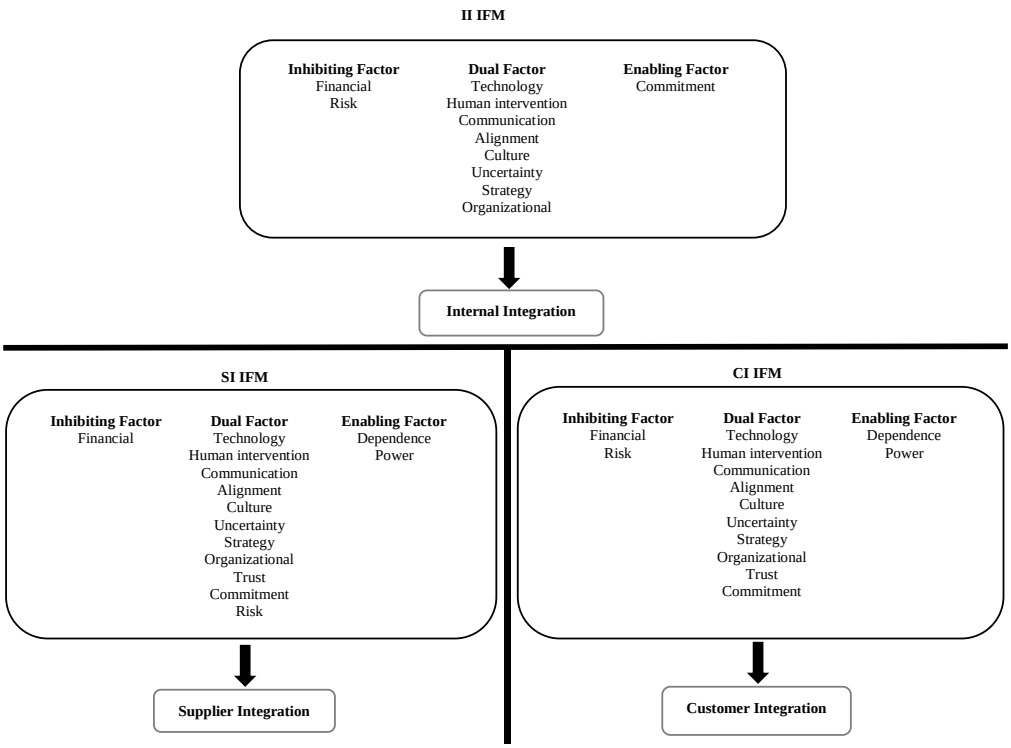

Figure 3. SCI Influencing Factors Model

Conclusion

This paper investigates factors that influence realization of SCI. From the analysis of 74 papers a three-path influencing factors model is identified at internal, supplier and customer scopes. Subsequently, influencing factors are classified as enabling, inhibiting, and dual according to behavioural patterns. The main outcome of this study is the establishment of a framework that explains the relationship between influencing factors and integration at specific scope levels. Hence, influencing factors to SCI act at scope level, with all three scopes influenced differently resulting in factors variation across scopes. This illustrates the complexity to understand SCI in practice and to achieve realization of the seamless SC. This framework should be used as a foundation to develop hypothesis and further empirical work.

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Supply Chain Management

Supply Chain Finance: a decision framework for inventory and equipment-based solutions

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Abstract
This paper aims at investigating a new stream of Supply Chain Finance literature called Asset-Based Lending that encompasses 3 inventory-based and 4 equipment-based financing solutions. The objective is to create a decision framework that could help in the choice of implementing a specific solution, given the objectives of a firm and the contingent factors that push companies in adopting it. The research was carried out adopting a case study methodology, in particular 25 embedded case studies by interviewing 15 solution providers. Results show which are the most relevant objectives and contingent factors that influence the adoption of ABL solutions.

Keywords: Supply Chain Finance; Asset-Based Lending

Introduction

Supply Chain Finance (SCF) is a mix of models, solutions, and services aiming to both optimise the financial performance and control working capital within a supply chain, exploiting a deep knowledge of supply chain relations and dynamics. (Gelsomino et al., 2016). The SCF solutions investigated in literature mainly focus on trade receivables and payables, more seldom inventories, while some authors suggest to include also the financing of fixed-assets within the scope of SCF (Caniato et al., 2019). Generally, the focus is on financing and cost optimisation of working capital within the supply chain, butalso the management of fixed assets covers an important role in the evaluation of firms' performances (Gomm, 2010). For these reasons, some authors are extending the SCF vision to the domain of assets and an important stream of literature, called Asset-Based Lending (ABL), is emerging (Berger & Udell, 2006; Buzacott & Zhang, 2004; Hofmann, 2009; Cornaggia et al., 2013). Asset-Based Lending includes all those solutions in which a physical asset is the collateral of the financing agreement. (Osservatorio Supply Chain Finance, 2018). Unlike traditional loans, that tend to focus first on the amount of cash to be lent and then on finding an appropriate collateral, ABL focuses first on the valuation of the asset as a collateral, followed by the cash flow definition. Thus, the amount of credit offered is strictly linked to the value of the asset being pledged. In the area of ABL, first of all two main streams of literature are identified on the basis of the collateral taken into consideration, namely inventory (Buzacott & Zhang, 2004; Hofmann, 2009; Chen & Cai, 2011) or fixed assets (Adams & Clarke, 1996; Berger & Udell, 2006). Including both

inventory and equipment financing solutions from a Supply Chain Finance perspective is quite innovative for Asset-Based Lending, since most of the studies focus only on one of the two. Besides, complete decision models guiding firms in the choice of the most suitable ABL solution are still missing.

From the analysis of the extant literature two relevant gaps can be pinpointed: i) The first gap is the absence of a holistic perspective on ABL concept, especially with respect to the definition we assume. Many authors address ABL solutions separately focusing either on equipment-based (Berger and Udell, 2004) or inventory-based solutions (Buzacott and Zhang, 2004); those who deal with ABL in a broader sense, anyway include in the assets used as securities for the financing only current assets, namely inventory and receivables, neglecting noncurrent physical assets, and they tackle ABL just from a financial perspective. No one has elaborated yet a study presenting ABL as the set of solutions in which the collateral of the financing can be either inventory or equipment. ii) The second gap concerns instead the lack of an organic view about which could be the factors leading a firm to select an ABL solution in terms of both objectives driving the choice and contingent factors that may influence the decision for an ABL solution. Indeed, literature provides some insights in this regard, presenting some possible variables that could be relevant in the adoption process (e.g. Hofmann, 2009; Pfohl and Gomm, 2009); however, there is no clear understanding on how these variables are and how they affect the selection process. Therefore, understanding this point can be helpful for managers who need to orient themselves in the ABL solutions landscape to select the most suitable solution for their firms and their supply chains.

This paper aims at filling these two gaps using the contingency theory as theoretical lens. In order to operationalize this goal, we formulate 3 research questions and propose a comprehensive research framework.

Research questions and Research Framework

Objectives

The first step in selecting an ABL solution is the objective definition. (Martin & Hofmann, 2015) In order to configure the best solution, companies need to specify these objectives and rank them on the basis of their relevance. Thus, objectives identification triggers the decisional process driving firms to adopt an ABL solution in terms of aims and purposes. The main objectives leading a firm to adopt an ABL solution have been clustered into firm-focused and supply chain-focused objectives. The first ones are objectives leading a firm to adopt an ABL solution mainly for its own interest, while the second ones are those triggering the adoption of an ABL solution to gain a positive outcome for the whole supply chain or at least a part of it. Three firm-focused objectives have been identified and considered: i) Liquidity increase, referring to the need of liquidity firms may have for several reasons (e.g. to sustain a project). From academic literature and secondary sources clearly emerges that increasing liquidity is what leads firms to look for a “pure ABL” solution. Specifically, firms ask for a credit line using inventory or equipment as collateral to generate liquidity and take advantage of the utilisation of their current/non-current assets (Merrill Lynch, 2014); ii) Flexibility, referring to the possibility to use an asset without owning it and to repossess the asset more easily at the end of the contract and reallocate the capacity at a lower cost. Flexibility is one of the objectives leading to the adoption of leasing, especially of Operative Leasing, since it allows the lessee to recover some flexibility when making its managerial decision (Bourjade et al., 2017); iii) Asset derecognition: removal of an asset or liability (or a portion thereof) from an entity's balance sheet. For instance, currently Operative Leasing allows firms to derecognize the leased goods that, consequently, do not appear in the balance sheet of the lessee but stay in the hands of the lessor. In addition, three

supply chain-focused objectives have been identified: i) Reduction of supply chain disruption risk, i.e. reduction of the risk of failure or bankruptcy of one or more players of the supply chain, with a subsequent effect on the other members (e.g. shortage of supply) (Wuttke, 2013; Gelsomino et al., 2016; Martin and Hofmann, 2015); ii) Reduction of supply chain cost of capital, i.e. the reduction of overall financial cost sustained by different actors of supply chain for financing their net operating working capital or fixed assets (Randall, 2009; Hofmann, 2009; Martin and Hofmann, 2015); iii) Minimization of supply chain cost of adoption, referring to the cost to adopt the considered solution.
Since the objectives of adopting an ABL solution seemed to be an important decisional variable, the first research question is:
RQ1) What are the objectives for which a company selects an ABL solution?

Contingent Factors
Contingent factors that can affect the adoption of an ABL solution once defined the primary objectives. Literature gives insights into what contingent factors are, what variables they are influenced by and which type of effect they have on solutions. In particular, 5 relevant contingent factors were identified: i) Balance sheet composition: the structure of the assets of a company. It depends on the amount of current assets, which include inventory, non-current assets, composed by machinery, equipment, intellectual property and their relative weight in the balance sheet. A firm tends to choose a solution employing either current assets or non-current ones according to its balance sheet composition; ii) Loan-to-value (LTV) ratio: the ratio between the amount of granted loan and the liquidation value of the borrowing base (Song, 2016). The borrowing base is the combination of the assets the borrower uses to secure the ABL loan and their value (book value) (Buzacott and Zhang, 2004); iii) The marketability of underlying assets, i.e. the easiness of reselling goods in the market in case the borrower fails in fulfilling its obligations, is crucial in choosing solutions in which the financier retains ownership of the asset, such as Operative Leasing, rather than solutions in which the customer owns the asset, such as Financial Leasing (Gavazza, 2010); iv) Visibility: the degree of visibility along the supply chain, i.e. the amount of information that a player in the supply chain possesses about other players (Pfohl and Gomm, 2009). In a condition of low visibility the absence of information induces providers not to offer any solution (Pfohl and Gomm, 2009); Legal system: it concerns the strength of the lending infrastructure for what concerns movable assets; in particular, it refers to the existence of laws safeguarding lenders for asset repossession (strength of contract enforcement laws) (Berger and Udell, 2006; Calomiris et al., 2017).
In extant literature, contingent factors seem to play an important role in the solution's decision as they may act as moderating variable. Hence, the second research question is:
RQ2) What are the main contingent factors that influence the choice of an ABL solution?

Solutions
Studying the extant literature, a common framework that help to identify all ABL solutions does not exist. Moreover, there is not a model that links objectives and contingent factors to the decision of a specific ABL solution. After a deep investigation, the ABL solutions that have been taken into account are classified into two categories: Inventory-based and Equipment-based solutions. The first category refers to those solutions that have Inventory as object of financing, while solutions belonging in the second group are triggered by the value of company's equipment. In *Table 1* the considered solutions are reported with their definitions.

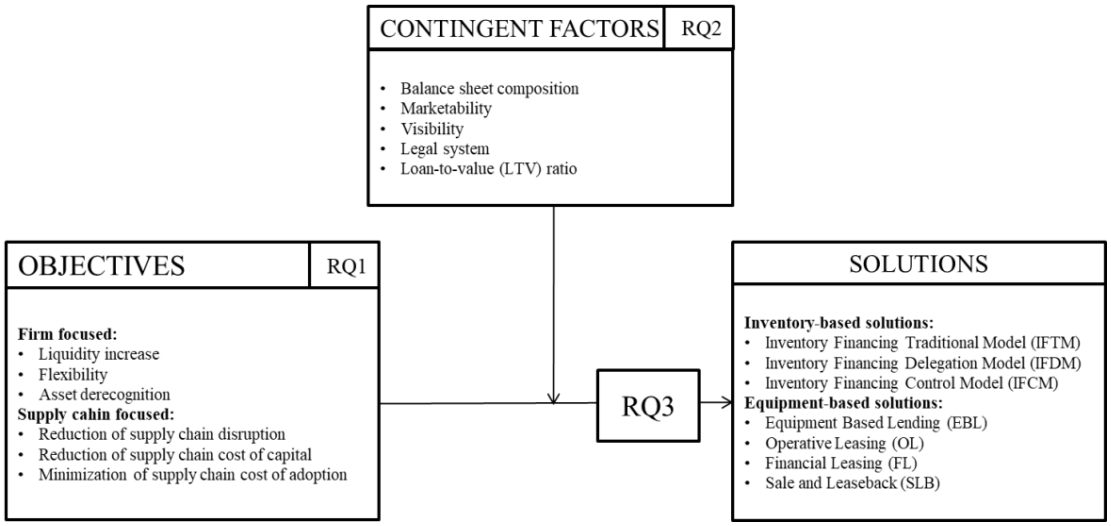
Hence, the third research questions that came out was:
RQ3) How do objectives and contingent factors influence the choice of an ABL solution?

Table 1: ABL solutions

Category of ABL solutions	Solution	Description	References
Inventory-Based	Inventory financing Traditional Model (IFTM)	Short-term loan provided by a financial institution and using inventory as collateral. The 3PL provides only logistics services when the firm borrows capital from the bank.	Chen and Cai (2011); Chen and Hu (2011); Hofmann (2009); Buzacott and Zhang (2004)
	Inventory financing Delegation Model (IFDM)	Short-term loan provided by a financial institution in which inventory is used as collateral and a logistics enterprise is entrusted to manage and monitor pledged goods.	Chen and Hu (2011); Chen and Cai (2011)
	Inventory financing Control Model (IFCM)	Inventory is financed by a Logistics Service Provider that buys goods from a manufacturer and obtains an interim legal ownership before selling them to the manufacturers' customers.	Chen and Cai (2011); Chen and Hu (2011); Osservatorio SCF of Politecnico di Milano (2018); Hofmann (2009)
Equipment-Based	Equipment-based lending (EBL)	Loan in which an equipment (more generally a fixed asset) is used as collateral.	Bank of America Merrill Lynch (2014); Berger and Udell (2004)
	Operative Leasing (OL)	Method of financing equipment, machineries and real estate in which the lessor (the "lender") purchases the fixed assets and simultaneously enters into a rental contract with the lessee (the "borrower") that specifies the payment schedule.	Berger and Udell (2004)
	Financial Leasing (FL)	Method of financing equipment, machineries and real estate in which the lessor (the "lender") purchases the fixed assets and simultaneously enters into a rental contract with the lessee (the "borrower") that specifies the payment schedule. The difference with operative leasing is that financial leasing generally implies a final purchase option for the lessee	Berger and Udell (2004)
	Sale and leaseback (S&L)	Particular form of leasing through which firms leverage upon assets they already own to free tied up liquidity.	Adams and Clarks (1996)

To answer these research questions, a preliminary framework developed on the basis of a literature was developed (see *Figure 1*).

Figure 1: the research framework



The model aims to shed light on the potentialities of ABL solutions focusing on:
- The objectives of a firm in choosing an Asset-Based Lending solution;
- The contingent factors that push a company in adopting an ABL solution;
- The specific solution that has been chosen on the basis of the two previous variables.

Methodology

Due to the exploratory nature of the topic, case study methodology was chosen. In particular multiple embedded case studies were selected: interviews with different providers have been conducted to collect relevant data which were subsequently analysed and compared with a solution-oriented perspective. The adopted unit of analysis is the solution and each provider was interviewed for each ABL solution offered. The final sample includes 15 providers with 25 final case studies, combination of provider and solution (*Table 2*). Although the framework is meant to be a decision model to help customer firms in the selection of the most suitable solution, interviews have been made with providers of ABL solutions both in Italy and abroad. The focus was on providers in order to leverage the experience they gained by offering the same solution to many clients, thus having the possibility to collect their perspective about commonalities and differences among different users. A semi-structured interview protocol was developed; interviews were conducted face-to-face by at least two researchers and recorded upon permission.

Table 2: list of final case studies

Case identifier	Type of interviewed provider	Role of the interviewee(s)	Origin country	Explored ABL solutions
A	Financial Service Provider	Innovation Specialist – Digital Lending & Supply Chain Finance	Italy	IFTM, EBL
B	Financial Service Provider	Managing Partner	Italy	IFDM, IFCM

C	Financial Service Provider	Head of Commercial Unit	Italy	IFDM
D	Financial Service Provider	Account Manager	Netherlands	Operative Leasing, Financial Leasing, Sale and Leaseback
E	Financial Service Provider	Managing Director / Executive Board Member	USA	Operative Leasing, Financial Leasing
F	Legal Expert	Expert in Business and Labour Law	Italy	IFTM
G	Financial Service Provider	Business Development Officer	USA	IFTM, EBL
H	Financial Service Provider	Senior Vice-President	Canada	IFTM, IFDM, EBL
I	Financial Service Provider	Chief Risk Officer	USA	IFTM, EBL
J	Logistics Service Provider	Logistics Manager	Italy	IFCM
K	Logistics Service Provider	Supply Chain & Clients Solution Director	Ireland	IFCM
L	Logistics Service Provider	CEO	Italy	IFDM
M	Platform Provider	Account Executive	Italy	IFDM
N	Advisory	Director	Italy	IFCM
O	Financial Service Provider	Director	Italy	Financial Leasing

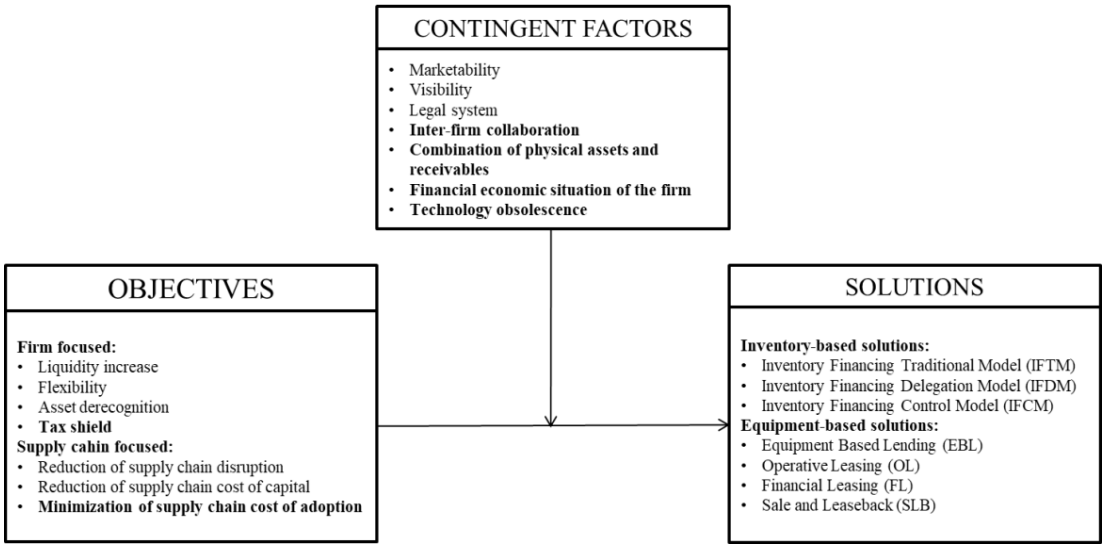
The decision of interviewing different providers for the same solution gave the possibility to conduct a multiple case study, in which first was carried out a within-case analysis, where each of the cases were analysed as a stand-alone entity, and then a cross-case analysis to compare answers about the same solution from different informants in different firms. For each solution all the relevant interviews have been compared across the considered variables to understand which factors were considered the most relevant by the informants (cross-case analysis). However, with the purpose not to limit the scope to the variables already taken into consideration by thee literature, an investigation has been made to find new variables from the interviews through an inductive coding approach: starting from the transcripts, it was looked for "in vivo" codes or constructed new ones, then comparing such codes among different interviews and trying to find common patterns to turn into more aggregate concepts, with the purpose of identifying new variables. Finally, data were triangulated with secondary sources, such as reports and providers' website. At the end of the data analysis, new variables emerged from the interviews through an inductive coding

approach and a final framework was created.

Preliminary Results

The cross-case analysis allowed to answer the research questions and to start get some preliminary results. First of all, the framework was revised in order to identify which are both objectives and contingent factors relevant for the choice. This step allowed to eliminate some variables (e.g., Balance sheet composition and Loan-to-value (LTV) ratio) and to add new ones (e.g., Tax Shield). In *Figure 2* the revised framework.

Figure 2: the revised framework



The first outcome of the interviews is the detection of new variables that were added to the revised framework: tax shield and inventory cost reduction (included in minimization of supply chain cost of adoption) are two new objectives which emerged to be strongly relevant respectively for OL, FL and for IFCM. Instead, tax shield is not mentioned as an objective leading the adoption of SLB(OL) and SLB(FL). Among contingent factors, economic and financial situation of the firm was added since it affects mainly leasing solutions. Other relevant added factors were the combination of physical assets and receivables, that has an impact only on ABL solutions where the collateral is mainly the mean of financing (IFTM, IFDM, EBL), and technology obsolescence, that only affects Leasing solutions (OL and FL). It emerged also that digitalisation has an impact on all the solutions, hence it was added among the contingent factors in the revised framework.

Then, objectives (see *Table 3*) and contingent factors (see *Table 4*) relevant for each specific solution were identified.

Table 3: objectives of the revised framework

		Solution	IFTM	IFDM	IFCM	EBL	OL	FL	SLB(OL)	SLB(FL)
RQ1	Objectives	Liquidity Increase	X	X	X	X	X	X	X	X
		- Access Liquidity	X	X	X	X			X	X
		- Preserve Liquidity					X	X	X	X
		Asset Derecognition			X		X		X	
		Flexibility					X		X	
		Reduction of supply chain disruption risk					(X)	(X)		
		Reduction of supply chain working capital cost	(X)	(X)	(X)					
	New Objectives	Tax Shield					X	X		
		Inventory Cost Reduction			X					

Table 4: contingent factors of the revised framework

		Solution	IFTM	IFDM	IFCM	EBL	OL	FL	SLB(OL)	SLB(FL)
RQ2	Contingent factors	Balance Sheet Composition	(X)	(X)	(X)	X				
		Marketability	X	X	(X)	X	X		X	X
		Inter-firm collaboration	(X)	X	X	(X)				
		Legal System	X	X	X	X	(X)	(X)	X	X
		Digitalisation	X	X	X	(X)				
	New contingent factors	Combination of physical assets and receivables	X	(X)		X				
		Financial & Economic situation of the firm	(X)			(X)	X	X	X	X
		Technological obsolescence					X	X	X	X

Starting from the initial framework, some variables that were thought to influence the decision of implementing an ABL solution, actually do not: reduction of supply chain disruption risk and reduction of supply chain working capital emerge to be weak objectives sought through the adoption of none of the considered Asset-Based Lending solution. In the same way, balance sheet composition was a relevant variable only in Equipment-Based Lending. Instead, three variables emerged as strongly influencing the choice of adoption: the marketability of the collateral, the financial and economic situation of the firm and the objective of liquidity increase. For example, the marketability of the collateral linked to the objective of ABL adoption may address the choice of the company towards one specific solution. Most of the solutions under scrutiny need a high marketability of the collateral asset to be implemented. However, some solutions are available even if the marketability

of the collateral good is low (IFCM, SLB(FL), FL). On the other hand, while Inventory-Based solutions have the only purpose to access further funding sources, the landscape of Equipment-Based ones is more nuanced, since there are solutions that allow a preservation of cash flow (FL and OL), others that grant access to additional liquidity (EBL) and others both (SLB(OL), SLB(FL)). Moreover, for some solutions the lending is not only based on the marketability of the good, but the lender takes into consideration also the financial and economic situation of the firm. Indeed, from the case studies, it emerges that the assessment of the good is more relevant compared to that of the firm for what concerns "pure" ABL solutions (IFTM, IFDM, EBL), confirming what already stated in literature. However, for the other solutions this does not hold true and the assessment of the financial and economic soundness of the client acquires importance. The only solution that potentially does not have high requirements both in terms of marketability of the goods and financial and economic situation of the firm is IFCM.

Relevance

In terms of theoretical contribution, the paper extends the concept of Supply Chain Finance to the set of ABL solutions. The results obtained make it possible to fill the gaps in the literature that were highlighted during the definition of the research questions: the creation of a framework that includes holistically the solutions of Asset-Based Lending, both those based on inventories and those based on equipment, and the main relevant variables that have an influence in the process of adoption is useful to have clear what is the starting perspective when considering this category of solutions in view of future developments. An academic literature review and the analysis of the interviews have allowed to identify the main criteria for the adoption of each specific solution, exploring also new factors such as the legal frame in which ABL solutions are offered. On the other hand, from a managerial perspective, the paper provides a decision-making tool for managers who are considering the adoption of ABL as it is supporting the choice of the most suitable solution, given the firm's objectives and its contingent situation. The findings also have value for solutions' providers: financial providers can understand how to adapt their solution offerings based on their customers' objectives and characteristics and how to manage the adoption process in the most efficient and effective way possible, considering all relevant aspects, so as to propose a low-risk solution that is winning for all parties involved. Future research could use more quantitative methods to define the relative importance of variables (e.g. survey) as the results were built in a qualitative way, considering variables that are relevant and comparable, on the basis of information received. Moreover, given the nowadays dynamic context, characterized by strong innovation (especially technological), solutions are in continuous evolution. Future research should therefore monitor the evolution of the analysed paradigms, performing a continuous assessment of the model, in order to have a constantly updated classification of solutions.

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The impact of platform strategies on supply chain finance and financial performance

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Abstract
This study aims to explore the information integration practices adopted by small and medium sized enterprises (SMEs) (borrowers), and their impact on the supply chain finance (SCF) decisions of a core firm of a supply chain (lender) and SMEs' financial performance. This study conducts a case study of a supply chain in Chinese smartphone industry. A mixed method design is used. We find that information system integration is positively associated with SCF and financial performance whereas social interaction is negatively associated with SCF and does not significantly affect financial performance. In addition, SCF is positively associated with financial performance.

Keywords: supply chain finance, mixed method research, information integration

Introduction
Supply chain finance (SCF) is the inter-organizational optimization of financing and involves the integration of financial with information and physical flows in supply chains in order to decrease the cost of capital. Small and medium sized enterprises (SMEs) in supply chains usually lack financial resources to support operations (e.g. purchasing of raw materials and large scale production) and growth (e.g. investment in research and development and commercialization of new product designs) (Xu et al., 2018). Meanwhile, a supply chain's core firm's operational decisions can be severely constrained by its suppliers' financial resources (Wuttke et al., 2016). Cash constrained SMEs may increase supply chain risks and negatively influence supply chain efficiencies. To improve working capital and optimise supply chain processes, a core firm of a supply chain is motivated to offer SCF to alleviate its supplier's financial distress through the collaboration with financial institutions and technology providers (Gelsomino et al,

2016). The core firm may also benefit from exploiting the differences in the cost of capital between different supply chain members and from the reduced risk of bankruptcy throughout the supply chain (Bals, 2018).

Although SCF is challenging existing business models and supply chain management, and is receiving growing attention in research, there is a lack of empirical analyses addressing SCF implementation and the empirical evidence on its effects is still fragmented. For example, Gelsomino et al. (2016) review SCF research and find that only around 20% of the studies use empirical methods. They also highlight there is a lack of practical guidance on the adoption of SCF and point out that the impact of SCF on financial performance has generally been neglected in the literature. Xu et al. (2018) conduct a bibliometric analysis of SCF studies and find that the majority of SCF research uses analytical models to investigate the issues related to trade credit and operational decisions. They also call for more empirical evidence on the management of SCF. Researchers further argue that the adoption process of SCF is complex and information integration plays a critical role in the success of SCF. Enabled by the information systems and internal-organizational processes, the connectivity and information flows of supply chains can be significantly improved, leading to lower information asymmetry between a core firm (SCF lender) and SMEs (SCF borrowers). Although researchers argue that information integration allows SMEs to access financial resources which can improve their performance, how SMEs can create processes to successfully collaborate with a core firm in a supply chain to reduce information asymmetry is largely ignored in the literature.

Credit rationing provides a useful perspective to explore SMEs' information integration with a core firm and the implementation of SCF. Credit rationing occurs when a core firm supplies a smaller loan size than that demanded by SMEs. A core firm must use a variety of screening devices and mechanisms to identify the SMEs who are more likely to repay SCF loans. SMEs and a core firm may have differential access to information about a project's risk. The uncertainties of SMEs' ability or willingness to repay SCF loans may also lead to moral hazard and adverse selection. Therefore, when information asymmetry between SMEs and a core firm is high, the core firm tends to implement more credit rationing by reducing SCF loans. As a result, SMEs must develop strategies and systems to integrate with a core firm which can improve the transparency of the information flows and reduce the core firm's uncertainties and risks.

The objective of this study is to empirically investigate the impacts of information integration on SCF and financial performance. We aim to answer two research questions. First, what are the information integration practices SMEs can adopt to integrate with a core firm of a supply chain? Second, how does information integration affect SCF and financial performance? The findings can provide empirical evidence on how SMEs can successfully integrate with a supply chain to obtain financial resources. The study also enhances current understandings of SCF implementation and the mechanisms through which information integration between a lender and borrowers affect the lender's SCF decisions and the borrowers' financial performance. In addition, the findings can provide guidelines to SMEs' on how to alleviate a core firm's credit rationing and benefit from implementing SCF.

Research methods

This study adopts a case study approach and uses a mixed method design. This choice is motivated by the research objectives and the lack of empirical evidence on SCF. The mixed method design links qualitative and quantitative data which allows us to provide analytic texture of SCF and strengthen the analytical findings. Specifically, we combine the inductive theory-building and natural experiment methods of case studies (Welch et

al., 2011, Ridder, 2017). First, we conduct an explorative case study which uses an inductive logic and aims to propose associations between constructs and variables and develop testable hypotheses which large-scale quantitative testing is based on. Qualitative data is collected from both the core firm and SMEs of the supply chain and is used for theory building and contextualization (Welch et al., 2011). Second, we conduct a confirmatory case study based on deductive logic. Quantitative data are collected from SMEs and the core firm at both project and firm level to test the hypotheses, leading to the modification and extension of the theory. Finally, a follow-up interview is carried out with the senior managers of the core firm to discuss analytical results of quantitative data. Therefore, this study combines theory-building and theory-testing approaches of case study which allows us to capture the richness of empirical context and generate internally valid explanation (Ridder, 2017). Qualitative data can help the quantitative side of the study by aiding in conceptual development and instrumentation, and also by validating, interpreting and clarifying the quantitative findings. Collecting qualitative and quantitative data from a core firm and SMEs of the supply chain enables us to yield data from multiple sources (i.e. both lender and borrower) for triangulation and derive solid research results based on theoretical and analytical generalization.

Explorative case study

A supply chain in the Chinese smartphone industry was chosen because it can offer insights into SCF and allows the researchers to provide detailed description and analysis to gain a better understanding of how information integration affects SCF. Specifically, the core firm of the supply chain (CJ) offers SCF to supply chain members who are cash-constrained SMEs since 2009. CJ is acknowledged as one of the most successful SCF providers in the great bay region of China. For example, it has gained the "AA" rating of enterprises recognized by the Chinese customs and the "Direct Passage" status awarded by Shenzhen tax bureau. CJ has also developed a thorough process and information system to collaborate with SMEs and support their supply chain management. Therefore, the case offers opportunities to open a black box of the relationships between information integration and SCF.

The research team interviewed ten senior managers in CJ, including president, director and vice director of information system department, director and vice director of risk control department, director of financial department, two business managers and two operations managers, and nine managers in the members of the supply chain who are SMEs, including four general managers and one finance manager from four smartphone designers, one vice general manager and two product managers from two smartphone manufacturers, and one marketing director from a raw material supplier. Each interview lasted approximately 2 to 3 hours and was conducted in Chinese.

As SCF offered by CJ is different from bank loans, communications and interactions between CJ and SMEs' employees play a critical role in facilitating the SMEs to understand their obligations and CJ's internal standards and regulations, especially how CJ controls SCF risks and manages supply chain operations. The SMEs also rely on social interactions to share information and collaborate with CJ to reduce information asymmetry. For example, managers in the SMEs all mentioned that their employees keep close contact with CJ to ensure that they can get support in the purchasing, production and delivery processes which are jointly managed by CJ. They actively share information about market environment and process improvement suggestions through social interactions. Through frequent social interactions, CJ and SMEs can also align business processes and coordinate decision making. Therefore, social interactions help CJ accumulate knowledge about SMEs and their operations.

Moreover, CJ has spent a great deal of efforts and resources in information technology architecture and has developed an E-SCM with a myriad of software systems. CJ's directors explained that CJ had installed a SAP ERP system as the backbone of the information technology infrastructure. It has purchased an IBM Si integrated data centre and developed a B2B web-based database to interact with supply chain members which allows them to use the system through an Internet portal. The CJ's president commented that the system enables faster communication, shorter lead time, lower transaction costs, lower pipeline inventory and more effective planning and coordination in supply chains. However, CJ's managers noticed that E-SCM cannot realize its full potential because some SMEs do not have a compatible information technology infrastructure and the information system integration between CJ and them is weak. Therefore, CJ encouraged the SMEs who do not have an adequate information system to use E-SCM directly to acquire, share and analyse data or to develop a compatible information system that can be easily connected to the E-SCM. CJ's directors also emphasized the SMEs can improve the quality, quantity and speed of the information sharing through using E-SCM. The operational and financial information exchanged on E-SCM forms a foundation for the collaboration between SMEs and CJ on supply chain management which reduces information asymmetry and risks for the SCF loans. CJ's president further commented that the degree of information system integration has become a key criterion for CJ to make SCF decisions. Therefore, the case evidence reveals that information integration between SMEs and CJ relies on both social interaction and information system integration.

Social interactions allow employees in CJ and SMEs to develop a common expectation of their roles and responsibilities in SCF. They also facilitate the exchange of tacit knowledge such as organizational culture and technical knowhow. As explained by CJ's directors, social interactions help them identify and collaborate with the SMEs with compatible culture, goals and strategies, which build a foundation for developing trust and long-term relationships. CJ's managers also emphasized that such relationships can avoid SMEs' opportunistic behaviours and deal with the problem of moral hazard. In addition, CJ can accumulate more knowledge of SMEs' capabilities and operational processes, which decrease uncertainties and help CJ better evaluate SCF projects. Thus, social interactions reduce information asymmetry about SCF projects and motivate SMEs and CJ to coordinate business decisions and strategies. As CJ's perceived SCF risks are reduced, it will alleviate credit rationing. Therefore, we propose the following hypothesis.
H1. Social interaction between a core firm and an SME is positively associated with SCF received by the SME.

As commented by CJ's president, E-SCM allows CJ to link different stakeholders such as designers, raw material providers, manufacturers, and logistics service providers together. He believed that the integration between SMEs' information systems and E-SCM plays a critical role in the success of SCF projects and hence CJ uses the degree of information system integration as a key criterion in evaluating the risks of SCF projects. Supported by highly integrated information systems, CJ can timely and accurately acquire operational information including procurement, production, logistics, and settlement, from SEMs which improves the transparency of the SMEs' operations and allows CJ to monitor and control the financial flows in real time to ensure the repayment of SCF loans. In addition, the large amount of structured data stored in E-SCM about past projects helps CJ develop a better understanding of SMEs' capabilities on profiting from different SCF projects and the risks associated with the projects. Information system integration thus can reduce the information asymmetry and uncertainties of SCF projects, which promote CJ to alleviate credit rationing. Therefore, we propose the following hypothesis.

H2. Information system integration between a core firm and an SME is positively associated with SCF received by the SME.

Both CJ and SMEs agreed that social interactions help them coordinate supply chain processes which can improve operational efficiency and financial performance. The case evidence reveals that social interactions help CJ and SMEs collaborate on supply chain management. For example, the communications with SMEs' employees help CJ grasp technical specifications and requirements of SMEs' products and processes. This is very important for improving supply chain performance as CJ is actively involved in the SMEs' operations. In addition, social interactions provide a channel for SMEs to provide improvement suggestions, increasing supply chain processes. They also help SMEs understand CJ's procedures and rules better, which can reduce miscommunications and misunderstandings during cooperation. Thus, SMEs can reduce costs and improve flexibility by creating a seamless and smooth physical flow, which increase financial performance. Therefore, we propose the following hypothesis.

H3. Social interaction between a core firm and an SME is positively associated with the SME's financial performance.

The case evidence also reveals that information system integration plays an important role in improving SMEs' operational efficiency and financial performance. The interconnected information systems allow CJ to obtain real time operational and market information from SMEs and their customers which help CJ reduce operational costs, product defects, and lead-times. CJ also motivates SMEs to use its E-SCM system to interact with customers and manage financial flows which can avoid miscommunications and greatly improve SMEs' cash-to-cash cycle. As SCF projects are co-managed with CJ, information system integration enables SMEs to obtain speedy and high quality information in respect to purchase and delivery of raw material, production and delivery of finished goods, and settlement and repayment, which allow SMEs to improve operational scheduling and strategic planning, ultimately increasing financial performance. Therefore, we propose the following hypothesis.

H4. Information system integration between a core firm and an SME is positively associated with the SME's financial performance.

CJ's president commented that the SCF offered by CJ can improve SMEs' financial performance for two reasons. First, SCF allows SMEs to expand their businesses by capturing more marking opportunities and serving more customers even if they have limited financial resources. As highlighted by the SMEs, it is impossible for them to conduct and profit from some projects without the SCF loans offered by CJ. Second, SCF greatly reduces SMEs' financial costs and the cash-to-cash cycle. With the loans from CJ, SMEs do not need to pay a high interest rate to banks or financial institutions for cash. In addition, they can invest capital in upgrading equipment, improving human resources and developing new products and processes instead of occupying all cash into daily operations. In this way, SMEs can improve their operational capabilities, resilience for supply chain risks, and responsiveness for market changes, increasing financial performance. Therefore, we propose the following hypothesis.

H5. SCF is positively associated with an SME's financial performance.

Confirmatory case study

Quantitative data were collected from CJ and SMEs to test the hypotheses. Specifically, transactional data about SCF projects were collected from CJ and survey data about information integration were collected from SMEs. After consulting with CJ about the data availability, we decided to focus on the SCF projects financing SMEs' raw material purchasing. There were 39 SCF clients who were SMEs and successfully obtained SCF

loans from CJ. After contacting the SMEs, 33 were willing to participate in this research and allowed CJ to share their project data with us. Then, through the collaboration with CJ, we have identified and collected data of 207 SCF projects from E-SCM system. Both firm (e.g. number of employees and interest rate) and project level data (e.g. SCF loan, sales, total purchase amount, payment terms and service fee) were collected. A questionnaire has been designed based on existing literature and the exploratory case study to collect information related to information integration from the SMEs.

Information integration was measured in the questionnaire using a seven-point Likert scale to capture the perceptions of the respondents. Specifically, social interaction was measured by four items concerning the interactions between CJ's and SMEs' employees through which they share improvement suggestions, rules and procedures, and information about business processes and requirements. Information system integration was measured by four items about the interconnectedness between CJ's and SMEs' information systems and the practices of sharing information and managing business processing by using information systems. The respondents were asked to assess the degree of agreement of the statements (1= "totally disagree"; 7= "totally agree"). The data about SCF and financial performance were extracted from CJ's database. SCF was calculated by the proportion of SCF in total purchasing cost of raw materials in a project. SMEs' financial performance was measured by the cash-on-cash return of a project, which is calculated by the ratio of total cash income over total cash investment. The measures were developed in consulting with CJ and SMEs. During the interviews, CJ and SMEs both mentioned that SCF loan is used to finance part of the raw materials purchasing. CJ also explained that the credit rationing will consider SMEs' financial needs and risks, and the SCF invested in a project is largely influenced by the overall raw material procurement costs which is related to project size. The amount of SCF cannot accurately reflect CJ's credit rationing decisions because a large amount of SCF may be caused by high procurement cost of a large scale project and is a result of high credit rationing. Therefore, we use the ratio of SCF loan over the total purchasing cost to control the influences of project size. A high ratio indicates that CJ is willing to finance a large proportion of the raw material purchasing costs, which reflects that CJ believes the risk of the project is low and applies lower level of credit rationing. As highlighted in the interviews, SCF borrowers are all cash-constrained SMEs and the main reason for using SCF is to improve cash flow. The managers in SMEs also emphasized cash flow management and viewed speeding up turnover of their working capital and cash return generated from projects as key performance indicators of SCF. Cash-on-cash return captures cash income earned on the cash invested, which reflects the effect of SCF in alleviating SMEs' cash constraint. We also included firm size, which was measured by the number of employees and interest rate as control variables for SCF and financial performance. Moreover, we controlled the effects of uncertainty of purchase and uncertainty of receivables on SCF. We also controlled the duration of a project, which is calculated by the days between an SME starts to cooperate with CJ and CJ collects the principal and interest of an SCF loan from customer payment, on financial performance.

We first conduct the psychometric tests of the two constructs (i.e. social interaction and information system integration). An exploratory factor analysis was conducted. The results indicate that the items have strong loading on their corresponding constructs. We use the composite reliability and Cronbach's α to evaluate reliability. The results show that the composite reliability values are 0.94 and 0.93, and the Cronbach's α values are 0.91 and 0.90, showing that the reliability of the constructs is acceptable. Average variance extracted (AVE) is used to test the convergent and discriminant validity. The AVE values are 0.80 and 0.76, indicating that the convergent validity is acceptable. A

comparison of the correlations and square roots of the AVEs indicates adequate discriminant validity for the constructs. We then conducted the multicollinearity test. The results reveal that the smallest tolerance is 0.768 and the largest variance expansion factor is 1.302, indicating that multicollinearity is not a serious problem.

We use the multilevel structural equation modelling with robust maximum likelihood method and MPLUS software to test the hypotheses because we proposed a two-level model with data collected from both firm and project level. The unidimensional parcels of the two multi-item constructs, which are calculated using principal component scores, are used in data analysis. The model fit index are as follows: Chi-Square/df = 1.15, p = 0.327, comparative fit index = 0.991, Tucker-Lewis index = 0.958, root mean square error of approximation = 0.029, standardized root mean square residual (SRMR) (value for within) = 0.015, and SRMR (value for between) = 0.014, which are better than corresponding threshold values. The findings show that the R^2 for SCF is 32.9%. Information system integration is positively associated with SCF (b=0.305, p<0.05), whereas social interaction is negatively associated with SCF (b=-0.284, p<0.05). Therefore, H2 is supported whereas H1 is not. The results also show that interest rate (b=0.138, p<0.01) and uncertainty of purchase (b=0.212, p<0.01) are positively associated with SCF whereas uncertainty of receivables (b=-0.188, p<0.05) is negatively associated with SCF. Firm size does not significantly affect SCF. We find that R^2 for financial performance is 27.4%. Information system integration (b=0.413, p<0.05) and SCF (b=0.212, p<0.01) are positively associated with financial performance whereas the impact of social interaction is not significant. Therefore, H4 and H5 are supported whereas H3 is not. Moreover, we find that the impacts of project duration, interest rate and firm size on financial performance are not significant.

Discussion

This study contributes to literature in three ways. First, the findings contribute to SCF literature by providing empirical evidence on the implementation of SCF (Gelsomino et al., 2016, Xu et al., 2018). This study adopts a mixed method design and both qualitative and quantitative data have been collected from SCF lenders and borrowers. The design includes both explorative and confirmative case studies, which allow us to triangulate the evidence to verify and generalize the findings. Moreover, the multilevel statistical analysis can provide insights into the impacts of firm level practices on SCF projects. The case study thus allows contextualization of credit rationing in SCF and provides a holistic picture on how to reduce information asymmetry through the collaboration of different stakeholders. As a result, the case study offers a balanced view of information integration and credit rationing from both a core firm's and SMEs' perspectives. In addition, this study provides empirical evidence on how the information integration between a lender and a borrower affects credit rationing. The case study also sheds light on the impacts of SCF on supply chain management. The findings thus extend current understandings on how a supply chain can successfully implement SCF.

Second, this study empirically identifies two kinds of information integration practices and examines their individual effects in SCF credit rationing, enhancing existing knowledge on the integration and coordination of information and financial flows in supply chains (Bals, 2018). The findings reveal that SMEs use both social interaction and information system integration to integrate information with a core firm, providing insights on how a core firm makes credit rationing and SCF decisions and how an SME can create processes and systems to avoid credit rationing. The statistical analysis further discovers that information system integration can reduce credit rationing, whereas there is a gap on the perception and reality of the impacts of social interaction on SCF. The

finding that social interaction increases credit rationing enhances current knowledge on the effectiveness of relationship lending in SCF and the special characteristic of SCF comparing with bank lending, revealing that social interaction and information system integration play different roles in affecting a lender's SCF decisions. In addition, the result highlights the importance of information system integration in reducing information asymmetry and supporting SCF. The findings also contribute to supply chain integration literature by linking information integration with SCF and enriching current understandings of the benefits of information integration.

Third, this study contributes to the supply chain management literature by enhancing current understandings on the impacts of SCF and information integration on management of cash flow and by highlighting the importance of joint management of information, financial and physical flows in a supply chain (Wuttke et al., 2016). The findings reveal that information system integration and SCF are positively associated with cash-on-cash return, which enhances existing knowledge on how SMEs can alleviate cash constraint. In addition, the result improves current understandings on the performance outcomes of SCF (Wuttke et al., 2016). By linking information integration with financial performance, this study finds that social interaction and information system integration plays different roles in affecting cash flows in a supply chain. Although existing empirical evidence reveals that social interaction can improve operational and marketing performance based on survey data, this study finds that social interaction does not affect the cash flow by combining survey and objective data. The finding thus contributes to the supply chain integration literature by providing insights into the performance outcomes of information integration.

The findings can provide guidelines for both a core firm and SMEs of a supply chain to successfully adopt SCF and benefit from its application. We suggest a core firm of a supply chain offer SCF to SMEs because it is a very effective method to improve the cash flow of the supply chain and reduce financial risks. A core firm should establish close relationships to get loans from banks and other financial institutions. It should also select and offer SCF to the SMEs who have compatible culture and high market and technological capabilities but lack physical assets for collateral and have weak cash flows and hence encountering difficulties to get loans from traditional channels. The study suggests a core firm apply credit rationing based on the degree of information asymmetry and manages and controls risks of SCF by actively participating in SMEs' supply chain operations, such as purchasing, production, delivery and payment processes to monitor and control the physical, information and financial flows. In addition, we suggest a core firm implement a digitalization strategy to integrate information, financial and physical flows to form a closed-loop system and invest to develop an integrated and advanced information system to manage SCF and the supply chain. For example, a myriad of software systems, such as ERP, CRM, and AI, and an Internet platform to promote fully automated transaction exchanges and enable different stakeholders, such as SMEs, customers, and government agencies who have different information systems to communicate and share information. Moreover, a core firm should motivate SMEs to integrate and use the information system and digitalize their processes. Furthermore, a core firm should be aware that although social interaction with SMEs facilitates the exchange and transfer of knowledge, it may lead to more credit rationing.

We suggest cash-constrained SMEs who have low credit rating and cannot get loan from banks to apply SCF from core firms of their supply chains to improve their cash-to-cash return. The SMEs should understand that SCF could be used to finance raw material purchasing which enables the SMEs to expand businesses and grow with limited financial resources. SMEs should be aware that the SCF requires them to closely cooperate with a

core firm on supply chain management. To demonstrate commitment and improve transparency, they must allow a core firm to participate in and manage some of their operations. Therefore, SMEs must develop inter-organizational processes to integrate the physical and information flows with a core firm and develop long-term and collaborative relationships in supply chains. In addition, SMEs should understand that reducing the information asymmetry on a project can alleviate a core firm's credit rationing and allows them to get more credits. We suggest that SMEs adopt information integration with a core firm when applying for SCF. They can also rely on information system integration and the digitalization of operations to improve financial performance. For example, SMEs could integrate their information systems with a core firm's information system and exchange information and knowledge and collaborate with the core firm on supply chain and business process management using the system. However, SMEs should be warned that although social interactions with a core firm, such as the communications and interactions between employees, may improve supply chain operations, they may reduce the SCF obtained from a core firm and do not significantly affect their financial performance.

Conclusion

This study conducts a case study of a supply chain in the smartphone industry in China. We adopt a mixed method design and collect qualitative and quantitative data from both a core firm (SCF lender) and SMEs (SCF borrowers) to empirically investigate the relationships among SMEs' information integration practices, a core firm's SCF decision and the SMEs' financial performance. Based on the credit rationing and sociotechnical systems theories, we first conduct an explorative case study using qualitative data. We have identified that SMEs and CJ can integrate information via social interaction and information system integration. A framework has been developed which proposes that social interaction and information system integration positively influence SCF and financial performance, and SCF improves financial performance. We then conduct a confirmatory case study using quantitative data. A multilevel structural equation modelling analysis based on survey and second-hand data reveal that information system integration is positively associated with both SCF and financial performance and SCF enhances financial performance. However, social interaction is negatively associated with SCF and does not significantly affect financial performance.

This study has three main limitations which open avenue for future research. Frist, the findings of the study are based on a case study of a supply chain in the smartphone industry in China. The implementation and effectiveness of SCF might be influenced by the industrial and institutional environments. Future studies could verify and generalize the findings in other contexts. Second, this study focuses on information integration. Researchers argue that the integration of financial, information and physical flows and collaboration in supply chains are critical for SCF. Future research could extend this study by investigating the impacts of business process and strategy integration on SCF. Third, this study focuses on the interactions and collaboration between SMEs and a core firm. During the case study, the CJ's managers mentioned that its long-term objective is to develop a platform on which different stakeholders, such as SMEs, customers, banks, and government agencies, can collaborate with each other to create an ecosystem. Future research could adopt a longitudinal design to explore the establishment of and transition to ecosystem and how the ecosystem affects SCF and the performance of supply chain members.

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An empirical study of supply chain upscaling in automotive manufacturing

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Abstract

This paper explores how companies in automotive manufacturing supply chains can successfully upscale and respond quickly to market demand. Specifically, we look at the capabilities across the supply chain and we examine the impact of supply chain architecture on upscaling. We use multiple case study method and we draw data from 3 manufacturers and 2 tier-1 suppliers. The findings provide insights of the upscaling process, the challenges and the capabilities needed across the supply chain. Moreover, results show how different sets of capabilities are combined with different supply chain architectures which in turn, leads to different upscaling performance.

Keywords: Supply chain upscaling, Capabilities, Supply chain architecture

Introduction

In periods of growth the demand for existing or new products increases and supply chains need to be ready to upscale in order to achieve a quick time-to-market and time-to-volume, meet the demand and increase the revenues (SMMT, 2018). In the UK, automotive manufacturing experienced continuous growth until 2018 and there is a well-expressed need for government support and investments, especially in a post-Brexit environment where more indigenous/UK-centric supply chains are needed (HM Government, 2018). In addition, new technologies and mobility trends (e.g. autonomous driving, electrification, digitalisation) put enormous pressures on manufacturers to develop new products and supply chains to seize these opportunities in the market (APC, 2016). For example, demand for electric vehicles is constantly rising (SMMT, 2018), new registrations of plug-in cars in the UK increased from 3,500 in 2013 to more than 195,000 by the end of January 2019 (Lilly, 2019) and EV manufacturers (e.g. Tesla) face a number of challenges with regards to upscaling their supply chain (McKevitt and Patrick, 2017).

Previous research has shown how to strategically plan for a ramp-up with the use of lean and integrated approaches to support decision-making, and how important the investments into R&D and production capabilities are (Becker et al., 2017; Christensen and Rymaszewska, 2016). Researchers have also looked at the importance of knowledge management and how it can inform the upscaling process (e.g. spillover learning, copy-exactly strategy) (Terwiesch and Xu, 2004). From a supply chain point of view, only a

few researchers have investigated the ramp-up and they have highlighted the need for collaboration, flexibility and responsiveness (Kalaitzi et al., 2019; Li et al., 2014). But the literature is scant on the capabilities that manufacturers and suppliers should have in order to be ready to upscale and also on the role of supply chain architecture in upscaling.

In light of the gap in the extant literature, this research aims to explore how companies in automotive manufacturing supply chains can successfully upscale and respond quickly to market demand. In particular, we answer the following two research questions:

- What is the right mix of capabilities that companies should have in order to succeed in upscaling?
- Does supply chain architecture affect upscaling and how?

We anchor our research on dynamic capabilities theory in order to capture the dynamic nature of automotive manufacturing and guide the capabilities assessment process for a successful upscaling (i.e. quick time-to-market and time-to-volume) (Teece, 2007). Based on prior research and dynamic capabilities theory, we develop a conceptual framework proposing that the capabilities internally –into the organisation– and externally –across the supply chain– impact the upscaling performance and also that supply chain architecture impacts the upscaling performance.

We begin our paper by reviewing the literature on upscaling and dynamic capabilities theory. We then present the research methodology followed by the findings. Finally, we conclude by discussing both research and managerial implications.

Literature review and theoretical background

A well-established stream of literature that examines the upscaling or ramp-up phase uses the definition given by Terwiesch and Xu (2004) who defined the ramp-up as 'the period of time during which a manufacturing process is scaled up from a small laboratory-like environment to high-volume production' (Christensen and Rymaszewska, 2016; von Gleich et al., 2012; Surbier et al., 2014) and that is because upscaling has been mainly approached as an internal challenge and not as a supply chain challenge. At the conceptual level, it is also unclear when this phase begins, which functions of the company are involved and what processes are taking place for managing the supply chain.

More specifically, a considerable body of literature exists on how companies should plan internally for production ramp-up, what strategies to adopt and what capabilities to acquire. A number of authors have recognised that for a successful strategic ramp-up, an integrated approach among different decisions (e.g. production volumes, transportation volumes, capacity) is more beneficial than a sequential approach (Becker et al., 2017; Ball et al., 2011) and the application of lean practices in strategic decisions can help companies to acquire competitive capabilities and achieve a faster time-to-volume (Christensen and Rymaszewska, 2016). Also, Juerging and Milling (2005) who examined the copy-exactly and process change strategies, suggested that the more innovative the product is, the more beneficial a copy-exactly strategy is. For a faster time-to-market and ramp-up time, researchers suggested investments in product development capabilities, development of global R&D networks (Carrillo and Franza, 2006, Kuemmerle, 1997) and allow time for "learning before doing" (Terwiesch and Xu, 2004).

However, there is limited knowledge about the supply chain implications of upscaling and the capabilities across the supply chain needed in order companies to succeed in upscaling. Nugroho (2010) and van Echtelt et al. (2008) looked at the supply chain relationships during upscaling and they supported that long-term collaboration between the buyer and the suppliers yields great benefits (e.g. supply flexibility, shorten ramp-up). Likewise, Kalaitzi et al. (2019) who explored the dependencies in supply chains during production ramp-ups suggested a relational approach in inter-company relationships and

Li et al. (2014) supported that a collaborative network of the focal firm and its suppliers can contribute to a rapid production ramp-up. Moreover, Johansson (2011) provided some empirical insights into the ramp-up process and concluded that integration of customers and suppliers, use of outsourcing strategy, collaboration, responsiveness to changes and flexibility across the supply chain can act as enablers to a more quickly ramp-up process.

In our study we use the theory of dynamic capabilities to guide the capabilities assessment process and help us come up with a set of capabilities that companies should have to succeed in upscaling. These capabilities can be ordinary or dynamic. Ordinary (or operational) capabilities are the sets of learned processes and activities that every company in the same industry can learn about them (Kleiner, 2013). Dynamic capabilities are idiosyncratic and unique because they are related to companies' history and path over the years (Helfat et al., 2007). Teece (2007) highlighted that the most critical capabilities an enterprise should have in order to build and sustain a competitive advantage are the ability to sense and shape opportunities, the ability to seize opportunities and the ability to manage threats and reconfiguration. These capabilities can help managers to get the future right by preparing existing resources for the future (Kleiner, 2013).

Dynamic capabilities is the most appropriate theory to use in order to capture the dynamic nature of automotive manufacturing (e.g. product lifecycle compression, needs continuously change) (Becker et al., 2017) and the dynamic nature of the upscaling where high risks and low initial level of knowledge exist (Surbier et al., 2014). Also, it is a well-suited theory to help us come up with a set of capabilities that companies should have in order to succeed in upscaling since an effective upscaling is an important factor in gaining competitive advantage (Akkermans et al., 2019). Moreover, dynamic capabilities theory has been widely considered to look into capabilities at the supply chain level enhancing its applicability to this study (Mitrega et al., 2017; Lee and Rha, 2016).

The architecture of the supply chain is another factor that has been linked to the upscaling performance measures (e.g. time-to-market, time-to-volume, quality and cost) but not directly addressed within the upscaling context (Fine, 1998). A supply chain that exhibits close geographic, organisational, cultural and electronic proximity among its parties is characterised as integral supply chain. In that case, the degree of outsourcing is low and the processes are highly synchronised. Close collaboration and a great deal of interactions and efforts is required to yield results and it is not very flexible, but it has the potential for high performance (Nepal et al., 2012; Park, 2014; Ülkü and Schmidt, 2011). A supply chain that exhibits low geographic, organisational, cultural and/or electronic proximity among its parties is characterised as modular supply chain. Of course, modular supply chain architectures do not have low proximity in all the elements described otherwise it would be hard to survive let alone to be advantageous (Fine, 1998). In that case, the degree of outsourcing is high and the suppliers have responsibilities over the final product which create risk sharing opportunities (Nepal et al., 2012; Park, 2014). Modularisation is characterised by a mix-and-match of capabilities allowing for cost reduction opportunities, increased quality and increased product variety (Doran et al., 2007). The rational for designing integral supply chains is usually based on performance while for modular supply chains is usually based on time-to-market and cost considerations (Fine et al., 2005). Ülkü and Schmidt (2011) suggested that when the development capability difference between the firm and its supplier is large then a more integral architecture is preferable.

The empirical study that follows draw from our synthesis of prior literature on upscaling and from the theory of dynamic capabilities. Figure 1 presents our conceptual framework which proposes that capabilities in the supply chain impact the upscaling performance and also the architecture of the supply chain impacts the upscaling

performance. The capabilities have been collected from the literature on upscaling and dynamic capabilities and these can be ordinary or dynamic. We also explore if there is any relationship between the factors capabilities and supply chain architecture.

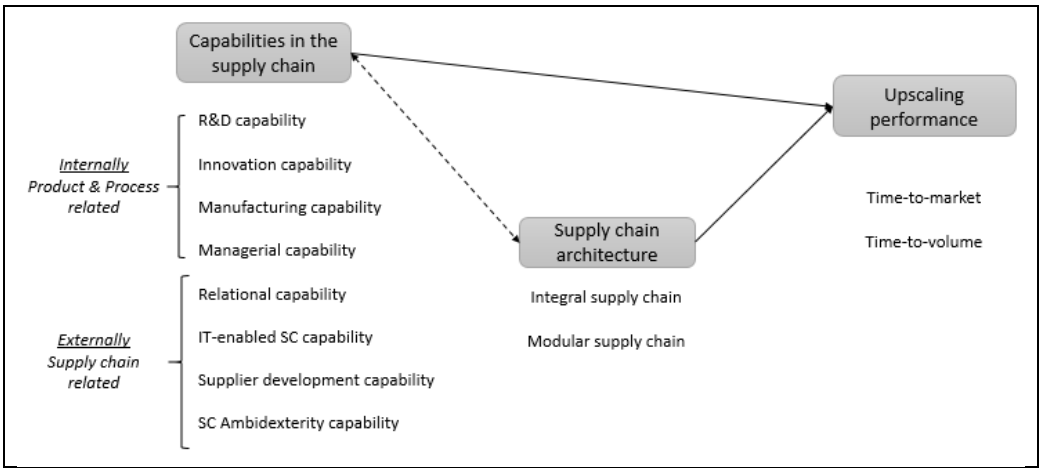

Figure 1 – Conceptual framework

Research methodology

We focused on the automotive manufacturing sector to investigate the upscaling as it is a highly competitive and dynamic sector with frequent ramp-ups because of continuous market changes and technological advancements (SMMT, 2018; APC, 2016). The rational to select a single sector was the different ramp-up drivers (e.g. product lifecycle, frequency of ramp-up, product complexity, industrial set-up) between different industries (von Gleich et al., 2012). So, the focus on automotive manufacturing provides a rich setting for our research and offers the potential for important insights into the capabilities needed and the impact of supply chain architecture on upscaling.

Multiple case studies and unit of analysis

The case study research was opted as the most appropriate method to conduct exploratory research (Yin, 2014). Multiple case studies were used to offer a deep understanding of the upscaling process and to produce robust results to reveal the case companies' capabilities and supply chain architecture that allowed them to succeed (Huq et al., 2016). Moreover, multiple case studies enhance the reliability of findings and reduce researcher bias as they offer the opportunity to compare and contrast different cases improving the external validity (Busse et al., 2017). The criteria for selecting the case studies were to be automotive manufacturers and suppliers, start-ups and well-established companies with research and design activities and manufacturing capabilities and to produce products of high volume and variety. Firms' capabilities, supply chain architecture and upscaling performance were investigated. So, the unit of analysis, i.e. case, is the firm with each having a clear supply chain role (i.e. manufacturer or supplier).

Data collection and analysis

We collected data from 5 case studies: 3 manufacturers and 2 tier-1 suppliers and the data collection process took place from May 2018 to February 2019. The main sources of data were semi-structured interviews mainly because of their strength to focus on the research topics allowing at the same time explanations and personal views. A semi-structured interview protocol was used and the interviews designed to last about 1 hour, allowing for enough time to gather the data and respecting the informants' availability. The

exploration began with some rational and direction from the conceptual framework. A total of 17 face-to-face semi-structured interviews were conducted with directors, supply chain, purchasing, logistics and production managers (Table 1). The interviews were recorded unless participants objected. We supplemented the interviews with five factory site visits, internal reports and multiple sources of secondary data to support interview data and also protect against researcher bias. Also, two secondments took place within the supply chain departments of two suppliers in order to gain rich insights on how to get the supply chain ready for production ramp-up and get hand-on experience.

Transcripts together with comprehensive notes were produced and unclear issues were clarified in follow-up emails. The analysis was performed using a combination of within and cross-case analysis (Wilhelm and Sydow, 2018). In the within-case analysis, we sought to understand what upscaling is, how they manage it and get their supply chain ready for production ramp-up by assessing their capabilities and their supply chain architecture. In the cross-case analysis, we sought to identify commonalities and differences in the upscaling process between the 5 cases; manufactures and suppliers.

Moreover, to ensure methodological rigour, we used and met the criteria of internal validity (e.g. we draw on different literatures; ramp-up, dynamic capabilities, supply chain architecture), external validity (e.g. we used multiple case studies and collected data from multiple sources), construct validity (e.g. we presented the analysis to experienced academics and industrial experts) and reliability (e.g. we developed and used an interview guide) based on the recommendations of Garver (2019) and Selviaridis et al. (2016).

Table 1 – Description of case studies and data collected

Name	Role	Interviewees / Key informants	Time spent
Auto_1	Manufa-cturer	Chief engineer (CE), Procurement manager (PM1), Quality manager (QM), Project manager (PM2)	6 hrs
Auto_2	Manufa-cturer	Supply chain manager (SCM), Change control manager (CCM), Logistics manager (LM), Production planning manager (PPM)	6 hrs
Auto_3	Manufa-cturer	Supply chain manager (SCM), Project manager (PM), Head of purchasing (HP)	4 hrs
Auto_4	Supplier	Chief technology officer (CTO), Head of purchasing (HP), Head of production & logistics (HPL)	1 month secondment
Auto_5	Supplier	Lean processes & systems manager (LSM), Logistics project manager (LPM), Head of purchasing (HP)	1 week secondment

Findings

Within-case analysis

Auto_1 is a start-up automotive manufacturer specialising in the design and development of electric vehicles and is considered a highly technological and innovative company both in terms of product design and business strategy. In the upscaling phase, the company determines the resources needed, the associating costs, the people and the skills needed. The upscaling phase starts at the R&D stage and successful upscaling means reaching the production target and having the market ready.

Auto_2 is a well-established multinational automotive manufacturer. The company classes upscaling as a new product development which starts when a contract to build a vehicle is agreed. The supply chain team is instantly getting involved with sourcing to influence the suppliers or influence the selection of the suppliers. The SCM of Auto_2 reported that "*suppliers should match the company's capabilities otherwise they're limiting the company's ability to perform to their best of their capability*". Successful upscaling means that all of the targets for each of the different functions are met.

Auto_3 is also a well-established multinational automotive manufacturer which views upscaling as the introduction of a new product or modification of an existing one. The supply chain and purchasing team gets involved as soon as the engineering team pass them the project specification and a successful upscaling means on time deliveries, correct product specifications and be on budget.

Auto_4 is a start-up tier- 1 supplier of electric parts for the automotive sector. For the company upscaling is the whole preparation for ramping-up and the process for getting the company fit, getting the product fit and the getting the suppliers fit. Upscaling starts at the proof of concept stage and the successful upscaling means achieving the volume in time, in budget and in quality.

Auto_5 is a well-established global tier-1 supplier of electric parts for the automotive sector. The company classes upscaling as a new product introduction and successful upscaling means delivering to the customer on time without additional costs.

Table 2 briefly presents the case studies' capabilities and supply chain architectures.

Table 2 – Brief within-case analysis and quotations

Name	Capabilities in the supply chain	Architecture of the supply chain
Auto_1, Manufa-cturer	R&D, technology and production capabilities, key thing to the understand market *"The product design is changing & we look at ways of producing in cheaper & more efficient processes."* PM1 *"There is going to be a lot of investment to get the car into a production suitable car."* PM1	As technologies change, the company do not want to commit to suppliers, only one partnership and overall very little integration with suppliers *"We're outsourcing one of the biggest cost item at the moment but it will come in-house eventually because the supplier is not capable of doing our future volumes."* PM1
Auto_2, Manufa-cturer	Manufacturing, managerial, supplier development and relational capabilities *"We'll all get to the table with the supplier, understand the project right at the very start and then there are always forward meetings, for very high risks suppliers we do daily or weekly meetings to support them."* CCM	50% is outsourced, suppliers are all over the world, close relationships & continuous risk assessment *"We try to influence the suppliers' selection because it's a lot easier for us to manage and it's a lot cheaper in so many respects to have the suppliers all around our plant, very locally."* SCM
Auto_3, Manufa-cturer	Managerial and relational capabilities *"We do things to speed up the process, we are aware of the changes that are coming so we go to the suppliers ask them about lead times, cost etc."* HP *"Suppliers are always very flexible, that's all about good relationships."* HP	80% is outsourced, they only do final assembly, close relationships *"There is no use in designing something that cannot be manufacturing, so critical suppliers are instantly on board."* HP *"Lots of meeting with suppliers, it's all about relationships and trust."* HP
Auto_4, Supplier	Managerial, manufacturing capabilities *"You need to have enough experience in-house to be at least able enough to check your suppliers' promises."* CTO	20% is outsourced, no integration with suppliers but do have some partnerships *"To convince your partner to commit to your plan and invest you need to share the same vision of the future."* CTO
Auto_5, Supplier	Managerial, relational & IT capabilities *"Some of our teams have access to our customers' platforms, we can check information or feed the system with delivery information."* LSM	50% is outsourced, partnerships with customers *"The relationship between us and our customers is more of partners rather than customer-supplier relation."* LSM

Cross-case analysis

Our cross-case analysis indicated that both manufacturers and suppliers consider upscaling as a supply chain challenge and not solely as an internal challenge. The start-ups, Auto_1 and Auto_4 give most of their attention on planning internally for upscale by determining resources, costs and investments needed and they face a number of challenges with regards to building a supply chain able to support their future capacities, increase their credibility and develop trust (*"at the moment, there is a lot of begging involved where the supplier has all the power, ... but those relationships have to change"* SCM, Auto_1). On the other hand, the well-established companies, Auto_2, Auto_3 and Auto_5 class the upscaling as new product introduction where they either use their existing supply chain or add some new suppliers but in both cases they need to go through the process of assessing the readiness of their supply chain and making sure that they are able to upscale and support their volumes. All of the interviewees agreed that supply chain and purchasing functions should get involved in the upscaling project as early as possible, before even the proof of concept stage in order to design for manufacture ("*there is no use in designing something that cannot be manufacturing, so critical suppliers are instantly on board*" HP, Auto_3), plan and determine costs and investments needed.

Our research shows that manufacturers and suppliers have developed dynamic R&D capabilities as they are trying to generate innovation by exploiting external resources (e.g. suppliers, customers, market) to respond to the changing market condition (*"most of the flexibility is that we are talking about product flexibility and volume flexibility and will depend on what the market wants more"* CTO, Auto_4). Also, we observed manufacturing capabilities with companies highlighting the importance of designing for manufacturing and dynamic managerial capabilities with managers being able to sense forthcoming changes and being proactive to avoid delays in the process or managers recognising the importance of spillover learning (*"we do things to speed up the process, we are aware of the changes that are coming so we go to the suppliers ask them about lead times, cost etc."* HP, Auto_3*, "we transfer the knowledge from one project to another"* SCM*,* Auto_3, *"push much earlier for information than expected time"* LPM, Auto_5). Moreover, some of the companies had developed relational capabilities as a result of the good relationship with their supply chain partners, the information exchange, the regular communication and the development of trust. In particular, Auto_2, Auto_3 and Auto_5 had developed strong relational capabilities with their suppliers and customers resulting in increased flexibility, time savings and even cost reductions (*"always involve the suppliers at the very outset, it will save a massive amount of time"* HP, Auto_3, *"we tend to be more in a partnership relationship rather than customer-supplier relationship, ... we both have on target, to be successful"* LPM, Auto_5). In Auto_2, we also observed strong supplier development capabilities where the company has a separate department assigned to prepare the suppliers to meet production demand (*"at the moment we have many suppliers who are struggling to build and support our volumes, so many different suppliers, lots of different telephone conferences, lots of different visits from my team and try to understand how we can improve them"* SCM, Auto_2*, "good planning and preparation of the supplier from us means that we can reduce costs"* SCM, Auto_2).

Regarding the supply chain architecture we categorised the cases into two groups. Auto_1 and Auto_4 presented characteristics of an integral supply chain as they have low degree of outsourcing, low dependency levels, full control over their product design and quality for different reasons and no close relationships or partnerships with their suppliers. This architecture have given them the potential for high performance and quick time-to-volume, but not high products variety (*"when you're doing most in-house you're*

in control but it's costly and you cannot have a lot of projects, different projects, you cannot make everything in-house" HP, Auto_3). On the other hand, Auto_2, Auto_3 and Auto_5 presented characteristics of a modular supply chain as they have high degree of outsourcing and they have developed trust with their suppliers, strategic alliances and partnerships. This architecture have given them the advantages to produce products of high variety, share risks and increase their flexibility. Moreover, it is interesting to note that the cases with characteristics of an integral supply chain (Auto_1, Auto_4) have highly invested in developing core capabilities in-house while the cases with characteristics of a modular supply chain (Auto_2, Auto_3, Auto_5) have significantly invested in developing capabilities across their supply chain and they present a mix-and-match of capabilities.

Discussion and conclusions

Our research shows that dynamic R&D, manufacturing and managerial capabilities, should be coupled with strong relational and supplier development capabilities in order to carry out a successful upscaling. This is in line with the findings by Trebilcock (2016) and Thisdell (2012) who have showed that limited capabilities across the supply chain, unable suppliers and poor infrastructure make it hard for manufacturing companies to meet the demand. We also confirm previous findings in the literature about the importance of R&D capabilities, learning activities (Carrillo and Franza, 2006; Terwiesch and Xu, 2004) and supply chain collaboration (Kalaitzi et al., 2019; Li et al., 2014) and we demonstrate how different sets of capabilities are combined with different supply chain architectures which in turn, leads to different upscaling performance. Finally, our findings highlight dynamics in upscaling (e.g. market dynamics) and the importance of adapting to changes (e.g. design or volume changes) through increased flexibility across the supply chain.

Theoretical implications

This research increases our understanding of the upscaling process and adds further empirical evidence to the body of literature. In particular, we clarify the concept of supply chain upscaling and we consider implications for the supply chains during production ramp-up by demonstrating how the case study companies prepare and get ready their supply chain for upscaling. By drawing on the dynamic capabilities theory, we go beyond a structured way of investigating the upscaling and we identify and propose specific capabilities to allow companies in manufacturing supply chains to carry out a successful upscaling. Applying a dynamics perspective has also shifted our attention to the importance of adapting to changes (e.g. design or volume changes) through increased flexibility across the supply chain. Finally, our study not only contributes to the upscaling and supply chain management literature but also to dynamic capabilities theory by identifying dynamic capabilities in manufacturing supply chains that help companies to achieve a quick time-to-market and time-to-volume. Previous research in strategic management literature have explored and proposed specific dynamic capabilities to allow firms to successfully adapt to changing environments and gain a competitive advantage (Mitrega et al., 2017; Lee and Rha, 2016) but not in the context of upscaling.

Managerial implications

This research addresses a real industry need for strengthening and growing supply chains and our findings provide several implications for managers of automotive manufacturers. First, we propose specific capabilities to facilitate the upscaling process in dynamic environments. Second, we show how managers should match capabilities with the

architecture of their supply chain to achieve the desired upscaling performance. For example, we show that companies that deploy an outsourcing strategy have extended their upscaling to their suppliers and they should focus on developing supply chain related capabilities, support and guide their suppliers and strengthen the relationships with them. So, much of the responsibility for the success of upscaling lie with the supply chain and purchasing teams to manage the supply base. Also, at the very practical and operational level both manufacturers and suppliers should consider implementing shared platforms to facilitate transparency and information sharing especially when there are changes.

Limitations and future research

Notwithstanding the novel context of this study, the research is not without its limitations. First, the empirical data were collected only from the automotive manufacturing sector and that limits the generalisation of the results. Aerospace or high-tech manufacturing sectors which have been discussed in the literature with regards to upscaling may produce different results because the ramp-up drivers (e.g. product lifecycle, frequency of ramp-up) differ significantly. Second, more cases are needed to explore upscaling. This is an ongoing research so in the future more case studies will be included to build on these insights. And third, our research is positioned in periods of growth but there are also times of recession. So, there are promising directions for further research to explore how companies should manage the dynamics of upscale and downscale in automotive manufacturing sector following the work of Akkermans et al. (2019) in digital services.

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Exploring the effects of the agile, adaptable and aligned supply chain on performance: the mediating role of collaboration

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Abstract

This paper analyzes the mediating role of supply chain collaboration (SCC) in improving performance (SC efficiency and SC responsiveness) from the Triple-A SC variables (agility, adaptability and alignment). PLS-SEM has been used in a sample of 277 Spanish companies (more than 50 employees). The results show that there is a direct effect of SCC on both SC efficiency and responsiveness. The mediating role of SCC has been found in the relationship between SC agility and SC alignment, and both performance constructs. SC adaptability has no significant direct effect on collaboration and collaboration does not mediate its relationship with performance.

Keywords: Triple-A, Performance, Collaboration

Introduction and purpose

Managing the supply chain (SC) effectively has become critical for firms' growth and survival. Several authors highlight that supply chain integration (SCI) is the core component of SC (Kim, 2009). SCI implies "collaborative inter- and intra-organisational management on the strategic, tactical and operational levels of activities (and their corresponding materials, funds and information flows) that, starting with raw materials suppliers, add value to the product to satisfy the needs of the final customer at the lowest cost and the greatest speed" (Alfalla-Luque et al., 2013, pp. 2).

Previous research agrees that a higher level of SCI positively influences performance (e.g., Kim, 2009; Zhao et al., 2013), although there are some other studies that do not confirm this (e.g., Swink et al., 2007; Alfalla-Luque et al., 2015). Thus, results are inconclusive (Jin et al., 2013; Chang et al., 2016) and more empirical research is needed on this topic (Leuschner et al., 2013).

There is also a consensus in the prior research that customer and supplier collaboration (external collaboration or SCC) is a key factor and even an antecedent of SCI (e.g. Flynn et al., 2010; Alfalla-Luque et al., 2013; Tsanos et al., 2014; Liao et al., 2017). Previous studies confirms the impact of SCC on performance (Soosay and

Hyland, 2015; Ralston et al., 2017) but mixed results have been found (e.g., Anderson and Jap, 2005; Villena et al., 2011; Fawcett et al., 2015). Consequently, there has been a recent call for a better understanding of mediating routes by which SCI affects performance to gain a comprehensive knowledge of the phenomenon from an academic and management point of view (e.g., Chang et al., 2016; Ataseven and Nair, 2017; Niranjan et al., 2018).

SCC has been considered a crucial mediator between several SC dimensions and performance (Baihaqi and Sohal, 2013; Wu et al., 2014; Hui et al., 2015; Kim et al., 2017; Salam, 2017; Levi-Bliech et al., 2018). Therefore, the lack of consensus in stating that the relationship between SCI and performance is positive perhaps may be due to that SCI can be a transversal element in the SC management and, consequently, act as a mediator for the achievement of performance/competitive advantages (CAs) from business strategies and practices (Vanichchinchai, 2012; Alfalla-Luque et al., 2015). One of the most prominent strategies and practices has been proposed by Lee (2004), who states that a successful SC must be agile, adaptable, and aligned (Triple-A SC). There are some calls in recent literature for more attention and research efforts on these variables (Dubey et al., 2015; Li et al., 2015; Alfalla Luque et al., 2018; Feizabadi et al., 2019), but so far there are few research studies that have analyzed antecedents, consequences or moderated/mediated factors of the three variables together in the same framework. This research analyzes the mediation role of SCC in the relationship betweenTriple-A SC variables and performance. In this regard, the literature has considered Triple-A SC to be an antecedent of SC performance (i.e. Whitten et al., 2012) but has not explored the possible mediating influence of SCI determinants such as collaboration. Therefore, this study focuses on analyzing the mediating role of SCC in improving performance from the Triple-A SC.

Theoretical background and hypotheses

SCC and SC performance

SCC is defined as "a partnership process where two or more autonomous firms work closely to plan and execute SC operations toward common goals and mutual benefits" (Cao and Zhang, 2011, pp. 166). Consequently, SCC is based on mutual trust and goals, shared reward and risk, and joint decisions seeking a win-win relationship between partners that achieve more benefits than if they were to act independently (Cao et al., 2010). Coordinating efforts with SC partners enables responsiveness to real-time demand changes and competitor strategies (Kahn et al., 2006).

The ultimate goal of an effective SCC capability is to achieve differential performance and, ultimately, create and sustain a competitive advantage (CA) for SC partners (Cao and Zhang, 2011; Hui et al., 2015). Growing research interest confirms the impact of SCC on performance (Soosay and Hyland, 2015; Ralston et al., 2017). Among the main traditional operational benefits of SCC that should be noted are: cost reductions; enhanced quality and inventory management; shorter cycle times; delivery improvements; higher flexibility and adaptability to cope with uncertainty and variability; responsiveness; and enhanced customer service levels (e.g., Hui et al., 2015; Kim et al., 2017; Ralston et al., 2017).

Although there is a broad consensus in the prior research that a higher degree of SCC leads to superior performance and CA, it is important to highlight that mixed results have been found (e.g., Anderson and Jap, 2005; Villena et al., 2011; Fawcett et al., 2015). These mixed findings reveal the complexity of the SCC-performance relationship and further investigation is needed (Liao et al., 2017). In order to contribute

to the previous research, the following hypotheses are proposed:

H1: SCC is positively related to SC efficiency.

H2: SCC is positively related to SC responsiveness.

SC agility, SCC and SC performance

SC agility is the ability to rapidly detect and respond to short-term changes in real demand and supply in order to generate or maintain a CA (Alfalla-Luque et al., 2018). SC agility is identified as a key element of competitiveness and directly impacts on producing and delivering products in a timely and cost effective manner (Swafford et al., 2006). SC agility is essential for inventory reduction and the ability of firms to respond to final demand more quickly, adapt to market variations more efficiently, and integrate with customers and suppliers more effectively (Mason et al., 2002). Firms have responded to dynamic and volatile markets by developing an agile SC, which implies the capability of interpreting and responding to real demand (Scholten et al., 2010).

Scarce studies include all the Triple-A SC dimensions in the same framework and analyze the individual impact of each on performance/CA (Dubey et al., 2015; Dubey and Gunasekaran, 2016; Attia, 2016; Dubey et al., 2018; Alfalla-Luque et al., 2018). In this regard, SC agility has been demonstrated to have a positive impact on organizational performance (Khan and Pillania, 2008; Attia, 2016), logistics and human performance (Dubey et al., 2015), humanitarian SC performance (Dubey et al., 2015; Dubey and Gunasekaran, 2016), CA (Dubey et al., 2018), flexibility CA, and financial CA (Alfalla-Luque et al., 2018). However, the findings of some studies have been mixed. Thus, Alfalla-Luque et al. (2018) have not confirmed a positive impact on cost CA, quality CA and delivery CA.

Taking the previous research into account, new empirical evidence of the relationship between the Triple-A SC and performance is required. Hence, the following hypotheses are formulated:

H3: SC agility is positively related to SC efficiency.

H4: SC agility is positively related to SC responsiveness.

SCC plays a key role between several SC dimensions and performance. For example, Baihaqi and Sohal (2013) propose that information sharing across the SC is crucial but insufficient on its own to bring significant performance improvements. These authors confirm that collaboration with SC partners fully mediates the relationship between information sharing across the SC and organizational performance. In the same vein, Wu et al. (2014) test relationships between several SC drivers or antecedents (trust, commitment, reciprocity, and power), information sharing and SCC, and SC operational and financial performance and highlight that a successful SC could not be achieved without the mediating role of information sharing and SCC. In addition, SCC is shown to play a much greater mediating role in achieving SC performance than information sharing. However, no studies have been found analyzing the mediating effect of SCC between SC agility and performance. Consequently, the following hypotheses will be tested:

H5: SCC has a mediating effect between SC agility and SC efficiency.

H6: SCC has a mediating effect between SC agility and SC responsiveness.

SC adaptability, SCC and SC performance

SC adaptability can be defined as the ability to adapt strategies, products and/or technologies to structural market changes (Alfalla-Luque et al., 2018). The complex and

turbulent market environment requires an adaptable SC to increase the possibilities of survival and this has become a key prerequisite for achieving a sustainable CA. Scarce research has been found about adaptability in the SC context (i.e. Ivanov, 2010; Eckstein et al., 2015; Schoenherr and Swink, 2015).

Focusing on the papers that consider the three Triple-A SC variables in the same framework and analyze the individual impact of each on performance/CA, a positive impact of SC adaptability has been confirmed on organizational performance (Khan and Pillania, 2008; Attia, 2016), logistics performance (Dubey et al., 2015), humanitarian SC performance (Dubey and Gunasekaran, 2016) and cost CA, quality CA, delivery CA, flexibility CA and financial CA (Alfalla-Luque et al., 2018). Nonetheless, Dubey et al. (2015) did not confirm a positive impact on human performance. Based on previous mixed findings, the following hypotheses are formulated:

H7: SC adaptability is positively related to SC efficiency.

H8: SC adaptability is positively related to SC responsiveness.

As in the case of SC agility, the mediating effect of SCC in the relationship between SC adaptability and performance has not been analyzed in previous research. This research contributes to the literature testing the following hypotheses:

H9: SCC has a mediating effect between SC adaptability and SC efficiency.

H10: SCC has a mediating effect between SC adaptability and SC responsiveness.

SC alignment, SCC and SC performance

SC alignment is the ability to share information, responsibilities, and incentives with SC members to coordinate activities and processes (Alfalla-Luque et al., 2018). SC alignment implies strategic coordination between partners (Flynn et al., 2010) and pursues the consistency of all SC members' interests (Lee, 2004). The SC should be managed to meet the demands of product/market speed and complexity through the coordination of operations (Kehoe et al., 2007).

SC alignment has been determined to have a positive impact on organizational performance (Khan and Pillania, 2008; Attia, 2016), logistics performance (Dubey et al., 2015), human performance (Dubey et al., 2015) and cost CA, quality CA, delivery CA, and financial CA (Alfalla-Luque et al., 2018). A positive impact on humanitarian SC performance (Dubey and Gunasekaran, 2016) and flexibility CA (Alfalla-Luque et al., 2018) has not been confirmed, however. Consequently, the Triple-A SC dimensions show different impacts on different performance/CA measures, and the results are inconclusive. The following hypotheses are proposed:

H11: SC alignment is positively related to SC efficiency.

H12: SC alignment is positively related to SC responsiveness.

Finally, the mediating effect of SCC in the relationship SC adaptability – Performance will be analyzed through the following hypothesis.

H13: SCC has a mediating effect between SC adaptability and SC efficiency.

H14: SCC has a mediating effect between SC adaptability and SC responsiveness.

Considering all the above, this study contributes to the previous literature analysing the relationship between SCC and performance, specifically regarding SC efficiency (H1) and SC responsiveness (H2). Specifically, this study analyzes the mediating role of SCC in improving performance from SC agility, SC adaptability and SC alignment. This research analyze the individual effect of each Triple-A SC variable on performance (H3, H4, H7, H8, H11, H12) and the mediating effect of SCC (H5, H6, H9, H10, H13, H14). The proposed research framework is shown in Figure 1.

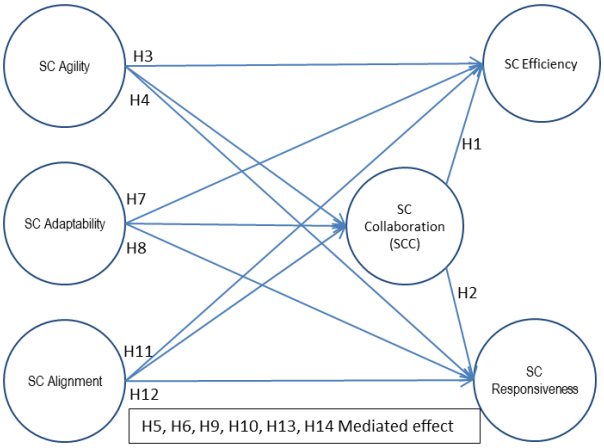

Figure 1 – Proposed research framework

Methodology

To provide empirical evidence of the different proposed research hypotheses, a population of 2,650 Spanish manufacturing firms (with a minimum of 50 employees) was established as the object of study. 277 companies (10.5%) responded to the survey (confidence level of 95 % for p = q = 0.5) from January to July 2018. No evidence of response bias was found in a comparison of respondents and non-respondents. The first forty responses and the last forty responses were compared and no significant differences ($\alpha = 0.05$) were found for any of the variables, which confirms that there was no late response bias. In short, the data and analysis confirm that the sample used in the study was randomly obtained and that it statistically represents the population.

SC agility, SC adaptability, and SC alignment scales have been adapted from previous research on this topic (Tachizawa and Gimenez, 2010; Arana-Solares et al., 2011; Qi et al., 2011; Gligor et al., 2013; Marin-Garcia et al., 2018). SCC has been measured through a simple scale focused not on the object or content of collaboration (activities, information, resources, etc.), but on the scope of collaboration (Barrat, 2004). SC efficiency measurement have been adapted from Liu et al. (2009) and Danese et al. (2012), and SC responsiveness from Reichhart and Holweg (2007) and Bortolotti et al. (2015). All the constructs were modeled as reflective with 3 to 6 indicators measured on a five-point scale.

The research model was tested using PLS-SEM with SmartPLS 3. This variance-based multivariate statistical technique is being increasingly used in many disciplines, including SCM. Model evaluation was carried out in two stages: a) assessment of the measurement model, and b) assessment of the structural model. The path weighting approach was used to estimate model coefficients and statistical significance was tested by bootstrapping with 5,000 subsamples.

Results

Measurement model

The research model includes six constructs. For the evaluation of the measurement model, reliability of these constructs (through the composite reliability index), convergent validity (by AVE, Average Variance Explained) and discriminant validity (with the Fornell-Larcker criterion) were verified.

As can be seen in Table 1, the constructs' composite reliability varies between 0.80 and 0.90, which is above the 0.7 minimum required to confirm their reliability. Convergent validity is also fulfilled, given that AVE is higher than 0.5 in all cases

(0.53-0.74).

Table 1 – Reliability and convergent validity of latent variables

Latent variable	# items	Loadings	Composite Reliability	AVE
SC Agility	6	.704 – .785	.840	.569
SC Adaptability	4	.708 – .806	.872	.533
SC Alignment	6	.692 – .847	.897	.593
SC Collaboration	3	.852 – .873	.895	.739
SC Efficiency	3	.681 – .845	.800	.573
SC Responsiveness	5	.664 – .845	.891	.622

Finally, discriminant validity is also demonstrated by the fact that all between-construct correlations are below the square root of the constructs' AVEs (Fornell-Larcker). In view of these results, we can conclude that the model is reliable and valid, so the structural model can be analyzed.

Structural model

Regarding the structural model, Figure 2 shows the results of the direct effects estimations (path coefficients and p-values in brackets). The results show that there is a direct effect of external collaboration on both SC efficiency and responsiveness, so H1 and H2 are supported.

In addition, some differences have been found in the analysis of the relationship between each Triple-A SC and the performance measures. SC agility has a positive and significant impact on SC efficiency and responsiveness (H3 and H4 confirmed), but neither SC adaptability nor SC alignment has confirmed these effects (H7, H8, H11 and H12 not supported).

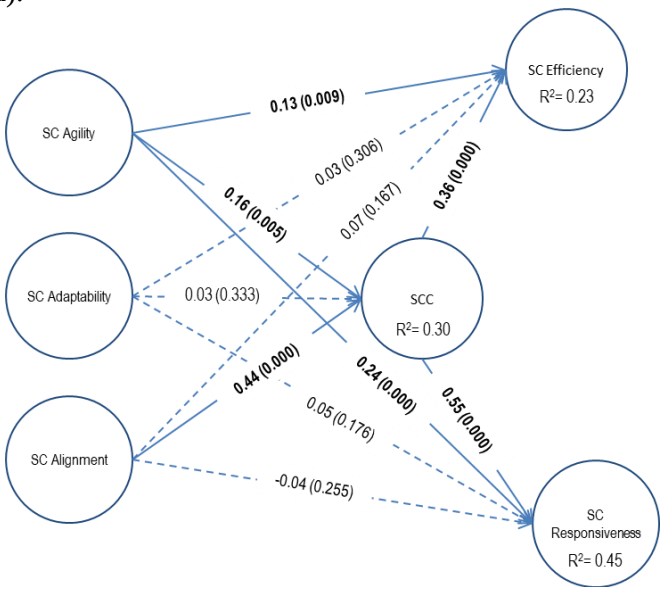

Figure 2 – Main results of the model

Table 2 shows the indirect effects in the model. The mediating role of SCC has been found in the relationship between SC agility (H5, H6) and SC alignment (H9, H10), and both performance constructs. SC adaptability has no significant direct effect on collaboration and collaboration does not mediate the relationship with performance (H13 and H14 not supported).

Table 2. Individual indirect effects (mediating variable: SC Collaboration)

	Path coefficient	*Std. Dev.*	*t - Student*	*p-value*
SC agility -> Efficiency	.058	.026	2.229	.013
SC agility -> Responsiveness	.088	.036	2.436	.007
SC adaptability -> Efficiency	.010	.024	0.421	.337
SC adaptability -> Responsiveness	.016	.036	0.426	.335
SC alignment -> Efficiency	.158	.037	4.270	.000
SC alignment -> Responsiveness	.242	.045	5.332	.000

Conclusions

The literature has considered Triple-A SC to be an antecedent of SC performance (i.e. Whitten et al., 2012) but has not explored the possible mediating influence of SCI determinants such as collaboration. By assessing the mediating effects of collaboration, the results of this study contribute to the SCM literature by answering the call for a better understanding of the interaction between SCI and performance (e.g., Chang et al., 2016; Ataseven and Nair, 2017; Niranjan et al., 2018) and, specifically, represent a clear step forward in the knowledge of Triple-A SC-performance relationship. This is especially appropriate and useful when mixed findings as to the relationship between SCI and performance have been detected in prior research, in general, and in the area of the Triple-A SC, in particular.

One of the main novelties of this study is that it goes one step further in the Triple-A SC by finding that the direct impact of each Triple-A SC variable on performance is different. Only the direct effect of the SC agility is significantly positive on efficiency and responsiveness. This finding is in line with a previous research (Khan and Pillania, 2008; Attia, 2016). Therefore, SCC acts a mediating variable in the relationship SC agility-performance and SC alignment-performance.

These results represent a novel contribution to our knowledge of the impact of a Triple-A SC on performance/CA and demonstrate the importance of SCC especially. It is important to remark that very few empirical studies have analyzed in the same framework the impact of Triple-A SC variables on performance (Dubey et al., 2015; Dubey and Gunasekaran, 2016; Attia, 2016; Dubey et al., 2018) and only one, their impact on CA (Alfalla-Luque et al., 2018).

Several managerial implications can be drawn from this study. OM and SC managers should be aware that their efforts to improve the implementation level of the Triple-A SC should be accompanied by advances in SCC intensity with partners. SCC has demonstrated its direct impact on performance and its mediating effect with SC agility and alignment.

Future research may find further evidence of the relationship between the Triple-A SC and performance, and the role of mediating variables such as SCC. This will enable progress to be made in the development of Triple-A SC theory through testing the hypotheses in different countries and samples.

This study is not free of limitations that could be the basis for future research. The aim of the analysis is exploratory in nature and data are cross-sectional and collected from only one country. In spite of this, one of the study's main strengths is worth stating: This is one of the few empirical studies on Triple-A SC that analyzes a broad, multisector (14 different sectors) sample and uses a relatively large sample (277 companies). A logical extension of this study is to replicate the research framework in other geographical settings and to conduct longitudinal studies to analyze interactions and interdependencies among Triple-A SC dimensions and CA, and track changes over

time (Li et al., 2015; Alfalla-Luque et al., 2018).

In addition, the analyzed mediating effects are consistent with prior SC research; however, there are many other SC aspects that could play crucial mediating, and even moderating roles in the relationship between the Triple-A SC and CA. Among the factors that could be suggested are type of industry, firm size, environmental dynamism, uncertainty, SC structure and complexity, position in the SC, competitive intensity, product characteristics and time. This would extend the research and allow new insights to be gained.

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How the implementation of new regulations impacts the digital transformation of the pharmaceutical supply chain – the case of product traceability in Europe

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Abstract

Purpose: To identify the factors of traceability that impact digital supply chain evolution and to provide a framework for successful digital transformation in such context
Methodology: A case study on the implementation of new traceability regulation in the distribution network of pharmaceuticals in Europe.
Findings: Provide an in-depth analysis, from a Supply Chain lifecycle perspective, of the contingent variables (enablers, barriers) and expected benefits of traceability implementation.
Relevance/contribution: Likely to be the first study providing empirical evidence on the digital transformation process of a whole sector through a Supply Chain lifecycle evolution perspective.

Keywords: Digital Transformation, Supply Chain Lifecycle, Traceability.

Introduction

Falsification of medicines has been on the rise since more than a decade. European Union (EU) statistics report a sharp (threefold), increase of falsified medicines seized at borders starting from 2006 (2,7M articles). The World Health Organization (WHO) estimates a market share of up to 1% for falsified medicines in industrialized countries, while the European Commission (EC) has estimated that approximately 1.5 million falsified packs make it as far as the legal Supply Chain (SC) (European Commission, 2015).

Besides the socio-economic costs of related illness (estimated at almost €1 billion a year in the EU), falsified medicines also represent a significant damage for the players of the pharma SC, through increased costs for recalls, loss of product trust and damage of company image. This also impacts the broader European economy, since protecting the competitiveness of the pharmaceutical sector is critical in meeting the Europe 2020

targets on qualified employment, Gross Domestic Product (GDP) and Research & Development expenditure. (European Commission, 2015)

In February 2016, a delegated regulation, known as EU Falsified Medicines Directive (FMD) was released by the EU commission to implement traceability in the SC of pharmaceuticals within three years (by 2019). This new EU regulation requires the implementation of the first traceability system for medicines across all the EU and the European Economic Area (EEA), and it is based on the authentication model of traceability through serialization (Greenberg, 2014).

The implementation of such a system impacts the whole Pharma sector, since it is the shared accountability of all the SC stakeholders: Pharmaceutical Companies, Generic manufacturers, Parallel traders, Wholesalers and Pharmacies (Retail and Hospital), who have the shared accountability over the new system (European Commission, 2016/161).

The FMD traceability system is also a major investment in the digitalization of the pharmaceutical chain in Europe since, before EU FMD, there was no pan-European system available and traceability systems where not even present in many countries or, if they were, they were not interoperable with each other (European Commission, 2015).

A total of 155.000 SC players will need to legally comply with the regulation and thus connect and operate in a new and single traceability system, where every single pack of medicine will have a serial number stored and a chain of events recorded through its lifecycle (European Commission, 2016/161, EMVO, 2019), making EU FMD one of the largest and most comprehensive product traceability implementations in an industry sector.

When looking at the academic literature on traceability, while different studies can be identified addressing traceability in SC (Greenberg, 2014, Rotunno et al., 2014, Oldland et al., 2015, Simoens, 2009, Engelseth, 2009, Banterle, Stranieri, 2008), few take into consideration a whole sector or move beyond a single player's perspective.

By illustrating the implementation of traceability in a whole sector and from a multi-stakeholder perspective, this paper wants to propose an understanding of traceability as a factor of SC lifecycle evolution (MacCarthy et al., 2016), and it aims to provide the first empirical evidence on the contingent factors and the expected benefits of digital SC transformation of such kind.

The SC lifecycle can be thought, similar to a product lifecycle, to comprise the different stages of emergence, growth, maturity and decline of a supply chain, this shifts the focus from the management of existing supply chains (at whatever stage they might be) to understanding the overall patterns of supply chains (MacCarthy et al., 2016).

Theoretical Background

Contingency Theory

Since the aim of this paper is to study the impact of a new regulation, in the frame of which the SC of pharmaceuticals needs to operate, and that the pharmaceutical supply chain is regarded as a highly regulated SC that takes its shape from the regulatory environment in which it operates (Greenberg, 2014, MacCarthy et al., 2016), our research will be guided by contingency theory (CT).

We provide a brief outline of CT and the reason why we believe it provides a good fit with this research, before moving on with the more specific theoretical background of our study.

CT stipulates that organizational performance is driven by the fit with the environment, enabled through a high level of integration in the organization itself (Lawrence, Lorsch, 1967).

From a CT perspective, the evolving Operations Management (OM) practices that organizations take, from time to time, are their response to the contextual variables, while their fit to the context is one of the pillars of performance (Sousa, Voss, 2008).

CT is one of the most enduring theories used in OM, while Supply Chain Management (SCM) is the most frequent topic of study in OM (Walker et al., 2015).

The relevance in taking a CT view in SCM is also highlighted by (Kembro, Selviaridis & Näslund, 2014), they have recognized an increased use of CT "acknowledging that there is no universal solution how to approach information sharing in a supply chain". They also suggest that the appropriate level of information sharing is determined by the supply chain context and call for more sophisticated ways to use continency theory through in-depth case studies.

CT is thus a well-grounded theoretical underpinning in both OM and specifically in SCM and its continued use is advised for research on SC collaboration and information sharing.

Virtual and Digital SC

Since a key element of traceability is the flow of information along the SC (Engelseth, 2009), we find useful to briefly mention some of the key research on SC digitalization from the outset of the internet era, as these can still provide important elements into our study of traceability from a SC lifecycle perspective.

The concept of virtual SC was articulated in the early internet era, during the development of e-commerce, to identify a network of firms that temporarily come together, enabled by the Internet, on an opportunistic bases to exploit fast changing business opportunities (Strader, Lin & Shaw, 1998).

A virtual SC has its own lifecycle going through the four phases of firms' identification, SC formation, SC operation and, ultimately, SC termination; with important enablers for a successful lifecycle being the level of SC integration, activity coordination, IT infrastructure and information sharing (Strader, Lin & Shaw, 1998).

The need for adopting a virtual SC is driven by a change in the overall business logic, which is challenged by underlying contingent factors such as shortened time to market, blurring of organizational boundaries, increased knowledge intensity and IT-based competition (El Sawy et al., 1999). Virtual SC also lead to the development of new capabilities to create value out of the knowledge in IT systems but require the integration of the IT strategy into the overall company strategy (El Sawy et al., 1999).

Key success factors for virtual SC have been identified in development of strategic alliances with partners, internet-based IT, process re-engineering and visibility in supply chain, with information sharing as the driving force of the SC (Gunasekaran, Ngai, 2004).

Taking stock of the previous virtual SC literature, (Swierczek, Kisperska-Moron, 2016) identify, through a quantitative study, the key attributes of manufacturers in virtual SC as being their level of IT investment, shorter planning horizons and higher levels of inventory of a wide range of standardized products; while also recognize as key enablers the ability of these companies in blurring the organizational boundaries, establishing partnership along the SC (even with competitors) and holding a strong customer orientation and superior product value.

Summarizing the key findings of the virtual SC literature, we can say that the virtual evolution of SC was triggered by some of the early trends of SC globalization, such as time pressures, boundary blurring and the advent of the knowledge economy, and it relied on some consistent enabling factors such as the level of IT infrastructure, the level of SC partnering, the level of information sharing permitting SC visibility. The development of Virtual SC has also led to the development of specific SC characteristics such as broad

standardized product ranges, increase in customer orientation and service and continued investments in IT, together with the development of new capabilities relying on an intensification of the use of data and information.

As the use of internet-enabled technologies became more established and widespread, the distinction between virtual and non-virtual SC blurred, as most companies adopted internet technology at different levels. We will call this new phase with the general term digital SC.

While the benefits of internet-enabled SC are now established, the reasons behind different levels of performance is further investigated.

Concerning the enablers in digital SC performance, some are similar to those identified in the earlier Virtual SC literature, like supplier synergy, IT infrastructure, information intensity, and executive's IT knowledge, however some new elements regarding the need of formal governance structures, IT systems interoperability and IT investment propensity start to emerge as key antecedents for the achievement of higher levels of benefits (Ranganathan, Teo & Dhaliwal, 2011).

The influence of broader contextual variables such as the level of Supply Chain Integration (SCI) and the level of collaboration of national cultures is also established as a moderator of SC performance (Davis et al., 2014).

It is recognized that information and knowledge management (KM) is not a "one size fits all" capability and that the achievement of higher organization performance requires the careful selection of a KM construct that fits with the organization's needs (performance criteria and dimensions of SC agility), so as to leverage the human capabilities within the organization (Raisinghani, Meade, 2005).

More recently, as the amount of data circulating in SC grows, research on the use of information (Big Data) is intensifying. The intensified use of data is expected to bring both opportunities, such us greater SC visibility and operations efficiency as well as challenges through a potential lack of IT capabilities and infrastructure and concerns over cyber-security, making the case for good SC integration and collaboration together with effective governance even more important (Kache, Seuring, 2017).

We can conclude that, with the evolution of digital SC the focus has shifted to understanding the different levels of performance in SC. New enablers (Governance, SCI) and blockers (Cybersecurity, IT capability) have emerged with information usage and KM seen as a key competitive capability.

SC traceability

As mentioned at the beginning, product traceability is a key trait of digital SC since the coordination and integration of different flows of information along a supply network is one of the foundations to enable the tracing of goods (Engelseth, 2009).

Following (Engelseth, 2009) further, traceability is more complex than just the technical integration of information. It first relies on the capability of interwinding such technical aspects of information connectivity with the organizational capabilities of SCI, that integrate the different forms of knowledge available in the network. The level of network integration also needs to be at a high level, to be capable at accurately capture, process and analyse data and make the resulting information available in a timely manner and according to customer needs.

The high level of change in network integration required by traceability and the impact it has on the stakeholders of a supply chain, requires further changes also to the governance and the coordination agreements of the network, making system management more standardized and centralized as well as calling for new specific agreements for vertical coordination (Banterle, Stranieri, 2008).

Different authors have studied the application of traceability in the pharmaceutical supply chain or in a health care setting from different perspectives. (Rotunno et al., 2014) have summarized the requirement on pharmaceutical traceability and analysed the impact of traceability on different aspects of the pharmaceutical production systems. They argue that traceability can both improve private companies' competitive advantage while delivering social benefits in terms of patient safety and quality of life. (Greenberg, 2014) presents the main responses from regulators to the concern of pharmaceutical counterfeiting through traceability, identifying two key models for traceability: the authentication model, which is a product serialization and end-point verification model, and the track-and-trace model where each product is authenticated in each node of the supply chain. She then moves into identifying several benefits, beyond compliance, that can arise from traceability systems, such as supply chain visibility, reverse logistics, pharmacovigilance, reimbursement of drugs and personalized medicines. (Simoens, 2009) has analysed the drug authentication system in Belgium to develop a threshold of product defects (recalled or expired products) that would make the implementation of similar traceability solutions cost effective in a country. (Oldland et al., 2015) have studied the benefits on dispensing error rates by introducing a bar code verification system for drugs in an academic hospital. Their empirical findings support the need to interwind technical and organizational integration in traceability as the rate of errors have decreased only after the introduction of staff training alongside bar code scanning.

While these studies in the pharmaceutical/health-care setting confirm the ongoing interest for traceability in SC and reinforce the role traceability plays in digital SC, they are either more theoretical in nature or focus on only one specific actor, or player, in the supply chain.

Summarizing our review so far, we can affirm that the introduction of product traceability in a supply network is a complex undertaking, that can have profound effects on the development of the SC as its implementation is increasingly required at the level of a whole sector (European Commission, 2016/161, Rotunno et al., 2014).

Further research is thus needed to understand the impact that traceability has on the evolution of digital SC, so we propose to take a SC lifecycle view on traceability in addressing the following RQs:

- RQ1: What are the most relevant contingent variables and how do they impact the digital transformation process?
- RQ2: Which benefits (or dis-benefits) is such a digital transformation and the greater availability of data expected to create?

We use an in-depth case study to answer our RQs

Research framework and study methodology

Summarizing the review of the literature, a theoretical framework was developed in light of the SC lifecycle model (MacCarthy et al., 2016) to understand which contingent variable are most relevant during successful digital transformation and in which areas are the benefits to be expected (Figure *1*) . (MacCarthy et al., 2016) identify six key factors that impact SC lifecycle evolution: technology and innovation, economics, markets and competition, policy and regulation, procurement and sourcing, SC strategies and re-engineering. They also postulate that a different subset of the factors will be at play in different lifecycle phases and that the industry sector will influence the pattern of emergence and evolution of the factors themselves.

We have thus identified two key factors that have influenced the evolution of digital SC: technology and innovation, SC strategy and re-engineering; these act across two SC lifecycle phases: establishment and growth. In addition, we have included the policy and

regulation factor as directly influencing the other two factors, since it is the EU FMD regulation itself that has mandated both the requirements for IT implementation and for specific governance structures as well as shaping the overall implementation of traceability in the pharmaceutical sector (European Commission, 2016/161).

This framework was used to develop the case study protocol and guided our enquiry during the case study.

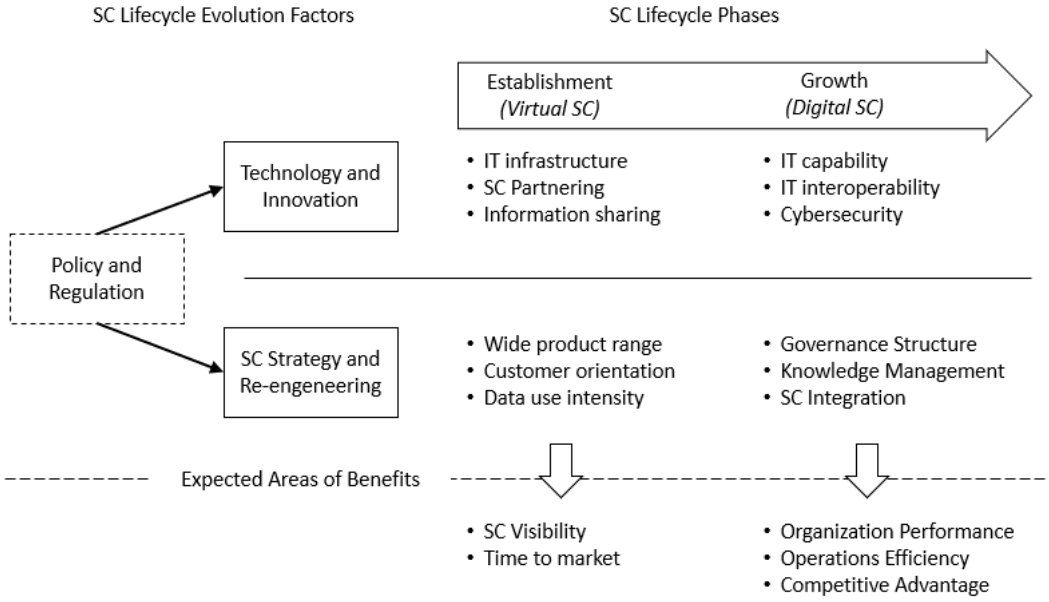

Figure 1 – Research Framework

The case study was carried out on the pharmaceutical distribution chain in three European countries. In a pharmaceutical distribution chain, products are shipped from pharmaceutical manufacturing sites into a distribution center serving the country or a group of countries. Products are then sold to the relevant in country full-line wholesalers who then sell products onwards to pharmacies and sometimes to hospitals. For certain products, distribution centers might ship directly to hospitals or pharmacies.

The study is set up as a case study on multiple countries with the distribution network implementing FMD being the unit of analysis.

To select the countries for the study, out of the thirty-two countries in scope for EU FMD, different strategies where combined. The countries should have been in an advanced stage of EU FMD implementation with key supply chain stakeholders ensuring adequate support in carrying out the study. A senior expert at EU level recommended countries to involve (reputational selection) based on interest for research and access to data. The researchers have then made the selection of the three countries, out of six eligible countries, based on preliminary discussions with leading EU FMD stakeholders from these countries and ensuring a good mix in country sizes, geographies and environments.

Data collection was performed following a case study protocol developed from the theoretical framework. Data on the key elements of the framework were gathered through documentation (slides, reports) and semi-structured interviews. The relevant documentation was gathered from different sources, publicly available data was searched, company documents were collected during and after the interviews and the researchers

had also EU FMD specific documents available as part of one of the researcher's practitioner role in the pharma industry.

A total of nineteen semi-structured interviews where run across the three countries and interviewees represent most of the supply chain in scope for the study in each country. All interviewees held senior roles in their organization with several years of professional experience in the sector/industry.

Findings

To date, the interviews and data gathering in all three countries has taken place and for one country we have conducted the transcribing, text coding and preliminary analysis. We will thus provide, with this working paper, a brief preliminary extract on this single case. This is meant to provide an illustrative example of the flow in the case study, in the most general and high-level terms. We aim to develop the work into a full paper once we have finalized the full analysis on all three country cases.

Description of the context

The country of study is a smaller country in the north of Europe with a specialized SC for pharmaceuticals, the key players in the network were included in our study (Figure 2).

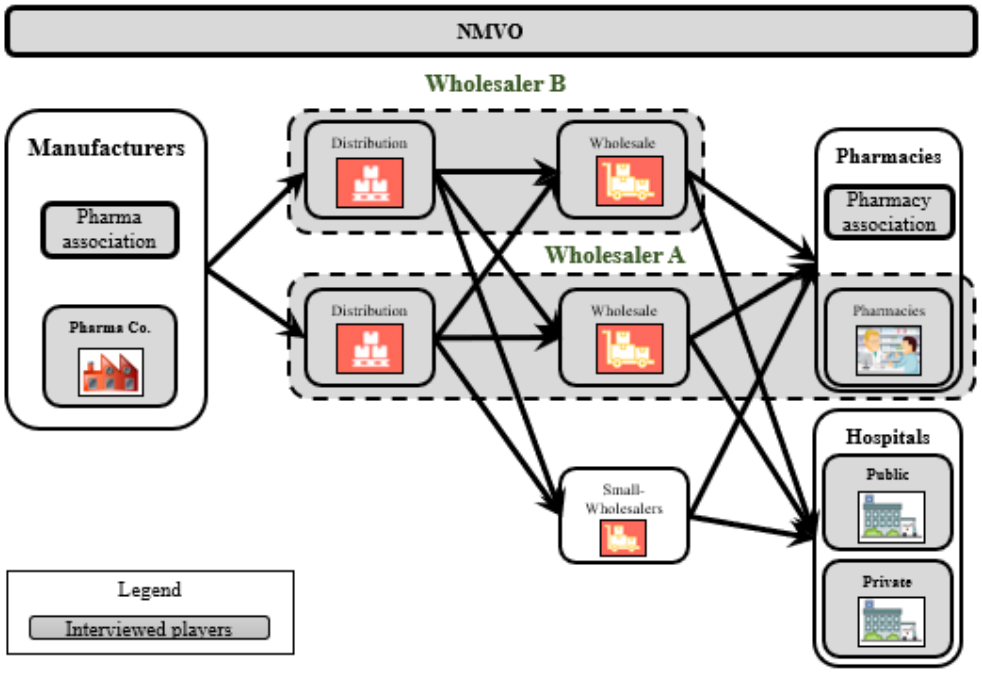

Figure 2 – Distribution network

Almost all large pharmaceutical companies have a presence in the country, they are the owners of the medicinal product and are responsible for the supply of the medicines into the country from a global network of manufacturing sites, so we regard them as the starting point in the supply chain in the country. Within this case, we have interviewed one major global company and the Trade Association of Pharmaceutical Companies.

The next tier involved in the chain are third party logistics providers (3PL). In this country the major 3PLs are vertically integrated with the full-line wholesaler business and this segment of the SC is also highly concentrated, with two companies holding 90% of the market share. Both companies have been interviewed in our study.

The last tier of the SC is represented by pharmacies and hospitals, which are the ones who dispense products directly to the patients. There are around 100 hospitals (including public and private) and around 1.800 pharmacies operating in the country. For the development of the case we have interviewed two major hospitals, one public and one private, located in the capital city and that attract patients from all over the country, being leading hospitals. For pharmacies, considering their high number and dispersion, we have interviewed for our study their national association, who is also the organization involved in the implementation of FMD on behalf of all the pharmacies in the country. For pharmacies is also worth noting that one of the two integrated wholesalers is also vertically integrated with a retail pharmacy chain, this has provided an additional perspective on pharmacies besides the association's.

Finally, the EU FMD regulation has mandated the establishment of a specific organization that is responsible for the implementation and running of the traceability system in the country, namely National Medicines Verification Organization (NMVO). We have included and interviewed this organization as well into our study.

Description of the case companies

Each organization interviewed was studied in detail as part of the case study, we provide below an example of a case company description.

Wholesaler B is an integrated health system provider of services and supplies. It has two fundamental branches of work; the first is in the manufacturing area, offering solutions for product manufacturers, the second is in the retail area in which it distributes products to community pharmacies, so that they can provide a better and more profitable service.

Wholesaler B was established in 1994 from the merger of a wholesaling group and a distributor. Its main headquarters are in the capital city, with approximately 400 employees and reported revenues of approximately €1.296M (for year 2016).

The main objective of the company is the creation of services and innovation for pharmacies and manufacturers, to make a difference in the pharmaceutical industry. The strategy to achieve this objective rests on two key pillars: implementation of technologies and implementation of innovation. In this way, Wholesaler B seeks to add value for the patient, and for those involved in medicines distribution, in terms of costs, product accessibility and service quality.

Wholesaler B vision can be summarized as working with pharmacies and manufacturers to improve patients' health by ensuring compliance in terms of times and costs of service to ultimately generate value for their partners and win the confidence of the consumers.

Case analysis

The evidence collected from the field research is analysed following the framework presented, to derive meaning from the collected materials and ultimately provide a synthesis in answering the two RQs. We offer an extract of such an analysis, in respect to Knowledge Management, below.

The different participants recognise the value of information but at different levels, with integrated wholesalers offering a good overview on the enabling factors and potential uses of KM (Table 1).

In terms of commercial benefits, the improvement in access to information seems key. Although some participants have already good access to SC information through agreements, the current process is tedious and resource intensive and information sharing is hindered by non-compatible information systems.

This led to highlight the important aspect of standardization of data and technological systems, to enable visibility along the chain.

Some of the benefits that emerged, pertaining the implementation of the regulation, are: i) improvements in the information management allowing the advancement of control mechanisms in the SC, ii) information precision increasing patients' safety, iii) improvement in performance measures, increasing transparency throughout the chain.

Table 1 – Key KM factors for wholesalers

	Knowledge Management
Wholesaler	**Role of data:** • There is no complete exploitation of the recorded data; it could be beneficial for the overall business with each client; business as pharmacy chains are very interested in data because it allows them to know the trends in their market. • The information is useful to not waste unnecessary resources and products coming downstream the chain to customers. There are some opportunities for the manufacturers in the commercial field. • Data is useful to know performance, what products pharmacies are selling, it can give a perspective, considering the recent changes in which pharmacies are more financially controlled, if their business model is right, if they need to reduce pricing, among others. • Problems could arise if important decisions are made based on poor data or partial data, it is difficult to have the whole picture. • At operational level, FMD is good in terms of the batch data - which is a major cost. Operationally it is good for the process of returns and recalls, safer for the patient and gives more certainty for the companies recalling a product. • It is a focus for the next years, to interpret better and deeper the data to give customers the possibility to improve. • Specific agreements with each client (manufacturer or customer) for data management and privacy - providing full information of the product chain. • For the manufacturers is good if the implementation reaches the stage in which they share their needs to the wholesalers and then they receive the information back from pharmacies, so they have the whole picture of their market; today that is not possible, the trace is lost at some points • From the perspective of the supply chain there is much more information - particularly to plan better the replenishment from manufacturers and to customers, knowing what is physically and potentially in every place **Patient information:** • Pharmacies can construct profiles of their clients also.

Discussion and Conclusions

Is beyond the scope of this working paper to discuss the findings of the study and develop the conclusions, since a full analysis of the case is still pending and the findings in this working paper serve as a mere illustration of the structure.

We however believe that this is the first empirical study to explore a SC lifecycle evolution of a sector. It also aims to be a comprehensive study on the impact of SC regulations on a whole industry sector across multiple countries and stakeholders.

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Preconditions and motivations for collaboration in the microbrewery industry

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Abstract
Collaboration in micro and small enterprises is often perceived as highly desirable, considering the limitations imposed on these enterprises due to their size and resources. However, the focus of academic and practitioner literature is on collaboration experiences amongst Small and Medium enterprises (SMEs). Adopting mixed method approaches of secondary research and a focus group, this research investigates the pre-conditions and motivations of the collaborative experience in SMEs. The study suggests that motivation to collaborate can be attributed to organisational, operational, marketing, knowledge transfer, and social factors. Furthermore, factors including organisational, strategic and resource-related are regarded as pre-conditions of collaboration.

Keywords: Collaboration, microbrewery, operations management

Introduction
Collaboration in micro and small enterprises (SMEs) has always been encouraged due to their restricted resources as a result of their size, skills and financial constraints. While these enterprises play an important role in the economic development of countries, usually they receive only scant attention with most studies focused on SMEs. This paper aims at contributing to filling the above gap by investigating the motivations and pre-conditions to instigate successful collaborations in SMEs.
According to Business Statistics (2018), there were 5.4 million micro businesses with 0-9 employees, which adds to 96% of all businesses in the UK. Micro businesses account

for 33% of employment and 21% of turnover of the whole UK economy. Around 4% is small businesses while less than 1% is medium. In 2017, there were approximately 6,700 SMEs in the UK food and drink sector with turnover of around £18 billion and 120,000 employees. But most published research focuses largely on the food industry and less research is evident on the drinks industry, although both sectors are strategic for UK economic growth.

Relatively little work has been published on the collaboration in micro and small drink enterprises, including the microbrewery industry. While research and practitioner literature in the brewery industry focuses on major companies and their supply chain, they omit the increasingly growing number of entrepreneurial new enterprises over the last decade. These new enterprises brew their own beers at a micro scale level, offering differentiated products that have gradually shaped the microbrewing movement (Cabras and Bamforth, 2016). Although consumers' beer preferences have changed and the microbrewery industry has become the center of media attention, there is a dearth of academic research on this industry (Karampela and Waehning, 2017).

Historical context has been discussed in previous research such as Cabras and Bamforth (2015). However, there is a lack of understanding on how micro-firms perform within their local networks and how they can survive in the competitive environment (Flanagan et al. 2017, Granata et al. 2018, Karampela and Waehning, 2017). One way to survive is to collaborate. Small breweries work in a collaborative/competitive environment, which is characterised by exchange of knowledge, information, and mutual support that facilitates creativity and innovation in both processes and recipes. However, literature is poor in portraying a clear description of what the motivations are for microbreweries to collaborate, what the preconditions are for such a collaboration and how this collaboration can work in practice (Flanagan et al., 2017).

Therefore, this research aims to fill these gaps by investigating the following research questions:

RQ1: What are the motivations for craft breweries to collaborate?

RQ2: What are the pre-conditions for craft breweries to collaborate?

This paper contributes to current knowledge on collaboration specifically in micro and small businesses by first illustrating the motivation factors for such collaboration. Furthermore, what pre-conditions need to be fulfilled beforehand? This information was realised through both analysis of secondary data and a focus group, with different stakeholders as attendees who present different viewpoints necessary to structure a comprehensive framework for collaboration in SMEs.

The paper is organised as follows: The literature review section includes discussion on horizontal collaboration with a focus on collaboration in micro and small enterprises, including the microbrewery industry, followed by synthesis of literature on motivations and pre-conditions to collaborate. Thereafter, we discuss methodology: secondary data analysis as the first phase; and the focus group as the second phase. In the next section, the results of secondary data analysis and focus group are reported. Finally, we make conclusions for each of the research questions. In conclusion, limitations and avenues for future research are discussed.

Literature review

The literature review conducted in this section is organised as follows: first, the relevant studies in the field of horizontal collaboration are reviewed and discussed; then, collaboration in SMEs, including the microbrewery industry, is specifically investigated.

Horizontal Collaboration

Collaboration is a strong strategy that facilitates the achievement of a vision which might not be possible for the entities working independently (Alonso and Bressan, 2017). Supply chain collaboration refers to "*no less than two autonomous firms working together across their boundaries for the fulfillment of a shared goal"* (Un and Kim, 2018). Collaboration is crucial to support long-term partnership and facilitate participating stakeholders to share their assets (materials, labour, infrastructures, facilities and equipment, and machines) and capabilities (technology, business processes, policy and legislation, and finance). Hence, uncertainties can be reduced, risks and costs can be shared, and finally, customers are served in the right time, right quantity, and right quality without disregarding the interests of other stakeholders (Dania et al., 2016).

In this study, we focus on horizontal collaboration, which is defined as *"concerted practices among companies operating at the same level(s) in the value system"* (European Union, 2001). These companies can be competitors or unrelated members of supply chains, such as suppliers, manufacturers and retailers that share information facilities and resources to reduce costs or improve services (Perez-Bernabeu et al., 2015). Such collaboration allows involved companies to achieve better performance than those who are working on their own (Pomponi et al., 2015). Reciprocal trust is crucial in successful collaboration (Wilhelm, 2011). Therefore, paying close attention to the initial stages of relationship development is very important (Pomponi et al., 2015). Thus, selection of collaborative partners and management of the negotiation phase are critical (Audy et al., 2012).

Horizontal collaboration has a more crucial role for SMEs. They have more limitations in terms of resources; therefore, there is more need to develop collaborative networks in order to benefit from complementary core competencies and sharing of joint resources. In this way, they can become stronger and achieve cost and risk reductions, and better access to information (Vlachos and Gutnik, 2016). However, considerable research gaps remain in exploring collaboration from different perspectives: the development of university and industry relationships; implementation of e-collaboration among SMEs; and collaboration in emerging industries, as in the case of the growing craft brewing industry (Alonso et al., 2018).

Craft brewery industry means independent, traditional and small breweries tend to work together to help the industry as a whole, rather than competing with each other (Berning and McCullough, 2017). This cohesion could build and maintain human capital or lead to collaborative brewing efforts, which can result in a variety of products. Micro and small breweries tend to be defined as craft breweries (Cabras, 2018). Two common classifications regarding the definition of microbrewery that exist in the literature follow the number of employees and production threshold. First, microbrewery is defined as a business with fewer than 10 people, while a small brewery employs between 11 and 49 people. Second, a microbrewery is defined as a small-scale brewery operating under the UK Progressive Beer Duty threshold of 5000 hectolitres annually (Danson et al., 2015). The growth and performance of craft beer sector can be influenced by four different contexts: institutional context (legislation and regulation in different countries); business context, which is the effect of market and industry; spatial context (place matters significantly to microbrewing) and social context (closeness to consumers and related issues). The social context is where brewers share crucial resources and collaborate in different areas (Drakopoulou Dodd et al., 2018).

This research focuses on the social aspect, which includes collaboration in the microbrewery industry. We have conducted our literature review in two parts: first, we look at motivations and then the preconditions. We look at the agri-food industry,

specifically the drink sector, as there is limited available literature on the brewery industry. Table 1 presents the motivations of collaboration.

Table 1- Motivations of collaboration

References / Motivations	1	2	3	4	5	6	7	8
Gaining new insights and accumulating knowledge through learning from partnerships	x							
Shared communal ethos of collaboration		x						
Improved product quality for the entire sector		x						x
Combining strengths to achieve competitive advantage		x			x	x	x	
Increased innovation capacity and technological performance			x	x				
Improved Sales performance			x					
Redefining service offering (manufacturing capability as perceived by customer) to maintain or improve their supply chain position			x	x				
Information exchange capability acquisition			x					

1- Alonso and Bressan (2017), 2- Drakopoulou, Dodd et al. (2018), 3- Granata et al. (2017), 4- Hanna and Walsh (2008), 5- Fearne et al. (2001), 6- Moutaoukil et al. (2012), 7- Lima, M. J. S., & Carvalho, L. C. (2018), 8- Dania et al. (2016)

There are some pre-conditions for collaboration. Trust is an important element. Therefore, firms first look at those whose working philosophies are the same and who have a comparable business reputation (Hanna and Walsh, 2008). Table 2 lists preconditions of collaboration.

Table 2- Pre-conditions of collaboration

References / Pre-conditions	1	2	3	4	5	6	7
Trust	x	x	x		x	x	x
Geographical proximity		x			x		
Commitment		x			x	x	
Personal resources		x					
Information and communication technology			x				
Strong communication			x				
Common aims			x	x			
Mutual dependency			x				
Interoperability / Flexibility				x			
Willingness to share risks					x		

1- Alonso and Bressan (2017), 2- Granata et al. (2017), 3- Hanna and Walsh (2008), 4- Fearne et al. (2001), 5- Moutaoukil et al. (2012), 6- Dania et al. (2016), 7- P´erez-Bernabeu et al. (2014)

It can be concluded from the literature review that, first, there are few academic papers looking into motivations and pre-conditions of the collaboration in micro and small businesses, specifically in the drink industry. This highlights the research gaps and calls for more research on collaboration in micro and small businesses, specifically the drink

industry as an important industry in the UK. Second, it can be concluded that "combining strengths to achieve competitive advantage" is the most important motivation for collaboration in the industry. Furthermore, "trust" is a crucial pre-condition for collaboration. To have a clear portrait of motivations and pre-conditions of collaboration in micro and small businesses, we further investigate the industrial reports, followed by a focus group with different stakeholders.

Methodology

A very limited number of academic papers investigate collaboration in the craft brewery industry. Therefore, we decided to review industrial reports on this issue as part of our research methodology. The review focuses on industrial reports, including cases from Spain, France, New Zealand, Australia and the United States. Then, to gain in-depth knowledge to understand motivations and pre-conditions for collaboration, we conducted a focus group with different stakeholders. Therefore, the research methodology adopted in the first phase was secondary data analysis of practitioner literature, followed by a focus group of three hours.

In designing the focus group, there are two important factors: group size and composition. A manageable group size for focus group is between six and ten persons. We sent our invitations to 44 microbreweries who had websites among 110 microbreweries in Wales and five industrial partners, including consultancy companies and trade associations. All industrial partners replied to emails and three confirmed their attendance. Among breweries, just one email confirmation was received. The rest were followed up three weeks later by phone. Ten confirmed that they would attend. However, only five managed to attend the session. Thus a total of eight participants including three trade associations attended the session. This enabled the capture of different perspectives that shaped a complete and overarching understanding of collaboration in the microbrewery industry. In terms of composition of the group, there is a need for a mix of interests and expertise so the purpose of the research can be reflected properly. The focus group was designed in an unstructured approach i.e. raising a few questions so that free discussions between participants can be started. This approach is more popular within exploratory studies (Sanchez Rodrigues et al., 2010). The focus group was held in South West Wales in July 2018. It included two sessions of one hour and a half. The sessions were facilitated by authors of the paper who have knowledge in this research area and experience of conducting focus groups. The focus group was recorded with the permission of participants for transcription and summary for the analysis later.

Findings

Findings emerging from secondary data analysis

Different collaborative models are reported in the industrial reports concerning the microbrewery industry.

Collaborative partnership can have different motivations. Reports from 2013 presented a collaboration in which Beavertown, a microbrewery based in East London, collaborated with Jameson, which is an Irish whisky distillery, for St Patrick's Day product offerings. Both partners shared similar ethos and ideology that shaped their collaborative process. They developed an imperial stout aged in rare Jameson casks (World top brewery, 2013). Many brewers, such as Titus Bentley, brewer at Fort Collins's Horse & Dragon Brewing Co., believe that it is an opportunity to learn new techniques and improve their processes. He states that working with brewers whose processes and procedures are different from his broadens his horizon significantly (The Brew Enthusiast, 2016). Collaboration for most brewers is an opportunity to learn new brewing techniques, to see different brewery set ups, and experience different styles and ingredients. Another motivation is exposing

their brands to new drinkers, especially in foreign markets. It can also simply be for fun. Many brewers see collaboration as an opportunity to hang out with friends and relax as community, which is very important in the craft beer industry. Also, for many, collaboration is a desire to promote craft beer as artisanal, experimental and celebratory (Sammartino, 2015). *"I prefer to be a travelling artist collaborating at someone else's facility so I can see how things are done outside our environment*". Each collaboration is a chance to explore other breweries, invest in new friendships, and make others aware of the brands (Arthur, 2013).

Collaboration needs different pre-conditions. One is mutual respect, which was highlighted by Green Flash brew master, Chuck Silva, who explains the evolution of his relation with St. Feuillien brewmaster Alexis Briol as allowing them *"as international counterparts to find common grounds"*. They believe that they are always eager to learn from each other. They even have opposite specialities and approaches but could collaborate successfully for three years for three different products (Johnson, 2015). Justin Tilatto, head of sales and marketing at Boulder's Twisted Pine Brewing Company believes having a good relationship with those they know results in good collaboration, whereas with strangers it is almost impossible. He believes that trust and tolerance lead to good collaboration (The Brew Enthusiast, 2016). Brewers rarely collaborate with those they don't know. Good reputation of the partner is important for shaping the collaboration (Sammartino, 2015). *"There isn't a published set of rules for collaborating on beers, but there are a few things I consider before agreeing to make bedfellows with another brewery. First and foremost, I believe with conviction there needs to be a legitimate reason for collaborating. Without this, you have no story, and interest in the project will be tepid at best."* (Arthur, 2013).

Findings from focus group

In the focus group, participants were asked to comment on why they collaborate (Motivations). One of the motivations stated by the breweries was being Welsh language oriented: "*…he's a Welsh-language brewery, so we have a lot of synergy. Like I said, there aren't a lot of people out there marketing themselves in the Welsh language, which we do, to a certain extent, not as much, perhaps, as this other guy … So, it makes sense for us to work together, to gain greater access to the market surrounding, which tends to be fairly stitched up by specific bigger ones, they do the bars and stuff and other events as well. And they have recently got into bed quite heavily with another big name to command better prices on beer, which means that we are further excluded from what ought to be a natural market for us. So, it's a way of trying to get closer."*

They also considered collaboration as a strategy to get closer for stronger voice: *"It makes sense for us to work together, to gain greater access to the market surrounding, which tends to be fairly stitched up by specific bigger ones, they do the bars and stuff and other events as well. And they have recently got into bed quite heavily with another big name to command better prices on beer, which means that we are further excluded from what ought to be a natural market for us. So, it's a way of trying to get closer."*

Another motivation was entering new areas: *"We've done sort of collaborative partnership … we go to spaces that they'd rather not go to".*

An important pre-condition is the element of trust mentioned by different stakeholders during discussions in the focus group "*I think the premise of collaboration is trust; there has to be an element of trust."*

Furthermore, knowing the partner was a stated pre-condition for collaboration. One of the participants stated that he shared his excel based accounting system with another partner because he knows him quite well: *"One of the ones I work with…, so I know him quite*

well and so I'm going to basically do a little cut-down version of mine that he can pick up, because he's like… "I haven't got a clue about accounting, I haven't got a clue about Excel, so I'll use that."
Having surplus capacity was also mentioned as a pre-condition for collaboration *"…running a lorry is expensive, running a lorry half-full is even … you know, astronomical really, so where there's surplus capacity, definitely [collaboration is helpful]."*

Discussion and conclusion

Knowledge on the specificities of micro firms is still partial and fragmented (Grananta et al., 2018). Among all micro industries, craft brewing is still in its emerging stage (Alonso et al., 2018). This research aims to shed light on collaboration in the microbrewery industry as a strategy whereby these micro and small firms can overcome their limitations in terms of resources. One of the first steps is to investigate motivations and preconditions which are needed for collaboration. We began this research with a complete literature review on motivations and preconditions in the agri-food industry, as there was very limited research available on collaboration in micro and small industries, specifically the drinks industry. Because of this lack of academic research to respond to the research questions, we conducted extensive secondary data analysis in order to be able to fully respond to the two research questions. Furthermore, the focus group, with different stakeholders, could intensify our conclusion regarding motivations and preconditions for collaboration in micro and small businesses, specifically in the microbrewery industry.
We conclude from our secondary data analysis and focus group that microbreweries can collaborate with operational, organisational, marketing, knowledge transfer, and social motivations. These motivations are presented in Table 3.

Table 3- Motivations for collaboration from the focus group and secondary data analysis

Operational	- Information exchange capability acquisition - Develop distribution
Organizational	- Shared ethos and ideology - Get closer for a stronger voice
Marketing	- Gaining attention and blowing up - Build brand and social media profile - Expose the brand to new drinker - Make others aware of the brand - Develop brewery's image in particular areas
Knowledge transfer	- Brew something different from normal - Chance to let loose and create a beer outside the typical style - Stream of new ideas and techniques - Improve skills - See different brewery setups - Chance to explore other breweries - Experiment with different styles and ingredients
Social	- Invest in new friendships - Fun

While the specific hierarchical categorisation does not exist in literature, some of the items related to the main categories gained from the secondary data analysis and focus group are in line with what we have found in the literature. The main themes gained from

our focus group and secondary data analysis, "shared communal ethos of collaboration", is in line with literature review (Drakopoulou Dodd et al., 2018). Furthermore, our finding of "knowledge transfer" theme is in line with the literature (Alonso and Bressan, 2017). "Combining strengths to achieve competitive advantage" was the most important motivation for collaboration in the literature review. This means that improving different performance outcomes, such as quality (Drakopoulou Dodd et al., 2018), sale (Granata et al., 2017) and technical performances (Hanna and Walsh, 2008), are more highlighted in the literature. However, our findings show that marketing issues, specifically brand issues, are the important motivation in both industry analysis and our focus group attendees' viewpoints.

We conclude from our secondary data analysis and our focus group that organisational, strategic and resource-related pre-conditions are needed for collaboration. These pre-conditions are presented in Table 4.

Table4- Pre-conditions for collaboration from the focus group and secondary data analysis

Organizational	- Trust - Mutual respect - Open mind and sharing - Tolerance - Good relation - Knowing the partner
Strategic	- Similar mission - Legitimate reason for collaborating
Resource-related	- Surplus capacity

While the specific hierarchical categorisation for pre-conditions of collaboration does not exist in literature, some items related to the main categories gained from the secondary data analysis and focus group are in line with our literature findings.

Above all, "trust" is the most important pre-condition stated in almost all academic papers, including Alonso and Bressan (2017), Granata et al. (2017), Hanna and Walsh (2008), Moutaoukil et al. (2012) and Dania et al. (2016), highlighted by our attendees in the focus group, and our secondary data analysis. Furthermore, our findings in strategic pre-conditions, such as "similar mission", are in line with literature considering common aims (Hanna and Walsh, 2008; Fearne et al., 2001) as important pre-conditions for collaboration. In addition, "surplus capacity" was highlighted as a resource-related pre-condition in our focus group, which is in line with Granata et al. (2017) stating personal resources as an important pre-condition for collaboration.

In conclusion, this study sheds light on collaboration in micro and small enterprises; specifically in the drink sector; thereby, contributing to the operations and supply chain management research.

In terms of managerial contribution, this research will raise awareness amongst managing directors of drinks companies on how collaboration in their operations and supply chains can improve the performance outcome of their company as well as the sector. As the first step, understanding of motivations and preconditions can prepare owners and managers in breweries to establish effective collaboration.

Limitations and avenue for future research

One of the obvious limitations is the issue of generalisability. As the data is taken from a sample of microbreweries in Wales, there is restricted generalisability to the wider food and drink sector across the UK. However, this research can be seen as a starting point to

investigate collaboration in micro and small businesses with specific focus on the drink sector as an important sector within the UK economy. As most research has concentrated on SMEs, there exists an obvious gap in terms of micro and small businesses.

Based on this scoping research, future research can investigate how microbreweries, and the drink sector in general, can collaborate in order to improve their performance outcomes. This also calls for designing research in both a qualitative and a quantitative way and gathering data both nationally and internationally for a more in-depth research into collaboration in micro and small businesses, specifically in the drink sector.

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Supply Chain Involvement in new product development and new product performance: the role of team rewards.

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Abstract

This paper analyze the impact of team rewards (TR) on NPD success. In particular, we analyzed whether the use of TR affect the success of NPD team projects not only by accomplishing for their work as a team and the performance their perform but also considering the enhancement of the involvement of internal functions and external actors (suppliers and customers) in these projects. Using SEM we observed that TR do not produce a direct effect, but do it through the involvement of SC members in the early stages of NPD. Without involvement, it is not possible to obtain desired NPD success.

Keywords: New product development; Team Reward; Involvement; Supply Chain

Introduction

New product Development (NPD) is a critical concern for manufacturers in an increased global competition. Literature on NPD success has mainly been positioned in the domain of supply chain management (SCM) (Mazzola, Bruccoleri and Perrone; 2015). The most cited references in the field advocate for the involvement of suppliers and customers in NPD process (Flynn et al. 2010) and also to look for complementarities involving internal functions in a collaborative way to achieve NPD success (Homburg and Kuehnl, 2014).

Involving heterogeneous actors in NPD allows firms to enhance the value of knowledge-based resources (Cabrera and Cabrera, 2005). In this sense, evidences has shown that combination of broad and varied information and points of view is positively related to new product performance in terms of cost, time to market and quality (Mishra and Shah, 2009) and also with firm innovation capabilities, and firm performance (Petersen, Handfield and Ragtz, 2005). Nevertheless, some researchers also highlights the costs and challenges of collaborative competences in NPD among SC members (Fawcett et al, 2015), referring to what is known as the "dark side" of collaborative NPD process (Villena, Revilla and Choi, 2011).

As a result, the debate is open, and more research is needed to improve the understanding on how to involve a number of SC agents in the process of developing new products (bringing them closer and involving them), and how to design mechanisms to promote this process (Yang and Wagner, 2017). More specifically, researchers in the field have made a call to analyze organizational issues that promote SC relationship in order to overcome dark-side effects of involving external and internal sources of information and knowledge to achieve NPD success.

With this framework, the aim of this paper is to analyze the impact of team rewards (TR) on NPD success. In this context, an interesting question is whether the use of TR affect the success of NPD team projects not only by accomplishing for their work as a team and the performance their perform but also considering the enhancement of the involvement of internal functions and external actors (suppliers and customers) in these projects.

Overall this study makes three important contributions to the extant literature. First, this study advance in the study of TR on NPD success considering TR as a tool to work in-group involving different and distant actors in the process of NPD. This approach is aligned with the new trends in the field of R & D that recognizes the need for openness and integration of different sources of information and knowledge, providing a clear vision about the importance of adopting integrative strategies as the best way to achieve innovation performance (Crisquuolo et al., 2017). Second, the analysis consider different dimensions of NPD success distinguishing between time to market, technical issues and cost of manufacturing, usually considered in an aggregated way. Third, empirical evidence use an ample database including a more than three hundred of manufacturing

companies from fourteen countries, including developed and developing countries, and from three industry sectors, thus giving more relevance to the results found.

Theoretical background.

Team Reward in New product Development Projects

A reward system entails the use of the pay system to guide, control and affect the behaviors and efforts of individuals and sub-units toward the achievement of organization´s strategic goals (Gomez-Mejia and Balking, 1992). Total reward is defined as the combination of both the financial and non-financial rewards made to the employees and usually includes basic salary, variable pay, pension benefits, death-in-service benefits, long-term disability benefits, private medical insurance, vacation entitlement, and others (see Jiang et al., 2009).

The group-based incentive plans, such as profit sharing, gainsharing, and team-based reward, may provide an effective means of linking pay to performance in work settings where high-powered individual incentive plans are difficult to implement. Sarin and Mahajan (2001), based on the principles of the organizational control literature proposed to distinguish TR in process-based rewards and outcome-based rewards. Process-based rewards are tied to the accomplishments of procedures, behaviors and other means of achieving desired outcomes, while outcome-based rewards are defined as the degree to which team rewards are tied to the bottom-line profitability of the project. Process controls are exercised during the execution of a task while output controls are exercised after a task is completed. Researchers highlight the both types of rewards may have positive effects on team performance but depends on contingencies of projects.

Team Rewards and NPD success

Empirical evidences exploring the relationship between TR and NPD is scant and varied in terms of the measures of TR and performance measures used and mixed in terms of findings. Bonner et al. (2002) considered TR in three ways: financial rewards, internal promotion and recognitions for successful performance. They measure project performance in terms of adherence to budgets and costs, meeting schedule and ask managers to rate for product performance and team functioning performance. They find out no statistical significant relationship between TR and project performance, but all measures were treated in an aggregated way as additive indexes. Chang et al. (2007)

analyzed the effects of joint rewards on NPD performance. The authors distinguished five types of joint reward systems (reward allocation, process-based reward, outcome-based rewards, risk-free of participants, and over-reward incentives) as antecedents of NPD performance. In this case, performance refers to innovation performance in terms of sales, profits and market share, and comparing this measure with regard to competitors, and finally performance in term of the overall profitability. They find out that the overall joint reward system was positive and significantly related to NPD performance. However, only two types of overall reward systems were significant: reward allocation and risk-free to participants, but no significant effect was observed for process-based reward or outcome based rewards.

More recently, Carbonell and Rodriguez-Escudero (2016) analyzed the impact of both process control and process-based rewards (based on procedures and activities) on new product performance and job satisfaction. They find out mixed results since find out a negative association between process-based rewards and quality of new products, a positive association of rewards and the adherence to project schedule and not significant with project budget. The authors also looks for interaction between process control and process-based rewards, but results were not significant to explain project performance, but positive interaction between both tools to explain the quality of new products.

In this paper, we focus on "internal" NPD success measures, considering technical performance, time to market and manufacturing cost (Mishra and Shah, 2009). The adoption of TR is expected to be positively associated with NPD success. Rewarding all team members according with achieving project goals reinforce the perception of workplace justice, avoiding opportunistic behaviors and encouraging cross functional and interfirm collaboration. As a result, the application of TR it is expected that affect team project promoting to work hard to achieve NPD goals.

According with this arguments, we propose the following hypotheses:

H_{1a}: Team rewards positively impacts on technical performance.
H_{1b}: Team rewards positively impacts on time to market.
H_{1c}: Team rewards positively impacts on manufacturing cost.

Team Rewards and the involvement of SC members on NPD

In this section we analyze the effects of adopting TR onthe involvement of SC members in early stages of NPD. In particular, we consider bundles of practices in hand of the NPD team, both internal and external, aimed to involve SC members in providing valuable information and ensuring their effective participation in the decision-making process in the early stages of NPD. External involvement (EI) include practices fostering the coordination of decision making and the implication of suppliers and customers in providing valuable information. Internal involvement (II) of manufacturing function encompasses practices concerned with matching design requirements and process capabilities.

The resource based view-RBV (Barney, 1991) suggest that integrating heterogeneous interdependence and complementary source of knowledge is beneficial for all partners involved in NPD processes (Zhao et al., 2011). Related studies have suggested the benefits of adopting bundles of practices aimed to involve complementary sources of information from external and internal SC actors. However, involving internal and external SC members in NPD is a paramount, mainly due to knowledge sharing risk and the hidden cost of coordinate and support relationships with SC actors (Um, Ki-Hyun, and Sang-Man Kim, 2018), which sometimes generates socio-structural resistance by the different members implicated (Fawcett et al., 2015).

In addition, the social capital theory highlight the value of capital as those resources inherent in social relations which facilitate collective action. Related literature stated the positive effects of social capital among the supply chain, promoting cooperative behavior between members, sharing vision, trusting relations, and social ties and reducing the likelihood of conflicts. Nevertheless, some scholars find out the risks and potential negative consequences associated with social capital, which have been recently named as the dark side of social capital (Villena, Revilla and Choi (2011).

From a different perspective, the expectancy theorycons iders the effort of employees as a function of the perceived value of a reward and the perceived effort-reward probability. As a result, NPD team members will strive more in the search of collaboration of the SC agents if the companies have established a reward system based on the achievement of the objectives of the project especially if these objectives are achievable.

According with this arguments, we propose the following hypothesis:

H_2: Team rewards positively impacts on involvement practices of SC agents

Involvement of SC members and NPD success.

Evidences analyzing the process of NPD suggest the benefits of adopting involvement practices with all SC actors in early stages of NPD. Researchers highlight the absorptive capacity of team members, defined as the ability of companies to effectively acquire and exploit both external and internal knowledge to achieve innovation success, as one of the main reasons behind the success in NPD in manufacturing firms (Laursen and Salter, 2006). While firms learn from their external partners, they need to have the internal absorptive capacity to enhance their innovation performance. Hence, Daghfous (2004) highlight the importance of internal mechanisms to learn, to disseminate, and to exploit knowledge to enhance NPD performance.

Thus, practices aimed to involve SC actors are determinant to resolve manufacturing issues in early stages in order to achieve easy manufacturing and improving manufacturability. Johnson and Filippini (2009) comparing collaborative NPD practices such as CI, SI and II across the world on performance, stated that the use of internal involvement is more emphasized than external integration and this was translated into better product performance. In the same way, Ragatz et al. (1997) suggest that the effective integration of suppliers into NPD processes can yield benefits through reduced time to market an improved access to the application of technology). Similarly, involving customers in early stages allows NPD team to know customer assessments in early stages.

According with these arguments, we propose the following hypotheses:

H_{3a}: Involvement positively impacts on technical performance.
H_{3b}: Involvement positively impacts on time to market.
H_{3c}: Involvement positively impacts on manufacturing cost.

Methodology

Sample

The data used for empirical analysis was collected from the fourth round of the High Performance Manufacturing Project (HPMP), a research project conducted by a team of researchers working in different universities all over the world. The survey was conducted during 2013-2015 in manufacturing plants operating in three industry sectors: machinery, electronics and automotive components (SIC codes: 35, 36 and 37, respectively) and located in different countries: China, Germany, Sweden, Japan, Korea, Spain, Italy, Israel, Brazil, Finland, Austria, Taiwan, United Kingdom and Vietnam). The final data set consists of 309 responses. In table 1 we can observe the profile of the sample for the different countries and for the three industries.

Measures

We used 16 items to measure supplier involvement, customer involvement and manufacturing involvement in the NPD process. The items included in the scales have been used by other researchers who have addressed the issue (Mishra and Shah, 2009). The annex shows all these items, to which respondents indicated their agreement/disagreement on a five-point Likert-type scale (from 1 = strongly disagree to 5 = strongly agree). The survey included also other questions related to the country where the companies are located and its activity sector.

We model involvement as a reflective second order construct to capture complementarities arising from the three first order constructs (.suppliers, customer and manufacturing). This second order, involvement construct accounts for multi-lateral interactions and covariances among the first order constructs. The use of second order construct to represent complementarities among first order constructs has been well documented in existing studies (Shah and Ward, 2007).

NPD success is assessed using three commonly used items reflecting time-to-market, technical performance and unit manufacturing cost. NPD project managers were asked to rate the success of the product development project relative to the set goals and objectives on the three measures on a 5-point Likert-type scale ("How successful were the new products in terms of reaching their goals?").

In order to check for common method variance we used Harmann´s single factor test (Podsakoff & Organ, 1986). This test was conducting using principal component analysis and loading all 20 items (variables of interest) on one factor. The 33,8 % variance explained by a single factor shows that the common method bias is not a major concern in this study (less than 50% cut-off point).

The methodology was developed in two stages. First, the validation of the assessment scale for involvement was settled. The second stage was the assessment of the. hypothesized structural relationships of our model .The analysis was conducted using Structural Equation Modeling (SEM) techniques, also with EQS 3.0 software , The seminal works of Baron and Kenny (1986) and Zhao et al. (2010) have inspired the analysis of the mediation role of involvement. Results are summarized in Table 1.

Table 1. Decomposition of the parameters of the research model.

	Total effect	Indirect effect	Direct effect
Team Rewards □ Involvement	0.614 (4.51)	-	0.614 (4.51) (H_1 Accepted)

Involvement □ Technical performance	0.574 (4.19)	-	0.574 (4.19) (H_{2a} Accepted)
Involvement □ Time to market	0.494 (3.73)	-	0.494 (3.37) (H_{2b} Accepted)
Involvement □ Manufacturing cost	0.453 (3.18)	-	0.453 (3.18) (H_{2c} Accepted)
Team Rewards □ Technical performance	0.202 (1.175)	0.352 (2.48)	-0.150 (-1.810) (H_{3a} Refused)
Team Rewards □ Time to market	0.279 (1.622)	0.303 (2.37)	-0.024 (-0.267) (H_{3b} Refused)
Team Rewards □ Manufacturing cost	0.284 (1.512)	0.278 (2.15)	0.006 (0.064) (H_{3c} Refused)

Standardized parameter (t-value).

Findings confirm the first hypothesis that team rewards have a positive impact on involvement; the overall involvement construct is directly influenced by team rewards and the standardised coefficient is 0.614. First hypothesis is then confirmed. In its turn, involvement impact on positive and significantly on the three NPD success items considered, hence the hypotheses H_{2a}, H_{2b} and H_{2c} are also confirmed. One the other hand, neither of the last three hypotheses (H_{3a}, H_{3b} and H_{3c}) can be confirmed.

Conclusions

New product development (NPD) is critical for firm competitive (Brown and Eisenhardt 1995). Studies analyzing NPD success factors have neglected the study of how to involve SC members in early stages of NPD process through the use of motivational practices.

The estimations results shed novel evidence. The main finding shows that TR positively affect NPD success in terms of cost, quality and TTM, but, surprisingly, this effect are throughout the involvement of SC members. For NPD projects, linking rewards to the output produced by the team (outcome-based rewards) has a positive influence on SC agents involvement and finally on the internal dimensions on NPD success. Regardless of the type of reward implemented, if team rewards are used to motivate the members of the NPD team, it will be easier to achieve the objectives regarding quality, unit manufacturing cost of products launched and, also, the time to market of new products.

In sum, all the impacts of team rewards on NPD succeed are achieved through the mediation of involvement, which highlights the paramount importance of this construct (involvement). On other words, no effect of TR is achieved without the mediation of involvement.

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The protagonism of Cash & Carry in the supply chain in Brazil: fashion or trend?

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Abstract

New formats of retail stores continue to emerge, in order to better meet the needs of consumers. In Brazil, the Cash & Carry format occupied a leading position due to the high growth in number of stores and billing volume. This research aimed to characterize the value chain of the Cash & Carry format in Brazil, in comparison to the traditional physical stores in search of the justification for this phenomenon. Through a documentary research, the ten largest retail chains of the country and their brands of physical stores and wholesale stores were analysed, in order to construct the presented models.

Keywords: Supply Chain Management; Cash & Carry; Value Chain

Introduction

Retail organizations are diverse and new forms continue to emerge so that consumers can now buy goods and services in a wide variety of stores (Da Conceição, 2018). The idea of cash & carry, better known as "Cash & Carry" in Brazil, came into being in Europe and was more developed in the United States from 1980 onwards. The idea came from the following understanding: having a store capable of bringing the desired product to small retailers or objective consumers, without offering any services but with a more robust mix of products (Napoleão, 2017).

According to Abad (2016) and Napoleão (2017), Brazilian families has preferred the "Cash & Carry" to the supermarket and hypermarket. This research aims to characterize the chain of values and the format Cash & Carry, demonstrating the main advantages obtained by this business model in comparison to the traditional physical retail that justify its recent rise and its impacts in the retail supply chain in Brazil. The contribution of the results obtained here derives from the example of this operation in an emerging country.

Literature Review

Chain of Values For an examination of the activities performed and the way they interact, for a broad approach and identification of the main process flows of the company, the chain of values can be introduced as a systematic tool for such an evaluation.

According to Porter (1990: 31): The value chain disaggregates a company into its strategically important activities so that it can understand cost behavior and existing and potential sources of differentiation. A company gains competitive advantage by performing these strategically important activities at a cheaper or better way than the competition.

The performance of the value chain represents a process of differentiation between companies and their processes and the establishment of competitive advantages. Figure 1 illustrates the value chain model proposed by Porter (1990).

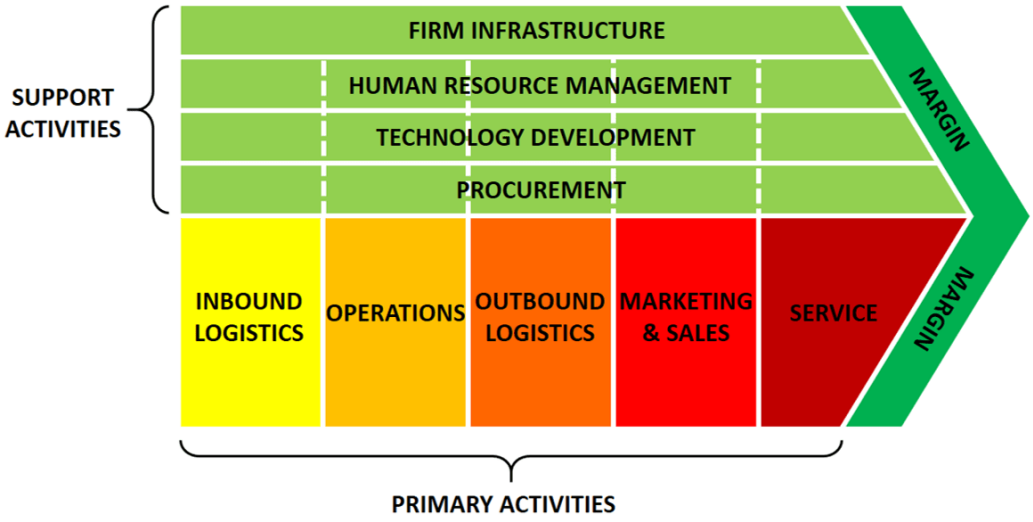

Figure 1 – Value Chain Model, Porter (1990)

Primary activities are those involved in the physical creation of the product and its sale and transfer to the buyer, as well as after-sales service. In any company, primary activities can be divided into five generic categories: (1) internal logistics: the activities associated with the receipt, storage and distribution of inputs in the product, such as material handling, warehousing, inventory control, fleet scheduling, vehicles and return to suppliers; (2) operations: the activities associated with the transformation of the inputs into the final product, such as working with machines, packaging, assembly, equipment maintenance, testing, printing and production operations; (3) external logistics: the activities associated with the collection, storage and physical distribution of the product to buyers, such as storage of finished products, material handling, delivery vehicle operations, order processing and programming; (4) marketing and sales: these are the activities associated with providing a means by which buyers can buy the product and induce them to do so, such as advertising, promotion, sales force, quotation, channel selection, channel relationships and pricing; and (5) technical assistance: these are activities associated with the provision of service to enhance or maintain the value of the product, such as installation, repair, training, parts supply and product adjustment.

Support activities can be divided into four generic categories. Like the primary activities, each category of support activities can be divided into a series of activities of

value that are distinct and specific to a particular company. The generic categories of support activities are:

(1) acquisition: refers to the function of purchasing inputs used in the company's value chain, not to the purchased inputs themselves. Inputs purchased include raw materials, supplies and other consumer items, as well as assets such as machinery, laboratory equipment, office equipment and buildings. Although these acquired inputs are commonly associated with primary activities, they are present in each value activity, including supporting activities;

(2) technology development: it consists of several activities that can be broadly grouped together in efforts to perfect the product and process. The development of technology related to the product and its characteristics can support the entire production chain;

(3) human resource management: consists of activities involved in the recruitment, hiring, training, development and compensation of all types of personnel. Human resource management affects competitive advantage in any company, through its role in determining qualifications and the cost of hiring and training; and

(4) company infrastructure: consists of a number of activities, including general management, planning, finance, accounting, legal, government affairs and quality management. Infrastructure, unlike other support activities, generally supports the entire production chain and not just individual activities.

Porter (1990) relates an advantage to value creation, that is, the competitive advantage arises from the value that a company can create for its buyers and that exceeds the cost of manufacturing the company and provides the difference between a firm's offer and that of others.

From the evolution of Supply Chain to Cash & Carry

When looking to analyse the dynamics and structure of the chain of supermarkets, it is necessary, at first, to understand some basic concepts that guide the actions of the products and services that are in networks. The need to understand the performance scenario is fundamental for assertive and optimized decision making throughout the chain.

By understanding the organizations and the ways that these are instituted, it becomes perceptible to understand the dynamics and structure of the business and therefore outline the strategies needed to gain competitiveness. The understanding of economic reality requires interpretations that are based on a systemic environment, which involves not only the parts, but the whole and their interrelations (Capra & Jakobsen, 2017).

Antonialli et al. (2016) infer that it is emphasized as the importance of studies on productive chains requires evaluations of both economic and technical operations throughout the stages of production and consumption of goods, ranging from (organizational, institutional, consumer) environments that permeate the production chain, essential for the construction of the competitive advantage of the chain (Antonialli et al, 2016).

Although dynamics is different from that of the Supermarket Supply Chain, these studies converge to the same point, being applied to all sectors, which are the structures of their respective chains (Zylbersztajn, 2005). By using the concepts of chains, production systems and coordinated subsystems, the expansion of volumes of empirical research volumes, both national and international, was evident from the 1980s to the present day. Whether in agro-industrial systems or in any other organization, they all employ the concept of continuous production steps, from the raw material to the finished product, in order to guide their analysis (Andrade, 2015).

The supply chain, according to the Supply Chain Council (2002), infers that "the supply chain covers all efforts involved in the production and delivery of an end product from the vendor supplier to the customer's customer" (Machline, 2011). Thus, typical transactions and the influence of institutional and organizational environments (which are defined as determinants of competitiveness) are common to all chains, regardless of the theoretical conceptualization (Zylbersztajn, 2000).

This relationship between supplier, producer and client creates and models the organizational and institutional environment, from which it is intrinsically linked to the cultural environment and the consumer environment, as shown in figure 1. Thus, the Supply Chain can be understood as the "main cell" in all production dynamics of products or services goods, since each chain link is affected, directly or indirectly, by any actions that affect one of its agents.

When we turn the perspective to retailing in the dynamism of information and interpersonal relations, new approaches emerge not only in the academic environment, but also in the commercial relations and the Cash & Carry is one of those results coming from the modifications in the organizational and institutional environments, as mentioned above.

Cash & Carry

According to Oliveira, Lima-Filho and Watanabe (2013), it is understood as Cash & Carry being the format of store known in Brazil for being a mixed operation of wholesale and retail, of which its actions are intended to serve preferentially, purchase (Silva, 2017).

In addition, it is important to note that the quality of the food service is not limited to the food service sector. According to Broud (2016) and Levy (2000), Cash & Carry is understood to be: The "Cash & Carry" is a phenomenon nowadays, mainly in Brazil, this model joins features of wholesale retail and aims to provide products with lower prices to the client to offer good services. This model does not have a refined structure, the design is low cost and its focus is on "pay and carry" (Broud, 2016; Levy, 2000).

Napoleão (2017) advocates that over the years, the development of this type of business has brought from new purchasing systems to adoption of new practices, such as the agglomeration of additional services added to the physical structure of the store, and in this way, it is possible offer not only cheaper products, but also, better quality services whose situation ends up adding more value to the enterprise.

Methodology

This work, in terms of its concept, is characterized as qualitative, through documentary analysis as scientific articles, as well as reports of specialized journals in the field, descriptive-exploratory. This infers that this type of research seeks to understand a reality that has not yet been studied, in which one can describe how the phenomena related to it occur (Gomes, 2006; Reis, 2018).

Pimentel (2001), shows us that studies based on documents as primordial material, be they bibliographic reviews or historiographical research, extract from them all the analysis, organize them and interpret them according to the objectives of the proposed research, giving them the specific treatment in order to corroborate with the object of study (Pimentel, 2001). Garcia Gutierrez (1984) apud Junior, Medeiros & Augusta (2017), reflects on documentary analysis as "all recognition and study that is made of a document, requiring an identification of the physical characteristics, which would be the form, and the intellectuals, the content". These elements corroborate the establishment of the best method to organize all the "information" expressed in the document (JUNIOR, Medeiros & Augusta, 2017).

It was applied in this work the analysis of documents such as scientific articles, books and reports in magazines or nationally recognized electronic sites that dealt with the theme of evolution and modification in the structures and dynamics of the retail chain and seek to understand what the current panorama of the transition traditional market of the hyper and supermarkets for the recent cards.

As a study delimitation, we opted to work on the analysis with the top 10 retail chains in Brazil's supermarket or hypermarket sector, according to the Brazilian Retail and Consumer Society (Sbvc, 2017). From the list obtained, company flags were tabulated in a spreadsheet and classified according to their size and sales format (small retail, super / hypermarkets, cash backs, etc.). In order to obtain a broad analysis specifically of the cash cards, the analysis of the discount cards that make up the Brazilian Association of Wholesale Carriers (Abaas, 2017) was included in the analysis. Below, the table 1 presents the flags chosen for the analysis.

Table 1: Retailers chosen for analysis

Flag *or* Brand	**Type**	**Flag or Brand**	**Type**
Carrefour	Super/Hyper	Assaí Atacadista	Cash & Carry
Pão de Açúcar	Super/Hyper	Atacadão	Cash & Carry
Extra	Super/Hyper	Comercial Esperança	Cash & Carry
Wallmart	Super/Hyper	Makro	Cash & Carry
G. Barbosa	Super/Hyper	Mart Minas	Cash & Carry
Prezunic	Super/Hyper	Maxxi Atacado	Cash & Carry
Bretas	Super/Hyper	Roldão Atacadista	Cash & Carry
Perini	Super/Hyper	Spani Atacadista	Cash & Carry
Dia%	Super/Hyper	Tenda Atacado	Cash & Carry
Smart Supermercados	Super/Hyper	Fort Atacadista	Cash & Carry
Super Muffato	Super/Hyper	Villefort Atacadista	Cash & Carry
Big	Super/Hyper	Carrefour Bairro	Small retail
Bompreço	Super/Hyper	Carrefour Express	Small retail
Mercadorama	Super/Hyper	Pão de Açúcar minuto	Small retail
Comper Supermercados	Super/Hyper	Extra mini mercado	Small retail
Supermercados BH	Super/Hyper	Todo dia	Small retail

From the choice of the sample, the electronic websites and news related to the respective flags were searched and the data obtained were classified in a spreadsheet, so that the specific characteristics of each company were allocated according to each activity of the value chain. Then, the data collected and classified were submitted to content analysis according to Bardin (1977), and the content analysis categorization was based on Porter's value chain proposal (1990).

Findings and Discussion

In analyzing the Brazilian retail supply chain over the last decades, it is notorious to realize that there has been a restructuring between distribution channels both among internal and external agents and, therefore, shaping the structure and dynamics of the latter. With this, several consumers have migrated their shopping environment, but mostly inserted in the super / hyper format for the retail and small retail formats.

This fact can be evidenced when it is observed that the largest retail groups operating in Brazil started to enter this market more intensively over the years, especially in the

infrastructure and locality models of their stores. To better elucidate this phenomenon, the section will be presented in three stages. The first presents the comparisons of traditional retail value chains versus the retail value chain. Subsequently, the traditional structure of the Brazilian retail chain is presented, followed by the characterization of the chain after the rise.

The retail versus retail chain of value - Traditional structure of the retail chain in Brazil
The Cash & Carry in Brazil, although recent, presents a highly dynamic and increasingly comprehensive structure. The distribution channels between the suppliers of inputs, products or services to the final customer, generate impacts at all levels of the chain.

The more complex and long the relationships between the agents that feed the chain, the more financial and managerial resources will be needed, and this is the dynamics of the traditional retail model in Brazil, where the acquisition, inventory, distribution and sale management of products of the supermarkets, presents in its great majority, like an extensive and pushed system. Figure 1 summarizes the distribution channels of the products in the traditional retail markets in Brazil.

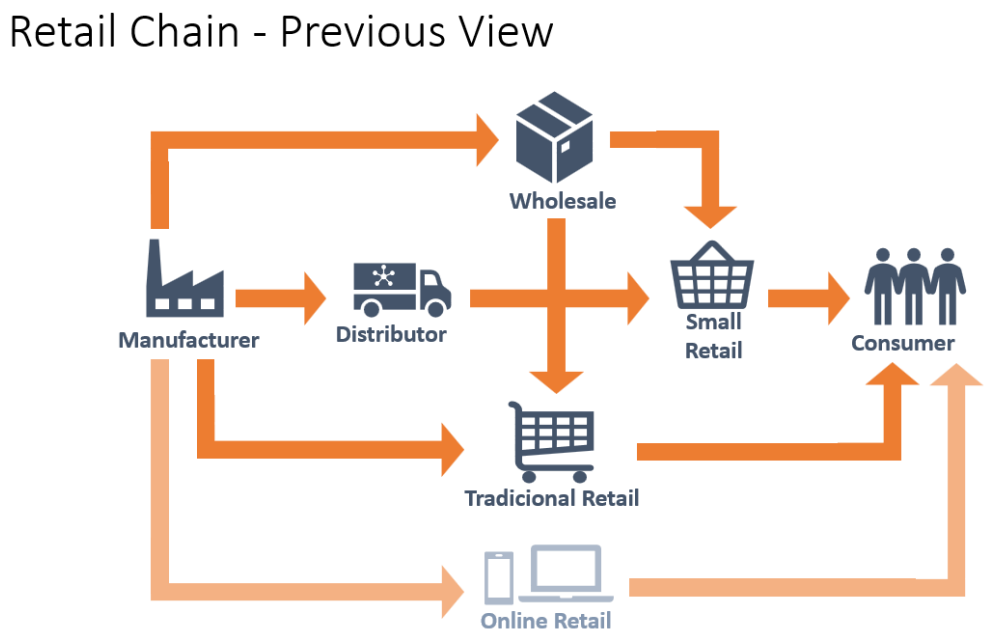

Figure 1 - Traditional structure of the retail chain in Brazil – By Authors

In this model, the product manufacturer presents itself not only as the one who produces a particular product, but also becomes a stockist (in this case, stockist would means the manufacturer as being the maintainer of the products in its own physical structure for later distribution) and sometimes acts as a distributor to the wholesale or traditional retailer. The Wholesale in turn supplies the small retailers that make the products available to customers, replacing them from time to time. The same happens with traditional retail, where the products are stored at the disposal of the final customer. In this model, the interfaces between the links in the supply chain show an increase in the final cost of the product, since each agent must receive a value for transportation, inventory and / or resale of the products to final customers.

Losses, low optimization of inventory management and costs, is recurrent in this type of marketing. Sometimes this commonly used structure has certain barriers that raise costs throughout the chain, as explained above. Linked to this favor, chain coordination

becomes fragile because it has several links between agents, which, due to the complexity of coordination conditioned to the various factors, can generate countless losses due to the organizational environment that this chain is inserted.

In addition, the operational costs of the distribution operations mean that the products that reach the end of the chain have an additional level of intermediation and consequently an added value that ultimately increases the final price of the product to the final consumer.

Current structure of the retail chain in Brazil

At Cash & Carry sector, dynamics and coordination of the chain become leaner, with the optimization of the distribution and storage of products. In the meantime, it is worth stressing with the performance of the chain is more dynamic, both the product outputs and the search for these products by the end customer. This coordination of the chain reinforces the considerations of the Value Chain proposed by Porter (1990) and demonstrate the impacts that the operations both internal and external, modify the organizational and institutional environment of the retail chain as a whole.

Thus, stores denominated Cash & Carry become the link between the manufacturer and final consumer, presenting not only as a retail store, but also as a wholesale center and as a Distribution Center (CD - It would be inferred that it is a warehouse whose purpose is to manage the inventory of goods in the fixed distribution (Abralog, 2016; Do Nascimento et al., 2018).). This changes the whole structure of internal logistics, operations and supplier, vendor and consumer relations. In this sense, Cash & Carry is a protagonist in relation to the position in the supply chain, since it occupies in a concentrated and strategic way, a new location in the structure of the chain. Figure 2 demonstrates the Chain Supply Chain and its structural arrangement differentiated from the traditional chain.

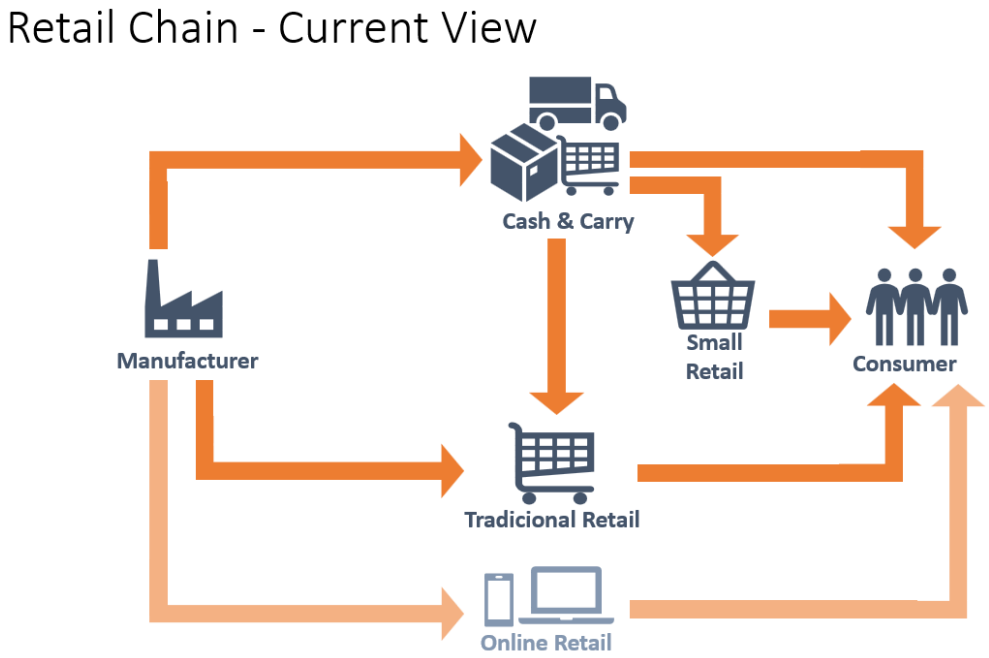

Figure 1 - Current structure of the retail chain in Brazil – By Authors

Notorious is the concentration of the agents under a single player that are nets of Cash & Carry. These, in turn, have the following characteristics: 1) attacked; 2) Retail and 3)

Distribution Center for himself as well as the small and medium retailers of the surrounding region. This explains the growth of this type of commercialization in recent years in Brazil, since in addition to reducing the costs of maintenance, personnel and charges with CD's, the cash cards provide a greater mix of products in a single structure and increase the capillarity of distribution of the products.

In addition to providing support to small retailers, the final consumer is also impacted by the quantity / price ratio, where more quantity, lower price than the cash cards provide and corroborates for the maintenance of small retail stores with quick purchases in small quantities and (which does not, on certain occasions, also exempt the consumer from purchasing small quantities in the card in certain situations or preferential).

This new arrangement solidifies the trend of the expansion of the Cash & Carry in Brazil, because it meets the assumptions of the Brazilian consumer (be it the final or internal consumer of the chain), which is the question of price. As the prices are better in the wholesale account, one can then refute, at first, that the card is a fad, but a new business model that emerges to consolidate over time.

Delimitations and Suggestions

This research was limited to a brief illustrative analysis of the structure and dynamics of the supply chain in Brazil, since the incipient studies are about this topic in depth and, thus, propose new perspectives and considerations about the Cash & Carry Brazilian. However, the limitation was only limited to some academic articles available and also focused on specialized magazines in Brazilian wholesale and retail.

As a suggestion for future research, it is the search for correlating international and national articles (if there is one) to understand the coordination of this chain and the economic, financial and social impacts that the attack provides to the region in which it is installed, such as employ ability, cost and inventory, logistic cost, among other determinants. Moreover, the authors of this work sought to demonstrate the Cash & Carry chain as a whole in its physical structure, but without neglecting or omitting, as shown in figures 2 and 3, the profound changes that online retailing causes and will cause in retail as a everything.

Thus, it is suggested that further studies are about what impacts online retailing can impact on the retail strategies, as well as, to understand the dynamics of Online Retail Supply Chain in the interfaces between supplier and buyer, restructuring the organizational and institutional environment of retail trade.

Conclusions

Cash & Carry, although widespread around the world for more than two decades, presents substantial growth in Brazil only from 2012 to the present day. However, the Brazilian retail sector is not in line with this expansion, since only large groups started to emerge for this new modality that is Cash & Carry. The perception of traditional retailers needs to be reviewed and, above all, studied and disseminated in their planning and management strategies so that there is no disappearance of traditional retails or even the bankruptcy of several of these, due to a strong and massive competition resulting from credit cards.

Since the Brazilian consumer is more closely linked to the prices of the products, the Cash & Carrys appear as an innovative and comprehensive business model, providing a more balanced inventory management between a push-pull management, since the latter occurs more strongly in the traditional retail. This leads to a reduction in the costs and concentration of the products in the own cards that not only replenish their stores in their gondolas, but also have their own stock at the same time, as well as serving as a CD for small retailers, that is, an anchor for other people in the chain.

This all leads to a reduction in costs and optimization of transactions across all interfaces, which today, is a matter of survival of most businesses. Thus, the exponential growth of Brazilian cash loans is more like a market trend than just fad or punctual actions of large corporations. The dynamics of the current relations are getting faster and faster and adapting to the new trends is and will be, in most cases, the threshold between the success or failure of the cash advance in Brazil.

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The role of management mechanisms on internal stakeholders' GSCM practices. An E-commerce supply chain perspective

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Abstract

Nowadays, the rapid growth of e-commerce supply chains has created substantial environmental problems, such as excessive energy consumption of logistics, packaging waste etc. By means of a case study of an e-commerce supply chain for a food SME, this research focuses on the role of internal stakeholders and how the management mechanisms work from a vertical perspective. The study indicates that the awareness, motivation and capability of GSCM implementation diminish down the hierarchical ladder, while, the advantage of the e-commerce supply chain in GSCM implement is obvious.

Keywords: Green supply chain management, Management mechanism, E-commerce supply chain

Introduction

Nowadays, the rapid growth of e-commerce has created substantial environmental problems, such as excessive energy consumption of logistics, packaging overuse and waste in general(Mangiaracina et al., 2015). Companies have already adopted green supply chain management (GSCM) as a creative marketing tool to contribute to the awareness of social responsibility and the improvement of environmental quality. However, in countries such as China, the implementation of GSCM is still in its infant stage. To improve the environmental behaviour of companies, the Chinese government proposed to launch a nationwide policy for collaboration in e-commerce and reverse logistics. Up till now, however, the academic insights and practical implications and regulations to guide companies in the development towards greener e-commerce supply chains are lacking and urgently needed(Wang et al., 2018, Maditati et al., 2018).

Scattered research on environmental behaviour of companies shows that (a) industries were not equally environmentally sensitive(Wilmshurst and Frost, 2000), (b) different manufacturing industries reflected different levels of GSCM implementation and outcomes, and (c) the specific nature of each industry has to be taken into consideration(Zhu et al., 2017). Research findings show that the electrical/electronic

industry has relatively higher levels of GSCM implementation and achieves better performance outcomes than others such as power generating, chemical/petroleum, and automobile manufacturer types, because of more experience (electronic industry) and regulation pressure (power generating industry). However, although at present insights in GSCM research are to a certain extent available for manufacturing, service , construction, automobile, and electrical/electronic industries (Mitra and Datta, 2013, Lin et al., 2011, Balasubramanian and Shukla, 2017), to our knowledge, no study has been undertaken from the perspective of e-commerce (Somsuk and Laosirihongthong, 2017, Vijayvargy et al., 2017).

With the development of e-commerce on both B2B and B2C trading, the traditional supply chain service changed. Because of information transparency, the gathering and distribution of information has become more important and is gradually replacing the physical logistics. Moreover, supply chains are facing the challenge of effectiveness when the trading process is shortened and trading cost decreased sharply. Consequently, companies in various industries organise their supply chain management activities in different ways. The main question is whether the disparities between e-commerce and traditional supply chains will bring companies new opportunities or rather obstacles when implementing environmental activities and developing environmental behaviour. Why certain organisational and network structures are chosen and why certain initiatives are undertaken in e-commerce is often unclear (Asrawi et al., 2017).

GSCM can help to translate a company's environmental sustainability strategy into value-creating activities at the operational level (Longoni et al., 2014). On this premise, it becomes imperative for managers to understand the factors that drive the adoption of GSCM. Among the internal and external drivers of GSCM, managerial characteristic constraints contribute towards an organization's inner motivation and managerial commitment toward environmental sustainability(Dubey et al., 2015). Management mechanisms are illustrative for the intra-organizational sentiment to the adoption of GSCM. In this perspective, research provides evidence to suggest that employees' empowerment, involvement and incentive programs (such as a reward and appraisal systems) are strongly associated with successful adoption and implementation of GSCM practices(Hanna et al., 2000, Jabbour and de Sousa Jabbour, 2016). GSCM initiatives require that the vision and staff members from all hierarchical ranks are aligned. However, few studies discussed the impact of management mechanisms from a hierarchical perspective on GSCM practices (Agi, 2017, Dubey et al., 2015).

The lack of specific understanding, of the impact of management mechanisms on GSCM in e-commerce supply chain formed the motivation of this research, which aims to develop and validate a multi-dimensional GSCM framework for e-commerce supply chains. This study covers: a) identify the key supply chain practices and the management mechanism (in this paper, “management mechanism” refers to the intra-organizational management of stakeholders within a company), b) the practices at a specific e-commerce supply chain company, and c) discuss the potential capability of GSCM practices.

The specific objectives of this study on e-commerce supply chains are as follows: a) to describe the management mechanism; b) to identify the obstacles and possibilities for environmental behaviour adoption.

The remainder of the paper is structured as follows:

In Section 2, this study will provide a basic conceptual framework for the holistic investigation. The methodology of this study will be illustrated in Section 3, including a case study approach, data source and analysis, and sample selection. Next, findings and discussion will be explored in Section 4 and Section 5, respectively. Finally, conclusions and implications will be drawn in section 6.

Conceptual Development

To illustrate the management mechanism, this study's focus is on the vertical perspective. In this respect, the difference between employees, middle management and top management is taken as a starting point. This study will focus on differences between hierarchical stakeholders with respect to "what is GSCM"（know）, "why should I act" (want), and "how can I act" (achieve), i.e. awareness, motivation and capability (Figure 1). In addition to this, the analysis will focus on differences between traditional and e-commerce-supply chains as well as company-specific characteristics.

This research is embedded in the self-determination theory. This theory originates from psychology and includes elements of human motivation and personality. Crucial within the theory is the motivation behind choices while making abstraction of external influences. The theory links the behaviour of the individual with self-motivation and self-determination. Three key elements of the self-determination theory are further explored in this research: awareness, motivation and capability.

Self-determination theory (SDT)

Self-determination theory (SDT) is a theory of human motivation and personality (Ryan and Deci, 2000b, Deci and Ryan, 2012). Based on SDT, the individual differences focus on concepts resulting from various stakeholders from a vertical perspective of management mechanism. According to the individual difference, we propose the individual difference of different hierarchical management levels(Ryan and Deci, 2000b). Intrinsic motivation will be explored from a progressive perspective. Firstly, this study proposed antecedent motivation as "awareness", which illustrate the initial knowledge and attitude of environmental issues. Secondly, the conception of "motivation" here only refers to initiatives and drivers that contribute to their environmental behaviour improvement. Thirdly, the study proposed "capability", to elaborate the link between motivation and performance.

Awareness

Awareness has been associated with autonomous functioning, and it is a crucial element in the existence of a self-determined process(Ryan and Deci, 2017). The sensitivity of environmental changes (e.g. the climate change, pollution etc.) varies in different individuals. The concept of awareness could be extremely useful to provide an antecedent understanding of the drivers' effect. Previous research shows that lacking awareness environmental knowledge of is an important inhibitor of GSCM (Sarkis, 2014). However, it was only recently that the researchers incorporated the idea of GSCM in SDT analysis, especially from the antecedent perspective of motivation(Murphy, 2014).

Motivation

The motivation of GSCM refers to the impetus or inspiration to act environment-friendly behaviour(Ryan and Deci, 2000a, Haddock-Fraser and Tourelle, 2010). Self-Determination Theory (Deci & Ryan, 1985), generally distinguishes between different types of motivation based on the different reasons or goals that give rise to an action(Deci and Ryan, 2012). Intrinsic motivation refers to doing something because it is inherently interesting or enjoyable, this kind of motivation has emerged as an important driver for internal-stakeholders in GSCM(Rao, 2002). Previous research proposed three different types of motivations of firms for pursuing GSCM, i.e. legitimization, competitiveness and ecological responsibility(Vanpoucke et al., 2016).

Capability

Capabilities are ‘‘complex bundles of individual skills, assets and accumulated knowledge exercised through organisational processes, that enable firms to coordinate activities and make use of their resources’’(Murphy, 2014). It is an essential link between motivation and performance to make sure the motivation can be transferred to practices effectively and efficiently. K.-C. Shang proposed that GSCM capability can be calculated by the sum of green purchasing, green materials management, green distribution, and reverse logistics for the whole company, which means the types of GSCM capability various according to different practices for different individuals(Shang et al., 2010). In this study, to compare the individuals from a vertical perspective, a comprehensive amount of capability among each hierarchical level will be tested.

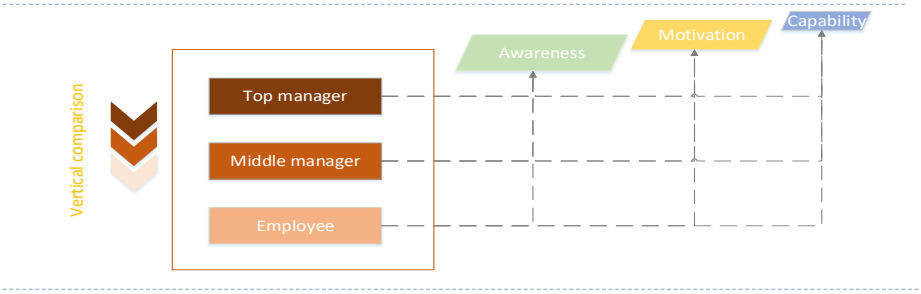

Figure 1- Framework of management mechanism analysis

Methodology

A case study approach

This study adopts a case study approach to gain insights into the role of management mechanisms on internal stakeholders’ GSCM practices. We used a case-based methodology in this study for two reasons. First, a case study is believed to be a better approach of theory building where the relationships between important constructs are poorly understood. Second, the use of series of research-motivated case studies has been encouraged within the field of operations management as a means of providing a rich description of phenomena in a natural setting, based on first-hand observation and examination of numerous factors and nuances (Boyer and Swink, 2008).

Following Ketokivi and Choi (Ketokivi and Choi, 2014) three different methodological approaches to case research can be distinguished: theory generation, theory testing, and theory elaboration. Theory elaboration is not aimed at generating new theories or testing existing theories but aims at introducing new concepts, examine boundary conditions, or investigate relationships between concepts. This research follows the theory elaboration approach by extending the knowledge from the self-determination theory into the field of green supply chain management.

The research is based on an in-depth case study of a Chinese food supply chain service e-commerce platform company. The case is used to explore and describe the role of management mechanisms on internal stakeholders’ GSCM practices in e-commerce supply chain perspective.

Sample selection

The case selected for this research is for a number of reasons. Firstly，the case company is a typical e-commerce supply chain service-company. The company is a subsidiary company and is one of the supply chain service-companies on its parent company’s

electronic system. Secondly, the case company is a newly established Small to Medium-Sized Enterprise (SME). In China, with the rapid development of e-commerce, more creators realized the opportunity of e-commerce and established their own businesses. Different from focal companies, who have already obtained the environmental strategy and economic capability, SMEs are facing more challenges relating to social responsibility. Thirdly, the case company focus on the food supply chain from a B2B perspective. Next, to the well-known B2C e-commerce (electronic product, cosmetics and garment) activities, this new multi-industrial supply chain (Information industry, Logistics and Agriculture) is a popular and typical phenomenon in China at present.

Data sources and analysis

In 2019, 12 in-depth, semi-structured interviews and semi-structured surveys were conducted (see Table 1 for an overview). Next, to primary data collection, secondary data such as company material, industry reports and press clippings were used as a means of data triangulation in order to strengthen external validity. In order to increase construct validity, we deployed different techniques: multiple sources of evidence were used, interviews on different levels were conducted and key informants reviewed the case in depth (Gibbert et al., 2008).

Table1- Record of fieldwork

No.	Department of Interviewee	Position level	Position description	Experience in the industry/months in the case company
1	Sale	A-1	Employee of sale department	1-3years/6months
2	Operation	B-3	Senior manager of operation department	5-10years /6months
3	Strategy&law	B-3	Consultant of law & Assistant of CEO	5-10years /6months
4	Sale	A-3	Senior manager of sale department	5years/6months
5	Purchasing	A-2	Middle manager of Purchasing department	3-5years/6months
6	Warehouse & Logistics	A-2	Middle manager of warehouse & logistics	3-5years/6months
7	Warehouse & Logistics	A-1	Employee of warehouse & logistics	5-10years/6months
8	Operation	B-2	Middle manager of operation department	5-10years/6months
9	Purchasing	A-1	Employee of Purchasing department	3-5years/6months
10	Quality management	A-1	Employee of Quality management department	3-5years/6months
11	Operation	B-2	Middle manager of operation department	1-3years/6months
12	Sale	A-1	Employee of sale department	1-6months/6months

"A": business department; "B": supporting department. "1": employee; "2": middle manager; "3" senior manager.

Findings

Background of the case company

This study offers a more nuanced view of how e-commerce supply chain service-company is greening its supply chain. As a subsidiary company, the case is the largest supply chain service-provider of its parent company, which is also the company running the electronic platform. It relies on the e-commerce supply chain electronic system for B2B services. Its main customers are retailers (supermarkets), restaurants, entertainment-casinos, etc.(Figure 2)

The case company was established in July 2018 with 100 million RMB, which means it is only 9 months old and is still at an infant stage. There are approximately 160 employees in total, including managers. In the Chinese classification system, the company is considered as an SME at present. When it comes to the management structure, there are four independent executive departments, i.e. purchasing department, sale department, warehousing & logistics, and quality management. Furthermore, there are

also three supporting departments: the CEO office, the operations department and the financial department. All departments report directly to the CEO. Departments collaborate and support each other with both online and offline business in supply chain service. The management team of the case company participates in an active and democratic atmosphere. According to the interviewees, most of the participants spontaneously mentioned they feel free to provide their suggestions and opinions, and think their company has a higher level of democratic decision-making than other peer companies. "As an SME company, it is easier to communicate and collaborate flexibly" (No.2 Senior manager of operation department). Moreover, No.3 Consultant of law & Assistant of CEO mentioned that "With the growth and development of the whole company, the democracy and standardization may have a different combination proportion but proper balance as well".

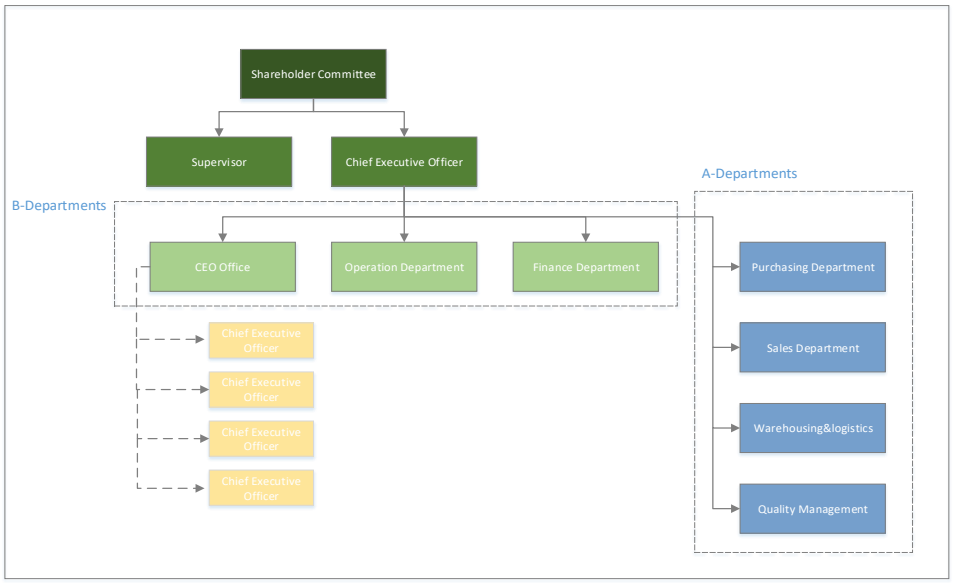

Figure 2- management structure of the case company

Awareness, motivation and capability comparison from a vertical perspective

To identify the management mechanism from a vertical perspective (top-down versus bottom-up), we compared the participants with different hierarchical management positions and their GSCM awareness, their environmental motivation, and their working implement capability to capture "to what degree do they know of GSCM", "would they like to do" and "can they realize and achieve". We established an evaluation system from the three perspectives above, in each perspective 5-6 progressive evaluation points are included (Scores vary from 1 to 5). The disparities among senior manager, middle manager and employee are shown as Figure 3.

The results show that the averages of senior management on all three indexes (awareness, motivation and capability) are highest than both middle and employee levels. According to the educational background and the knowledge of social and environmental concerns, it is easier to understand that top managers are more aware of GSCM. However, the difference between middle management and top management seems small. An interesting observation is that senior management obtains a higher level of capability to implement environmental activities. The capability to implement can be divided into different types depending on the position in the company. The work senior manager requires more consciousness consideration while the employee is supposed to obtain

higher degrees of standardized implementation capabilities. However, yet, the capability of lower staffs still remain at a relatively low level.

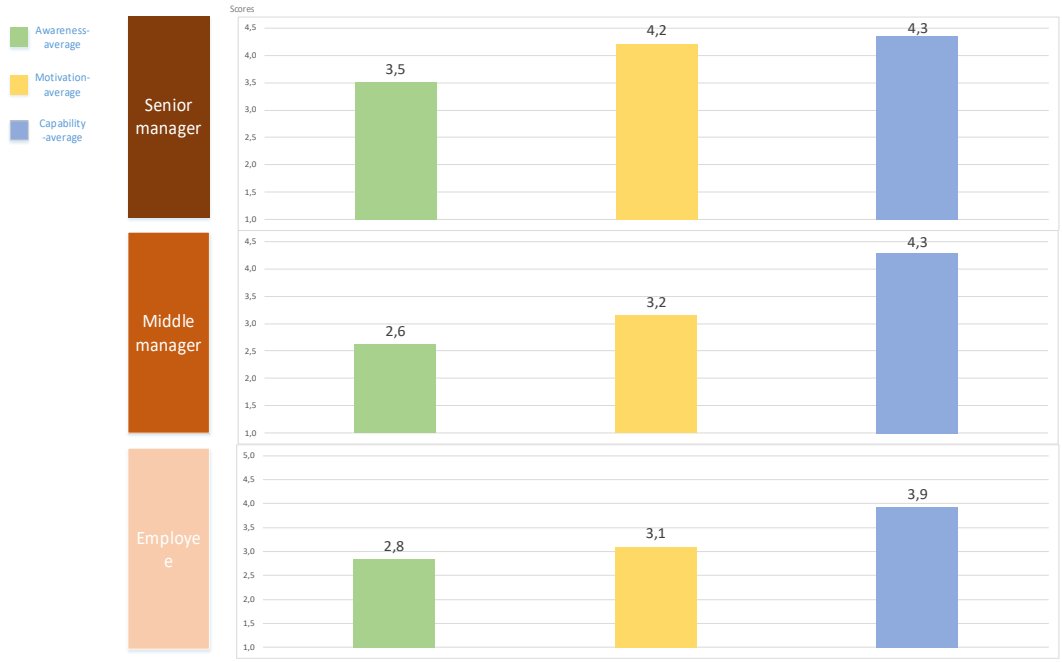

Figure 3- Disparities of management mechanism from a vertical comparison of individuals

Discussion

The underlying mechanism of how a company behaves is complex. GSCM practices are no exception to this rule. To illustrate how the management mechanisms work and what the role of different internal-stakeholders is, we give a number of examples of practices in relating to environmental behaviour, and misunderstanding and opportunities in GSCM.

Top-down motivation in new energy cars plan

In this specific environmental practice, most of the awareness and motivation is at the level of the senior management, while middle managers and employee present to be a more neutral role. There are three reasons for a senior manager to consider new energy cars. Firstly, it is easier to get licenses for the cars in Beijing compared with traditional cars. Secondly, new energy cars might be much cheaper when it comes to cost. Thirdly, based on its electronic system, e-commerce supply chain companies can insert their own electronic system on new energy cars for digital monitoring. However, barriers still exist for implementation of new energy cars plan, which needs the help and professional support from middle managers. First and foremost, new energy cars can't replace traditional logistic transportation totally; not only because of the capability to deliver (amount and distance limited) but also because of functional weaknesses. The demand for temperature requirements for food logistics is not optimal, as a professional transportation needs normal temperature, 0-4℃ fresh and freezing function are all needed. However, new energy cars can only realize a normal temperature now. In addition, as the batteries of new energy cars need to be changed after 4-6 years, the further cost needs pre-tested. More financial forecasting and professional distribution design for the new routes are essential.

Bottom obstacles in reusing and reducing package practices

Sometimes, motivations of environmental initiatives diminish from top to bottom, and obstacles from motivation and capability of employees can become a relatively controversial power, which needs higher policy strategy and management regulation adjustments. After the last half-year operation, senior management found their low-value consumables usage is much too high. Because of the improper usage or package overuse of employees, there is still a certain improvement environmental behaviour by professional training, while recycled baskets can be used for the supply chain service company to cut the cost without any impact of the food quality as well. Senior managers tried to adopt two new practices: "reduce" and "reuse" by training and responsibility regulation relatively.

Based on less awareness of employee, it is not easy for them to recognize environmental behaviour themselves. For daily work, they prefer to choose convenient behaviour to meet the basic standard. However, the capability of the employee differed in the two practices above. Reduce the usage of package behaviour needs employee not only realize the problem but also needs professional guidance by training, as the profit rate of training is not clear, this plan is still in planning stage. On the contrary, the other plan for reuse the plastic baskets. They published a new regulation to confirm the responsibility of plastic baskets at each delivery worker/driver, i.e. if the plastic basket is lost, the worker/driver should pay himself. The results of this small step recovered and retrieved 80% of lost plastic baskets. As no further or difficult capability demand, this regulation achieved as soon as the employees' awareness and motivation changed.

GSCM practices are noticed and ignored

There is a big misunderstanding or incorrect knowledge of one particular element of awareness on an individual level, which is the environmental behaviour derived from social responsibility. Moreover, in their opinion, the company won't consider the environment issue until they have more economic support after they get through their infant stage. However, saving energy and recycling are considered in their daily management already, while GSCM is not in their mind. The original motivation comes from a financial consideration; a cost-cut for both energy saving and recycling behaviour. The operation department and CEO office recognized the cost of their daily energy usage and an optimization plan is considered. This kind of management greening derived from profit pursuing, which can be titled as internal motivation. On the contrary, there is also another kind of supply chain greening practices derived from the pressure of customers. The demand of the customers sits at the first position especially for such an SME company at an infant stage. As non-coercive requirements from government, they prefer to focus on the financial reasons, both income from customer demand and cost-cut from operational consideration. What's more, GSCM practices are already implementing in different departments and their implement stages are varied.

Linkage in relating traditional food security to new GSCM

In China, "green food" is a crucial linkage in relating traditional food security to a new GSCM. However, it is still far from the aim of installing an environmental management system based on green food development. At present, Green food management required the practices and collaboration of quality management and marketing demand considerations. GSCM and environmental traceable systems can obtain the establishment more efficiently if it depends on and develops from "green food" management systems. Meanwhile, it is crucial to establish a tracking system for the products' original region management based on green food managerial improvements. As an e-commerce supply

chain, the electronic system provides them with a more easy way to realize information transparency. However, there are still obstacles. Higher qualified and environment-friendly food leads to a higher price, because of the limited consumption ability of most customers in China, this "green food" demand finally performed weakly to green the supply chains now. In addition, even if the tracking system is a plan and a trend in the food industry already, at present, companies focus much more on the final quality of the food itself instead of what the product "experienced" before. In other word, further responsibility and non-coercive standard of their supplier still need a long run to realize.

Conclusion

Management mechanisms performed different roles in the e-commerce supply chain at different levels. This study illustrates how the management mechanisms contribute or limit the improvement of GSCM from a vertical perspective.

First, the awareness, motivation and capability of GSCM implementation all showed a top-down decreasing trend. The knowledge of GSCM is still lacking from all hierarchical levels of staff. However, there is still space for GSCM practice improvement, which can be realised by professional training.

Second, the advantage of the e-commerce supply chain in GSCM implement is obvious, even if the development is not standardized and lacks guidance now. The electronic system and its information transparency enable the company to realize more environmental collaboration with its suppliers and customers. Moreover, information technology and electronic system also contribute to the new energy logistics in e-commerce supply chains.

Third, at present, the management mechanism involved Green food management in both quality management and marketing demand consideration. In China, "green food" management is a crucial linkage in relating traditional food security to new GSCM. GSCM and the environmental traceable system can obtain a more efficient establishment if it depends on and develops from "green food" management system.

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Innovation models for supply chains in knowledge-based economy

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Abstract

The paper provides the attempt to combine 6 types of innovations offered by BCG in 2017 and supply chain strategies in modern knowledge economy where the role of information became crucial. Logistics providers create supply chains as owners and outsource all production, transportation and other physical processes keeping the position of "control towers" with efficient utilization of information. Two innovations models out of six are suitable for this supply chain models, they are "Expander" and "Fast follower" with main focus on agility based on information utilization.

Keywords: innovations types, supply chain, knowledge economy

6 types of innovations

The current management theory trends are oriented to digitalization, new business models, the transformation of paradigm and the word "innovation" is not on the cutting age last decade. Despite this fact we shouldn't underestimate the role of innovations in any type of development, so we tried to combine the theoretical background of innovation management and the tendencies of switching management focus to the supply chain management. We agree with the position about growing role of supply chains comparing with the roles of discrete firms. Furthermore we share the opinion (Gassman, 2016) about the new way of competition based on different business models instead of product or process innovations.

The research done by Boston Consulting Group in 2017 offered the classification of innovations. These types of innovations are not something radically new but they used as examples modern companies and justify the actuality of the classification. They describe six types of innovation (BCG, 2017):

1. Creator
2. Solution builder
3. Leverager
4. Expander

5. Defender
6. Fast follower

The Creator model is the most visible: Apple, Tesla and Netflix. According to the BCG report, these companies are highly innovative, managed by a strong visionary leader, introducing disruptive (radically new) products to the market, which then become the industry standard.

A Solution builder is a company that implements improving innovations and actively listens to the needs of customers, creating niche solutions for different groups. An example would be the manufacturer of sports equipment Nike.

A Leverager is a model of a company that can be described with the slogan "we make our business better than anyone." The firms applying this model concentrate on continuous improvement of the basic version of the product. The best example is the automaker Toyota - the "cradle" of the concept of continuous improvement, although BCG gives other examples, such as the Spanish clothing manufacturer Zara.

A Expander is a type of company that takes away part of the market from existing players through radical innovations. At the same time, the company focuses on one or two “advanced” product features and is constantly experimenting, looking for new ways to better meet the needs of the market. Here we will name the company Amazon as a leader in this model. So the apply best in class technologies expanding their role in supply chain from storage to selling to distributing and sometimes production.

Defender is another type of model that uses innovation to counter expander and others. The model is found in capital-intensive industries with high research and development costs, examples being such giants as pharmaceutical Pfizer and insurance AIG. The key activity here will be constant monitoring of new disruptive innovations of competitors, protective measures, including mergers, acquisitions and cooperation agreements with the most promising rivals. Another key activity in the “defender” model is continuous improvement, as in the “leverager” model.

The Fast follower - the last of the six models - provides for tracking the actions of the advanced and most progressive competitors, as well as following their decisions with the first market evidence of their success. Due to this model, a fast follower saves costs, because the “pioneers” bear most of the risk and initial costs of bringing innovations to the market. In such organizations, the speed of implementing decisions is highly important; the ability to change quickly is more typical for “flat” organizational structure. That is how the financial leader JP Morgan Chase works, for example.

As we can see from the descriptions, BCG was focused only on individual firms, they didn’t estimate supply chains and partners of focal company. We add to this analysis of strategic aspects of supply chains of companies in order to combine and find connectivity of their types of innovations and supply chain characteristics. We believe that such combined analysis can give new insights to management theory and offer practical implementation. The theoretical hypothesis we formulated as following: companies with different types of innovations should use different supply chain strategies. Thus, there is a need to adapt management methods so that measures applied to one company, for example, innovation strategy, take into account potential factors of influence on other companies of this supply chain.

Supply chain strategies

When organizing supply chains, three basic types of strategies are used: effective, focused on minimizing costs and reducing losses; agile, flexible or manoeuvrable, focused on factors of unpredictability of demand and other external factors and tuned to

the ability to quickly respond to changes; hybrid, combining the advantages of both strategies, that is, preserving the necessary level of flexibility while minimizing costs.

From the description of supply chain strategies, it is obvious that hybrid strategy should prevail, but the complexity of this strategy is the decision on the ratio of an effectiveness and flexible. The literature identifies as the main difficulty of implementing this strategy the identification of the "point" of decoupling from an effective to a flexible strategy. This "point" is determined by analyzing information about the unpredictability of demand or directly by the occurrence of a particular order. Within one company there is no such a "point", rather it should be in the whole supply chain. It is also important who is the owner of the supply chain; it means which company has main influence on the operationalization of supply chain. Traditionally it is based on the specifics of goods and services served by particular supply chain. As two polar examples it is possible to allocate the supply chain formed by industrial companies, defining a common strategy for the supply chain based on the type of product and the supply chain, where the main requirement originates from the distribution network and retail.

Nowadays we can face more and more supply chains controlled by the retail as an owner. Big retail chains become the company which role in value creation for the final customer is the biggest as these chains are able to satisfy the demand quickly. Such chains serves as distributors, they control amount and price of product etc. We found the reason for this change in supply chains in logistics provider’s development.

In this regard, it is important to mention the classification of logistics providers, which appeared at the end of the last century due to the fact that the role of logistics operators has increased significantly. According to the "United Nations Convention on international multimodal transport" of 1980, logistics operators began to be included in contracts between the manufacturer and the destination of the goods as a third party with its rights and obligations.

Role of logistics providers in innovations

This classification identifies 4 types of logistics service providers for the set of functions for which they are responsible. Accordingly, the first level providers are manufacturing companies that are responsible for delivery by their own transport. So here we can imagine transportation task as just deliverance from point A to point B without any optimization schemes. The second level includes companies that have vehicles and are external logistics service providers. Typically such companies are called transportation companies and their main task is to optimize utilization of vehicles. At the third level of classification, consulting is added to the logistics functions, that is, logistics companies already partially assume management functions, including responsibility for the results of the logistics component of the company. The fourth-tier providers include operators that do not have any transport or other capacities, but are centers of competence. At the same time, such companies should not only have knowledge in the field of logistics operations, but should also be competent in market trends. As they create the supply chain based on their knowledge about the market they define supply chain strategy and innovativeness level. As we can see the level of innovativeness will influence the supply chain strategy and we can try to combine the BCG’s innovation classification with strategic aspects of supply chains.

The creator is a highly innovative company that influences the entire industry, both at the level of the products being developed, as well as technologies and operations. As an example of such a company that changed the principles of the automotive industry, could be Ford Motor Company. In-line production of cars has changed not only the

product itself, but also had a huge impact on the supply chain. With this level of innovation, the company does not yet have an existing market, it forms it, so it cannot wait for market signals to determine the demand. Such an innovative strategy leads to the choice of a push strategy to bring the product to the market, which allows to focus on an effective strategy.

Solution builder - a company looking for solutions based on market signals, its innovations are focused on meeting current customer needs and adaptation. The greatest priority for such an innovative model is flexibility, including flexibility in the supply chain. An example of such a company is Nike, which can customize its products to customer needs.

For the leverager - the main priority of this innovation strategy is a business model that allows capitalizing on market opportunities. That is, in this case, the supply chain itself is an innovative solution. Such companies as ZARA, Uber, Dell showed successes in the implementation of this innovation strategy. It is important to note that currently there are enough followers of these business models, which proves that the effect of a change in the supply chain can also give significant results and be innovative.

The expander - such an innovation strategy is characterized by the development of new areas or even industries due to the obtained successful experience and existing competitive advantage. An example is Amazon, which has changed the focus of its business from sales to technological sales services, in other words, to the process infrastructure. Using this logic not for one company, but for the supply chain, it can be assumed that the company - participant of the supply chain chooses vertical integration in order to gain the position of the "owner" of the supply chain.

Defender strategy of innovation characterizes resistance to innovation. Such a strategy is suitable for functional product industries, where an effective functional supply chain strategy is most applicable. A company choosing such a strategy is most at risk due to the lack of flexibility of both the product or service and the supply chain as a whole.

Fast follower companies prefer to copy the most successful practices, while gaining a competitive advantage due to the speed of reaction, which confirms the need for flexibility in the supply chain. The level of product innovativeness here could be quite low, but the level of competences in supply chain should be very high, over wise the followers couldn’t be fast.

Thus, from the strategies described above, three types of strategies that characterize the most radical innovations and three types of less innovative strategies can be distinguished (Table 1).

Table. 1. Innovation types and supply chain strategies

	Supply chain strategy			
Innovativeness level		Efficient	Hybrid	Agile
	High	Creator	Leverager	Solution builder
	Low	Defender	Expander	Fast follower

Accordingly, the radical innovation strategies will include Creators, Leveregers and Solution Builders, with each strategy being able to match the type of supply chain strategy. Also, for the incremental level of innovation, three relevant strategies can be distinguished: “Defender”, “Expander” and “Fast Follower”. From the point of view of supply chain management, strategies that focus on flexible strategies are of the greatest interest, since it is in the implementation of these strategies that organizational and process innovations in the field of operations come to the fore, allowing the successful operation of the entire supply chain.

Applying the strategy of a logistics operator of the fourth level, the company leaves the category of service providers, and becomes the "owner" of the supply chain, creating it to meet the needs of the final customers. As an example of such companies, organizations that place orders for production in countries where it is most profitable, still most often in China, then hiring a third-level logistics operator to arrange transportation to markets. Such companies retain solely the management function, which is characterizes them as “owners” of the supply chain. So we can assume these logistics providers as "Solution builder" with a high level of innovation activity and "Fast Follower" with low innovation activity according to the Table 1. The degree of their dependence on any capacity is practically minimal, allowing them to be as flexible as possible, and the market knowledge requirements are extremely high. From the knowledge economy point of view, these innovation models are most closely associated with the competence of logistics providers of the fourth level, which, based on the idea to create full-fledged supply chains to meet customer needs, while maintaining maximum flexibility.

Supply chain innovators in knowledge-based economy

Recently, this classification began to include another type of providers - the fifth level. They are also called “virtual” logistics companies due to the fact that they organize the network business using the global information space and operate in the global market. The literature describes as examples of 5PL-providers online stores such as eBay, Aliexpress, Amazon. Nevertheless, it is worth noting that these companies do not position themselves as logistics operators. Other examples of companies that provide integrated supply chain services based on modern information technology capabilities include Küehne + Nagel International AG and DHL, which have so-called Control Towers, that is, information centers that act as platforms for aggregating data on logistics flows and external factors affecting the supply chain system.

Such organizations use the “Control Towers” approach, aggregating huge amounts of information across all streams. Such control centers are used to be information hubs, they can serve the purposes of one client-company, then they are created on its basis, and can serve many different customers, in this case, most often this hub is a "superstructure" of the logistics operator.

This information flow provides maximum transparency of the supply chain, the ability to track cargo, control costs, and also allows to increase the speed of reaction to external factors. These factors could include both demand fluctuations and natural or market changes that affect the supply chain. For example, a hurricane on another continent, which can lead to supplier transport problems, can give an alert for searching an alternative supplier if information is available in advance. Without an information hub, the customer would first be faced with a delivery delay, and only then would he start looking for an alternative provider.

Data from tracking cargo on all transport lines can provide estimation about potential supply on the market. For example, the market price is primarily influenced by the

volume of supply of perishable goods from distant countries like fruits and vegetables, as suppliers do not have an ability to store goods in a warehouse until demand increases. The information hub can have information about upcoming deliveries and use this information effectively.

The complementation of the information hub with the ability to carry out commercial activity makes the company very competitive with the potential for rapid response to any market fluctuations. Thus, the reasons for the growing popularity of the information component in business and the development of big data analysis technologies become competitive advantages based on the availability of timely information. At the moment, the knowledge economy is becoming more focused on information about market demand, and this knowledge is valued most in supply chain management.

In addition, analysis of demand and consumer data allows responding to changes in demand with fewer fluctuations. Analyzing data from all participants in the supply chain also allows greater transparency and, therefore, increasing the level of partner confidence, allowing for a quick and coherent response to changes in the market situation. Companies engaged in the development of innovative products often do not have the ability to use retrospective data. Nevertheless, customer data allows them to bring to market the product at the right time and make it most attractive to customers.

Conclusion

Despite the tradition understanding the classification of innovations types, based on product innovation, current knowledge economy shows the transformation of most prolific innovation types as “Solution Builder” and “Fast Follower” facilitating supply chain efficiency instead of product innovations. The research about trends of changing owners of supply chains and role of logistics provider give an understanding of information influence underestimation as a competitive advantage. The focus to the innovations in supply chains oriented to the flexibility should be a specific topic for research. We believe that it could be the niche where new types of innovations could be found and described.

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When supplier development initiatives fail: exploring the causes of opportunism and unexpected outcomes

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Abstract

Buyers often seek to enhance the capabilities of their suppliers through supplier development initiatives. However, these initiatives are not always successful and may have unintended consequences. This study investigates a 'dark-side' of supplier-buyer relationships, specifically the link between supplier development initiatives and supplier opportunism. Agri-food supply chains in Vietnam is the context for the study. We employ an explorative, qualitative methodology, analysing data from 30 interviews with fruit and vegetable buyers. The findings identify different supplier development initiatives and the specific forms of opportunism that may arise from each. Attention is paid to strategies to curb opportunism.

Keywords: Opportunism, Supplier Development, Supply Chain Management, Vietnam

Introduction

Companies increasingly seek to create sustainable competitive advantages in co-operation with suppliers. Suppliers' capabilities affect, either directly or indirectly, firms' costs, quality, delivery, and level of technological directly or indirectly (Krause and Scannell, 2002). It is, thus, no surprise that firms often enhance the capabilities of their suppliers through supplier development initiatives, which can be defined as "any effort by a buying firm to improve a supplier's performance and/or capabilities to meet the manufacturing firm's short- and/or long-term supply needs" (Krause et al., 1999, p. 206).

The extant literature, informed by theories of knowledge transfer and co-operation, investigates the impact of supplier development programmes on suppliers' and buyers' performance as well as on supplier-buyer relationship outcomes (e.g., Li et al., 2017, Humphreys et al., 2011, Lawson et al., 2015). Supplier development can lead to positive outcomes such as product and delivery performance improvement (Wagner, 2010), and increasing suppliers' operational performance (Krause et al., 1998). In terms of relationship outcomes, capital-specific supplier development can also increase suppliers' satisfaction and commitment to the supply chain (Ghijsen et al., 2010). Overwhelmingly,

the literature presents positive assessments of supplier development initiatives, often characterised as a 'win-win' for suppliers and buyers alike.

However, even when both suppliers and buyers accept the importance of supplier development, these initiatives are not always successful and may have unintended consequences. Specifically, supplier development initiatives can prove counterproductive if they stimulate supplier opportunism (Proch et al., 2017). Opportunism, seen as a dishonestly oriented breaching of business obligations, is defined as "self-interest seeking with guile," (Williamson, 1985). When participating in supplier development initiatives, suppliers may behave opportunistically if they perceive a missing control mechanism (Li et al., 2017) and Transaction Cost Theory (Williamson, 2008) predicts that suppliers will breach supplier development contracts if the benefits of violating them exceed the cost.

To date, very few studies consider the potential downsides of supplier development initiatives and the circumstances under which they stimulate rather than curb opportunistic behaviour by suppliers. Exceptions include Huo et al. (2016), who discern that buyer specific-investments increase the likelihood of suppliers engaging in opportunistic behaviour. Specific-investment induces the investment receiver to act opportunistically because it is a non-transferable investment, and dependent to a specific relationship (Huo et al., 2016).

One-sided investments in relationship-specific assets are sensitive to opportunistic behaviour, especially in an unpredictable business environment (Hawkins et al., 2008, Proch et al., 2017). However, the prevailing view in the literature is that supplier development initiatives provide a "win – win" for suppliers and buyers, especially where the latter seeks greater control over the quality and appropriate incentives are provided (Li et al. 2017).

Given theoretical and empirical uncertainty regarding the effects of supplier development initiatives on opportunism and the circumstances under which investments in supplier development trigger or limit suppliers' opportunistic behaviours, further research is warranted. This study investigates to what extent, and under what circumstances, do supplier development initiatives curb and/or stimulate supplier opportunism?

The context for the study is agri-food supply chains in Vietnam. Emerging economies often lack strong, formal institutions for contract enforcement(Kirsten and Sartorius, 2002), negatively affecting both suppliers and buyers (Saenger et al., 2014). It is common in agri-food supply chains for processors to provide credit and physical inputs (e.g. seeds, fertilisers) to farmers as part of a contract. However, difficulties of monitoring and contract enforcement may allow farmers to misuse the investment, or sell their product elsewhere (Bellemare, 2010). This can lead to buyers withdrawing support, with negative impacts on the long-term quality, safety and quantity of supply chain outcomes (Gow and Swinnen, 2001). There is anecdotal evidence that such problems beset the Vietnamese agri-food sector. The country has two main types of food supply chains for fresh fruit and vegetables: wet markets and supermarkets. The former comprises numerous small-scale operators, dominates total sales and regulations are poorly enforced (Cadilhon et al., 2006, Shepherd and Tam, 2008, Maruyama and Trung, 2007), raising concerns regarding food safety. The supermarket sector is growing and more likely to insist on suppliers being certified (e.g. VietGap and GlobalGap). Some supermarkets or their suppliers support farmers through credit or training although these have not always delivered the outcomes intended. The Vietnam case is thus exemplary for studying the relationships between supplier development initiatives and supplier opportunism.

Theoretical Background

Prior research on supplier development indicates that buying firms employ various activities to improve suppliers' performance and/or capabilities (e.g., Zhang et al., 2017, Wagner and Krause, 2009). Initiatives may be introduced in response to a problem ("reactive approach"), or proactively initiated to develop suppliers even though there are no immediate problems ("strategic approach") (Friedl and Wagner, 2016). Much research classifies supplier development initiatives by the level of commitment from buyers to a specific supplier (e.g., Zhang et al., 2017, Proch et al., 2017, Ghijsen et al., 2010, Humphreys et al., 2011, Wagner, 2006).

Supplier opportunism is an important risk in buyer-supplier relationships. Parties should safeguard themselves against partners' opportunistic behaviours in supplier development initiatives because they often require relationship-specific investment. If a buyer is unable to introduce satisfactory safeguards, they may reduce the provision of supplier development initiatives, causing underinvestment and possibly impairing the buying firms' long-term competitiveness (Rokkan et al., 2003).

Transaction Cost Theory, Social Exchange Theory and Agency Theory

Supplier development initiatives involve a collaborative relationship between suppliers and buyers. From a social exchange theory perspective, partners in supplier-buyer relationships prioritise the pursuit of their long-term benefits, which curbs opportunism as the latter may lead to the termination of the relationship (Li et al., 2017). By contrast, according to transaction cost theory (Williamson, 2008), relationship-specific investments suffer from asset specificity, so that the reuse value of the investment would be less or even zero beyond the relationship (Crosno and Dahlstrom, 2008, Wang et al., 2013). Accordingly, dependence on a supplier increases when a buyer makes specific investments in a relationship, and the supplier becomes more powerful in dealing with the buyer, therefore endangering them to more risk and uncertainty (Huo et al., 2016, Humphreys et al., 2004). Hence, specific-investment builds a locked-in environment that induces supplier opportunism (Brown et al., 2000, Liu et al., 2009, Rokkan et al., 2003).

From the perspective of agency theory (Morgan et al., 2007, Jap and Anderson, 2003), indirect supplier development (i.e., supplier management practices) reduces the likelihood of supplier opportunism because it controls directly against self-interest seeking behaviours of suppliers (Maestrini et al., 2018). Furthermore, incentives encourage suppliers to perform in a manner that satisfies the buyer's performance measurements and should reduce the chances of suppliers misbehaving. Once again, however, transaction cost theory (Williamson, 2008) suggests contrary predictions, looking humans are self-centred, calculative, and only "weakly moral" (Wang et al., 2017), so parties act opportunistically to pursue their self-interests as much as possible, once possible benefits exceed the expected costs (Das and Rahman, 2010, Ghoshal and Moran, 1996). Hence, when linking specific targets to incentive schemes, suppliers are encouraged to bypass or subvert performance measures to their own benefit, consequently reducing favourable outcomes from the buyer's perspective (Maestrini et al., 2018).

Recognising the contrary views from different theoretical perspectives, we undertake further research on the relationships between supplier development and opportunism, distinguishing between the specific types of each.

Methodology and Data collection

As theoretical and empirical work in business management often overlooks opportunistic behaviour stemming from supplier development initiatives, we conducted an exploratory deep-dive investigation. The study draws on 30 face-to-face, in-depth interviews with

managers in the fruit and vegetable supply chain in Vietnam. The sample is cross-sectional, including nine organisations which solely act as buyers, and 21 organisations which are both buyers and suppliers of fresh fruit and vegetables. The Ho Chi Minh City Department of Industry and Trade, the Business Studies and Assistance Centre, Southern Horticultural Research Institute (SFORI) Vietnam, and Lam Dong Province Agricultural Extension Centre helped recruit interviewees. Potential interviewees received a participant information sheet (outlining the purpose of the research and guarantees of anonymity and data confidentiality) and signed informed consent forms before commencement of interviews. Some interviewees recommended other potential participants (snowball sampling).

Data collection took place in summer 2018. Interview data were coded and inter-code reliability checks undertaken, utilising Nvivo12 software. A start list of code was created from the conceptual framework, a list of research questions, and problem areas of the research, including the structure of the code within supplier development, and opportunism concept. The list has been revising as new codes are generated while coding the materials. Three independent experts were invited to code 19 random transcripts, which accounted for 63.33% of total transcripts. After independently code the transcripts, coders discussed the code to reach the inter-coder reliability at above 75%, which indicates a good level of agreement.

Findings

Supplier Development Initiatives

Most buyers provide feedback on quality to suppliers and provide training to farmers (see Table 1). To a lesser extent, buyers offer cash support in the form of advanced payments or zero-interest loans, and providing physical inputs. Buyers can offer suppliers a guaranteed sale, which means they will purchase all of the supplier's output of a given good, at a pre-specified price over an agreed period of time. Supplier incentives refer to financial inducements to the supplier to meet particular quantity and quality thresholds. Two cases stated that they do not have the capability to develop suppliers in term of technical processes and skills since they believe suppliers have more experience and knowledge on growing fruit and vegetables.

Table 1 – Supplier Development Initiatives Offered by Buyers

Supplier Development Initiatives	Cooperative (n=11)	Supermarket (n=4)	Small Retailer (n=3)	Tier 1 Company (n=12)	Total (n=30)
Train Farmers	11	3	1	9	24
Supplier Assessment and Feedback	10	4	2	12	28
Provide physical inputs	9	0	0	5	14
Cash Support	10	1	0	9	20
Supplier Incentives	6	1	0	4	11
Guaranteed Sale	4	2	0	5	11

Table 1 presents the frequency with which buyers employ different supplier development initiatives. The first column lists the initiative, while the next four columns

detailing the number of interviewees stating that they have deployed such an initiative. As can be seen, buyers often employ a mixture of supplier development initiatives rather than just use a single solution. For example, a buyer may provide some physical inputs, as well as training and guaranteed prices to farmers. Although many buyers provide a particular type of supplier development support, implementation in practice may be very different. For instance, quality assessment activities - one buyer may only assess product appearance quality purely visually (i.e., good size, looks good on skin, weight as agreed), another may test quickly for pesticide residues, but another assesses the product's microbiological index which requires an independent third party and is far more expensive. Evidences include "*We can only have a quick test, a quick test on some indicator. We can't check on everything"* (Interviewee 30, Manager, Supermarket), "*The supermarket, they have some test periodically, but they also have a quick test. Every day, they have a department, for example, today we supply 10 products, but they choose only one product and perform a quick test, they analyse the result at the time, if they suspect the product has some over-permitted pesticides indicator, they will test, if it serious, they will destroy the product, if it is lightly over-permitted, they will bring back to check at farm, if it acceptable they will buy it, if not they will cancel the whole batch*" (Interviewee 26, Director, Vegetable Cooperative), and *"During the time of working with suppliers, we go there to take sample to test, for example, occasionally you visit the farm, you will take random sample then send it to test, or you can do a quick test yourself"* (Interviewee 16, Manager, Vegetable Company).

The relationship between Supplier Development and Opportunism

Further analysis of the data suggest the supplier development measures can lead to supplier opportunism (Figure 1). Specifically, six supplier development initiatives, represented by six rounded rectangles, lead to six types of opportunistic behaviours displayed in the six ellipses.

Firstly, one common initiative to improve suppliers, namely training for farmers, can fail because farmers may stop following the processes introduced in the training in order to sell products to other buyers who can offer a higher price. For example, as a manager stated *"When they are aware of the market price is higher, they stop to follow our process. They do their own thing, in order to keep the vegetable away from diseases, so they can sell to the market at a higher price"* (Interviewee 09, Manager, Vegetable Cooperative).

Secondly, supplier assessment and feedback may be susceptible to two forms of opportunistic behaviour. First, a supplier can bypass the assessment criteria, as Interviewee 14, a Manager at Supermarket reported *"Suppliers do not deliver quality products. They cover the freshest vegetable on the surface, […], in the middle they put lower quality ones; we can only test on 1-2 samples, so sometimes it happens"*. Moreover, suppliers may mix products from different sources to supply to their buyers, as mentioned by another director *"They buy from wholesale markets, then process the product and mix it together. It means the uncontrolled-quality-product in the wet market. They process it, pack it under their name and sell to the supermarket"* (Interviewee 13, Director, Fruit and Vegetable Company).

Buyers can offer suppliers a guaranteed sale, implying that they will purchase the entire output of the supplier at a given price during a particular period of time. This initiative stimulates two different types of supplier opportunism. For example, a director states: *"When the market price is low, they mixed products from their relative's farm to sell to us"* (Interviewee 17, Director, Vegetable Cooperative). With the guaranteed price offered, they cheat on product quantity by including output which was not produced by the supplier and maybe of inferior quality. The second form of opportunism involves the

supplier breaking the contract to sell to other buyers when the latter offer a higher price. For instance: *"We sign a contract with suppliers with a fixed price for 3-6 months, for example. At the time, we fix the price, for example, 10.000đ per kg, but then when we order, because we fix the price for three months, at that time they agreed. But after one month, the market has some change, the price increases. The price increases, then the farmer will break the contract with us to sell to other buyers, to traders"* (Interviewee 01, Manager, Fruit Export Company).

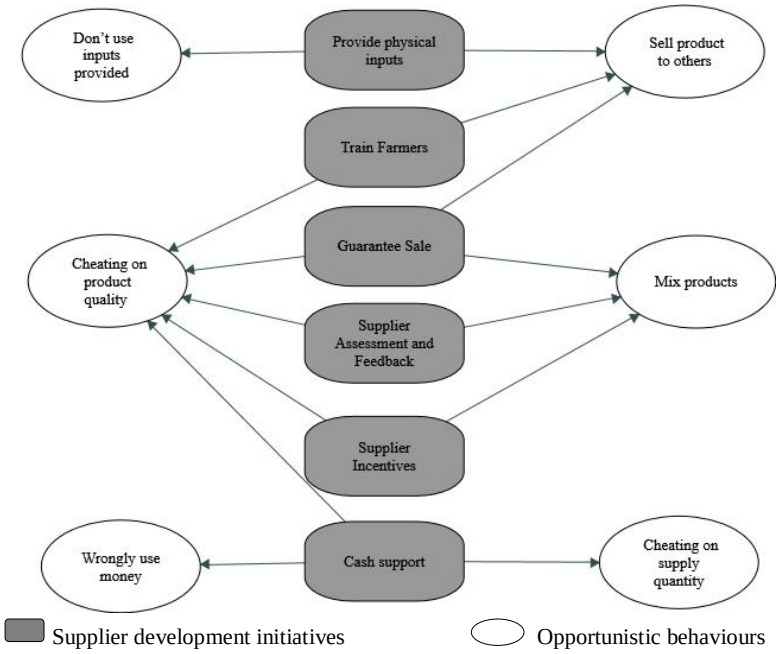

Figure 1- Supplier Development Initiatives link to Opportunism

Cash support may also provoke supplier opportunism. Firstly, when receiving cash, a supplier can use it for purposes that are different from other agreed with the buyer, such as *"The fact is, there are businesses that use the money for the wrong purpose…that means… they take that money to do something else…."* (Interviewee 13, Director, Company). Secondly, the supplier may use the cash support to improve the quality and quantity of production but then not supply the enhanced output to the buyer who provided the support. For example, "*when we need to buy from them… with the fresh product in the farm, they harvest the product and sell to somebody else, then they buy products from the wet-market and resell to us […] We look at their dairy and we see that they harvested, but when we ask them for supply, they said they don't have anything to sell […] We request them to obtain the VietGap certificate many times, but they didn't do so"* (Interviewee 16, Manager, Vegetable Cooperative).

When buyers provide some physical inputs for suppliers, the receiving party may not use the provided inputs for production purposes. Instead, resources may be diverted to other uses as one manager notes *"they use 100 trays per day… we lost some of those, they don't return enough…. They use the trays to make a henhouse, use as a bin, in general they use for everything…"* (Interviewee 22, Director, Cooperative). As with cash support, a supplier may utilise the inputs for production as intended but then fail to sell the enhanced product to the investing buyer.

Buyers often provide financial incentives to deliver specific volumes of a pre-specified quality. To gain these inducements, farmers may mix products from different sources in

order to meet quantity thresholds, or cheat quality control processes. For instance: *"we need 100kg, but they only have 70kgs, and they…if they supply 70, they won't meet the quantity required, if they don't meet that, it affects to the reward we offer. So, they think - I will take that quantity from another farm – those products can be safe, can be unsafe, don't they."* (Interviewee 16, Manager, Company).

To counter problems of supplier opportunism, buyers pursue two main strategies: to increase *monitoring* and *offer a bundle of supplier development measures*. Monitoring, via the stationing of some of buyer's employees at the supplier's farm can help ensure that cash and other physical inputs provided are used in accordance with intended plans. The interviewee No. 28 remarked: *"the farms have contracts with us have to follow us because we monitor very carefully, also there are people think that the process provides by she is fine so we just follow"*. However, monitoring is inevitably incomplete – the buyer's employees cannot oversee every action on a farm and such monitoring costs can be significant. The second response, involves *bundles of supplier development measures*, so that the combined effect of the support makes the contract more valuable to the supplier and the long-term costs of breaking it more severe. In such cases, opportunistic behaviour can be rare even in markets where it is ubiquitous. As Interviewee No.22 reported *"When it comes to the situations that the market price is high. If the farmer collaborates with company X, they have been working together for more than three years, they received so many benefits, and they will…listen to you. Other farmers who haven't been through difficult situations together, never receive any benefit…so benefit is on top, they are willing to sell to any buyer that offer higher prices."*

Discussion

This paper identifies a dearth of studies on the "dark side" of supplier development initiatives. The paper identifies the supplier development activities employed by buyers, and the specific forms of opportunism that may arise from each.

The identified relationships provide a detailed picture of what may go wrong in supplier development efforts. It provides a counterpoint to supply chain perspectives, which merely focus on "win – win" outcomes and the upside of supplier development initiatives. Rather than treating supplier development and opportunism as homogenous concepts, we respond to calls to identify the linkages between specific types (e.g., Zhang et al., 2017, Salimian et al., 2017, Li et al., 2017).

Transaction cost analysis theory emphasises that people will behave in the most profitable way for themselves when opportunities presented (Hawkins et al., 2008). The theory well explains the situation when supplier development initiatives stimulate supplier opportunistic behaviours. First, buyers invest in training suppliers to help them improve capabilities and skills. Consequently, it changes the relative dependence (Wang and Yang, 2013) between the two parties as suppliers become more competent. This creates a spillover effect to other buyers, who now regard the trained supplier as a more desirable supply chain partner. Hence, suppliers may receive offers to break commitments with their existing buyer(s).

The complexity of the knowledge transferred to suppliers through training leads to multiple forms of opportunism. First, training may increase compliance costs (with the trained process). Hence, suppliers may disregard what they have learnt,, especially in a market that is dominated by poor standards like the fresh fruit and vegetable supply chain in Vietnam. Second, the impossibility of buyers evaluating fully what they procure leads to suppliers subverting the buyer's assessment criteria in ways that are less costly for them. Third, the offer of guaranteed sale prices offers certainty for suppliers operating in markets often characterised by high price volatility (Romsdal et al., 2011). However,

guaranteed prices will not always be in the favour of suppliers. Hence, they often only keep to a contract terms when the agreed price is favourable compared against market or spot rates.

Overall, the supplier development initiatives create openings for opportunism because the benefits to suppliers from engaging with the initiatives do not outweigh the benefits of opportunistic behaviours. This is in line with transaction cost theory (Williamson, 2008) that focuses on the self-interest seeking behaviours of relationship parties. However, bundling supplier development measures can lessen supplier opportunism. While this involves extra coordination efforts (Yan and Kull, 2015), the long-term costs of violating the relationship increase, where it leads to the supplier losing access to the bundle of measures in the future.

Conclusion

This study closes the gap in the literature relating to the relationship between supplier development and opportunism. It addresses the research question of the extent to which and in what forms may supplier development initiatives trigger opportunism. The study provides a comprehensive view of supplier development efforts as well as the linkages between the different supplier development initiatives and opportunism. The study also contributes to the literature by recognising ways in which buyers seek to address opportunism, so that supplier development initiatives can curb supplier opportunism rather than trigger it. Understanding the impacts of each supplier development initiative offers a managerial contribution, as managers can decide whether they should or should not deploy particular initiatives. The study focuses on fresh fruit and vegetable supply chains and would benefit from consideration of the generalizability of its findings to other sectors. Further research is also warranted to unpack other factors (i.e., relational norms, supplier selection) that may affect the relationships between supplier development initiatives and opportunism.

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The relationship between internal supply chain structure and operational performance: Japanese manufacturers survey results

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Abstract

In the field of supply chain management, internal supply chain structure has hitherto received minimal attention. This study focuses on two dimensions of internal structure, namely formalization and centralization, and empirically examines the relationship between these structural properties and relative operational performance. Survey data were collected from 108 Japanese manufacturers. Based on structural equation modelling, the correlation between centralization of operational tasks and centralization of strategic tasks, the impacts of centralization of both operational and strategic tasks on formalization, and the effect of formalization on relative responsiveness performance were demonstrated.

Keywords: Supply chain management, Organizational structure, Centralization, Formalization, Operational performance

Introduction

In the field of supply chain management (SCM), there have been empirical studies on the main management elements including supply chain strategy, external structure, and internal and external processes. However, the organizational structure of internal SCM has hitherto received minimal attention; researchers have not sufficiently discussed the design of internal supply chain structure.

This study focuses on two dimensions of internal structure: formalization and centralization. Existing studies use either one or both of these dimensions in the fields of logistics management, operations management, and SCM. On centralization, these studies are mostly concerned with 'the vertical distribution of decision-making', specifically, the locus of hierarchical authority. In contrast, the authors pay attention to 'the horizontal distribution of decision-making', specifically, the locus of authority between an SCM department and functional departments. By adopting such a definition of centralization, the authors address the research question: how do formalization and centralization affect operational performance in the SCM context. Specifically, the authors examine whether or not it is necessary for a firm to formalize its SCM tasks and centralize the authorities of these tasks in a particular department. Based on the results, the authors discuss the roles of an SCM department.

Theoretical background

Formalization and centralization

In the field of SCM, Kim (2007) is a pioneering empirical study on internal supply chain structure. He defines formalization as 'the degree to which decisions and working relationships for SCM activities are governed by formal rules and standard policies and procedures' (p. 325). Similarly, he defines centralization as 'the extent to which the power to make SCM decisions is concentrated in an organization' (p. 325). However, these definitions do not reflect the accumulation of vast amount of research on formalization and centralization.

In the field of organizational theory, two groups initiated the research on main structural properties in the 1960s. These are 'The Aston Group' including Derek S. Pugh and David J. Hickson, using institutional data (e.g. Pugh et al., 1963, 1968) and 'The Wisconsin Group' including Michael Aiken and Jerald Hage, using perceptual data of organizational members (e.g. Aiken and Hage, 1966; Hage and Aiken, 1967). Thereafter, the research expanded not only in the field of organizational theory but also in other fields such as marketing, logistics management, operations management, and SCM. Through a literature review of the various fields listed above, the authors redefined formalization in the SCM context as the following;

- The degree to which SCM activities are clearly written;
- The degree to which SCM activities are governed by rules and procedures;
- The degree to which the discretion of SCM activities is constrained by rules and procedures; and
- The degree to which SCM activities are supervised in conforming to the standards by job codification.

Similarly, referring to the results of our literature review, the authors modify Kim's (2007) definition as follows: 'the degree to which the power of decision-making, evaluation, control, and responsibilities for SCM activities are concentrated in a department'.

Roles of an SCM department

Morgan Swink and his colleagues continue to report their studies on SCM organization (SCMO). They define SCMO as the formal organization, or group of organizations, that manages internal supply chain activities and processes for a firm (Swink et al., 2013).

According to Swink et al. (2010), which is an interview-based study, the functions performed by the centralized SCMO are divided into two sets: staff functions and operational functions. The former tends to be more strategic and focuses on issues such as standardization and harmonization of processes, strategic support across the supply chain, and communication efforts. On the other hand, the latter focuses on integration and consolidation efforts with respect to purchasing and logistics functions. Swink et al. (2013) use a survey to further specifically investigate these results and note that a majority of the SCMO managers reported that they maintained 'full authority' of transportation, distribution centres/warehousing, purchasing, sourcing, demand/supply planning, make/manufacturing, and long-range planning. All of these would correspond to the operational functions of Swink et al. (2010). On staff functions, for example, strategy/change management, a majority of the SCMO managers reported that they 'shared authority' with business heads or other functional managers. However, these studies remain exploratory.

Hypotheses development

In the field of SCM, little empirical evidence is available to construct hypotheses on the relationship between formalization/centralization and operational performance. The case study of IKEA by Jonsson et al. (2013) would be helpful to develop such hypotheses. They regard IKEA as a company having 'a high degree of competence with SCM' (p. 346). This company centralizes the authority and responsibility of supply chain planning and demand fulfilment in one group of planners. Such a planning organization facilitates the establishment of standardized working methods. In turn, increased standardization leads to improved operational performance. Specifically, IKEA had less obsolete inventory, led to positive long-term effects on cost, and increased delivery performance. The case of IKEA, which is a leading SCM company, illustrates that high degree of centralization of operational tasks such as supply chain planning leads to high degree of formalization. In addition, this case suggests that firms with high degree of formalization achieve high levels of relative performance on both firm-centric (e.g. inventory, cost) and customer-centric (e.g. delivery performance) indicators.

Based on Swink et al. (2010), high degree of centralization of strategic tasks also results in high degree of formalization. The survey by Swink et al. (2013) reported that 80% of respondent firms had full or shared authority of both operational and strategic tasks. For example, the proportions of firms having full or shared authority are 55.9% and 39.9%, respectively, for demand/supply planning, which is an operational task, and 42.3% and 52.1%, respectively, for strategy/change management, which is a strategic task. This implies that firms with a high degree of centralization of SCM tasks tend to have a broadening span of authority including both operational and strategic tasks. However, centralization does not directly impact operational performance; it has an indirect impact on operational performance through formalization. Thus, the authors propose the following hypotheses:

H1: The higher the degree of centralization of operational tasks, the higher the degree of centralization of strategic tasks.

H2a: Centralization of operational tasks has a positive impact on formalization.

H2b: Centralization of strategic tasks has a positive impact on formalization.

H3a: Formalization has a positive impact on firm-centric relative operational performance.

H3b: Formalization has a positive impact on customer-centric relative operational performance.

H4: Centralization of either operational or strategic tasks does not have a direct impact on relative operational performance.

The above hypothesized relationships are summarized in the following conceptual model (Figure 1). In the figure, a solid line represents a significant relationship, while a dotted line represents an insignificant relationship.

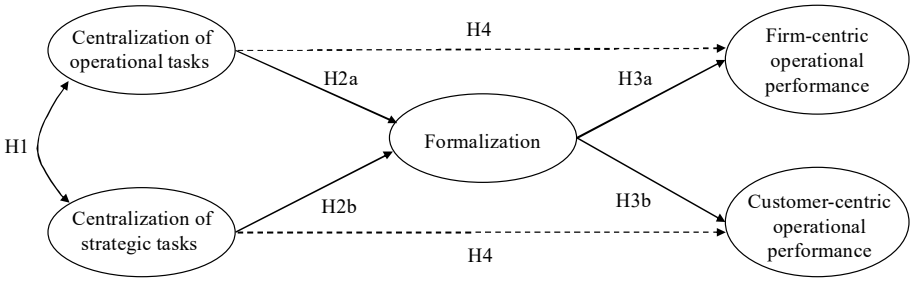

Figure 1 – Conceptual model

Method

Data collection

Data were collected through a survey mailed to Japanese manufacturers. Specifically, the questionnaire was mailed to 2,000 manufacturers selected from the database of a credit research firm in April 2018. To reduce the time and cost of data collection, the authors used only one key respondent per manufacturer, who was a manager belonging to the SCM, production, or logistics department. These respondents were asked to answer questions on the firm's SCM activities in their main business area. After removing incomplete responses, the total number of effective responses was 108, at a response rate of 5.4%. Non-response bias, common method variance, construct reliability and validity of latent variables, and convergent and discriminant validity were each assessed carefully. In regard to the sample demographics, almost 76% of the respondent firms have annual sales exceeding 30 billion yen (approximately US$273 million). In addition, nearly 73% of the respondent firms have more than 600 employees. These imply that three-quarters of the respondent firms are in the large-size category. A majority of the respondent firms are finished goods manufacturers rather than raw materials or components suppliers.

Measures

The hypothesized model illustrated in Figure 1 mainly comprises four constructs:
(1) centralization of operational tasks;
(2) centralization of strategic tasks;
(3) formalization; and
(4) operational performance.

Table 1 lists the observed variables.

First, to measure the degree of centralization, this study focused on cross-functional tasks that were difficult to assign to specific functional department such as logistics, production, purchasing, and sales/marketing. On the basis of the literature review, the authors' previous study (Nakano and Matsuyama, 2016), and the pre-test of the survey instrument, the following six tasks were recognized as typical cross-functional tasks: demand forecasting, demand-supply matching, inventory control, sales and operations planning (S&OP), performance management (key performance indicators (KPIs) definition; goal setting, evaluation, and control), and planning and steering of SCM reforms. Of these, demand forecasting, demand-supply matching, inventory control, and S&OP are operational tasks (C1-C4 in Table1). On the other hand, performance management and planning and steering of SCM reforms are strategic tasks (C5-C8 in Table 1). These were designed using a five point Likert scale between 1 = 'strongly disagree' and 5 = 'strongly agree'.

Second, based on our redefinition of formalization, the observed variables of the above operational tasks (demand forecasting, demand-supply matching, inventory control, and S&OP; F1-F4 in Table 1) and strategic tasks (defining KPIs; F5-F6 in Table 1) were used. These were also measured on a five point Likert scale ranging from 1 = 'strongly disagree' to 5 = 'strongly agree'.

Third, operational performance was measured using typical indicators that were often employed in prior empirical studies on SCM (Nakano and Akikawa, 2014). Specifically, unit logistics cost, finished goods inventory turnover period, on-time delivery, order fill rate, and delivery lead time were adopted. The first two indicators are related to efficiency (OP1-OP2 in Table 1), while the remaining three indicators are concerned with responsiveness (OP3-OP5 in Table 1). For these items, respondents were asked to indicate their perceptions based on a five point Likert scale ranging from 1 = 'much worse than

competitors' to 5 = 'much better than competitors'. As such, these indicators represent relative performance.

Table 1 – Observed variables

	Variables (References)	Mean	SD
Centralization of operational tasks			
C1	We centralize the power to make decisions of demand forecasting in a department (Kim, 2007)	3.14	1.25
C2	We centralize the power to make decisions of demand-supply matching in a department (Kim, 2007)	3.59	1.11
C3	We centralize the power to make decisions of standard inventory quantity in inventory control in a department (Kim, 2007)	3.57	1.10
C4	We centralize the power to make decisions of S&OP process in a department (Kim, 2007)	2.95	1.09
Centralization of strategic tasks			
C5	We centralize the responsibility of efficiency-related KPIs for SCM activities in a department (Kim, 2007; Ranganathan et al., 2004; Stanley, 1993)	3.25	1.08
C6	We centralize the responsibility of responsiveness-related KPIs for SCM activities in a department (Kim, 2007; Ranganathan et al., 2004; Stanley, 1994)	3.20	1.07
C7	We conduct performance evaluation and control for SCM activities in a department (Budde et al., 1982; Kim, 2007)	3.23	0.98
C8	We centralize the power to make decisions of SCM reforms planning in a department (Kim, 2007)	3.32	1.01
Formalization			
F1	We standardize the demand forecasting procedures (Aiken and Hage, 1966; Mrela, 1980)	3.38	1.10
F2	We standardize the demand-supply matching procedures (Kim, 2007)	3.57	1.00
F3	We control inventory using standard inventory quantity (Aiken and Hage, 1966; Dewsnap and Jobber, 2000)	3.61	0.99
F4	We standardize the S&OP process (Kim, 2007)	3.37	1.11
F5	We define efficiency-related KPIs for SCM activities (Dewsnap and Jobber, 2000)	3.46	1.16
F6	We define responsiveness-related KPIs for SCM activities (Dewsnap and Jobber, 2000)	3.44	1.18
Operational performance			
OP1	Unit logistics cost (Nakano and Akikawa, 2014)	3.05	0.73
OP2	Finished goods inventory turnover period (Nakano and Akikawa, 2014)	3.09	0.84
OP3	On-time delivery (Nakano and Akikawa, 2014)	3.59	0.84
OP4	Order fill rate (Nakano and Akikawa, 2014)	3.57	0.76
OP5	Delivery lead time (Nakano and Akikawa, 2014)	3.27	0.80

Measure assessment

The authors assessed reliability and validity of latent variables following the guidelines outlined by Anderson and Gerbing (1988). First, the authors conducted an exploratory factor analysis for each construct (Table 2). On centralization, the authors found two factors with eigenvalues greater than 1.0; these were named 'centralization of operational tasks' and 'centralization of strategic tasks', respectively. Regarding formalization, the authors found one factor with an eigenvalue greater than 1.0. Concerning operational performance, the authors found one factor with an eigenvalue greater than 1.0. The factor was named 'responsiveness performance' because the observed variables with factor loadings greater than 0.5 were performance indicators of responsiveness, such as on-time delivery, order fill rate, and delivery lead time. In addition, the authors calculated Cronbach's alpha and composite reliability, conducted a confirmatory factor analysis (Table 2), and assessed average variance extracted for all constructs (Table 3). These results provided evidence of construct reliability and convergent and discriminant validity.

Table 2 – Exploratory and confirmatory factor analyses

Latent and observed variables	Exploratory factor analysis		Confirmatory factor analysis	
	First factor	Second factor	Standardized coefficient	t-value
Centralization of operational tasks (eigenvalue = 1.098; alpha = 0.813; CR = 0.818; AVE = 0.532)				
C1	0.196	0.748	0.738	8.466
C2	0.274	0.790	0.834	9.898
C3	0.318	0.629	0.714	8.250
C4	0.351	0.505	0.616	6.770
Centralization of strategic tasks (eigenvalue = 4.524; alpha = 0.887; CR = 0.890; AVE = 0.674)				
C5	0.665	0.403	0.726	8.735
C6	0.683	0.407	0.849	10.542
C7	0.907	0.249	0.877	11.201
C8	0.756	0.235	0.823	9.925
Formalization (eigenvalue = 3.993; alpha = 0.898; CR = 0.900; AVE = 0.590)				
F1	0.820		0.844	10.685
F2	0.845		0.906	11.819
F3	0.736		0.721	8.596
F4	0.771		0.761	9.259
F5	0.735		0.705	8.071
F6	0.732		0.641	7.242
Operational performance				
OP1	0.289			
OP2	0.370			
Responsiveness performance (eigenvalue = 2.319; alpha = 0.766; CR = 0.772; AVE = 0.534)				
OP3	0.718		0.760	7.949
OP4	0.781		0.795	8.348
OP5	0.660		0.626	6.417

Table 3 – Means, standard deviations, and correlations

	Mean	SD	COT	CST	FO	OP1	OP2	RP
Centralization of operational tasks (COT)	3.31	1.17	0.532					
Centralization of strategic tasks (CST)	3.25	1.04	**0.483**	0.674				
Formalization (FO)	3.47	1.10	**0.307**	**0.419**	0.590			
Unit logistics cost (OP1)	3.05	0.73	0.000	0.007	0.012	-		
Finished goods inventory turnover period (OP2)	3.09	0.84	0.001	0.010	0.029	0.048	-	
Responsiveness performance (RP)	3.48	0.81	0.009	0.008	**0.108**	0.065	**0.108**	0.534

Notes: Values on the diagonal shows the AVE. Off-diagonal values represent the constructs' squared correlations.
Bolded correlations are significant at $p < 0.01$.

Results of hypotheses tests

The conceptual model shown in Figure 1 was tested using structural equation modelling (SEM) via IBM SPSS AMOS 25. First, the model without the direct effects of centralization on operational performance was tested. Responsiveness performance, which consists of on-time delivery, order fill rate, and delivery lead time, is used as a customer-centric operational performance indicator in Figure 1. Firm-centric operational performance in Figure 1 is divided into unit logistics cost and finished goods inventory turnover period. Figure 2 displays the result. The results of multiple fit indices provide evidence of the overall validity of the hypothesized model.

Specifically, solid lines represent statistically significant paths ($p<.05$), while dotted lines represent paths that are not significant. Based on the significant path coefficients, H1, H2a, H2b, and H3b are supported. Centralization of operational and strategic tasks are inter-correlated (H1). Both centralization of operational tasks and centralization of strategic tasks are positively related to formalization (H2a and H2b, respectively). Formalization is positively related to customer-centric relative operational performance

(observed variables: on-time delivery, order fill rate, and delivery lead time; H3b). Regarding H3a, formalization does not have a significant impact on firm-centric relative operational performance in terms of either unit logistics cost or finished goods inventory turnover period. Hence, H3a is not supported.

Second, the model including the direct effects of centralization on operational performance was tested. As shown in Figure 3, the results of the same alternative indices prove the overall validity of the hypothesized model. Regarding H4, both centralization of operational tasks and strategic tasks do not have a direct impact on any of the relative operational performance indicators. Hence, H4 is supported. Other path coefficients show the same tendency as Figure 2.

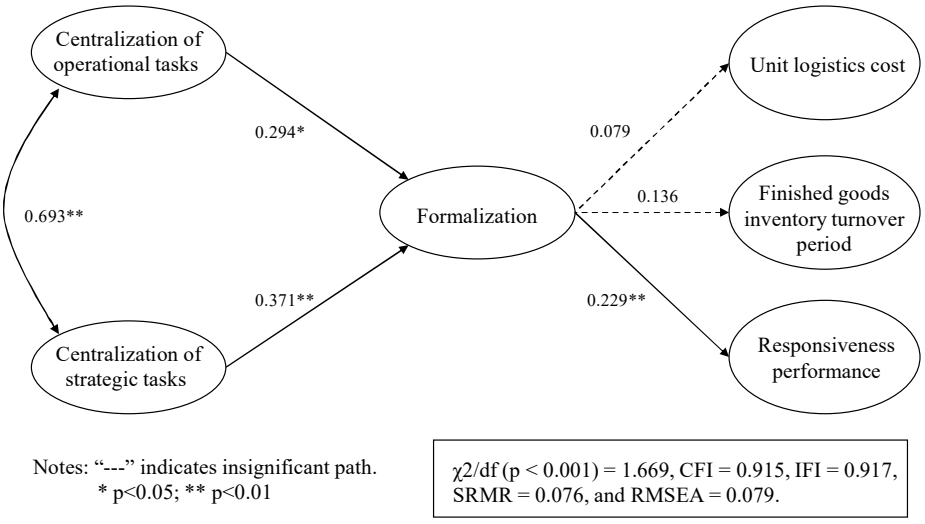

Figure 2 – Structural equation modelling results without the direct effects of centralization

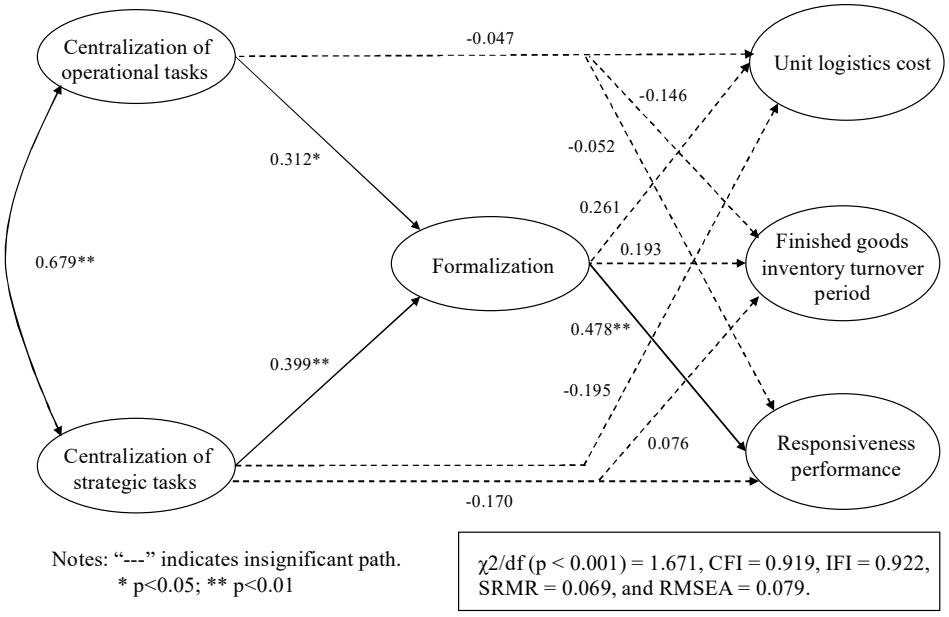

Figure 3 – Structural equation modelling results including the direct effects of centralization

Discussion

The support for H1 suggests that there is a positive relationship between centralization of operational tasks and centralization of strategic tasks. This result confirms the exploratory findings of Swink et al. (2013). Specifically, Japanese manufacturers with high degree of centralization of SCM tasks tend to have a broadening span of authorities including both operational and strategic tasks.

H2a and H2b are supported, which suggests that centralization of operational tasks and strategic tasks, both exert positive influences on formalization. The former is consistent with Jonsson et al.'s (2013) case study of IKEA. Specifically, centralizing forecasting and planning tasks in a particular department facilitates the establishment of formalized working methods in Japanese manufacturers. Similarly, the latter is identical to Swink et al.'s (2010) interview-based study whereby Japanese manufacturers centralizing strategic and change management tasks in a particular department increase formalization of SCM tasks.

The support for H3b statistically generalizes a part of the results of Jonsson et al. (2013). This result implies that formalization leads to competitive advantages in customer-centric operational performance for Japanese manufacturers. However, such a relationship does not apply to firm-centric relative operational performance because H3a is not supported. This suggests that many Japanese manufacturers have not realized better logistics costs and/or finished goods inventory levels than their competitors by formalizing SCM tasks. One possible explanation is that Japanese manufacturers tend to undertake higher logistics costs and/or finished goods inventory levels so as to prioritize achieving relatively better responsiveness performance for customers.

The support for H4 also statistically generalizes Jonsson et al.'s (2013) case study. Specifically, centralization of SCM tasks does not directly lead to competitive advantage in terms of operational performance. Formalization mediates the relationship between centralization and relative operational performance.

Consequently, centralization has an indirect impact on relative operational performance through formalization. Hence, it is necessary but insufficient for a manufacturer to centralize the authorities of its SCM tasks in a particular department in order to achieve better operational performance than its competitors. Formalizing SCM tasks, such as demand forecasting, demand-supply matching, inventory controls, sales and operations planning, and defining key performance indicators directly leads to competitive advantages in operational performance. Therefore, the authors insist that one of the important roles of an SCM department is to formalize its SCM tasks. However, operational excellence by formalization among Japanese manufacturers is valid only for responsiveness performance. Future research is needed on internal supply chain structure that can realize the competitive advantages of both efficiency and responsiveness.

Implications and future research

Using survey data of Japanese manufacturers, this study empirically examined the impact of structural properties in internal supply chain on relative operational performance. Specifically, this study focused on two structural properties, formalization and centralization, and classified relative operational performance into firm-centric efficiency and customer-centric responsiveness. The results reveal the correlation between centralization of operational tasks and centralization of strategic tasks, the impacts of centralization of both operational and strategic tasks on formalization, and the effect of formalization on relative responsiveness performance. It is necessary to note that these

results are limited to the main business area of a manufacturer. Nonetheless, this study has important implications for both researchers and practitioners in the SCM field.

For researchers, this study proposes the measures of formalization and centralization in the SCM context. These measures were developed on the basis of literature review not only in the field of organizational theory but also in other fields such as marketing, logistics management, operations management, and SCM. Accordingly, Kim's (2007) definition of these structural properties were redefined. In addition, as far as the authors are aware, this is the first study that has statistically examined the impacts of these structural properties on both firm-centric and customer-centric relative operational performance. As mentioned in the introduction, there are few comprehensive studies on SCM organization. Swink et al. (2010) propose the roles of a centralized SCM department, while Swink et al. (2013) investigate the functional span of authority of an SCM department. However, these are exploratory rather than confirmatory studies. By conducting the statistical analyses of survey data, this study substantiates that Japanese manufacturers with a centralized SCM department in charge of both operational and strategic tasks can formalize their SCM activities and, as a result, achieve better responsiveness than their competitors.

With regard to the implications for practitioners, as much as possible, manufacturers need to formalize a wide range of SCM tasks to realize the operational excellence of their SCM activities. Specifically, they are required to standardize the procedures of demand forecasting, demand-supply matching, and S&OP process; control inventory using standard inventory quantity; and define both efficiency- and responsiveness-related KPIs for SCM activities. In other words, these procedures and performance management should not be individual-dependent. In order to establish such formalized working methods, it is effective to centralize the authorities of both operational and strategic tasks in a particular department. Swink et al. (2010) mention that creating a functionally integrated organization is a means of managing the various sources of uncertainties related to changing conditions, for example, rapidly changing customer and supply markets, short product lifecycles, short economic business cycles, aggressive competitors, and rapidly changing process technologies. Hence, manufacturers in such dynamic business environments have an increased need for more centralized SCM department.

This study has the following limitations and opportunities for future research. First, the impacts of the structural properties in internal supply chain on relative operational performance may differ depending on specific business contexts. Utilizing multi-group analysis, the authors need to empirically assess possible contingency effects including the above dynamic business factors. Second, this study does not identify an internal supply chain structure that has significant impacts on the competitive advantage of not only responsiveness but also efficiency. More in-depth investigations including case studies would be useful to explore such a structure. Finally, limiting the research setting to Japanese manufacturers is definitely insufficient for generalizing the findings of this study to other regions. By conducting additional analyses using data from different cultural settings, we can discuss the similarities and differences between countries.

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Is the Triple-A supply chain's effect on competitive advantage different in developed and emerging countries?

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Abstract

The purpose of this paper is to empirically analyze the relationships of the Triple-A supply chain (SC) and competitive advantage (CA) in emerging versus developed countries. Consistent Partial Least Squares (PLSc) is applied on an international multiple informant sample of 220 manufacturing plants in developed and emerging countries. The results confirm the positive significant relationship between Triple-A SC and CA, with no significant differences between emerging and developed countries. The present study brings new evidence to the literature on the Triple-A SC and their relationship with CA in different contexts.

Keywords: Agility, Adaptability, Alignment, Triple A

Introduction

Lee (2004) states that only Triple-A (agility, adaptability and alignment) supply chains (SCs) can lead to a sustainable competitive advantage (CA). No empirical research was developed by Lee (2004) and only limited empirical research has analyzed the relationships between the Triple-A SC and performance (Whitten et al., 2012; Attia, 2015) or CA (Alfalla-Luque et al., 2018). These studies conclude that a positive relationship exists but also coincide in stating that further research needs to be done. Whitten et al. (2012) and Attia (2015)' works have limitations, which have been mentioned by the authors: focus on a single country (Egypt and USA, respectively), data are taken from single respondents, and the scale is exclusively taken from Lee's (2004) theoretical reasoning, with no analysis of the previous literature. Besides, Attia's research is done on a single sector (textile).

In order to contribute to theory building on this important SCM topic, this study seeks to overcome the mentioned limitations of previous empirical research and to analyze in greater depth Lee's statement (Lee, 2004) that "only supply chains that are agile, adaptable, and aligned provide companies with sustainable competitive advantage". Previous research has still not considered any contextual factors, even

though they may influence the impact on performance (Flynn et al. 2010). Following Contingency Theory (Lawrence & Lorsch, 1967), contextual variables could have an influence on the level of achievement of business practices. The influence of the country or region as a possible important contextual factor has been analyzed in operations management and SC management research (e.g., Katiyar et al., 2018, Miras-Rodríguez et al., 2018). Due to the important role played by emerging countries in global SCs, one crucial point is the growing need to improve SC performance in these economies. However, in spite of this importance, only one of the three mentioned previous works (Attia, 2015) analyzes the Triple-A - SC performance relationship in emerging countries, but in a very limited way (only one country (Egypt) and one industry (the textile sector)). The other two articles focus their analysis on developed countries (Whitten et al., 2012; Alfalla-Luque et al., 2018).

Therefore, the aim of the present research is to fill this gap by using a wider sample of emerging countries to analyze: (1) whether the positive relationship between Triple-A SC and CA exists in different country contexts (emerging vs. developed countries); (2) whether for the achievement of CA there is a difference in the weights of the components of the three Triple-A SC variables between emerging and developed countries.

This paper is structured as follows. Section 2 analyzes earlier studies and establishes the hypotheses to be tested. Section 3 describes the sample and the methodology, followed by data analysis and the results in Section 4. Finally, the main conclusions, contributions, implications for practitioners and academics, limitations and future research are presented.

Previous research and hypotheses

Scarce research has considered a Triple-A SC construct formed of the three dimensions (Attia, 2015; Whitten et al., 2012; Alfalla-Luque et al., 2018; Marin-Garcia et al., 2018). Previous research shows a positive influence of Triple-A SC on performance or in CA. In this regard, Whitten et al. (2012), based on a survey to 132 APICS members (USA), conclude that a Triple-A SC-based strategy is positively related to SC performance and that the SC performance - financial performance relationship is mediated through marketing performance.

For his part, Attia (2015) uses data from 153 companies in the Egyptian textile industry. He analyzes the relationships between Triple-A SC and marketing strategy alignment with SC performance (output performance; resource performance; flexibility performance) and organizational performance (operational performance, strategic performance)). His results show that Triple-A SC and marketing strategy alignment are positively related to SC performance and that SC performance is positively related to organizational performance. He compares his results to those of Whitten et al. (2012) and, regarding the relationship between Triple-A SC and, marketing strategy alignment with organizational performance, concludes that the results are similar. In both studies, the need is recognized to test this relationship in different samples and countries.

Finally, Alfalla-Luque et al. (2018) overcome some of the limitations of the previous works by using a wider database from 151 manufacturing plants (with over 100 employees) in three industries (automotive components, electronics and machinery) in 8 developed countries. These authors analyze the Triple-A SC and its relationship with CA (cost, quality, delivery, flexibility, and financial proxy). They found that this relationship is positive and significant for all the CA measures except quality. The strongest relationships are found with financial CA and delivery CA.

The above literature review shows that the analysis of the Triple-A - CA for different contextual situations (e.g., developing vs. emerging countries) is still missing in spite of its importance for facilitating appropriate global SC design. The case by Attia (2015) with only a country (Egypt) is clearly insufficient, as the author recognizes. And a comparison of the results of his work with those found by Whitten et al. (2012) (again only one country, USA) is neither sufficient nor appropriate for drawing robust conclusions on the matter. Consequently, the present research seeks to contribute to the literature on this topic by filling this gap through an analysis of the Triple-A SC - CA relationship in a wide sample of emerging and developed countries. Therefore, the first hypothesis has been formulated as follows:

H1. There is a positive relationship between Triple-A SC and CA in different country contexts (emerging vs. developed countries).

To dig deeper into possible improvements to SC design, a further step forward in the contribution to the topic under study might be to analyze whether the Triple-A SC components (SC agility, SC adaptability and SC alignment) act (or not) with different weights in the relationship between Triple-A SC and performance/CA depending on the country context. This could be considered a key element for SC design in global contexts. Unfortunately, very scarce research has been found on this topic.

Although there is no full consensus, the majority of studies (e.g., Whitten et al. 2012; Attia, 2015) seem to show that no differences in the weights of the Triple-A SC components can be confirmed. Therefore, taking into account the previous literature, and in order to contribute to the scarce research on the topic, this work will analyze whether there are any differences in the weights of the three Triple-A SC variables for the achievement of CA. We analyze results for the total sample and also identify whether there are any differences in the way that weights are distributed in plants in emerging and developed countries. The second research hypothesis is therefore established as follows:

H2. There are no differences in the weights of the components of the Triple-A SC variables (agility, adaptability, and alignment).

Methodology

The empirical analysis uses part of the current database of the fourth round of the international High Performance Manufacturing Project, HPM (data collection completed in 2016), obtained from 220 manufacturing plants (with over 100 employees) in three industries (automotive components, electronics and machinery) in 9 developed countries (Austria, Finland, Germany, Italy, Japan, Spain, Sweden, UK, USA) and six emerging countries (Brazil, China, Israel, South Korea, Taiwan, Vietnam). HPM fourth round questionnaires were developed and updated from the HPM international project (Flynn et al., 1995; Sakakibara et al., 1997; Ahmad and Schroeder, 2002; Cua et al., 2002; Marín et al., 2018), where survey questions were based on a wide-ranging review of the Operations Management literature.

Items for SC agility (SC-Ag), SC adaptability (SC-Ad), and SC alignment (SC-Al) were measured on a 1-7 Likert scale (Marin-Garcia et al., 2018). Informants were asked to indicate their degree of agreement (1–strongly disagree, 4–neither agree nor disagree, 7–strongly agree). As the present study focuses on the specific CA of the operations area, only operational measures were targeted and grouped in four dimensions (cost CA, quality CA, delivery CA and flexibility CA). CA items were measured on a 1-5 Likert scale with informants asked to give their perceptions of their company's past performance compared to their competitors' (1–poor, 3–average, 5–much better).

The SC agility, SC adaptability, and SC alignment constructs were operationalized as a composite (Mode B aggregate multidimensional construct) (Hair et al., 2017) with each based on three dimensions; these were the first-order composites calculated from the measures taken from the questionnaires (Marin-Garcia et al., 2018).

CA was modelled as an aggregate multidimensional construct (composite Mode B) formed of four first-order common factors (Cost CA, Quality CA, Delivery CA and Flexibility CA). The CA first-order scales (Mode A) were designed and validated by other authors (Konecny and Thun, 2011; Alfalla-Luque et al., 2012 and 2015). Authors' operationalizations were strictly followed and each dimension's indicators chosen so as to be inter-correlated.

As the model contained higher order constructs (HOC), a two-stage approach was used (Hair et al., 2018; Marin-Garcia, 2018). Consistent Partial Least Squares (PLSc) was chosen to estimate the model in the first stage as it is a better proxy when common factors are included in the same model as composites (Sarstedt et al., 2016; Becker et al., 2013; Henseler et al., 2016; Rigdon, 2012 and 2016). PLS was used to analyze the second stage, as all the HOC used were modeled as Mode B composites (regression weights). SmartPLS v3.2.8 was used to analyze the model (Ringle, 2015). Finally, GPower (Faul et al., 2007) was used to test whether the sample size guaranteed a power>= 0.80 for power analysis (Hair et al. 2019; Marin-Garcia et al., 2019).

Results

The full sample used is sufficient to achieve a power above the bottom threshold of 0.8 (0.99 or above in all the dependent constructs in the first stage).

The measurement model meets all the validation criteria specified in the methodology section. However, in stage 1 there are two Triple A-SC composite indicators that are not significant. As their loadings are above 0.5, they have not been omitted from the model. In stage 2 (Figure 1), some weights are not significant (Cost CA, Delivery CA and Quality CA for CA composite; and SC Alignment for Triple-A SC composite), but their loadings clearly exceed 0.5, so no modifications are required to the measurement model.

All lower-order constructs (stage 1) and higher-order constructs (stage 2: see Table 1) present both configural (MICOM step 1) and compositional invariance (MICOM step 2). This is referred to as partial measurement invariance and is the required condition for group-specific comparisons with multigroup analysis. It is, therefore, confirmed that all the measurement model subscales are absolute equivalents in the developed and emerging country samples. This enables conclusions to be drawn as to whether differences in the two samples' LVs mean and variance values are significant.

Table 1. Stage 2 MICOM Step1 and Step 2 Configural and compositional invariance emerging vs. developed countries

	Step1	Step2 compositional invariance			
	Configural invariance?	Original Correlation	5.0% quantile of empirical distribution	Permutation p-Values	Partial measurement invariance
CA	yes	0.908	0.677	0.606	yes
Triple-A-SC	yes	0.995	0.742	0.952	yes
Bootstrapping based on n = 5000 subsamples. Multi-group test based on 5000 permutations. Significance at 5% level. Two-tailed test for group comparisons					

In MICOM step 3, stage 1 model, developed country companies present significantly lower mean values in cost CA, use of technology (SC-Ad2), medium- and long-term market knowledge (SC-Ad3), short-term sensitivity to market (SC.Ag1) and incentive alignment (SC-Al1). Similarly, there are no significant differences in most of the constructs' latent variable score variances, but they are lower in developed country companies than in emerging country companies for flexibility and quality CA. In general, there is a lower dispersion of the developed countries' values than the emerging countries.

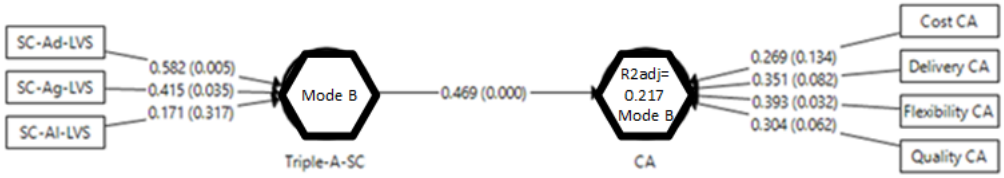
When repeating MICOM analysis step 3 for stage2, there are significant differences between the means of the Triple-A SC latent variable scores for the emerging and developed countries (Table 2). Similarly, plant variances are significantly smaller for CA in the developed countries sample than in the emerging countries sample. Despite these differences in the descriptive statistics, as already commented, there are no significant differences between emerging and developed countries regarding Triple-A component and CA weights. Also, as will be commented below, no significant differences have been noted between the paths of the emerging and developed plants in the analysis of the structural model. Therefore, from here on, only the results for the total sample will be reported.

Table 2. Stage 2 MICOM Step 3 equal means and variances betweenemerging vs. developed countries

	Mean differences (emerging - developed)					Variance differences (emerging - developed)				
	Original Differ-ence	2.5% quantile	97.5 % quantile	Permuta-tion p-Values	Equal means?	Original Differ-ence	2.5% quantile	97.5% quantile	Permuta-tion p-Values	Equal variances?
CA	0.152	-0.267	0.263	0.262	yes	0.640	-0.467	0.461	0.005	No
Triple-A SC	0.292	-0.259	0.263	0.028	no	0.259	-0.421	0.417	0.220	yes
Bootstrapping based on n = 5000 subsamples. Multi-group test based on 5000 permutations. Significance at 5% level. Two-tailed test for group comparisons										

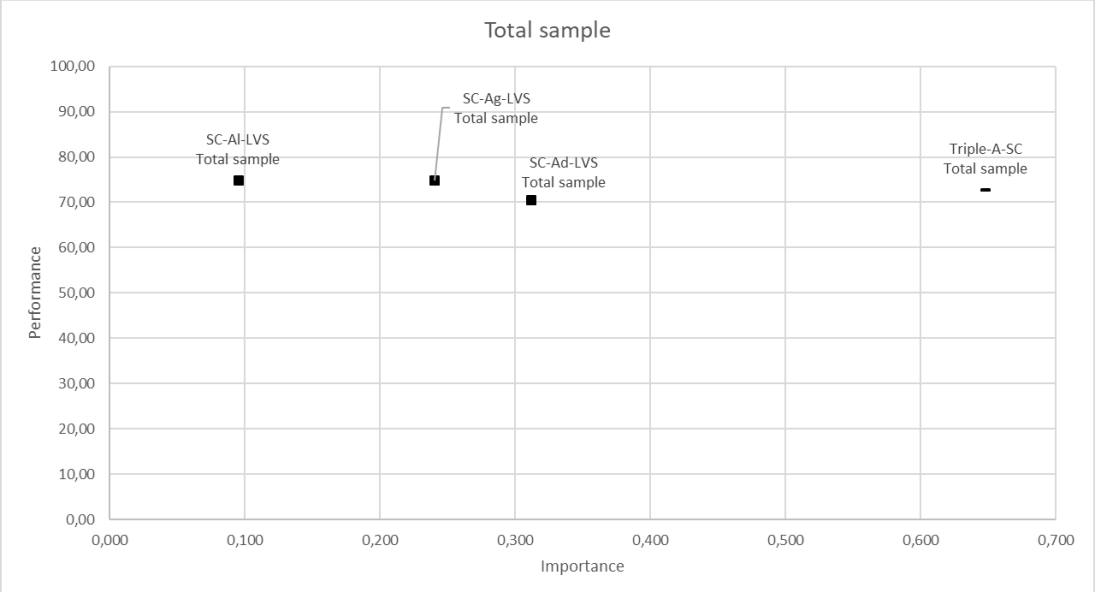
As the measurement model is adequate, the structural model results can be interpreted to test the research hypotheses. It was previously confirmed that there were no collinearity issues in the structural model (Figure 1) and that the model has an adequate fit. H1 has been confirmed. The in-sample explanatory power of the Triple-A SC (R2adj = 0.217) is weak but significant. The standardized path value (0.469) can be considered to be relevant and in line with the results obtained by previous research for the relationship between these constructs (e.g., Attia, 2015). Thus, a positive relationship has been confirmed between Triple-A SC and CA for the full sample and for the emerging and developed country groups (although the relationship is more intense in emerging countries—path=0.525—than in developed countries—path=0.411—the difference is not significant). Regarding H2, SC adaptability and agility are seen to have the greatest strength in the construction of the Triple-A SC. This has been confirmed for the full sample weights of adaptability and agility, which are significant and greater than the weight of alignment. Consequently, H2 has not been supported, as no difference in the weights of the components of the Triple-A SC variables has been found.

Figure 1. 2nd stage structural model full sample (standardized values)



The importance-performance map analysis (IPMA) extends the results and enables managerial actions to be prioritized (Figure 2). As no significant differences were found for the full sample and for the emerging and developed country groups in the previous analysis of the Triple-A SC and CA relationship, the IPMA analysis will only be conducted for the full sample. The results show that practically all the Triple-A SC variables have a similar degree of development (values between 70 and 74) (see performance in Figure 2), around two-thirds of the scale. Despite these values being relatively high, they have not reached the maximum, so plants in the sample have a certain margin left for further development of all three variables. The relative importance of the various variables for CA dictates what should in principle be the order of deployment to follow.

Figure 2. Full sample IPMA graph (non-standardized values)



Discussion and conclusions

The results of this research confirm Lee's (2004) proposal and build on the previous literature by showing that the positive relationship between Triple-A SC and CA exists in different country development contexts. These conclusions are in line with the previous research on the relationship between Triple-A SC and performance/CA in developed (Whitten et al., 2012; Alfalla-Luque et al., 2018) and emerging countries (Attia, 2015). After comparing his results in Egypt with the results of Whitten et al. (2012) in the USA, Attia (2015), wrote: "it can be said that the effect of Triple-A SC on the SC performance is the same for both the developed and developing countries". In

our opinion, for this statement to be established would need more than two single countries. This is overcome by the present research, the results of which confirm this affirmation using a broad international and multi-informant sample of 9 developed and 6 emerging countries. This has been considered an important issue in the (scarce) previous research, which has called for new analyses of different samples and countries to obtain stronger empirical evidence of Lee's statement.

In relation to the impact of each of the Triple-A SC variable on the Triple-A SC construct and CA, SC adaptability and agility are seen to have the greatest strength in the relationship between the Triple-A SC and CA for the full sample. Therefore, these results indicate that special attention should be devoted to these variables when seeking to build a Triple-A SC. However, caution should be shown in relation to this assessment, as the limited research on this topic does not offer conclusive results. As such, the present results are not in line with those obtained by Whitten et al. (2012) for developed countries and Attia (2015 and 2016) for emerging countries, which show similar weights for SC agility, SC adaptability and SC alignment in their relationships with performance. However, the results of this research are in line with studies in emerging (Dubey et al., 2015) and developed countries (Alfalla-Luque et al., 2018), which show differences in the weights of each Triple-A SC variable on performance/CA. However, the fit is not full, as the weight of each variable differs in these studies. For example, Dubey et al. (2015) find SC alignment strongly related to performance, with SC agility also significant but less strong, and SC adaptability not significantly related to human performance. Alfalla-Luque et al. (2018) conclude that SC adaptability and SC alignment present a significant contribution to the Triple-A SC construct but that SC agility makes no significant contribution (perhaps due to the sample size). Nevertheless, the authors conclude that major differences in the contributions of the Triple-A SC variables cannot be confirmed. The differences between the results of this research and those of Alfalla et al. (2018) should not be seen as surprising. The Alfalla et al. (2018) study includes financial CA as one of the variables in the structural model. This construct reflects a distal outcome, in contrast to the other CA dimensions which should be understood as an intermediate Triple-A SC result when operational CA is focused on and a possible mediator of financial CA. We believe that the inclusion of financial CA distorts the weights of the Triple-A SC components, which were being adapted to optimize the explanation of the two sets of variables with which they have different links. In fact, the best explained construct in that model was, precisely, financial CA. So, the Alfalla et al. (2018) results were skewed towards the Triple-A SC relationship with financial CA and masked the real relationship with the operational CA dimensions, which is the focus of the research presented in this paper. Therefore, it seems clear that further research is needed into the weights of agility, adaptability, and alignment in the Triple- A SC to obtain CA.

The above has major managerial implications. First, new evidence for both emerging and developed countries has re-confirmed the hypothesis that the Triple-A SC is significantly and positively related to CA. Consequently, SC managers involved in the design and development of global SCs in developed and/or emerging countries should have a strategy that recognizes that SC agility, adaptability, and alignment need to be achieved to obtain a CA. This implies coordinating a set of decisions in the long, medium and short term in order to obtain a Triple-A SC. This should be done under a perspective of continuous improvement that takes into account, on the one hand, current accomplishments in the levels of deployment of each of the Triple-A variables and of the CA and, on the other hand, the established targets for the plant in relation to the competitive situation. In this line, the IPMA results offer useful information to be

considered. In the present case, at the full sample aggregate level, the three As were observed to be at a very similar CA deployment level, but their importance for achieving a CA is different. The obtained information (at the aggregate level) for the plants in the sample shows the first step should be to raise the deployment level of adaptability, which is the most important A for achieving the CA. This should be followed by agility, and lastly by alignment. Nevertheless, specific decisions will depend on the actual circumstances of each plant such as, for example, the available resources required for execution and the real deployment level of each of the variables, which can be different from the mean sample value.

For researchers, there is new empirical proof regarding the Triple-A SC and its relationship with CA. These results are a contribution to theory in the sense that they could be considered a clear step forward in the topic since, as has been indicated, the present study overcomes the limitations of some previous studies of the Triple-A SC (Whitten et al., 2012; Attia, 2015; Alfalla-Luque et al., 2018) and provides new evidence on the topic.

This study is not without its limitations, which can be a source for further research. First, the data refer to three specific industries (electronics, machinery, and automotive components). The results should, therefore, be analyzed in this context and cannot be extrapolated to other sectors. Second, the results have been obtained for a sample of emerging and developed countries and so their extrapolation to other countries may not be possible. As the proposed model is hypothesis-based and needs to be confirmed with other samples, it would be interesting to undertake future analyses to dig deeper into the topic by considering countries and production sectors with different contexts. Finally, a further limitation is shared with the majority of studies undertaken in the area: the cross-sectional analysis used does not give the opportunity to observe change and reactions to change in practice. Therefore, it has not been possible to test the effects of the Triple-A SC on obtaining a "sustainable CA", as new data are necessary to allow a longitudinal study to be undertaken. Due to the mentioned lack of data to analyze the CA's sustainability component, the current research focuses on the effects of the Triple-A SC on CA as, in any case, it is necessary to first have a CA before it can be maintained in a sustainable position in the future. A longitudinal study would allow the way that the variables evolve to be studied and so enable the evolution of the levels of the variables and the impact on CA to be analyzed. This would determine whether it is indeed Triple-A SC firms that are attaining sustainable CAs, as stated by Lee (2004). It is to be hoped that the database of the next round of the HPM project will make this further research possible.

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‘The map is not the territory’: the subjective and purposive nature of supply chain mapping

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Abstract

Supply chain (SC) mapping is a stream of research as well as a managerial activity. It is also important in SCM teaching. Despite this importance, very little empirical research has addressed SC mapping and SC maps. Based on a qualitative case study in an industrial company, this paper gives evidence of the discrepancies between how managers define the outbound SC, the SC map they draw and what they say when mapping. It supports the underlying hypothesis about how individual mental representation of SC influences SC mapping. It opens avenues for further research about how using mapping and maps in SCM.

Keywords: Supply Chain Mapping, Outbound supply chain, Case study

Introduction

Since the 1990s, supply chain mapping has been a common practice and an important research topic (e.g. Lambert *et al*., 1998; Gardner and Cooper, 2003). Many different pictures of supply chains (SC) are made by companies, teachers and consulting firms. However, few studies question the role of these “pictures”, their use in companies and their usefulness for people involved in SC operations or management, as well as their influence on SCM concepts and practice. In line with Carter *et al*. (2015) or Fabbe-Costes (2017), we advocate that they are not neutral and could play a key role in SCM.

A supply chain map, like a geographical map, is supposed to represent the “territory”. Since no map can represent everything, people who map make choices, and, in particular when there is no mapping convention (Gardner and Cooper, 2003), often adopt personal representation codes, both of which reflect biases. Moreover, since a map is a “model”, it is “projective” (Le Moigne, 1990). Supply chain maps thus might reflect the viewpoint of the people drawing them, as well as their project or expectations related to SCM. Supply chain maps might also be influenced by people’s history, discipline, culture, experience of the territory, etc. They might also reflect the purpose of the mapping, being a sense-making activity (Henneberg *et al.*, 2006)…

The purpose of this paper/research is to study supply chain mapping as a managerial activity and to question the impact of SC maps on SCM. In the literature review, we combine perspectives from SCM and from the 'network pictures' literature in industrial marketing (e.g. Henneberg *et al.*, 2006) to ask the following: Do companies produce and use SC maps? Do managers' individual SC maps reveal different "viewpoints" of/in the supply chain that could reveal different mental representations of what a SC is? When managers map a SC, what are the differences between what they draw, how they explain their mapping, and how they define the SC? The research design section details our qualitative case study focusing on the outbound supply chain of an industrial company. After presenting the empirical results of the research, we discuss their managerial and academic contribution before concluding.

Literature review

Supply chain management and the "images/pictures" of supply chains

Since the early 1980s, the study of SCM has involved the drawing of pictures of supply chains. Some famous figures are commonly cited. They show different aspects of what supply chains are. Stevens (1989) focuses on internal *functions* that have to be integrated with a linear representation of what an integrated chain is. Harland's figure (1996) highlights the *structure* of the "chain" (from a line to a network) and the number of *echelons*. Mentzer *et al.* (2001) adds the types of *actors* participating in the chain. Some figures (e.g. Lambert *et al.,* 1998) are clearly "centred" around a *pivot* with an upstream SC (up to initial suppliers) and a downstream SC (to end customers). In their framework, Cooper *et al.* (1997, p.10) identify *actors*, *flows* (information and product), *business processes* and SCM *components*. With the influence of the network approach (Haakansson and Snehota, 1995), supply chains are also seen as networks (webs) evolving through interactions of *activity* links, *actor* bonds, and *resource* ties (e.g. in Skott-Larsen *et al.*, 2007). Consultants (e.g. Cohen and Roussel, 2005), who focus on the supply chain architecture, frame SCs around *entities* (actors), *processes*, *data*, *applications*, and *infrastructure* (IT and physical assets) referring to resources. The SCM literature review shows a variety of 'pictures' including different aspects depending on what message authors want to deliver about SCM. A cumulative list of categories of elements that figure on academic SC pictures can thus be established.

Supply chain mapping in SCM

SCM scholars have noted a "profusion of map styles", with a variety of categories of elements figuring in academic SC maps, and suggesting the need for a supply chain mapping convention (Gardner and Cooper (2003, p.37). Hines and Rich (1997), who studied 7 mapping tools, point out they are contingent and address different objectives, which suggest taking care of the context when choosing one. Probably the best-known source on mapping for SCM is Lambert et al. (2008), which groups maps in two categories. The *relationship-based* maps often take the perspective of a focal firm, thus they "will look different depending on a company's position in the supply chain" (ib., p.200). It points out the importance of the "viewpoint" and related "views". *Activity-based* maps include: time-based process mapping (TBPM), pipeline inventory process mapping focusing on physical flows and steps in the logistics-production-distribution process, and extended value stream maps. For these maps, "the determination of the unit of analysis is critical to any mapping effort" (ib., p.212). The chapter concludes with: "Many managers believe that supply chain maps, whether they are relationship-based or activity-based are not worth the effort to prepare. However, once management has these maps in hand, they often report that they cannot think of a better way to understand the

nature of their supply chain" (ib., p.216). Maps are useful tools to better understand the "SC territory" and could also be considered as decision tools. Since there is no convention or set of conventions by which to represent SCs, SC maps are influenced by personal mental representations, the SC being a social construct (New, 2004). It is thus worth studying the individuals' SC maps and the one(s) organizations provide to support SCM activities. It is also worth deconstructing SC mappings to unveil the implicit assumptions "behind" SC maps and the use of maps as tools of "power" in SCs.

Lessons from the network picture literature

Most contemporary SCs are named "networks" and SCM scholars refer to the IMP literature to better understand inter-organisational networks. Thus, the "network pictures" literature (in particular Henneberg *et al.,* 2006 and 2010; Geiger and Finch, 2010 or Leek and Mason, 2010) is relevant to deepen the study of SC maps. In line with this literature, individual SC maps are the managers' "theories-in-use about what the relevant business network looks like, and how it 'works' " (Henneberg *et al.,* 2010, p.356). Considering the variety of actors in a SC, these views could potentially be different, even between persons belonging to different functions in a company, and the mismatches could reveal important SCM issues.

To our knowledge, no empirical study has been done to question the making, use, usefulness of SC maps in companies and in SCs, as well as to question how mapping (as an activity) could reveal mismatch between mental representations of SCs and be useful for SCM. The research presented is an attempt to fill this gap.

Research design and methodology

We conducted a case study (Voss *et al.*, 2002) in the downstream (outbound) car supply chain of Renault Group (RG), collecting data from December 2018 until March 2019. We gathered existing maps of the distribution chain – from the manufacturing plants to the end dealers – and analyzed their purpose (why do they exist?) and use (how are they used?). We conducted facilitated mapping exercises, combined with semi-structured interviews, with 18 RG managers involved in the management of RG outbound SC. To gather as many different "visions" as possible of the RG outbound SC, we interviewed key informants from different RG functions (manufacturing, logistics/operations, Supply Chain, quality, informatics, commerce), at different hierarchical levels (among the 18 persons, 8 are *managers*). Table 1 summarises the 18 informants, in 4 main categories. We also gathered many relevant internal documents from RG.

Table 1 – Type of interviewees [n°of the interview]

Direction / Position	Managers	Others key informants	Total
Logistics and Supply chain Alliance	5 [1]; [6]; [10]; [15]; [16]	4 [2]; [4]; [5]; [13]	9
Quality, Informatics, Commerce	3 [11]; [12]; [14]	6 [3]; [7]; [8]; [9]; [17]; [18]	9
Total	8	10	18

The interview guide was structured around 4 themes, always asked in the same order:

1. Interviewee's profile (background, current position in RG, role in outbound SC);
2. Interviewee's definition of the outbound SC of RG (how he[she] represents him[her]self the "territory" of the outbound SC);

3. Does the interviewee have ready-made maps of the outbound SC? If yes, does he[she] use them in his [her] work? If no, would a map be a useful device in his[her] job?;
4. Can the interviewee draw a map of the outbound SC? The facilitated mapping exercise was done on a paper sheet A4 format that was scanned at the end of the interview (Figure 1 shows an example map).

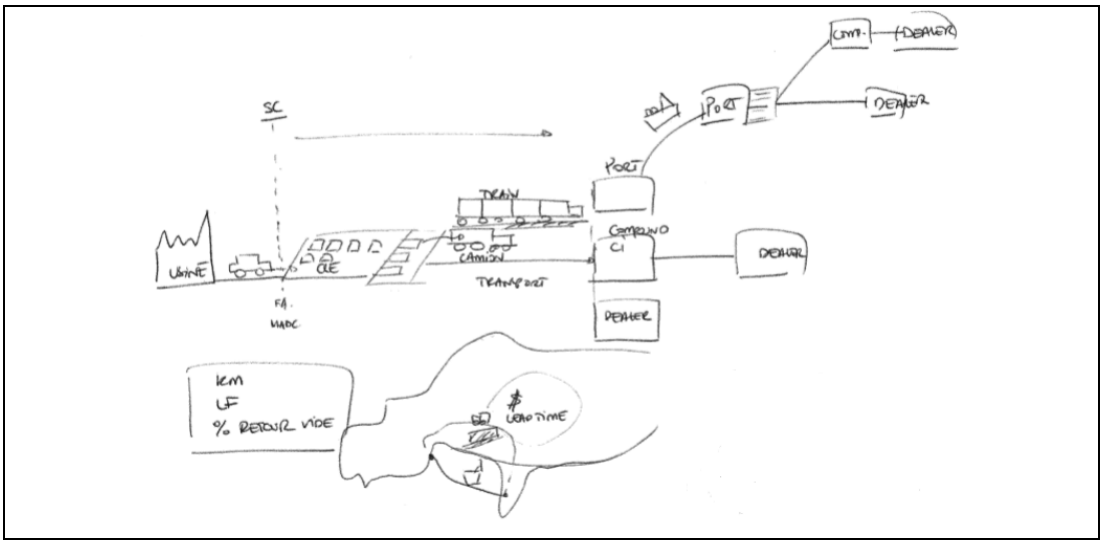

Figure 1 – Respondent's n° [1] map

After recording and transcription, two of the authors coded separately the data collected and discussed and resolved any difference of their coding. This was done in four steps using a cumulative open coding: i.e. adding new items at each step. First, the collected maps were coded (what is drawn by respondents). Every piece of the drawings were named (*items*) and characterised referring to the *categories* found in the literature review. Second, the discourse of the respondents during the mapping (what is said during drawing) was coded in the same way, including new items if any was found. Third, the outbound SC definition (territory) was coded. Finally, the answers concerning the existence/usefulness of maps were analysed.

We used presence-absence matrices to produce results. At each step, we identified core items in SC maps (sum per line) and difference between respondents (comparisons of the columns). Table 2 shows the coding of the 18 maps (step 1). We then compared the tables produced at each step of the coding process. Appendix 1 shows the items found at each step. We also collected significant verbatim to illustrate some of the results. The internal documents of RG helped us to interpret some results. We split the respondents in 4 groups (cf. table 1) to explore the potential influence of respondent's role in the management of RG outbound SC on mapping.

Findings

About the company maps. In fact, there are few maps of the outbound SC available in the company. There are two popular maps used in every presentation to sketch out the outbound SC. They are quite simplistic (linear and including few actors), mainly used for training new staff. They are so old that nobody can remember who drew them! They give a standardized representation of the SC from the moment cars leave the manufacturing plants, helping to develop a common vision and share objectives within

the company. In these maps, the *plant*, the customer (*dealer*) at an international level (*geography*), intermediary warehouses and *logistics points*, *operations* done on cars in warehouses, means of *transport* and the *physical flow* of *cars* are all represented. It is worth noting that, during the interviews, five participants (respondent [1], [5], [6], [15] and [16]) mentioned other maps. In the 2 extra maps provided, one is a geographical map of RG distribution; the other links the outbound SC with the overall SC of RG.

About the 18 outbound SC maps. The mapping exercise was not so easy for a lot of people, some respondents being at first reluctant to draw: "I am not good at drawing" (e.g. [E4], [E9], [E12], [E13]); "my picture is not clear" (e.g. [E11]), "have others made better pictures than mine?" ([8]). However, everyone produced a map. Table 2 gives the result of the analysis of the 18 maps. Thanks to the variety of respondents (different view points), we ended with **20 items** in total, referring to **8 categories** found in the literature.

Table 2 – Result of Step 1 (coding of the 18 maps)

Category of item	Items represented on respondents'maps	Respondent n° (total = 18 respondents)																			
		15	1	3	12	4	6	9	14	2	16	11	13	8	5	17	18	10	7	Total	%
Place	Manufacturing plant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	16	89%
Place	Warehouses (CLE), platforms (PDC), ports	1	1	1	1	1	1	1	1	1	1	1	1	1	1	+/-	1	0	0	15	83%
Actor	Dealer Renault (customer)	1	1	1	1	1	1	+/-	1	1	1	1	1	1	1	1	+/-	0	0	14	78%
Tool/Ressource	Means of transport (trucks, boats, etc.)	1	1	+/-	1	1	1	1	1	0	0	1	0	0	0	1	0	0	0	9	50%
Flow	Physical flow (1 if arrows)	1	1	1	1	+/-	+/-	+/-	+/-	+/-	1	1	+/-	1	+/-	+/-	+/-	1	+/-	8	44%
Place	Points of tracking	0	0	1	1	1	0	1	0	0	1	0	1	1	0	0	0	0	0	7	39%
Flow	Car	0	1	0	0	1	1	0	1	0	0	0	1	0	0	1	0	0	0	6	33%
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	1	1	0	1	1	0	0	+/-	0	1	0	0	0	0	0	0	0	0	5	28%
Flow	Time, leadtime…	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	5	28%
Activity	Operations done on cars (in logistics centres)	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	4	22%
Actor	Enduser (who buy the car)	1	0	0	1	0	0	+/-	1	0	0	0	1	0	0	0	+/-	0	0	4	22%
Actor	Organizational boundary (intra Renault group)	0	0	1	0	0	0	1	0	1	0	1	+/-	0	0	0	0	0	0	4	22%
Actor	Logistics suppliers + other suppliers	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	3	17%
Tool/Ressource	Information system (IS)	1	1	1	0	0	0	0	0	0	0	0	0	+/-	0	0	0	0	0	3	17%
Flow	Information flow	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3	17%
Tool/Ressource	Computer (IT)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	11%
Decision	Impacts on outbound of decisions taken before	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2	11%
Place	Geography (spatial)	+/-	1	0	0	+/-	0	+/-	+/-	+/-	0	0	0	0	1	0	+/-	0	0	2	11%
Decision	Planning (production, SCM…) in Renault	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	6%
Event	Hasards	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	6%
Total of represented items on respondents' maps (max = 20 items)		**11**	**10**	**9**	**9**	**8**	**8**	**8**	**8**	**7**	**7**	**6**	**6**	**5**	**4**	**4**	**3**	**1**	**0**	**114**	

Legend : (1) The items is represented on the respondent's map
(0) The items is not represented on the respondent's map
(+/-) The items is implicitly represented on the respondent's map

Three items are quite systematically represented (plant, warehouses, dealers) and four others are frequently present (means of transport, physical flow, points of tracking and the cars). Note that these items are the ones present in the official company map. The total per column shows a variety of richness of the maps. The individual maps confirm that every manager has his own supply chain vision. If the maps are not focused (centred) on the respondents' activity, they seem influenced by their experience (e.g. figure 1 has been drawn by a logistics person). Most of the 18 maps are much more complex than the company maps. The richer maps were done by respondents [15], [1] and [12], who have more experience in the company, a transverse role (interacting with many people and functions) and with operational field contacts.

About the 18 discourses during the outbound SC mapping exercise. First, the analysis of what the respondents say while drawing the maps confirms the importance of the 20 items found at step 1. Second, it shows (see Appendix 1) some differences between discourses and pictures: 7 new items mentioned by respondents were not in the maps. The new items did not lead to add any new category of items. Third the comparison of matrices done at step 1 and 2 (see Appendix 2) shows that all items are more cited (step 2) than drawn (step 1). The discourse during mapping is richer than the map for every respondent and every item (except for 2 items) and it confirms that respondent's experience of SCM influences his[her] way of mapping SC (e.g. [2] "since I am in the

export flow…"; [4] "you can have port or not, but since I like ports…"; [E17] "being in charge of quality, necessarily it is the vagaries that give us grain to grind"). Finally, like for maps, there is a difference in richness of the discourses of respondents (range from 17 to 4 items). The mapping exercise led some respondents to ask themselves some key questions regarding: SC *perimeter* (e.g. [E9] "does the outbound SC begin here or there? [...] for me it is a bit unclear"; [12] "the perimeter must go there [the dealer], but it should go further [the end customer]"), or how to *represent* some items ([E18] "there is also a kinematic part that seems to me to be missing from that representation. But on an A4 sheet I'm sure we can do better than that").

About the 18 definitions of what the outbound SC is (territory). In line with the previous results, the analysis of the definition of outbound SC given by the respondents confirms the importance of the 27 items found at step 1 and 2. 7 new items mentioned by respondents were not in the maps and the discourse during mapping (see Appendix 1). The new items did not lead to add any new category of items. Comparison of maps and definitions (see Appendix 3) shows that all items are more present in definition (step 3) than pictures (step 1). If most definitions clearly mention that the outbound SC begins "when the car comes out of the plant" ([E1]), it is less clear where it ends. In line with the company maps some persons mention the *dealer* as the end point of the outbound SC, while most (10 out of 18) clearly go up to the *end-user*. Most definitions (13 out of 18) mention the *performance objectives* related to the management of the outbound SC that were not much present in maps (5 out of 18). Some respondents go into detail in some aspects of the outbound SC, in line with their experience or their responsibility (e.g. [E3] insists on the SC information system giving visibility to the commerce). Some definitions clearly state that the outbound SC is "complex" and some point out a fuzzy difference between the SC in terms of "physical *operations*", "company *function*" and "company *department*" (e.g. [E14]).

About the use and usefulness of outbound SC maps. Appendix 4 sums up every point gathered in interviews concerning use, usefulness, existence of maps, experience of mapping… The need for having maps is clearly mentioned by a majority of respondents, even if most of them say that they don't use maps and do not map. Respondents express the need for mapping tools… Could this refer to the need for convention of Gardner and Cooper (2003)? Since SCs are complex (which is a problem for mapping them for a majority of respondents), maps are useful to visualise, represent and better understand the SCs. Respondents spontaneously mentioned 11 types of map usefulness and 7 sources of mapping difficulty. There is a controversy over whether a map should be as complete as possible or not. But some respondents insist on the need for maps to be as faithful as possible. [E13] states "I think for a long time the carmakers didn't take care of the downstream SC because they didn't really see the stakes". Could this explain why there are so few outbound SC maps in RG?

Difference between the 4 groups of respondents. The analysis of the differences between the maps, discourses and definitions of the four groups of respondents, even if subject to caution due to the low number of respondent per group, gives support to the importance of the experience of the territory (company, automotive sector, logistics operations and SCM, etc.) on mapping.

Discussion

In our case study, the alignment between organisational and individual maps is good. The organisational maps of RG, used for training, are simple and so old that they probably influence employees' representations. They include such basic and core elements of the outbound SC that it is not surprising they also figure in the individual

maps. The comparison of the individual maps reveals that there are mismatches (e.g. type of map, what is represented, perimeter…). All in all, the sum of what is represented on individual maps is not so different from what is represented in the collection of academic maps. The 18 maps (maid by RG key informants) tell us about managers' visible horizon (Carter *et al.*, 2015) of RG outbound SC.

The mapping of SC is not an easy task for managers who express the need to develop tool to map. None of the 18 maps refers to or looks like the mapping tools or maps found in the literature. However SC mapping is considered as useful for managers participating to the management of a SC. This encourages researchers to go on working on this aspect of SCM, and to better communicate their results to industry.

The comparison of the results obtained at each steps gives evidence of the varied and more or less complex SC maps, discourses and definitions. This variety confirms the subjective nature of mapping and probably reveals the variety of SC mental representation of managers. It suggests that sharing individual maps could be helpful to improve collaboration between SC actors and eventually to align representations.

The comparison of results from step 1 with step 2 as well as the comparison between the four groups of respondents supports the influence of individual experience and projects (and objectives) in the SC on the individual maps. It suggests, in case of dysfunctions in the management of the SC, that studying the mismatches between individual SC maps could help to better understand where problems come from and to solve them. In line with the network literature perspective, the interviewees' discourses also suggest that drawing maps made them understand things differently i.e. drawing doesn't just represent the world, it (re)constructs it.

The comparison of results from step 1+2 with step 3 attests that "the map is not the territory". The overall list of 33 items and 8 categories obtained at the end of step 3 is a valuable output to discuss and build SC diagnosis tool.

Conclusion

Our research questions the "neutrality" of supply chain mapping and helps to better understand the mapping process at the individual level. It also improves our understanding of the role/usage of maps in SCM. Philosophically speaking, it points to the importance of revealing the underlying ontological and epistemological vision of SC managers and researchers, respectively. Maps objectivize but are not objective pictures! Companies need to be fully conscious of the power of SC maps and to take greater care with their mapping activities.

The collected data did not permit us to unveil the implicit assumptions "behind" SC maps and the use of maps as a "powerful" tool in SCM. To go further on this understanding, a focus group with the respondents and other SC actors could be organized to discuss differences between maps and discuss the result of the research. The focus group could also discuss the following two questions. Does a better understanding of the differences between individual SC maps could help explain and solve SCM dysfunctions?

Our data did not permit us to study the potential influence of SC maps and mapping activity on SCM. This could be the aim of the continuing research collaboration with RG, with an action research approach. Can maps be considered (or serve) as intermediary or boundary objects in multi-function SCM teams (Carlile, 2002)?

Since the focus of our case study was the outbound SC of RG, adopting the point of view of the industrial company and studying first the internal actors' SC maps, further research could replicate the methodology to study the maps of 'external' actors such as suppliers (for transport, logistics and operations-on-car activities), dealers, etc.

Finally, the research questions the need for a company to spend time and resources to map its SC. It questions the kind of map to promote and the relevance to adopt a convention (Gardner and Cooper, 2003). Is it a good thing to standardize maps? It also questions the use of maps and mapping in industry as well as in academia. Can maps influence managers', students' and researchers' mental representations of SCs? Do persons' mental representations of SC influence their mapping of SCs? More generally, how can maps be used in SCM?

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Appendix 1 – Items founds at each step of the coding process

Category of item	Step 1: Items found in maps	Step 2: new items from discourses	Step 3: new items from SC definitions
Place	Manufacturing plant	Perimeter of/in outbound SC	Points of control **quality** (car)
	Warehouses (CLE), platforms (PDC), ports		
	Points of tracking (traceability)		
	Geography (spatial, countries...)		
Actor	Logistics suppliers + other suppliers		Role/importance of **contracts**
	Dealer Renault (customer)		**Politcal/relational** aspects in the SC
	Enduser (who buys the car)		**Transversality between actors** in the SC
	Organizational boundary (intra RG)		
Tool / Ressource	Means of transport (trucks, boats, etc.)		Importance of **standards**
	Computer (IT)		
	Information system (IS)		
Flow	Car	**Link** information/physical flow	**Link** physical flow/finance
	Physical flow		
	Information flow		
	Time		
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	On time delivery, leadtime…	
Activity	Operations done on cars (in logistics centres)	Transfer (of responsibility)	**Animation** of suppliers
		Process (related to outbound SC)	
Decision	Planning (production, SCM, logistics…) in RG	Dynamic piloting (thanks to traceability)	
	Impacts on outbound of decisions taken before		
Event	Hasards (in transport or logistics)	Security (IS hacking)	
Total	*20 items represented in maps*	*7 new items in discourses (total 27 items mentioned)*	*7 new items in SC definitions (total 34 items mentioned)*

Appendix 2 – Difference between maps (step 1) and discourses during drawing (step 2)

2.1. Difference per item

Difference between maps (step 1) and the discourse during mapping (step 2)				
Items found at step 1 of the coding process		Step 1	Step 2	Difference
Place	Manufacturing plant	16	16	**0**
Actor	Logistics suppliers + other suppliers	3	10	**7**
Decision	Planning (production, SCM, logistics…) in Renault	1	7	**6**
Tool/Ressource	Means of transport (trucks, boats, etc.)	9	14	**5**
Place	Warehouses (CLE), platforms (PDC), ports	15	17	**2**
Activity	Operations done on cars (in logistics centres)	4	6	**2**
Actor	Dealer Renault (customer)	14	15	**1**
Actor	End-user (who buys the car)	4	8	**4**
Flow	Car	6	16	**10**
Tool/Ressource	Computer (IT)	2	3	**1**
Tool/Ressource	Information system (IS)	3	6	**3**
Event	Hasards	1	6	**5**
Decision	Impacts on outbound of decisions taken before	2	3	**1**
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	5	10	**5**
Flow/objective	Time, leadtime…	5	12	**7**
Flow	Physical flow	8	8	**0**
Flow	Information flow	3	2	**-1**
Place	Points of tracking, traceability	7	6	**-1**
Actor	Organizational boundary (intra RG)	4	6	**2**
Place	Geography (spatial)	2	13	**11**
	Total	**114**	**184**	**70**

2.2. Difference for total of items per respondents

Total number of items mentioned per respondent																			
Respondents	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Total**
Nb of items step 1	10	7	9	8	4	8	0	5	8	1	6	9	6	8	11	7	4	3	114
Nb of items step 2	10	12	10	9	4	11	14	5	13	4	7	11	9	11	17	16	11	10	184
Difference	**0**	**5**	**1**	**1**	**0**	**3**	**14**	**0**	**5**	**3**	**1**	**2**	**3**	**3**	**6**	**9**	**7**	**7**	**70**

Appendix 3 – Difference between maps (step 1) and definition of SC (step 3)

Difference between maps (step 1) and the definitions of what the outbound SC is (step 3)				
Category	**Items found at step 1 of the coding process**	**Step 1**	**Step 3**	**Difference**
Place	Manufacturing plant	16	17	1
Actor	Logistics suppliers + other suppliers	3	15	12
Decision	Planning (production, SCM…) in Renault	1	11	10
Tool/Ressource	Means of transport (trucks, boats, etc.)	9	16	7
Place	Warehouses (CLE), platforms (PDC), ports	15	16	1
Activity	Operations done on cars (in logistics centres)	4	10	6
Actor	Dealer Renault (customer)	14	15	1
Actor	End-user (who buys the car)	4	10	6
Flow	Car	6	18	12
Tool/Ressource	Computer (IT)	2	9	7
Tool/Ressource	Information system (IS)	3	9	6
Event	Hasards	1	11	10
Decision	Impacts on outbound of decisions taken before	2	4	2
Objective	Performance (CO2, cost, quality, satisfaction, etc.)	5	13	8
Flow	Time, leadtime…	5	13	8
Flow	Physical flow	8	11	3
Flow	Information flow	3	6	3
Place	Points of tracking, traceability	7	9	2
Actor	Organizational boundary (intra RG)	4	16	12
Place	Geography (spatial)	2	13	11
	Total	**114**	**242**	**128**

Appendix 4 – Results concerning use, usefulness of SC maps

		Respondents [n°]																		
Topic related to research question	**Coding**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**Total**
Need of map	The respondant feels a **lack/need of map**	1	1		1	0	0		1	1	1		1	1	1	1	1	0,5	1	**12,5**
	The respondant express the need of a **tool to map**				1				1		1					1	1	1		**6**
Usefullness of maps	Maps provide **visual** documents, **visualise**	1	1		1					1	1		1	1	1	1	1	1	1	**12**
	Maps help to **represent** things (flows, plants, actors…)		1		1	1			1			1	1		1	1	1	1	1	**11**
	Maps help (new) staff of new interns to **understand**		1							1	1		1		1				1	**6**
	Maps help to **question** about SCM										1		1			1				**3**
	Maps open avenue to find potential **improvements**												1			1		1		**3**
	Maps help to **communicate (identifie** people in RG)								1						1					**2**
	Maps help to **share** information, knowledge									1				1						**2**
	Maps are usefull to (SC) **design** (before development)											1				1				**2**
	Maps represent a **memory**																	1	1	**2**
	Maps avoid **misunderstandings** between people													1						**1**
	Maps can help to take **decision**															1				**1**
	11 usefulness	**1**	**3**	**0**	**2**	**1**	**0**	**0**	**2**	**3**	**3**	**2**	**5**	**3**	**4**	**6**	**2**	**4**	**4**	
Difficulties of mapping activity	**Complexity** of SCs => difficult to map SCs		1		1				1		1				1		1	1	1	**8**
	The representation must be as **faithful** as possible		1										1			1	1	1		**5**
	Need to/must represent **everything** (but difficult)		1		1						1		0					0		**3**
	Need to **update** maps (operations change!)		1															1		**2**
	Difficult to have a **real-time (dynamic)** mapping																1	1		**2**
	Difficult to **simplify** complex SC				1															**1**
	Mapping consumes **time**																		1	**1**
	7 difficulties	**0**	**4**	**0**	**3**	**0**	**0**	**0**	**1**	**0**	**2**	**0**	**1**	**0**	**1**	**1**	**3**	**4**	**2**	
Existence of maps in the company	Does the respondant has/use a map of the SC outbound?	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0,5	1	1	0,5	**5**
	Are there SC maps in the company?	1				1	1									1	1			**5**
	Does the respondant has/use other type of "maps"?							1				1					1			**3**
Doing maps	The respondant tells he/she did a SC mapping		1		1										1	1				**4**
Effective use of maps in RG	Maps are used during staff training	1					1										1			**3**
	Maps are use to illustrate document					1														**1**

Legend of codes	0= NO	1= YES	= not discussed in the interview	= indirect answer

Supply network operations in the context of circular economy

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Abstract

This research investigates principles to design Circular Supply Networks (CSN). We derive key investigative variables employing Industrial Ecology (IE) theory and Supply Network (SN) research to observe impact of product, production, and location attributes on design and assessment of CSNs. We apply a single case study design guided by a research framework. Findings suggest that certain product, process, and location attributes are required for a reuse based CSN. The research novelty lies in scope and level of analysis of SN. This research contributes to SN design research by incorporating the system balancing concept from IE and principles of Circular Economy.

Keywords: Circular Supply Network, Performance measurement, Reusable packaging

Introduction

The modus operandi of traditional Supply Networks (SNs) is characterised by a unidirectional flow of materials in a take-make-use-dispose mode of operations, resulting in an annual general waste generation of 2.5 billion metric tons in the EU alone, USD 80-120 billion lost material value in plastic packaging, and increased risk of severe health impacts, such as cancer, resulting from these wastages (Tagliabue et al. 2016; EU 2014; EMAF 2016). In addition to these challenges, increasing demand of resources, led by population growth across the world, may lead to a potential gap of natural resource demand and supply of 8 billion tons by 2030, suggesting that the traditional linear model of production and consumption is no longer viable (Esposito et al. 2018).

It is argued, that Circular Economy (CE) might address the challenges of linearity in traditional models of SNs. CE is defined as *"an industrial economy that is restorative or regenerative by intention and design"*, which seeks to increase resource and process

efficiency while reducing waste (EMAF 2013). The Ellen MacArthur Foundation (EMAF) suggests benefits, such as potential material cost savings of USD 595 – 706 billion globally in the Fast Moving Consumer Goods sector (EMAF 2013).

Even though CE rarely fails to disappoint when it comes to postulating its benefits, its implementation, involving open and closed loop SN practices, is "blurred and uncertain" (de Jesus & Mendonça 2018). We argue that there are mainly three barriers for the limited application: (i) Conceptual development of CE overlooks the importance of its operationalisation, (ii) Circular operations require changes in operational design from the perspective of product, process, and location, and (iii) Understanding of SN relationships between product, process, and location is fragmented and not well understood. Therefore, in this research, we address a key theoretical and industrial challenge of how product, process, and location attributes create circularity in a SN and how these attributes can be evaluated taking environmental and economic feasibility into consideration. We do so by employing a qualitative case study design, informed by literature and guided by the theoretical lens of Industrial Ecology (IE) as key theory for CE. The research novelty lies in scope and level of analysis of SNs. This research contributes to SN design research by incorporating the system balancing concept from IE and principles of CE.

In the following sections of the paper, we present literature on IE and supply networks. Subsequently, we introduce the methodology employed including conceptual framework mainly derived from literature, case study design, data collection and analysis. We then offer the discussion of our results. Finally, we conclude our research with implications to theory, management practice and policy development along with further research opportunities.

Literature Review

IE developed various theoretical concepts suggesting that any system operates in a balance, such as the biological ecosystem, where limited disturbances to the balance in a system can be compensated, however if those limitations are surpassed, the system loses its capability to recuperate and may degrade permanently (Graedel & Allenby 1995). The balancing element of IE theory deals with circularity development in a linear system. The system part of IE is a preconceived notion and context-dependent. In this research, we refer SN as the system. This balance and system view, further extended by CE, proposes seven distinct circularity operations: (1) Reuse, (2) Recondition, (3) Repair, (4) Refurbish, (5) Remanufacture, (6) Repurpose, and (7) Recycle (Reike et al. 2018). However, operationalisation of these circularities remains vague. Circular Supply Networks (CSNs) extend SN theory into the sustainability domain. However, theoretical knowledge involving how to operationalise such CSNs is fragmented. It is noted that the implementation of CE is *"blurred and uncertain"* (de Jesus & Mendonça 2018), and there is an argument that CSN *"lack theoretical and paradigmatic clarity"* (Blomsma & Brennan 2017), suggesting that contextual and operationalisation requirements are yet to emerge.

SNs can be recognized as systems that are rather evolving than purposefully designed (Choi et al. 2001). However, in the last decades academics have taken the challenge to design such a network (Beamon 1999). SN analysis can be performed from mainly three perspectives: (1) Optimisation modelling approaches of facility-location against a set of objectives (Santoso et al. 2005; Charles et al. 2016). (2) A network theory perspective, based on the notion of multiple nodes in a SN and different types of interdependencies (Kim et al. 2011; Borgatti & Li 2009). These nodes represent a particular operation/factory/organization in certain locations, however, the significance of product

and process attributes is not taken into account. (3) The third perspective takes the focal company point of view, where product and processes are studied with SN mapping approaches but end-to-end supply network attributes are limited (Lambert et al. 1998; Choi & Hong 2002).

In SN design, the most important issue is to understand the dynamics of Product, Process, Location. Product - Process dynamics in SNs suggests that increasing demand for a large product variety results in the requirement of ever more diverse processes. Therefore, companies develop modularity strategies (Huang et al. 2005) to push the customisation of products further downstream to reduce the degree of process diversification. Whereas Process-Location dynamics suggest that geography dependent attributes may result in specific process capabilities: in this context, it is demonstrated that sourcing and production decisions were made on the basis of location attributes (Kumar et al. 2016; Srinivasan et al. 2019). Hence, we argue that understanding the relationship between product, process, and location becomes an integral part of SN design.

Further literature exploration revealed, that general product attributes include functions, architecture shape, etc. (Pahl & Beitz 2013; Ulrich 1995; Otto & Wood 2001). We observed that there are two types of product attributes - *Functionality*, and *Physicality* (Table 1). Process attributes include upstream and downstream SN processes, such as production planning, supplier management, stakeholder integration, etc. (Beamon 1998; Reuter et al. 2010; Seuring & Gold 2013), which can be classified into *Operational*, and *Management*. Location attributes include key actors, factors of production, demand, regulations, etc. (Brush et al. 1999; Stalk 1988; Kumar et al. 2017; Lorentz et al. 2018), which we classified into *Production and Distribution Infrastructure (P&D Infrastructure)*, and *Regulation and Market*.

*Table 1 - Product, Process, and Location attribute categories**

Product	**Process**	**Location**
Functionality *(6 attributes)*	Operational *(6 attributes)*	Production and Distribution Infrastructure *(11 attributes)*
Physicality *(6 attributes)*	Management *(10 attributes)*	Regulation and Market *(15 attributes)*

*Sources: various academic contributions, including the ones listed in the text

On the assessment of CSNs, IE theory interpretation leads to the understanding that the future circular system has to perform better from the environmental and economic perspectives. Here, the SN performance measurement system helps to understand what to measure and how to measure (Neely et al. 2005). In that sense, we refer to indicators and methods. The literature on indicators, which can also be classified from the product, process, and location perspectives, provides a huge library of possible choices (UNEP 2015; World Bank Group 2017; GRI 2011), however, the rationale for indicator selections remains nebulous. Furthermore, there is a wide variety of performance measurement mechanisms, dominated by Life Cycle Analysis (Piezer et al. 2019; Hossain & Thomas Ng 2019), however, lack the SN attributes of product, process, and location. The closest rationale we identified for selecting particular indicators and performance measurement mechanism was that *"Organizations should determine what success would look like for them"* and choose them accordingly (BSI 2017). However, this appears unsatisfactory considering that any CSN requires justification from the environmental and economic perspective, where a unified approach for comparability appears essential. We further argue that, if CSN design needs to incorporate product, process, and location attributes, a performance measurement system should be based on

the same dimensions. Therefore, we set out to investigate how product, process, and location attributes create circularity and how these attributes can be evaluated. A set of investigative variables is derived from this literature review that informed a research framework discussed in the next section.

Methodology

We argue that the general principles of developing circularity need to be investigated through empirical research within a set boundary of investigative variables mainly derived from literature. This research framework, that guided the data collection and analysis, is illustrated in Figure 1.

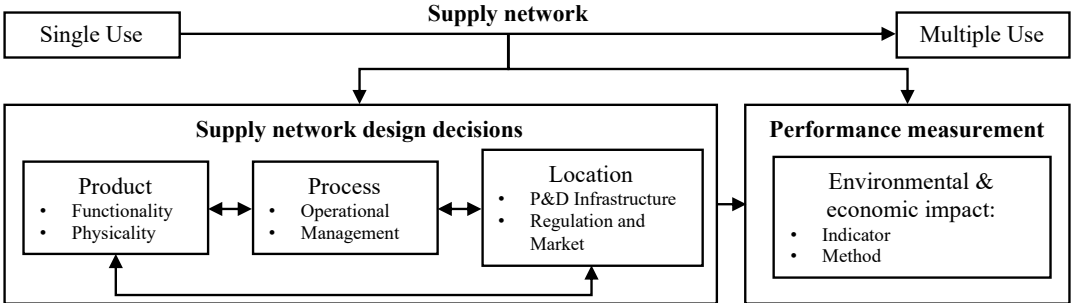

Figure 1 - Research Framework

The research framework has three key elements. The first element suggests the transformation process from single use to multiple use. The second and third elements are supply network attributes and performance measurement, demonstrating requirements for the transformation. We considered 12 product attributes from notable scholar, 16 process attributes, and 26 location attributes to investigate how those attributes create circularity. In order to avoid bias, we confirmed the classification of attributes into those groups with three other independent researchers. On the assessment side, we considered 536 indicators and 161 environmental and economic assessments.

In this research, we investigate the emerging CSN phenomenon with a single-case study design at Nestlé, who is known for their research into CSNs as widely reported in the news, with reusable Häagen-Dazs ice-cream packaging being considered as exemplar and revelatory case for reuse systems, representing a key case selection criterion for this research (Yin 2018). The unit of analysis of this research is CSN design projects and the level of analysis includes attributes of product, process, and location. The single-case study approach promises relevant results, due to the uniqueness and richness of detail required in order to generate key principles based on how multiple attributes of product, process, and location create circularity. We appreciate the limitations that come from single-case study research (Eisenhardt 1989), however follow Dryer & Wilkins (1991) and Flynn (1990)'s view of the benefit of using single-case study in contexts where greater depth and rich details are required (Dyer & Wilkins 1991; Flynn 1990). Other authors, who employed single-case study design on the basis of revelatory, unique and critical cases include (Simons & Russell 2002; Oliva & Watson 2011).

The first point of data gathering effort at Nestlé started with a site visit in December 2017. We conducted expert semi-structured interviews with 10 participants from Nestlé and TerraCycle (multiple use packaging solution provider) ranging from technical specialist to project manager, as well as environmental and economic assessment specialists. Additionally, we collected data from archival records with regards to product

specifications and environmental assessments conducted at the company. The total interview time was around 30 hours and archival records amounted to around 430 pages (product design, environmental assessments conducted by the company). In order to ensure reliability and construct validity, we developed a data collection protocol that guided the research, comprising aims, data collection procedure, and interview questions (Yin 2018). Secondly, we followed data triangulation techniques by using multiple sources of evidence (semi-structured interviews and archival records) and multiple sources per evidence (Yin 2018). Thirdly, we developed a database to maintain a chain of evidence between case study questions, findings, and evidentiary sources (Yin 2018). A high level excerpt of the data collection protocol, summarising attributes, source of data and participant designation is shown in Table 2.

Table 2 – Data collection template

Level of analysis	Attributes	Source of data	Interviewees
Product	*Functionality*	Semi-structured interviews; Archival records	Packaging design engineer
	Physicality	Semi-structured interviews; Archival records	Packaging design engineer
Process	*Operational*	Semi-structured interviews; Archival records	Process design engineer
	Management	Semi-structured interviews	Process design engineer
Location	*P&D Infrastructure*	Semi-structured interviews	Project Manager
	Regulation and Market	Semi-structured interviews	Project Manager
Assessment (incl. Product, Process, Location)	*Indicators*	Semi-structured interviews; Archival records	Economic specialist
	Method	Semi-structured interviews; Archival records	Environmental specialist

We analysed the data according to: (1) the three CSN domains product, process, and location, and (2) environmental and economic assessment by the means of a coding framework (Miles et al. 2014), which represented the attributes in each domain, as identified in literature. The second step involved complementing the interview data with data from archival records, such as product design records, environmental assessment reports, etc. We then conducted a product, process, and location analysis, individually and across, in order to identify key patterns and interdependencies.

Findings and Discussion

This section presents the key findings and discussion. Five key principles have emerged from our data analysis. The following paragraphs presents and discusses each of the principles. Table 3, on the next page, presents the data analysis, providing evidence for these key principles.

In the product domain, we observed that SN circularity requires changes in product functionality, which translates into changing product physicality. In the case of Häagen-Dazs, additional functional requirements, such as durability (100 use cycles) and cleanability lead to a new physicality of the product by changing its materials. It was stated by the company official, that *"The material selection was a decision made through an evaluation of the lifetime, […], quality concerns that could come from the material, […]".* We observed that changing physicality is a complex process involving not just material but also design of products. In the investigated case, certain designs can lead to higher risks of product safety, for example in the cleaning process, certain designs on the metal, such as embossing, will increase the risk of contamination.

Table 3 - Key findings

CSN	Attribute	Examples in the context of reuse	Depen-dencies	Evidence (Examples)
Product	*Functionality*	• Durability of materials • Cleanability • Additional food safety requirements • Insulation	✓	"On top we have reuse requirements, which are: easy to clean, 100 use cycles, insulation, etc."; "We had a Quality & Food Safety Expert that told us not to go for [a certain design], because residual food could potentially still be in the packaging after cleaning, which creates food safety issues."
	Physicality	• Material: Lifetime, quality concerns, consumer perception and branding	✓	"The material selection was a decision made through an evaluation of the lifetime of the material, the consumer perception of the material, the quality concerns that could come from the material, and how well it can bring out the brand's personality
Process	*Operational*	• Processes for reuse: (i) Cleaning, (ii) Filling, (iii) Lidding (packaging specific) • Key logistics processes: Transportation between (i) Manufacturer, (ii) Consumer, and (iii) Cleaning facility	✓	"Let's look at the container, we need to fill it […], lidding was one of the key things, and cleaning. I think these three process components were the key focus areas"; "[Company x] picks up the ice-cream from our filling facility and delivers it to the door of the consumer. […] whenever they emptied the ice-cream, it gets picked up, cleaned and delivered back to us."
	Management	• Integration of reusable packaging into SN processes • Supplier Management	✓	"We have to figure out the best way to integrate the new type of packaging into our current processes"; "For this product "these three process components were the key focus areas that we needed to integrate [with our processes]"; "Our reuse model requires us to be in a partnership with an external company [TerraCycle], knowing that they are potentially in partnership with competitors"
Location	*P&D Infrastructure*	• Transportation distance	✓	"Every 10 or 100 km you reduce from transportation will give you a positive impact in your environmental impact";
	Regulation and Market	• Consumer buying preference • Affordability	✓	"Location decision was driven by where we had the most consumers"; "A project like this needs ambassadors for sustainability […] and willingness to pay when it comes to sustainability"; "At the end of the day, it really is transportation distance that contributes the most to environmental impact"
Assessment	*Indicators*	• Economic: Profit, ROI; • Environmental: (i) GHG emissions, (ii) Abiotic resource depletion, (iii) Water scarcity, (iv) Land use impact on biodiversity, and (v) Eco-system quality	✓	"Financials is one of the key and one of the most difficult hurdles"; "It is about how much are we charging the consumer, where do we get materials, who are our partners"; "Profit margin for [own company] and [third party network actor] has to be allocated"; "At Nestlé we discussed what indicators are relevant and these [see previous column] are the ones where we create impact".
	Method	• Profit-Loss model • Life Cycle Assessment	✓	"The profit-loss model was not only an immediate loss-profit benefit but a strategic 5-10 year pipeline"; "We use LCA because it is standardised and despite the drawbacks from the database represent the environmental impact better than any other method".

On the topic of process, our analysis demonstrates that the implementation of circularity requires changes in the operational and management process, that may or may not result in a change of process-ownership. In the case of Häagen-Dazs, additional production processes such as collection of packaging from consumer, cleaning and delivering to Nestlé were contracted to TerraCycle, whereas filling and lidding of the reusable packaging is performed by Nestlé. While this resulted in minimal changes of the production processes for Nestlé, this process-ownership pattern required an alteration of management processes, such as additional supplier management. Nestlé stated that "*When we introduce reuse, we want the fewest changes to our existing operations as possible. [This model] required minimal adaptation of the production processes",* suggesting that the type of circularity employed by a particular company may depend on the adaptation requirements of the existing SN. Potentially, such partnership arrangement may shift the power in buyer-supplier relationship. In this case, it means the power shift from main manufacturing firms towards suppliers. Here, Nestlé stated that *"our reuse model requires us to be in a partnership with an external company [TerraCycle], knowing that they are potentially in partnership with competitors."*

From the location perspective, we argue that there are multiple unique attributess of location that determine the type of circularity in SNs. We observed, that the Häagen-Dazs reuse SN is dependent on key location attributes of New York linked to consumers' buying preference, affordability, and transportation distance. In New York, *"The success of the project was dependent on ambassadors for sustainability […] and willingness to pay when it comes to sustainability"*. Here, reuse may be particularly feasible for wealthy regions - nationally and globally – whereas other types of circularity may be more suitable for less affluent regions. Additionally, Nestlé stated that: *"At the end of the day it really is transportation distance that contributes the most to environmental impact, no matter what material you choose [for the packaging]"*. The importance of short transportation distances implies, that a reuse SN may require very localised manufacturing strategies. Therefore, understanding the particular location attributes with regards to the type of circularity is essential. However, this preliminary assumption needs to be tested.

We also observed inter-dependencies between Product, Process, and Location: (1) Product functionality impacts location. In the case of Häagen-Dazs, the ability of the reusable packaging to keep the ice-cream refrigerated contributed to the decision of the location. Nestlé stated that *"how long the ice-cream can stay frozen [in the reusable packaging] under ambient delivery conditions drives location"*. Especially, the longer the ice-cream can stay frozen the larger the distribution radius from the filling facility. (2) Production processes impact product functionality and physicality. In particular, the shape of the reusable metal container was constrained by the existing filling processes. Nestlé stated, that *"We have to figure out what the best way to integrate this packaging in [their] current processes was, [and …] there was not a lot of freedom to design"*.

In terms of evaluation of the attributes of the CSN, indicators and assessment of such CSN projects are dominated by profitability and return on investment. Nestlé stated that *"Financials are key. If we make profit after the 1st year and offset the investment in the next [x] years, we go ahead [with the reuse project]"*. Environmental considerations are difficult for companies to evaluate because there is an underlying assumption that any circularity is better than the linear system. However, the company stated that *"we need to understand under what circumstances reuse is environmentally superior to single use options"*. On the environmental assessment, LCA is widely applied, which has inherent limitations and there is a need for a new approach for environmental and economic assessment. In this area, theoretical justification is needed on indicator selection and data

access and capturing of new processes. Here, the company states that: *"We selected the indicators based on whether they would create this very impact in our operations".* Additionally, Nestlé mentioned that *"The data base we use provides average values of the environmental impact of processing 1kg of a particular material"*, neglecting the distinct operational set-up of the CSNs involving geographies and process intensities and efficiencies. This research suggests that specific methodological development requires a more operational perspective on capturing environmental impact directly from the operational set-up.

To conclude the discussion, we propose the following five key principles for CSN design: (1) Changes in usability of product, here: 100 use cycles, leads to changes in its physicality involving materials and design; (2) Changes in production processes may lead to changes in intra- or inter-firm management processes; (3) Certain types of circularity, here: reuse, require localised manufacturing; (4) The interdependencies between product, process, and location determine the type of circularity; (5) Environmental assessment requires access to primary data. We furthermore note, that if the attributes presented in Table 3 are not met, the reuse circularity might not succeed.

Conclusion

This research investigated how product, process, and location attributes create circularity in a SN and how these attributes can be evaluated taking environmental and economic feasibility into consideration. The key findings are threefold: (1) Implementation of CSN operations require operational and managerial changes in Product, Process, and Location attributes. These changes have to be made in careful consideration of the dependencies of attributes within and across the three domains including the type of circularity employed, (2) Current environmental assessments of CSNs reflect potential environmental impact within the limitations of the study, suggesting the development of an integrated methodology for CSN evaluation, and (3) We suggest five key principles for CSN design, demonstrating the impact of product, process, and location attributes on design and assessment CSN.

Theoretically, this study introduces the concept of balancing a system from IE theory and integrates it with supply network design. We provide key principles for developing and operationalising CSN. In other words, this research extends IE theory into the SN design research domain. It also extends SN research by incorporating product, process, location, which is not widely inferred in supply chain analysis. It is important to note that supply network research is mainly linked to operational efficiency and capabilities, which has its roots in the notion of manufacturing strategy dating back to Skinner's seminal work in 1969, challenging the Taylorism view of bottom-up efficiency improvements of manufacturing operations. This research builds on the capability perspective of manufacturing strategy to develop circularity in supply networks. The novelty of this research lies in the scope and level of analysis of supply networks. The scope of analysis included a product, which is not consumed (in this case packaging). The level of analysis incorporated product, process, and location.

From a management practice perspective, this research informs managers with regards to the decisions: How to select a product for the transformation to circularity?, What are considerations for the coordination of product, process, and location decisions in the SN design?, Why should the limitations of environmental assessments of circularity in transformation projects be well understood?

From a policy perspective, we can see that the transition to CE could benefit from developing a standard assessment methodology that integrates environmental and economic assessments to ensure comparability and therefore, helps create visibility

under what circumstances certain circularity projects are successful on a large scale.

We understand the limitations of this research as follows: the case study is limited to one company in fast-moving consumer goods, whereas circularity operations in different industries may result in other conclusions. Generalisability is further limited by the single-case study methodology employed.

Further research into the high-level key principles for CSN includes (1) establishing a hierarchy of attributes in each domain in the context of CE, (2) distributed manufacturing strategies for different types of circularity, and (3) development of an integrated environmental and economic assessment methodology. From an organisational theory perspective, a contingency based approach to investigating product, process, and location attributes can provide valuable insights about the internal and external contingencies that need to be considered in CSN design. This is particularly relevant since one of the interview partners mentioned the increasing number of constraints companies are confronted with. Employing an organisational learning perspective could also yield to relevant insights, in contexts where the scale-up from pilot-projects to projects is planned, in order to create generalisable theoretical insights, how CSNs can be expanded.

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Using a viable system model to investigate offshore wind supply chains

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Abstract

This paper discusses the effectiveness and importance of adopting a holistic systems approach to complex supply chain issues and illustrates the argument by using the viable system model to investigate offshore wind supply chains in the UK. Systems approaches are often mentioned in the supply chain management literature, particularly regarding supply chain integration, however they remain underutilised by supply chain academics. The discussion's output will be a proposed research agenda for a follow-up empirical study of the offshore wind industry.

Keywords: Viable system model, Offshore wind industry, Supply chains

Introduction

It has long been acknowledged that supply chains form complex networks of interconnected and interdependent organisations and researchers therefore need to consider them as 'complex systems' (Ellram and Cooper, 1990; Choi et al., 2001; Grant, 2012). The term 'system' comes from a meta discipline known as systems or holistic thinking and is described as a collection of inter-related parts that work together to create a coherent whole with a purpose (Espinosa and Walker, 2017). One of the key systems thinking ideas is that properties of the parts can be understood only within the context of the larger whole, as opposed to Cartesian science that believes the behaviour of the whole should be analysed in terms of properties of its parts (Capra, 1997). Understanding supply chains as complex systems could help academics and practitioner to understand supply chains holistically by respecting the interconnectedness of businesses that make up the supply chain.

Many logistics and supply chain management (SCM) scholars recognise the relevance of systems thinking, in general, as a valuable perspective needed for holistic understanding and learning of SCM processes, given that the term "supply chain management" itself was born out of the idea of viewing the chain of supply as a single entity (Oliver and Webber, 1995). Systems perspective relevance is especially evident in the concept of supply chain integration (SCI) that is characterised by *"joined up thinking, working, and decision making"* (Stevens and Johnson, 2016: 22) that lies at the core of

SCM, with a dominant view in the literature that greater SCI leads to better supply chain performance overall (Frohlich and Westbrook, 2001; Pagell, 2004).

Thus, a systems view of the supply chain can help achieve higher levels of SCI by emphasising process optimisation to assist the performance of an entire chain rather than optimisation of individual parts (Sadler, 2007). However, despite the general acceptance of the value of a systemic view for SCI, as well as in the wider logistics and SCM discipline, studies employing systems theories often use them only as a background philosophy rather than as a guiding methodology (Fawcett et al., 2012). Lindskog (2012a, b) found that in general systems theories and associated approaches remain underutilised within the logistics and SCM discipline. Similarly, Nilsson and Gammelgaard (2012) noted that those using systems approaches rarely explain on what grounds, theories and definitions those approaches are derived from.

The purpose of this paper is to address these shortcomings in our knowledge and practice by discussing one of the approaches in the systems thinking discipline, the viable system model (VSM), which focus on analysing organisations and networks as complex systems, and to describe its potential as a methodology to investigate the UK offshore wind (OSW) industry supply chain as a complex system and to aid in the structural analysis of SCI within that sector. The paper first provides a theoretical background of VSM and the UK OSW industry sector to develop a conceptual VSM within the OSW sector. Then, a proposed research agenda for empirical case study in 2019 and its anticipated contributions are provided before the paper is concluded.

Theoretical Background

Viable system model (VSM)

The viable system model or VSM in short was developed by Stafford Beer in his work on a theory of viable and effective organisations known as organisational cybernetics (Espinosa and Walker, 2017). Organisational cybernetics has developed as a separate strand of the wider science of cybernetics, explained as a science of communication and control (Wiener, 1985). Control, as argued by Beer (1967) does not refer to control in a coercive regulatory sense but to control as a system's strategy to achieve the organisational purpose. In cybernetic sense, it refers to 'homeostats', system's internal mechanisms able to maintain its state of *dynamic stability*, and the important principle of self-regulation. Self-regulation means the systems capability to adapt to a changing environment even when it means re-organising its own structure and functions. Organisational Cybernetics and the associated VSM thus draws upon a wider range of cybernetic principles including the theory of viability, the concept of requisite variety, homeostasis, autopoiesis, and the concept of recursive organisation (Ashby, 1958). From an organisational cybernetics perspective, the organisational patterns of higher-level systems can be repeated in the organisation or lower level systems. This can also be observed in supply chains that consist of many different suppliers that can be viewed as separate systems themselves and which are involved in many different interactions, taking the form of a nested system(s), explained as a system that is composed of embedded subsystems (Simon, 1962).

The example of a viable system that served as the basis for the VSM's birth is the organisation of the brain and the organs in the human body as a neural network, communicated through the neurological system; both the neural network type of organisation and its implicit principles of self-organisation and distributed control appear to be of equal relevance to social organisations of all shapes and sizes as suggested by core principles of organisational cybernetics (Jackson, 2005). Therefore, VSM can be described as a model of the organisational features within any viable system (Jackson,

1991). However, viability in this case does not refer to economic viability. Instead, viability in VSM terms refers to a system's ability to retain an independent existence within a specified environment (Beer, 1985). It suggests that central to organisational viability is the dynamic structure determining the adaptive connectivity of the system's components (e.g. some businesses might not survive even addressing all its financial constraints). For example, a company that runs a profitable business may well be regarded as a viable system, but if it depends only on one customer that decides to switch to another company, it puts its viability in question. The VSM, therefore helps to design an organisational structure that can be deemed viable and diagnose a faulty one. Viability, in VSM's terms, should also not be confused with the concept of 'sustainability' associated with the triple bottom line, including economic prosperity, environmental quality and social justice (Elkington, 1997). Espinosa and Walker (2017) argue that adherence to these sustainability principles would require further actions and new responsibilities to be added to the existing business practices and their organisational systems, therefore 'viability' can be and should be regarded as a precondition for sustainability.

VSM building blocks

The building blocks of the VSM consist of three main elements: a set of *operations* (O), consisting of system's basic activities, in which is embedded a *meta-system* (managerial support) (M); and an *environment* (E), in which O and M are embedded. The operations and the meta-system are further sub-divided into five interacting systems, called System one, two, three, four and five that can be understood as typologies of functions similar to those performed by the human body, its organs, nervous system and the brain (Espinosa and Walker, 2017).

System one (S1) is referred to a collection of operational elements of a system in focus, responsible for the primary activities, which are responsible for implementing the purpose of the system in focus. *System two (S2)* acts as a service for S1 by ensuring that S1 parts act cohesively and do not get in each other's way, i.e. it provides an anti-oscillatory function. According to Beer (1979), S1 may experience an uncontrolled oscillation unless a sufficient element of 'damping' is introduced and thus S2 exists to damp oscillations. In a manufacturing firm an example of an S2 would be a production protocol. Espinosa and Walker (2017) note that a lack of effective S2 mechanisms may lead to 'oscillatory disease' resulting in competition rather than collaboration, and conflict rather than harmony.

System three (S3) refers to general management of an S1. S3 is concerned with all that is going on inside the firm and 'now', as it has direct links with all managerial roles of S1s. S3 works closely with S2 which will be responsible for disseminating policies, guidelines and day to day information to and from the divisions. Therefore, S3 functions are managerial functions at the corporate level that relate to the continuous activity of the firm's internal operations. S3 primarily functions to govern the stability of the internal environment of the firm or organisation by ensuring synergy of S1 through resource bargain, since S1 may involve more than one operation, each requiring their own resources. In a business environment it would normally fall to the general managers to fulfil the S3 function (Beer, 1986).

System three star (S3)* is a servant of S3, fulfilling an informal auditing role to ensure that S3 specified targets and S2 rules and regulations are being adhered to (Jackson, 2005). S3* functions can include informal internal as well as external audits but are not there all the time and are rather triggered occasionally by S3. *System four (S4)* is dedicated to the larger environment. Beer (1986) called this function 'outside and then' by

explaining that every viable system is involved in an environment that is wider than the sum of S1 environments. While systems 1, 2 and 3 are considered 'inside and now' S4 is responsible for the 'outside and then'. S4 thus performs 'environmental scanning' by looking for and capturing information about anything happening in the outside world that may potentially either benefit or threaten the organisation (Espinosa and Walker, 2017). Activities like R&D, market research, corporate planning, economic forecasting, management development, etc., are all S4 type of activities. Organisations need to be responsive to changing environment and remain up to date with information and new innovations in the market. However, just to be up to date with information is insufficient as this information needs to be used. Therefore, whoever performs S4 activities within organisations needs to be able to communicate gathered information with S3 which, depending on a system in focus, can be organised in a more informal or formal way. According to Espinosa and Walker, Beer called this interaction between S3 and S4 the 'adaptation mechanism'.

System five (S5) is responsible for the organisational closure, identity and ethos and organisational policies. In autocratic organisations S5 may well be the corporate directors; but in a more democratic organisation S5 may consist of many people, for example the heads of S3 and S1. It is vital to achieve effective interactions between S4 and S3 on a continuous basis, to ensure system's viability, and therefore one of the main S5 tasks is to monitor the balance in the interactions between S3 and S4. Further, systems 2-3-4-5 types of roles in a viable system are meta-systemic to operational (missional) roles (S1). Figure 1 shows a graphical representation of the VSM, where S1 including multiple operations and their operational management (1a, 1b, 1c) are represented as (O); the meta-system (M), encompasses all the support roles S2, S3, S4, S5, and the environment (E) which includes all the stakeholders the organisation relates to, which are outside the organisational boundaries (e.g. customers, suppliers, competitors).

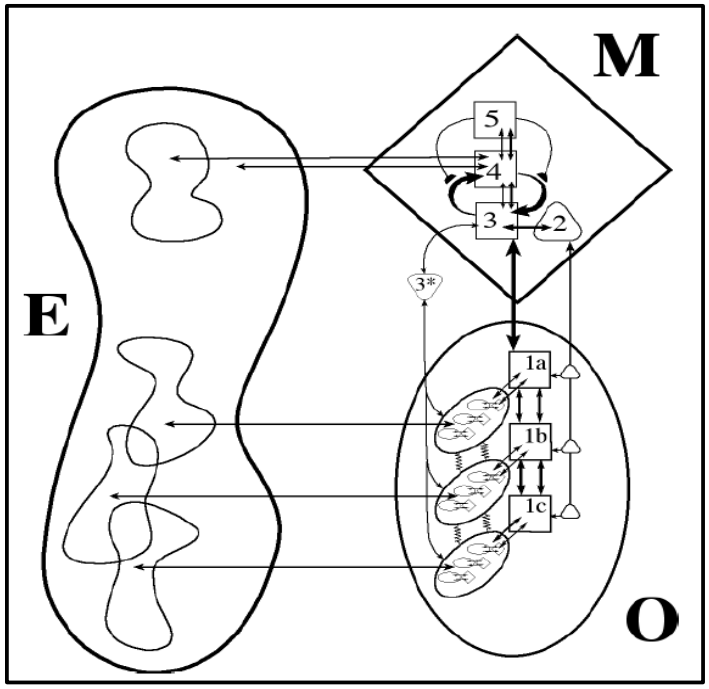

Figure 1: The Viable System Model (Source: Espinosa and Walker, 2017: 127)

The UK Offshore Wind Industry

The offshore wind (OSW) industry, together with onshore wind, form part of the renewable energy source sector and acts as a natural fuel to generate clean electricity by means of wind turbines that are designed to convert kinetic energy derived from wind into electrical energy (EWEA, 2009). What makes OSW different from onshore is that OSW farms are built out at the sea and due to the UK's favourable OSW market conditions, such as shallow seas and strong winds, the UK has been the largest OSW market in the world since 2008 and continues to maintain its leading position with nearly 40% of the global OSW installed capacity (Danilova et al., 2016). This makes OSW one of the key technologies in meeting the UK government's 2050 greenhouse gas (GHG) emission reduction targets, aiming to reduce 80% of the GHG emissions by 2050.

Recognising the advantage of its natural wind and sea resources, the UK Government is keen to capitalise on the OSW industry by securing inward investment and by the development of the UK domestic supply chain with an outlook to increase its global competitiveness and reduce costs (LEANWIND, 2017). To achieve its objectives the UK government offers a range of support mechanisms. One such support is a subsidy mechanism known as the Feed-in Tariff with Contracts for Difference (CfD) which became effective in 2017 and replacing the former Renewables Obligation policy. As part of this subsidy mechanism, developers of 300 mega-watt (MW) and above power generation capacity projects are required to submit the, so called, supply chain plan, outlining the ways developers expect to contribute to the domestic supply chain development (Danilova et al., 2016). This requirement is interpreted as a local content requirement (LCR), a policy requiring a foreign investor or other companies involved in the industry to contribute to the national economy by purchasing local goods and/or services (OECD, 2016). While such support mechanism is generally perceived as a positive contribution for the local economy, it might however pose some challenges for the existing supply chains, as the need to comply with LCR policy might put existing buyer-supplier relationships at risk, potentially affecting the viability of the whole supply chain. This, therefore, suggests the need for an in-depth systemic analysis of the OSW supply chain to understand its current integration levels, that according to literature, have direct relation to the performance of the whole supply chain, and to understand the role LCR policy plays in the formation of the OSW supply chain.

Offshore wind supply chain structures

Academic literature recognises that the context of the OSW supply chain is related to the project-based environment that differs from more traditional process-based environments like continuous manufacturing or retail environments (D'Amico et al., 2017). Therefore, the most common perspective currently used to describe the OSW supply chain is by describing its principle phases rather than its structure and processes, which is more accepted in the retail or process-based supply chain environments. Building on this perspective, this study distinguishes five phases that is development and consenting (D&C), manufacturing and supply (M&S), installation and commissioning (I&C), operations and maintenance (O&M) and de-commissioning (De-comm) phase, and views ports as decoupling points in the supply chain that decouple activities that happen onshore from those that happen offshore, as shown in Figure 2 (Danilova et al., 2016).

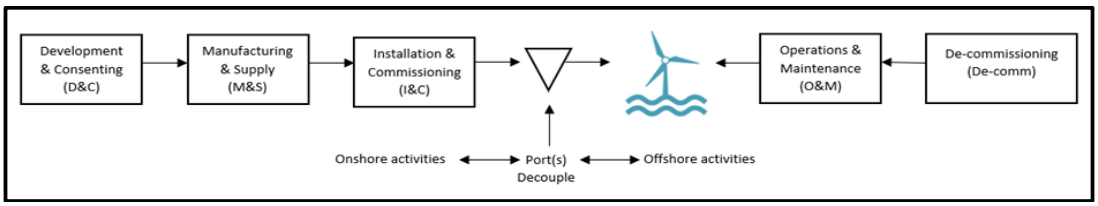

Figure 2: Phases in the offshore wind supply chain (Adapted from Danilova et al., 2016)

It is important to note that each phase may be considered as a different supply chain. The same holds true for all the different component manufacturers, who are likely to have their own supply chain networks for parts sourcing. Therefore, it suffices to say that OSW supply chain is complex, constituting different levels of different supply chain networks. Considering this complexity, this study offers another OSW supply chain representation, shown in Figure 3, that encompasses a network perspective and its associated flows (Grant, 2012).

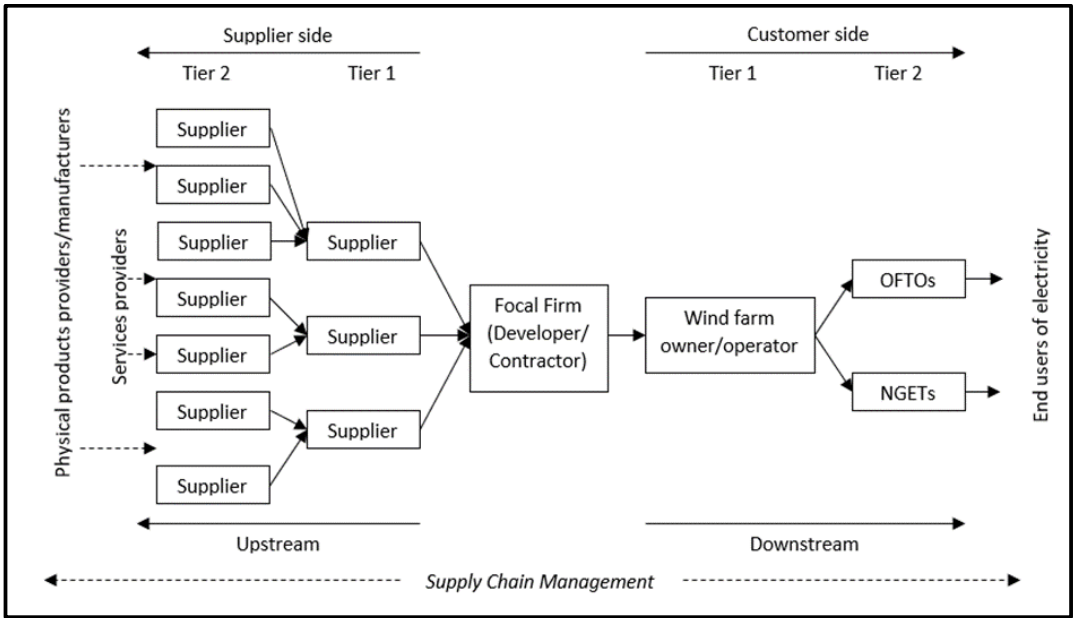

Figure 3: Network perspective of an offshore wind supply chain: (Adapted from Grant, 2012)

Development of a Conceptual VSM for the UK OSW Supply Chain

Espinosa and Walker (2017) suggest their 'methodology to support self-transformation' as a guideline to use the VSM for organisational design or diagnosis, as it helps participants to engage in improving their organisational viability (Espinosa et al., 2015). It involves several stages: The first stage is to identify the 'system-in-focus' for the VSM analysis by understanding its identity and purpose. This can be achieved using rich pictures, a cartoon like representation of a studied situation that allows to capture the main issues and opportunities people may experience in the studied system; and by doing a TASCOI analysis: TASCOI is a mnemonic that stands for **T**ransformation, **A**ctors, **S**uppliers, **C**ustomers, **O**wners and **I**nterveners (Espejo and Reyes, 2011), adapted from Checkland's (1990) CATWOE (customer, actors, transformation, worldview, owners, environment). The second stage involves Recursive Analysis. This concept of 'recursion' refers to Beer's "Recursive System Theorem", saying that "in a recursive organisational structure, any viable system contains, and is contained in, a viable system" (Beer, 1979:

118). The purpose of this analysis is to identify and map the relevant recursion levels of the system. The third stage involves structural diagnosis using VSM as seen in Figure 1. The fourth stage involves aligning strategy and structure, based on identified diagnostic issues. The fifth stage involves securing agreement on the necessary changes needed to achieve desired improvements and implementing them. The last stage then involves monitoring and assessing the changes.

For the purposes of the proposed research, a simplified version of 'methodology to support self-transformation' is adopted, involving the first three stages to explore the OSW supply chain based on a single case study of the OSW farm in the UK, namely "Hornsea Project One" that once built will be the largest OSW farm in the world. The stages of analysis include specifying identity of the system, performing recursive analysis to surface the system-in-focus and applying VSM analysis of the system-in-focus to make recommendations on potential improvements of the OSW supply chain integration and its performance. Based on TASCOI analysis, preliminary identity of the system is defined as: "*Hornsea Project One offshore wind farm development network is a system comprising businesses that are engaged in the process of building an OSW farm that once completed will produce clean electricity*".

A completed OSW farm is seen as the main output of the transformation process in the identified system; such transformation (T) can be realised through supply inputs as those products and services necessary to build the wind farm. The main actor (A) that carries out this transformation is likely to be the developer and his support organisations, that acts as a focal firm in the supply chain. Suppliers (S) in this case have the direct meaning of all those suppliers of the main components and services needed to build a wind farm. Customers (C) in this case would be those interested in operating the wind farm, once completed, and selling clean electricity, as well as receiving it. These would include offshore transmission owners (OFTOs), who act as owners and operators of electricity transmission assets, national grid electricity transmission (NGET), electricity suppliers and end consumers of electricity. The role of the owner (O) of this system belongs to the developer of the OSW farm. Finally, interveners (I) or external agents that might affect the performance of the transformation process of a given system, are likely to be national and regional governments, environmental agencies and competitors of different types of energy sources.

It is important to note, however, that the above 'working' definition of the system is produced initially by taking the researchers' perspectives aiming to use it to enable further clarifications from the real-world participants in a wind farm build project - as different actors would have different viewpoints about the identity of the system. The following stage involves recursive analysis necessary to identify the levels of recursion of the system, as well as the levels of its complexity. Recursive analysis is based on the primary activities of the system that are aligned with its transformation processes. As explained by Espinosa and Walker (2017), primary activities are directly related to organisation's purpose that transform certain inputs into products or services. Therefore, this process also helps to distinguish primary activities of the system from support ones.

Considering that this research focuses on the supply network for the Hornsea Project One OSW farm development and construction, its supply chain phases, up to the O&M phase, have thus served as the bases for distinguishing the system's primary activities or S1s. Figure 4 shows the preliminary recursive analysis of the system in focus, where certain numbers indicate lower recursion levels. For example, development and planning activity contains such activities as consenting, environmental surveys, engineering and consultancy etc, that are considered as the next level of recursion down and are thus numbered as level 1. Engineering and consultancy also contain several more activities

that are considered as the next level of recursion and are thus numbered as level 2. Three dots in brackets indicate that each activity would contain more levels of recursion, however, the importance of this analysis is to identify those activities that are of more concern for the subsequent analysis. Figure 4 only shows lower level of recursions of the system in focus, however, it is important to remember that the system in focus itself is embedded in higher-level systems, therefore upper recursion levels also exist which are not analysed yet in this preliminary research.

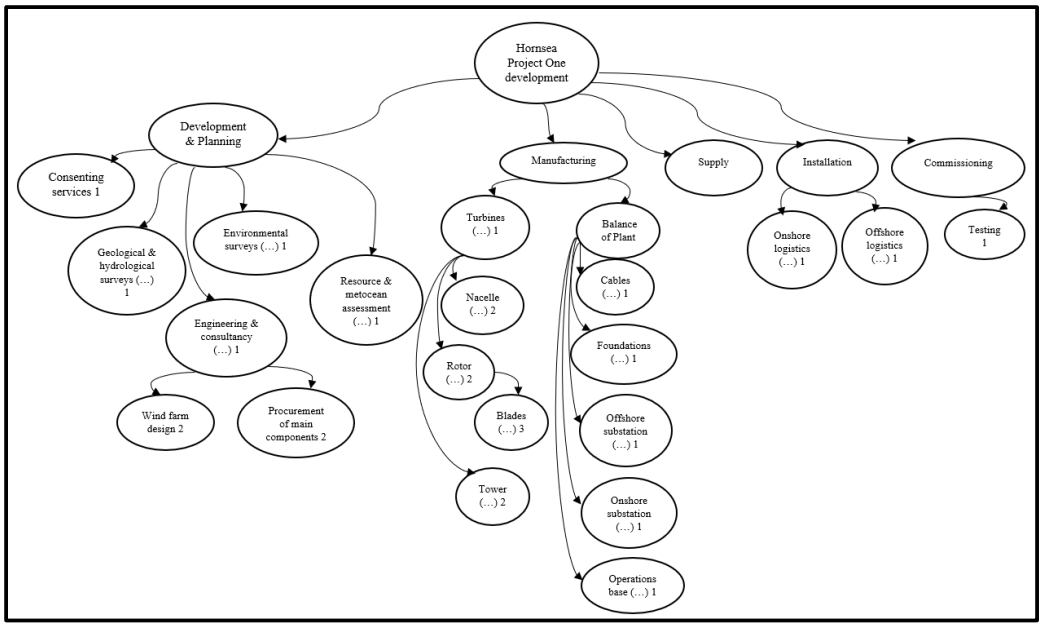

Figure 4: Recursion levels of system in focus

The identified system in focus with its levels of recursive organisation, will be used for the subsequent VSM analysis that will involve drawing several VSM diagrams, where each recursion level will be represented in terms of its own primary activities and their interactions with their local environments. Primary activities of each recursion level are considered as the S1s of the VSMs. In the Hornsea Project One OSW farm development, all suppliers of primary activities involving both physical products and services are considered as S1s. Systems 2 to 5 are meta-systemic functions responsible for bringing all operations together into a unified system. Considering that the S2 function is to ensure cohesion among S1s, it is, therefore, of particular interest to this research, which looks to identify the necessary supply chain integration criteria in the OSW farm construction. Part of the research will, therefore, involve identifying any standards in the existing supply chain processes, such as order standards, scheduling, communication etc., including any standards pertaining to supplier selection processes. While studying S3 -a function of which is likely to belong to the wind farm developer or a contractor - emphasis will be placed on the existing and potential synergies among S1s, as S3 needs to ensure that S1s perform their tasks with minimum risks to the performance of the whole system. Resource bargain is one of the mechanisms through which such synergy can be achieved; the accountability channel of S3 then helps to monitor that S1s have delivered on expectations, based on agreed resources. Another responsibility of S3 is to ensure that all operations are performed within legal and corporate norms. Thus, LCR policy compliance will be considered within S3. Within S4, the emphasis is placed on the system's in focus interaction and adaptation to any changes in the external environment, such as changes in

political and economic environment, technological innovations and so on. Within S5 the interaction between S3 and S4 will be assessed, as it is important for system's viability to achieve interaction between S3 and 4 on a continuous basis (Beer, 1979).

Proposed Research Agenda

The VSM analysis based on Espinosa and Walker's (2017) suggested 'methodology to support self-transformation', as outlined above, will be empirically tested during 2019 based on a single case study research strategy. The case study selected is the Hornsea Project One OSW farm, located off the East coast of the UK. This wind farm, which is currently under construction, will be the largest wind farm in the world, comprising up to 174 turbines with 1.2 gigawatts (GW) power generation capacity. It is selected to provide current ground to systemically explore the OSW supply chain and its integration levels, summarised in the main research question: How can an in-depth systemic analysis of the OSW supply chain support its level of integration and, therefore, increase its potentiality for improved performance? Data will be collected using semi-structured interviews (inspired in VSM theory) with representatives of the main operations of the Hornsea Project One wind farm development network to enable clarifications of system's identity and VSM concepts.

Conclusion

The paper's objective was to discuss the use of the VSM to investigate the UK OSW industry's supply chain and create an understanding of the structural organisation of the OSW supply chain and identify necessary SCI aspects pertaining to the construction of an OSW farm. From a theoretical perspective this paper contributes to the logistics and SCM literature by proposing and demonstrating that VSM and related methodologies, provides a useful systemic approach to analyse supply chain structures. This paper also contributes to practice by enabling UK businesses wanting to be part of the OSW farm construction and maintenance sector to understand their supply chain structures and integration factors by using VSM criteria and tools to improve them. As with all papers there are limitations. As a conceptual paper, which develops a conceptual model for the UK OSW industry it will need to be empirically tested later to confirm its efficacy: and this process is already underway and will be the central aspect of this research. Further, this paper only considers modelling and analysing one industrial sector in one geographic location. Future research should investigate application of the model to other sectors and to other wind farms elsewhere in the world.

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Game-based closed-loop supply chains: identification of metrics towards developing new models

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Abstract

CLSCs in the literature consist of some characteristics that identifying, studying and classifying these features help to formulate new models that do not exist. As there are lots of research on the investigated area, we concentrate on the CLSC models that used the game theory approach. Therefore, gathered works concern a game among the participant parties in the loop in the form of cooperation or competition known as centralized or decentralized frameworks respectively. A systematic literature review is carried as a four-step process containing material collection, descriptive analysis, category selection and evaluation stage. These characteristics are classified into twelve categories.

Keywords: Closed-Loop Supply Chain, Literature Review, Game Theory

Introduction

Closed-loops as a special configuration of the circular economy in the supply chains have received considerable attention due to their applicability in the sustainability process such as remanufacturing, refurbishing and recycling (Masi et al., 2017). They integrate material, financial and information flows connecting downstream to upstream enterprises through a supply chain to construct a unique system and create additional values (cf. Mishra et al. (2018) for real cases). CLSCs consist of many characteristics that identifying and classifying these features help to formulate new models (Souza, 2013; Govindan et al., 2015).

Operations in CLSC have predominantly shifted to exploit the techniques provided by the game theory to analyze the behaviour of the rational player, stakeholder choices and designing voluntary extended producer responsibility policies (Guo et al., 2017). Accordingly, in present research important factors, those which are applied especially quantitatively in the formulation of CLSCs are derived. These factors are categorized in several classes which help not only to build new CLSCs but also to find research gaps. Gathered works concern a game among the participant parties (i.e. manufacturer, retailer, consumer and etc) in the loop in the form of cooperation or competition known as centralized or decentralized frameworks respectively. Fig. 1 shows different parts of a

loops based on three phases as the loop structure (i.e. forward and revers directions) and the optimization method designed based on the game theory.

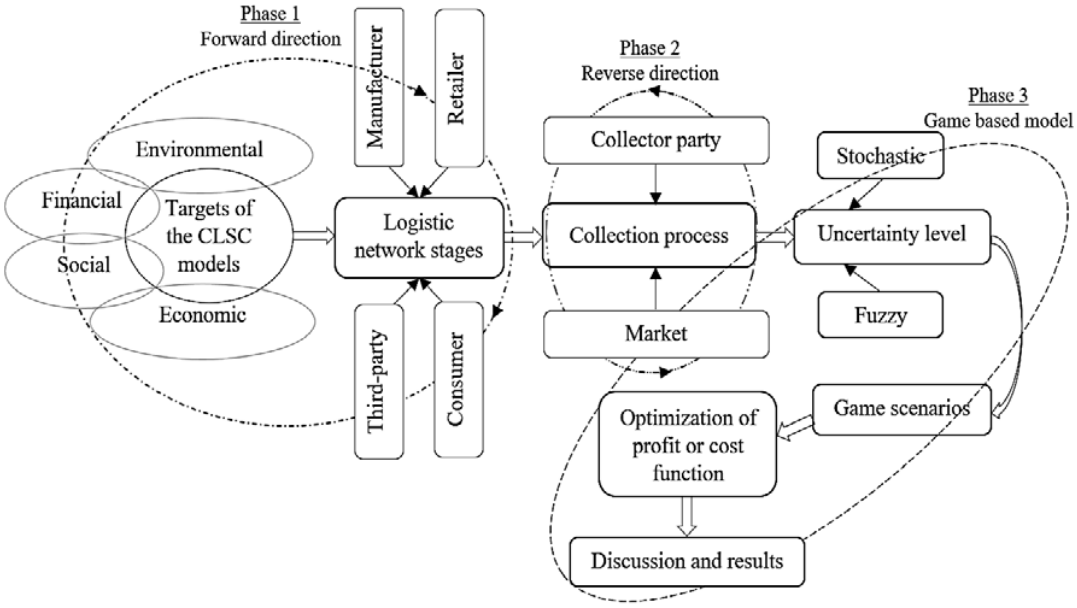

Figure 1 – Closed-loop structure

Objective and methodology

A systematic literature review is carried out based on the methodology suggested by Mey and Mruck (2010) that introduced a four-step process containing material collection, descriptive analysis, category selection and evaluation stage. It is tried to reply the main question of the research: "which factors are important and effective on the formulation of CLSC models designed based the game theory?"

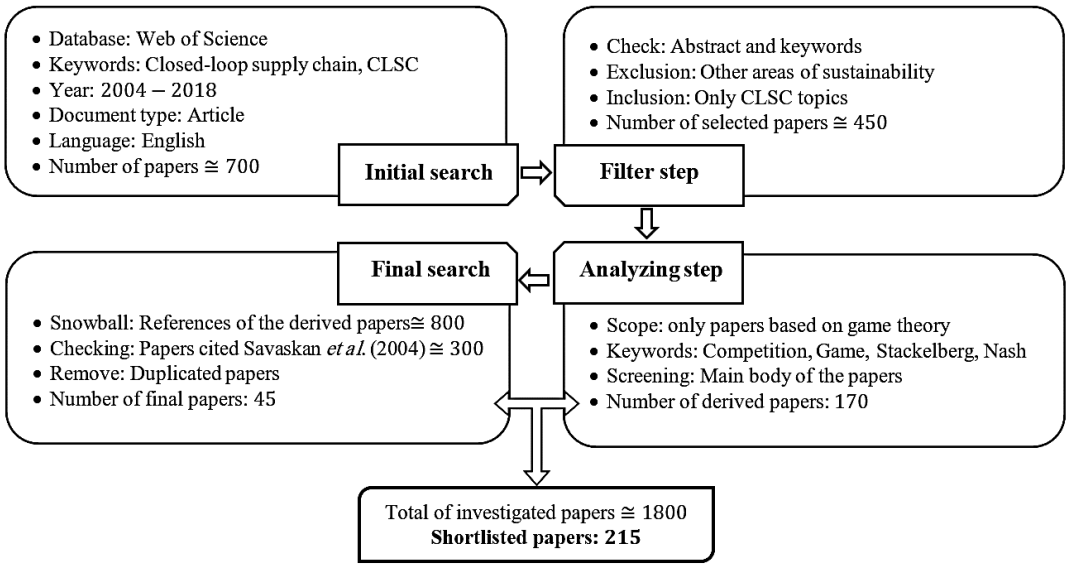

Figure 2 – Different steps of the research methodology

Literature search

Whole of the related literature is searched in four stages including initial search, filter and analyzing step and final search as explained in Fig. 2 in details. More than 1800 papers

are derived based on an initial search in Web of Science™ using the keywords "closed-loop supply chain" and "CLSC", and also a snowball on the references of the related works. Finally, the content of 215 papers published in the area of game-based CLSCs over the span of fifteen years (2004–2018) are carefully inspected and analyzed.

Descriptive analysis

Fig. 3 presents the academic peer-reviewed journals as to the number of papers that they are published regarding the investigated topic. Totally 62 journals are searched. However, only the journals with more than 2 published papers (i.e. 21 journals) are shown. *Sustainability* consists the largest number of research articles (≅ 12%). To build a strong integration of CLSC and game theory, *IJPE* has shown its significant contribution by the second largest percentage (≅ 10%) of the total articles.

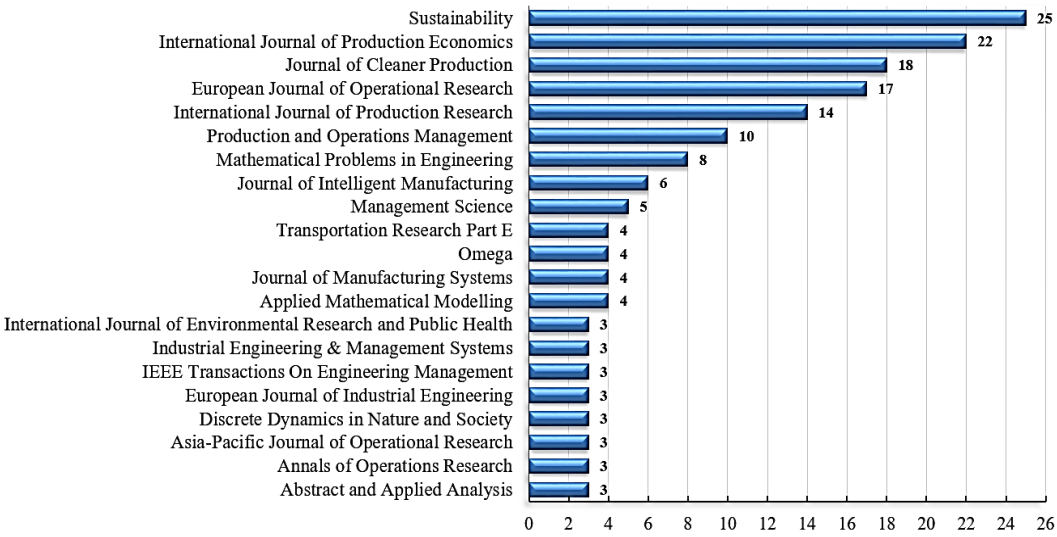

Figure 3 – Distribution of the reviewed papers by journal

Fig. 4 illustrates an overall increase of the total amount of articles published after 2011. An intermittent peak is apparent in 2013 when twenty papers are published before dropping to seventeen in 2014. Roughly 76% of the research are published throughout the recent 5 years, highlighting the importance of this field. Although the first paper was published in 2004, it seems this area had not received enough attention initially.

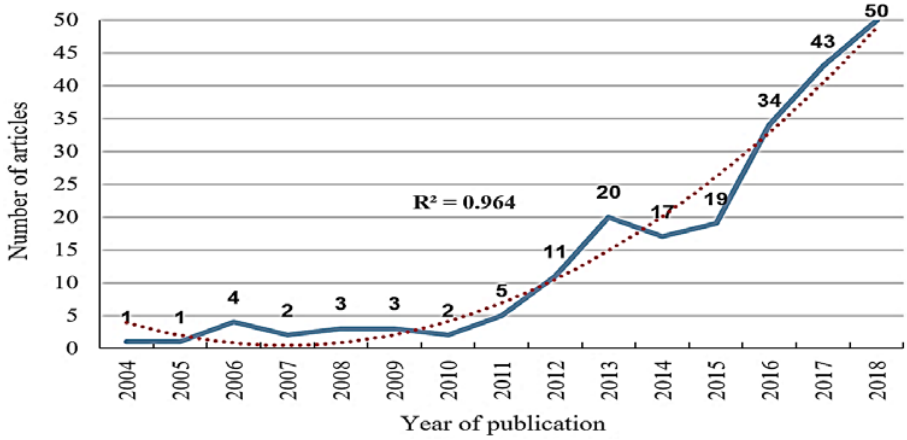

Figure 4 – Distribution of the reviewed papers across the period of the study

Category selection

Considered factors are derived according to studying whole of the selected papers and the objects of the model(s). To do so, after screening each paper carefully, especially studying the notations used in the formulation of CLSC models, the explained factors are derived according to the target of model(s) in each paper. It should be noticed there are 21 papers with the focus only on the structure of the CLSC network and the effect of different relation of the players in the loop in which none of the investigated factors could be found in the model such as the one related to Savaskan et al., (2004). The intention was to assign each factor to a specific class, however, whenever an overlap was seen between two categories, the factor was assigned to the nearest class.

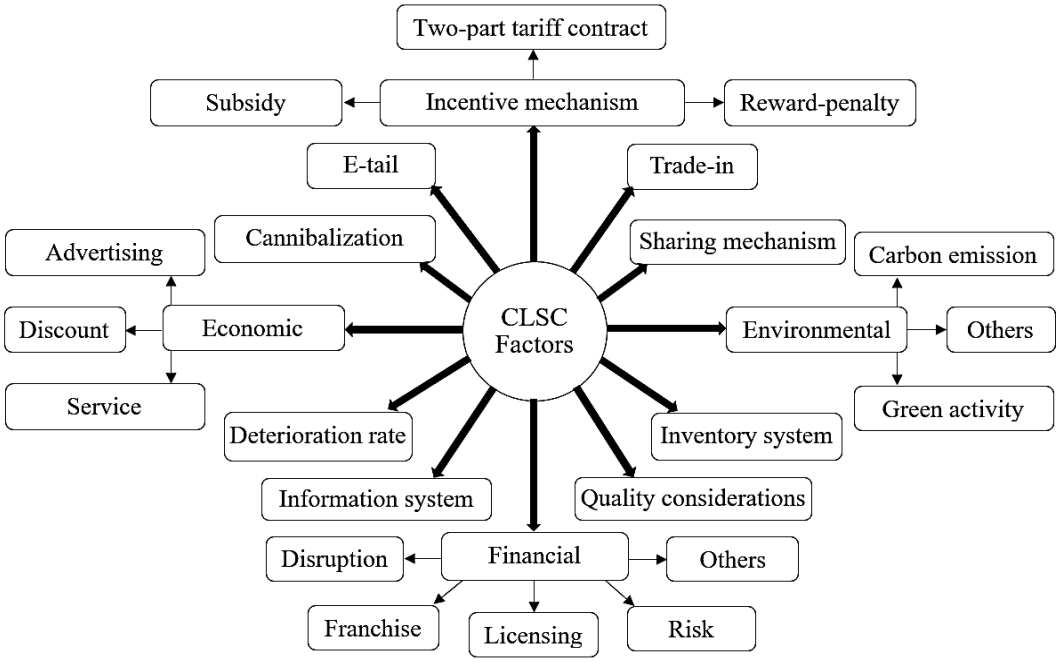

Figure 5 – Categorization of the investigated and derived factors in the CLSC models

Fig. 5 shows the categorization of the derived factors. They are organized into 5 main categories including (1) incentive mechanism, (2) economic, (3) environmental, (4) financial and (5) other factors. The first one refers to the operations in which improve the performance of the loops regarding the sustainability processes such as the subsidy considered for the manufacturer (he) by social planner if he involves in remanufacturing (Mitra and Webster, 2008). The second one is classified in three different categories which mainly can be regarded as economic factors such as the discount for the remanufactured products. The third one is related to the actions to care the environment such as the costs to reduce the hazardous material released to the environment mentioned as green activity. Fourth category deals with the financial factors such as disruption, which is, for example, a fluctuation of the remanufacturing cost due to occurring a natural phenomenon (Huang and Wang, 2018). There are other factors which are studied independently such as trade-in (Genc and De Giovanni, 2017).

Evaluation stage

Reliability and validity of the gathered papers are evaluated by the authors where deductive and inductive methods are conducted. In order to derive the structural dimensions which are led to correct classifications, in deductive approach the papers are

chosen and then analyzed, while in the inductive technique these dimensions are developed from the material by means of generalization (Mey and Mruck, 2010). The collected papers were again crosschecked with Scopus that it is one of the most comprehensive academic databases.

Review results

Analysis of the main categories shows the concentration of the research, those which model CLSCs as a game among the loop's players. Based on the Fig. 6, the percentages of the research approaching to the economic aspects is more than other categories. Although the difference is not very much, it can show a tendency of tying economic targets to the CLSC as a growing sustainable concept among the researchers. Meanwhile, integrating environmental elements to the CLSC still needs more attention with a current 12% frequency among all factors.

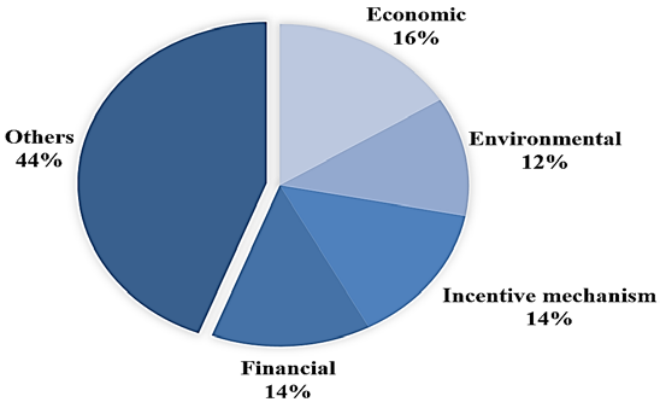

Figure 6 – Frequency of the main characteristics

Fig. 7 compares the application of classified metrics with more details. It is cleared sharing mechanism which is defined as all types of sharing such as sharing costs or operations on the collection process of the returned items has received a considerable attention.

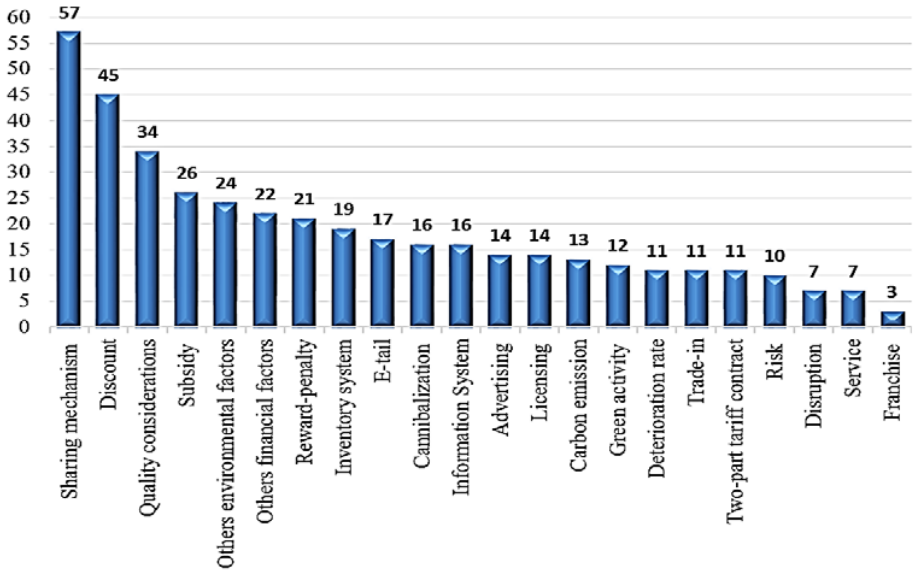

Figure 7 – Frequency of the derived factors among the investigated literature

Fig. 8 presents the complexity of the designed models regarding the investigated factors. The more the number of discussed factors in the studied CLSC model, the less papers can be found. It shows modelling real cases in this area is rather difficult.

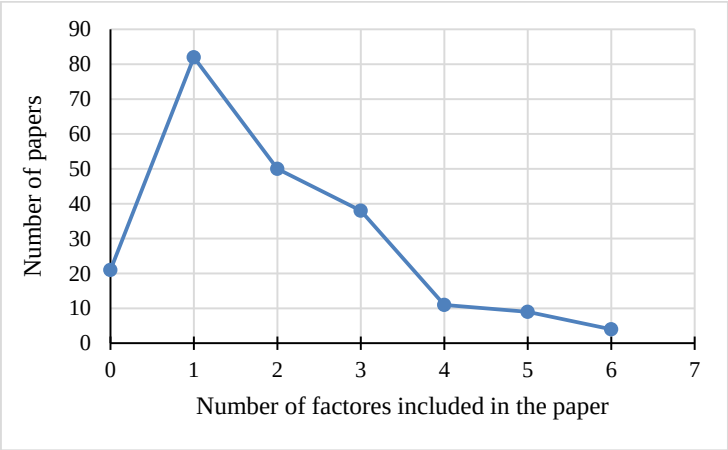

Figure 8 – Frequency of the derived factors among the investigated literature

Table 1 which is symmetric provides interesting results for the readers showing the potential gaps for future research. It shows a two-dimensional characteristic of the existent CLSC models addressed in the topic. For example, the blue square shows there is not any research integrating parameters related to the carbon emission with licensing matters considering the scope of present review. A multi-dimensional is also applicable.

Table 1 – Cross-frequency of the derived factors among the investigated literature

Factor	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
A	**5**	2			1	2			3					1		1		2	1	3		4
B		**9**		2	9	14	7	4	1			3	2	6	4	1	2	5	8	1	7	7
C			**2**	1			2	1										2		4		3
D				**1**		1	6	6							1		1	1	1	2	2	4
E					**0**	4	1	2					1	2	2	1	1	1	2			5
F						**2**	7	3				2		4	3		1	3	5	1	3	7
G							**3**	6	1		1		1	3	3	1	1	3	1	2	4	7
H								**2**			2	1	1	3	1	2	4	2	2	1	3	5
I									**3**		1	1	1	1		1	1	2		2		3
J										**1**		1	1					2				2
K											**0**						3					
L												**1**		2	2		1	3	2		1	6
M													**3**	2				1		1		1
N														**3**				5	2	1	1	5
O															**0**	2		4	1		4	2
P																**6**	3	4		1		4
Q																	**4**	2			1	4
R																		**7**	3	3	3	7
S																			**2**	1	1	1
T																				**2**		7
U																					**0**	
V																						**16**

Definition of notations in Table 1. An explanation for each one is presented at the end of conclusion section.

A: Advertising, **B**: Discount, **C**: Service, **D**: Carbon emission, **E**: Green activity,
F: Other environmental factors, **G**: Subsidy, **H**: Reward-penalty, **I**: Two-part tariff,
J: Disruption, **K**: Franchise, **L**: Licensing, **M**: Risk, **N**: Other financial factors,
O: Deterioration rate, **P**: Inventory system, **Q**: Information system, **R**: Quality consideration,
S: Cannibalization, **T**: E-tail, **U**: Trade-in, **V**: Sharing mechanism.

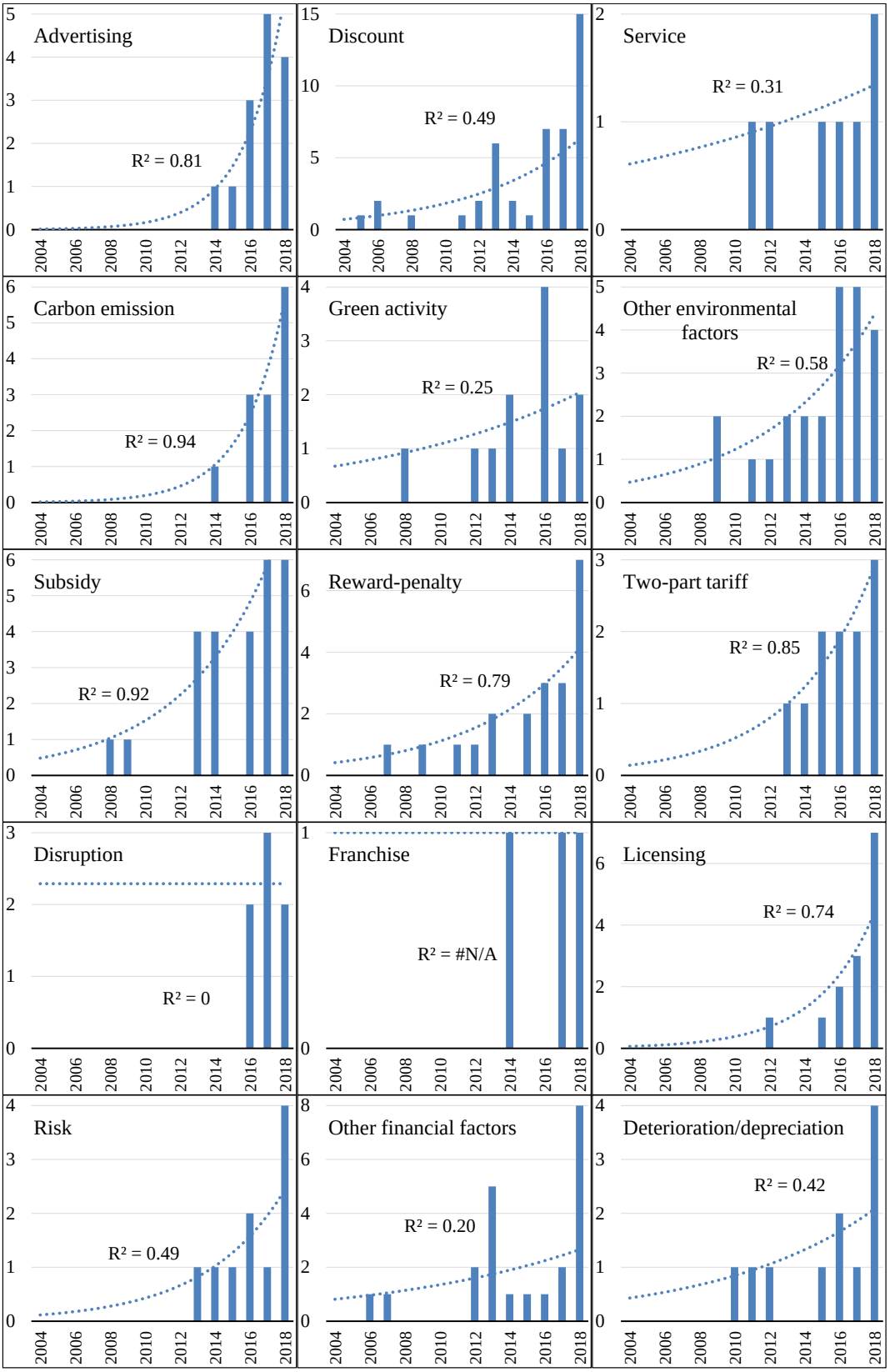

Figure 9 – Analyzing trend of the investigated factors during the considered period

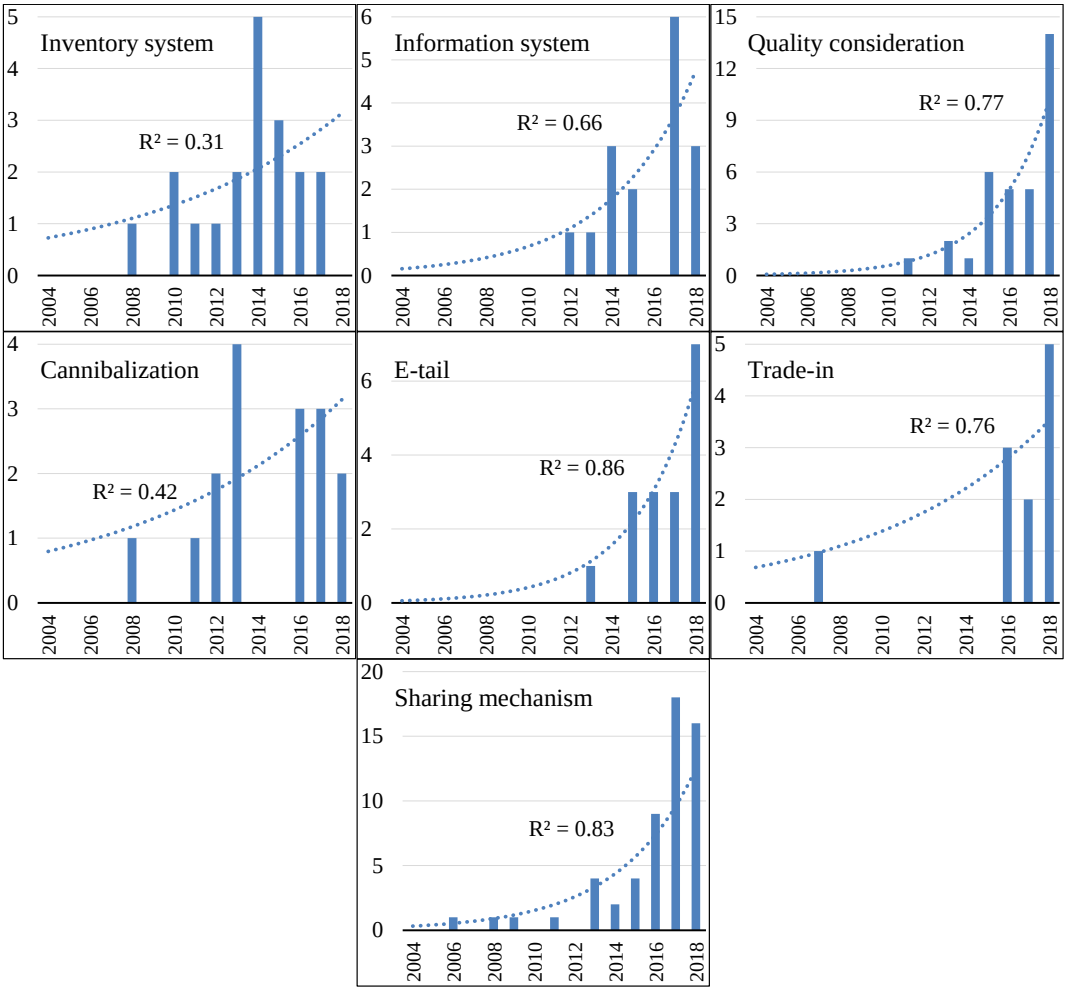

Figure 9 – Analyzing trend of the investigated factors during the considered period (continue)

An analysis is performed regarding each factor separately. Fig. 9 illustrates results of frequency of the derived factors over the period of the study. As it is clear, sharing mechanism and reward-penalty mechanism are two effective factors in which are growing almost consistently during the considered time horizon. Factors such as quality consideration, advertising and two-part tariff have received more attention and are applied incrementally recent years after 2012. Developing CLSCs related to the inventory systems and cannibalization has been slowly decreased recently. Researchers can use the results of other presented bar charts as a guideline in the CLSC area for future research.

Conclusion

Circular economy (CE) is a pivotal concept playing an important role in today's modern economic systems in the developed countries. The CE suggests replacing end-of-life products/materials with the reused, recycled and/or recovered ones (Kalmykova et al., 2018). At a micro level (i.e., activities related to the products, markets, consumers and enterprises) closed-loop supply chain (CLSC) operates as an effective approach in the context of economic, environmental and social systems.

This is the first time that a comprehensive research is conducted on the CLSCs existed in the literature in which the models are based on the game theory. Characteristics of these models shown quantitatively in the formulation are derived and categorized. It certainly

can serve companies and practitioners when playing and deciding in operational closed-loops.

A coding-cross-referenced database is designed matched to the discussed factors shown as "Reference: [used factor(s)]". Comparison of these combinations in pairs as provided in Table 1 (e.g. Reference A: [factor a; factor b; factor c] and Reference B: [factor b; factor d]) leads to identify the gaps in the literature while it allows addressing CLSCs with the novel combination(s) for new cases. The mentioned factors and studied papers are classified according to the descriptive statistics such as year of publication, journal, frequency and etc. Contents of the works are analyzed and patterns and research streams are found.

It is shown that updated versions of CLSC models exploit more factors addressing the real situation as compared to the initial models. Results clear that among the categorized factors, sharing mechanism has got the priority by the researchers. However, other areas such as the disruption which is an appropriate approach to control the market fluctuations still need to be investigated more thoroughly.

Explanation of the derived factors:

Advertising	It is cost of the party to increase the selling and demand market.
Discount	It is a discount on the product such as the remanufactured one.
Service	It is after-sales maintenance, warranty repair agreements and so on provided by a player such as the retailer to the customer.
Carbon emission	It is all parameters (e.g. cost or quantity) related to the gas pollutant such as carbon or CO_2.
Green activity	It is the actions to care the environment such as the costs to reduce the hazardous material released to the environment.
Subsidy	It is a support by the social planner, which is usually the government to a party to increase the performance of the CLSC.
Reward-penalty (RP)	If the incentive mechanism has a two-side effect which means includes not only incentive but also a penalty, it is a RP.
Two-part tariff	It is generally a contract in which usually the manufacturer pays a fixed amount to the retailer to motivate him for the recycling.
Disruption	It is related to analyzing the fluctuations of the cost, amount such as order quantity or price.
Franchise	Franchise fee is a common phenomenon in practice, such as franchised store or represents the fee paid by the retailer to the manufacturer for the sale of the product.
Licensing	It is a payment to the manufacturer, or the one who provides the technology licensing in the form of patent licensing fee.
Risk	It is considered to deal with risk matters such as risk aversion cases or the effect of risk reduction of demand and etc.
Deterioration rate	It is related to the depreciation or deterioration of items during their life.
Inventory system	It is related to consideration of the inventory parameters in the CLSC model such as holding cost.
Information system	It includes the subjects related to the information systems such as symmetric and asymmetric cases on information.
Quality consideration	It is investigation of quality matters such as the quality of the returned items or recycled products.
Cannibalization	It is analyzing the effects of selling remanufactured products on selling the new ones.
E-tail	It is online operations which usually defined as online retailing via internet.

Trade-in	It is operations in which a situation is provided for consumers to return back the used items and exchange it with a new item.
Sharing mechanism	It is all types of sharing such as sharing costs on the collection process of the returned items or sharing the return rate and etc.
Other financial factors	It mainly considers different types of cost such as a fixed cost imposed to the players in different process.
Other environmental factors	It is all other types of impacts which is related to the environment.

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Due to the limitation on the overall length of the conference papers to only 10 pages, if you would like to see and check all references, please contact directly to the corresponding author via email address eshokryan@gmail.com.

The relationships between competitive dynamics and strategy, and supply chain agility, adaptability and alignment

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Abstract
This paper seeks to analyse how some structural characteristics of the company's industry (the competitive intensity of the industry, the complexity of the supply chain, SC), and the company's competitive strategy influence the implementation of the SC's Triple-A dimensions (adaptability, agility and alignment). The hypotheses are tested using data from 277 Spanish manufacturing companies (10.5% response rate) analysed with PLS-SEM. The results show that competitive intensity is the most important factor, followed by SC complexity. Additionally, cost strategy is found to negatively affect adaptability and that the differentiation strategy does not exert a significant influence on any 'A'.

Keywords: Competitive dynamics, business strategy, Triple-A Supply Chain

Introduction
Contingency Theory (Lawrence & Lorsch, 1967) states that contextual variables can affect the level of achievement or implementation of tools and business practices. Therefore, since rivalry is increasingly being contested at the supply chain (SC) level (Ketchen & Hult, 2007), knowledge of the SC's context is important for the SC to be adequately managed, an indispensable requirement for the success and survival of companies. In this regard, the Triple-A SC emphasises the importance of orchestrating agility, adaptability and alignment for SC effectiveness (Feizabadi et al., 2019). Many authors agree with Lee (2004) that SC agility is important because it allows a SC to

address short-term changes and interruptions in supply or demand. The adaptability of SC that supports adjustments to long-term market changes is also considered necessary. Finally, the alignment of objectives and incentives among the members of the SC has been recognised as an indispensable requirement for success, since it focuses the entire supply chain on serving the final customer.

This study seeks to contribute to SCM by analysing three important drivers of the Triple-A SC that few studies have theoretically and empirically assessed. It also attempts to identify the individual influence of these drivers on each of the Triple-A SC dimensions following an approach that, while not greatly explored, has been used in recent previous research (Dubey et al., 2015; Dubey & Gunasekaran, 2016; Attia, 2016; Feyissa & Sharma, 2016; Gunasekaran et al., 2017; Dubey et al., 2018; Alfalla-Luque et al., 2018; Feizabadi et al., 2019). Considering these three dimensions separately allows any differences between them in temporal terms to be incorporated into the analysis — according to Tang & Tomlin (2008), alignment, adaptability, and agility connote long-, medium-, and short-term perspectives— as well as any differences in their specific effects on several performance measures (Alfalla-Luque et al., 2018). Therefore, this study addresses two relevant research questions: 1) Does a company's competitive dynamics (i.e., the level of competitive intensity in the industry and the level of SC complexity) influence the implementation of the Triple-A SC? 2) Does the type of competitive strategy (i.e., cost leadership or differentiation) imply any differences in the implementation of the Triple-A SC?

Following this introduction, next section presents a review of prior studies on Triple-A SC and on the three antecedents that are focused on here. The methodology used is subsequently described. The findings are then discussed and, finally, the conclusions are set out.

Theoretical background and hypotheses

Triple-A SC

According to Lee (2004), achieving a sustainable competitive advantage requires SCs to be agile, adaptable and aligned (Triple-A SC). However, although agility, adaptability and alignment have been defined in different domains (manufacturing, organisational, strategic, etc.), little research has been developed in the SC domain -especially regarding SC adaptability and alignment (Marin-Garcia et al., 2018).

SC agility has been defined as the ability to rapidly detect and respond to short-term changes in real demand and supply in order to generate or maintain a competitive advantage (Alfalla-Luque et al., 2018). An agile SC can adapt to market variations efficiently, respond to final demand quickly, produce and deliver innovative products with cost efficiency and on time, and generate an inventory reduction and external integration (Mason et al., 2002; Swafford et al., 2006; Gligor & Holcomb, 2014). Dynamic and volatile markets need agile SCs that can interpret and respond to customer needs (Scholten et al., 2010).

SC adaptability can be defined as the ability to adapt strategies, products and/or technologies to structural market changes (Alfalla-Luque et al., 2018). The complex and uncertain market environment (economic, political and social changes, demographic trends, changing consumer needs, global context and technological advances) requires an adaptable SC to improve the chance of survival (Tuominen et al., 2004).

Finally, SC alignment is the ability to share information, responsibilities and incentives with SC members in order to coordinate activities and processes (Alfalla-Luque et al., 2018). This holistic focus considers the SC as a single entity (Lee, 2004) and implies strategic collaboration between the different members, with consistent

objectives, strategies and processes (Skipworth et al., 2015; Flynn et al., 2010). The aligned SC should be managed to meet the demands of product speed and complexity by coordinating operations (Kehoe et al., 2007).

The present study follows the approach of considering the three Triple-A dimensions individually, since previous research has still not produced any conclusive results. In this line, Feizabadi et al. (2019) stress that a research focus is required on the antecedents of the Triple-A SC dimensions as a framework. In this regard, the present study analyses the role of three contextual variables as drivers of Triple-A SC, specifically, the competitive intensity of the industry, SC complexity and the company's competitive strategy.

Competitive intensity and the Triple-A SC

At the SC level, the characteristic turbulence of the business environment leads to an agile SC being a managerial imperative not only for the individual chain constituents, but for the entire SC. So, agile SCs outperform less agile competitors (Yusuf et al., 2014) and provide value for mitigating risks from the competitive landscape and for rapid response measures (Braunscheidel & Suresh, 2009).

Adaptability seeks to facilitate close coordination between trading partners and accurate product and service customisation. The objective is to maximise responsiveness, as strategic or extended alliances along the SC (Kim, 2006) are affected by market turbulence (Arora, et al., 2016). Innovativeness is a crucial dimension of SC adaptability since innovation is a means of changing an organisation in response to changes in its environment (Hult et al., 2004). Fundamental shifts in the SC and market environment require firms to increase innovation to remain competitive (Lee, 2004). So, the innovation literature stresses that the more salient competitive benefits that firms facing greater competition can derive are creating additional values for their consumers (He & Nie, 2008). SC adaptability emphasises the need for sensing changes in the SC and market environment and for flexibility in coping with them (Eckstein et al., 2014). Competitive intensity is an external driver that can be used to act on strategic positioning (Hallgren & Olhager, 2009) as it is able to influence SC adaptability.

Lastly, SC alignment involves incentive alignment to prevent any conflicts; information alignment to share equitable risk, costs and benefits; and process alignment to share and exchange knowledge and important and correct information for planning, controlling and decision-making in the SC (Simatupang & Sridharan, 2005). Competitive intensity shapes inter-firm knowledge acquisition (Zhou et al., 2014) and has made organisations rethink the need for cooperative, mutually beneficial SC partnerships and improving business performance (Wisner & Tan, 2000; Flynn et al., 2010). The goal is to achieve effective and efficient flows of information, products and services and money decisions in order to provide maximum value to the customer at a low cost and high speed (Frohlich & Westbrook, 2001; Moyano-Fuentes & Martínez-Jurado, 2016). Proactively sharing information with strategic chain partners is an attribute that is required for gaining a sustained competitive advantage (Roh et al., 2014). In fact, information flow integration provides the basis for financial flow integration and physical flow integration (Sacristán-Díaz et al., 2018). A context of high competitive intensity is what makes the benefits of collaboration with SC partners become more positive (Heirati et al., 2016), as it positively influences SC alignment.

Based on the aforementioned arguments, the following hypothesis is formulated:

H1: Higher levels of competitive intensity positively influence the implementation of the Triple-A SC dimensions (H1a: agility, H1b: adaptability, H1c: alignment).

SC complexity and the Triple-A SC

Complexity is inherent in the management of SCs. Blecker et al. (2005) state that in most cases, SCs operate in dynamic environments with multiple connections between companies, so they are exposed to a large number of sources of complexity. Hence, complexity is an important theme in the SC literature and there is a general consensus that SCs have become more complex over recent years (Bode & Wagner, 2015).

SC complexity generally has negative consequences. Despite prior research on supply complexity being relatively scarce, Blome et al. (2014) indicate that on the SC's upstream side the predominant, overall conclusion derived from the few studies that exist is that greater supply complexity negatively influences performance. Manuj & Sahin (2011) warn that a lack of understanding of the drivers of complexity, and poorly designed and executed strategies to address complexity in SCs, often lead to undesirable outcomes.

Serdarasan (2013) makes an inventory and classification of good practices for managing complexity in the SC. Some of those mentioned may be related to the Triple-A SC: reducing the number of outsourcing partners and distribution centres (to address static complexity), SC integration, collaboration with suppliers, customers and service providers and information sharing (to manage dynamic complexity), among others. We argue that the SC capabilities of agility, adaptability and alignment can also be strategies to respond to SC complexity. For example, Manuj & Sahin (2011) state that SC complexity can lead organisations to develop adaptability capabilities and also (citing Christopher, 2000) that complexity is argued to be a barrier to achieving SC agility. Fawcett & Magnan (2001) consider network complexity to be a barrier to SC integration, and alignment mechanisms to be one of the most important bridges to effectively achieve it. We think that in the case of SC agility and alignment, complexity can also be an incentive for the company to strengthen these capabilities. For all these reasons, we propose the following hypothesis:

H2: Higher levels of SC complexity positively influence the implementation of the Triple-A SC dimensions (H2a: agility, H2b: adaptability, H2c: alignment).

Business competitive strategy and the Triple-A SC

In most cases the literature has traditionally assumed that the generic business-level strategies of cost-leadership and differentiation are generally inconsistent. However, Hill (1988) stated that differentiation can be a means for firms to establish an overall low-cost position, and that a combination of differentiation and low cost may be necessary for firms to generate a sustainable competitive advantage.

With regard to SC strategy, three different strategies are usually distinguished: lean, agile and leagile SCs, depending on whether the chain focuses on efficiency, differentiation or combining lean and agile (Christopher et al., 2006). Qi et al. (2011) find that firms focusing on a differentiation strategy emphasise the agile SC strategy. Thus, when a company follows a differentiation strategy, an agile SC strategy should also be required and, consequently, a higher implementation of the three Triple-A dimensions should be expected. On the other hand, Gligor et al. (2015) state that SC researchers (i.e., Christopher et al., 2006; Sebastiao & Golicic, 2008) connect efficiency and waste minimisation strategies with lean management and suggest that agility is the ability to react quickly to changes and has less of a link with efficiencies. Indeed, Hallgren & Olhager (2009) investigate internal and external factors that drive the choice of lean (focused on efficiency) and agile (focused on flexibility) operations capabilities. The competitive strategy is modelled as a potential internal driver, and findings point to the fact that agile manufacturing is directly affected by a differentiation strategy and

negatively associated with a cost-leadership strategy. However, SC research provides no definitive empirical evidence to indicate that agile SCs cannot also be efficient, and arguments exist that suggest that the main difference between lean and agility appears to be related to the flexibility performance dimension, not cost (Purvis et al., 2014; Gligor et al., 2015). Indeed, Qi et al. (2011) conclude that cost leaders tend to implement both lean and agile SC strategies, although their emphasis on an agile strategy is significantly greater in a volatile than in a stable environment. In addition, Handfield et al. (2015) analyse alignment in supply management and find that internal stakeholder alignment (the extent to which the purchasing function focuses on the firm's competitive strategy) is an antecedent. Since business strategy planning is, by nature, long term, it could be expected that business strategy also has a clear impact on longer-term oriented Triple-A SC dimensions such as SC adaptability and SC alignment, although the fact that it also has an effect on short-term oriented SC agility cannot be disregarded.

So, the literature leads us to state that a differentiation strategy should be positively related to the Triple-A SC, whereas a cost strategy should be negatively related. On the basis of this evidence, the following tentative hypothesis is proposed:

H3: The business competitive strategy will influence (negatively for cost, H3C, and positively for differentiation, H3D) the implementation of the Triple-A SC dimensions (H3Ca and H3Da: agility, H3Cb and H3Db: adaptability, H3Cc and H3Dc: alignment).

Methodology

A literature review-based questionnaire was designed to gather the required information from a sample of 277 Spanish industrial companies with a minimum of 50 employees (10.5% response rate). Industrial sectors not in an intermediate position in their SC were excluded. To ensure its quality and validity, the questionnaire was divided into different areas depending on who the key informant should be to minimise key-informant bias and guarantee content validity. A pilot study was conducted with five experienced SCM researchers. CATI was used as the data gathering method. In general, there does not seem to be any non-response bias in the sample, including late response bias. In summary, the data and analysis confirm that the sample used in the study was randomly obtained and that it statistically represented the population.

The research model includes seven variables: four exogenous (competitive intensity, SC complexity, and the two types of competitive strategies) and three endogenous (the three dimensions of Triple-A SC). The measures used in this study are all based on previous studies of similar topics to ensure their content validity. Specifically, the scales used to measure these variables were taken, and adapted in some cases, from those proposed by Hallgren & Olhager (2009) for industry competitive intensity and competitive strategies, and Roth et al. (2014) for SC complexity. The Triple-A SC dimension scales have been developed ad-hoc from items in previous studies that specifically focused on each of these. Five-points Likert scales were used.

The model was tested using PLS-SEM with SmartPLS 3 (Ringle et al., 2015). PLS-SEM is a non-parametric, multivariate approach based on iterative OLS regression that seeks to maximise the explained variance of endogenous latent constructs. The choice of PLS-SEM or CB-SEM (covariance-based) is usually based on data characteristics, sample size, complexity of the model, and the degree of maturity of the underlying theory, *inter alia*. We opted for PLS-SEM as, although our sample is not small and our model is not very complex, our data are not normally distributed and the underlying theory is not advanced but, rather, exploratory. PLS-SEM models are comprised of two components: the measurement or outer model, and the structural or inner model. The

measurement or outer model must be validated before the structural or inner model (research hypotheses) can be assessed.

Results and discussion

Measurement model

The evaluation of the goodness of the measurement model usually includes three criteria (Hair et al., 2017): internal consistency or reliability, convergent validity, and discriminant validity. Internal consistency has been evaluated by composite reliability, which, as can be seen in Table 1, ranges between .73 and .93, and always exceeds the minimum of .70. Values higher than .95 are not desirable, since they may indicate that some indicators are redundant. Convergent validity can be measured at the indicator level and at the construct level. At the indicator level, convergent validity is demonstrated when the indicator loadings on the construct are statistically significant. In addition, they must have a value above .70, which indicates that the construct explains 50% of its variance. In our model, all the loadings are significant at $p < .001$, except for three of the four strategy indicators, which are significant at $p < .05$. Only one item of the Differentiation strategy is not significant (A12c, p=.155). As regards the value of these loadings, all are above .70, except for 2 values in SC agility, which are nonetheless close to the cut-off value, and a value of .57 in Differentiation strategy. Convergent validity at construct level is measured by Average Variance Extracted (AVE), which must be greater than .50. As can be seen in Table 1, this value has been exceeded in all the constructs. Some items in the original questionnaire have been eliminated from this validation process following the Hair et al. (2017: pp. 112-5) criteria. Discriminant validity has been verified by the Fornell-Larcker criterion, according to which the square root of each construct's AVE must be higher than its correlation with the other constructs. This criterion has been met. Additionally, the indicator loadings have been verified to be higher on their own constructs than their cross-loadings on the other latent variables.

Table 1 – Reliability and convergent validity of latent variables

Latent variable	# items	Loadings	Composite Reliability	AVE
SC Agility	6	.65 – .82	.870	.529
SC Adaptability	4	.75 - .78	.846	.578
SC Alignment	6	.71 – .83	.897	.594
Competitive intensity	3	.77 – .80	827	.614
SC complexity	2	.93, .94	.931	.872
Cost strategy	2	.80, .84	.805	.674
Differentiation strategy	2	.57, .93	.733	.593

Structural model

For this phase, PLS-PM as a non-parametric technique relies on resampling. The method used was bootstrapping with 5,000 subsamples. Following Hair et al. (2017), several aspects of the results of the model were analysed: multicollinearity, the sign and significance of the coefficients, the R^2 levels and the effect sizes of the relationships.

VIFs were analysed to rule out any multicollinearity problems that might affect model estimates. Values greater than 5 would indicate that more than 80% of the variance of a construct is explained by the other constructs. In our case, the VIFs of the structural model vary between 1.046 and 1.416, so no collinearity problems seem to exist. As for the relationships of the structural model (the hypotheses), competitive intensity has a positive and significant impact ($p<.001$) on all the Triple-A dimensions. SC complexity, however, positively affects SC adaptability ($p<.05$) and SC alignment ($p<.01$), but not SC agility. Regarding the two types of strategy, all the effects of both

strategies on the Triple-A SC dimensions are negative, but only one relationship is significant, that of cost strategy on SC adaptability (p<.05). There are two other relationships that would be significant at the p<.10 level: cost strategy on SC agility and differentiation strategy on SC adaptability. The 95% confidence intervals with corrected bias show a similar scenario, except for two exceptions: the SC complexity-SC adaptability relationship, the interval of which contains zero by a small margin and, therefore, would not be statistically significant according to this criterion; and the differentiation strategy-SC adaptability relationship, which would be significant.

Next, we evaluated the coefficients of determination of the endogenous constructs, which in our case were the Triple-A SC dimensions. The dimension that is best explained by our model is SC adaptability, with R^2=.153 and adjusted R^2=.140. This is closely followed by SC alignment with R^2=.145 and adjusted R^2=.132. The dimension that is least explained or predicted by our model is SC agility, with R^2=.077 and adjusted R^2=.063, practically half the values of the other two dimensions. These values are given in Figure 1, which also includes the coefficients and p-values (in brackets) of the different relationships associated with each of the hypotheses. In addition, the type of line used indicates the relationships that are supported (solid line) and not supported (dashed line). We have considered the two aforementioned relationships in which there was a contradiction between the p-value and the confidence interval to be supported.

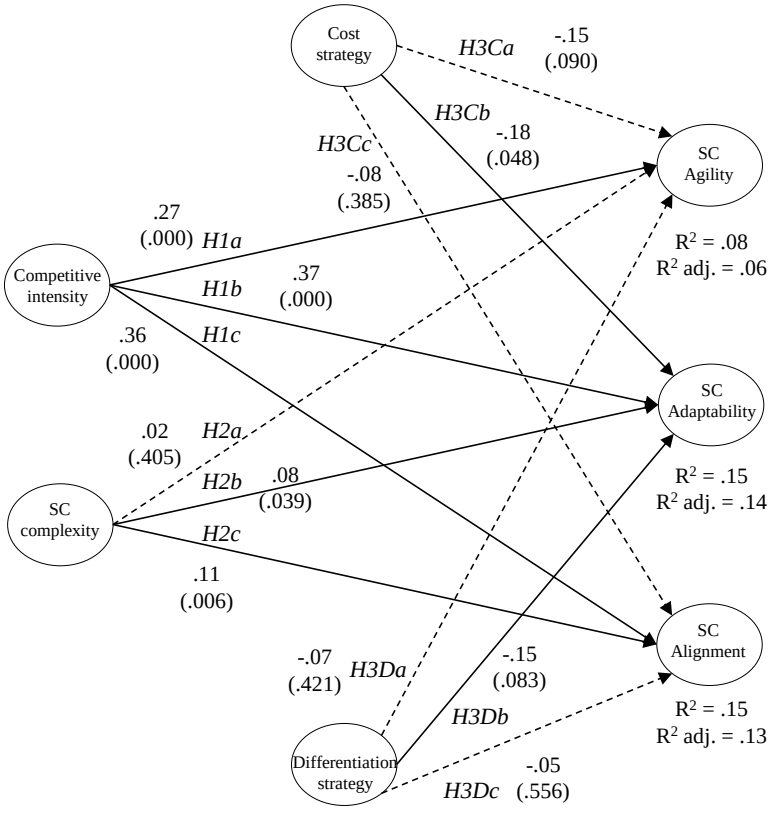

Figure 1 – Research model results

The next aspect to analyse is the size of the effects, which is related to the practical significance of the coefficients, rather than the statistical significance. This aspect is analysed using f^2, which measures the change in the R^2 of the endogenous constructs when an exogenous construct is omitted from the model. According to Cohen (1988), the values of this statistic are usually interpreted as small, medium and large for values

higher than .02, .15 and .35, respectively. In our case, competitive intensity has a small, slightly less than medium size effect on SC adaptability and SC alignment, and an even smaller effect on SC agility. The effect of cost strategy on SC adaptability is quite small (very close to the lower limit of .02). Also close to the minimum level are the effects of cost strategy on SC agility and of differentiation strategy on SC adaptability. All the remaining effects are very small and some practically null. It can be highlighted here that although the two SC complexity effects are statistically significant, they are practically negligible.

Conclusions

The results show that the determinant contextual variable that best explains Triple-A SC implementation is competitive intensity. This variable significantly affects the three dimensions and, in the cases of SC adaptability and SC alignment, with greater force and almost medium size effects. The other analysed competitive dynamics variable, SC complexity, is observed to have a significant effect on SC alignment and SC adaptability, but the coefficients are much lower than those of competitive intensity. Comparatively, the effect on SC alignment is almost a third of that of competitive intensity and the effect on SC adaptability almost a fifth. Thus, companies respond to the greater competitive intensity to which they are subjected with higher levels of SC agility, adaptability and alignment. SC complexity also has an effect, but to a lesser extent. We have seen that the higher the numbers of suppliers and customers that are part of the SC, the more companies seek to increase their SC alignment and SC adaptability levels, but SC agility does not appear to be necessary in this context.

As far as business strategy is concerned, cost and differentiation strategies only have an effect on SC adaptability, but the size of these effects is close to the minimum threshold. In addition, in both cases this effect is negative, which was expected for cost strategy, but not for differentiation strategy. These results are interesting in two aspects, at least. Firstly, the effect is greater on SC adaptability, which is a dimension of long-term flexibility, than on SC agility, which represents the short-term flexibility capability. This could be due to the fact that the nature of business strategy involves long-term planning, although its effects should also be seen in the ability to adapt in the short term, which is agility. On the other hand, it is interesting to note that differentiation strategy has a negative effect on SC adaptability, which is a longer term capability, although from a practical point-of-view, the effect size does not reach the threshold for it to be considered small.

Acknowledgments

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Exploratory study on the perception of supply chain strategies in different supply chain levels: the case of the aerospace sector

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Abstract

Although there are strategies -such as lean, resilient and green- that have been proven as beneficial for companies and their supply chain (SC), the real implementation of such strategies is not uniform in certain sectors. The purpose of this paper is to investigate the perception of the importance and degree of implementation of such strategies in the aerospace manufacturing sector. Results show that different SC levels have a different perception of the importance and degree of implementation and therefore, this difference may lead to discrepancies in the propagation of strategies along the SC as different interests may arise.

Keywords: multilayer analysis, supply chain strategy, aerospace sector

Introduction

Supply chain management (SCM) may help companies to increase their organizational performance and profitability if the right strategies are put in place. Additionally, SCM also facilitates the integration between companies and their suppliers through the development of partnerships and alliances. Therefore, special attention should be payed to the set of practices selected to manage those relationships with suppliers and to the specific strategies that should be implemented in order to achieve optimal results.

Lean, resilient and green strategies applied to the SC have been previously studied in the automotive sector demonstrating the positive impact of such strategies on both, sustainability and SC performance (Govindan et al. 2014, 2015).

Even though lean SC practices have proven to improve company's performance, companies along the SC still show a high resistance level to lean implementation in certain sectors such as the aerospace sector (Bortolotti et al., 2016).

The aerospace manufacturing supply chain (AMSC) has previously been studied and defined in terms of its structure and complexity (Bales et al., 2004; Ehret and Cooke, 2010; Hickie, 2006). The OEM is structured in Final Assembly Lines (FAL) that carry out the final assembly of aircrafts and Prime Contractors that manufacture and assembly the large aero structures and systems. Tier 1 is composed by large companies specialized

in design and manufacturing of large systems and components with engineering capabilities. Tier 2 and Tier 3 include SMEs that manufacture less complex components and provide basic services to Tier 1companies and even to OEM, with no design or engineering capabilities. The number of companies in each tier increases exponentially as we move down in the SC towards Tier 3. Additionally, companies become smaller, with fewer resources and manufacture/provide less complex products and services.

In the AMSC, OEM and even Tier 1 companies have successfully implemented lean strategies. However, when trying to extend lean strategies to Tier 2 and Tier 3 companies, Bortolotti et al. (2016) have observed that the needed collaboration for strategy implementation has been scarce and have found a high resistance level on these companies to lean adoption mainly because the final results did not match the initial expectation.

In this type of SCs, being resilient becomes critical due to the very complex final product and production process and the tight production lead time. Any disturbance can considerably affect the production process even stopping it and the final delivery time can substantially increase (Sinha et al., 2004). Additionally, lean strategies make companies and their SC less resilient as previous studies showed (Sezen et al., 2012) and therefore, AMSCs should work on increasing resilience. Finally, the aerospace sector has showed an increasing commitment to environmental and sustainability principles, not only in their final product but also in their manufacturing process (International Civil Aviation Organization, ICAO). Therefore, the AMSC becomes a key sector for the study of lean, resilient and green strategies.

This together with the fact that some of the strategies hardly propagate along the SC and companies' resistance to implementation becomes higher as moving down the SC leads to the objective of this paper, which is to investigate the perception of the importance and implementation degrees of the three strategies under study for different SC levels in the AMSC.

Supply Chain Strategies

The main strategies considered for this study and that are present in the ASCM are, as explained in the introduction, the lean, resilient and green strategies. For each strategy specific practices need to be identified and for that purpose, we borrow the list of practices for the three strategies -lean, resilient and green- identified in Ruiz-Benitez et al. (2017) (Tables 1, 2 and 3). A total of 34 practices that are relevant for the ASCM are finally considered for this study.

Table 1 – Practices for lean SC strategy (Ruiz-Benitez et al., 2017)

Code	Lean SC practice	Code	Lean SC practice
L1	Supplier selection, evaluating and monitoring.	L5	JIT delivery practices.
L2	Suppliers and company involvement in NPD (New Product Development)	L6	Pull production systems.
L3	Communication and information exchange between suppliers and company	L7	Value stream mapping (VSM).
L4	Electronic-enabled supply chains.	L8	Training in lean initiatives.

Table 2 – Practices for resilience SC strategy (Ruiz-Benitez et al.,2017)

Code	Resilience SC practice	Code	Resilience SC practice

R1	Use of information control systems	R7	Maintaining excess capacity in productions, storage, handling and/or transport.
R2	Communication and information sharing	R8	Enforce security
R3	Flexible supply base	R9	Contingency planning
R4	Core firm pays a proportion of costs derived from their supplier's redundancy	R10	Disaster recovery plan
R5	More mutually beneficial agreements between core firm and their suppliers with clearly stated incentives and obligations across time	R11	Alternative transportation routing
R6	Improve visibility, collaboration, coordination and understanding with suppliers	R12	Visible transportation

Table 3 – Practices for green SC strategy (Ruiz-Benitez et al., 2017)

Code	Green SC practice	Code	Green SC practice
G1	Joint planning	G8	Communication of environmental criteria for goods and services
G2	Cooperation with suppliers to solve end-of-pipe environmental issues	G9	To encourage suppliers to take back packaging
G3	Cooperation to minimize logistical impact of material flow	G10	To use recyclable pallet to delivery materials
G4	Environmental collaboration with suppliers	G11	Collaboration with suppliers in product design to reduce and eliminate product environmental impacts
G5	Environmental monitoring upon suppliers	G12	Communication and collaborative approaches to foster environmental improvements across the SC
G6	Green procurement/sourcing	G13	Suppliers environmental management systems requirement
G7	Prequalification of suppliers	G14	Supplier education, coaching and mentoring

Methodology and data gathering

The main goal of this research is to explore managers' perceptions about the importance and degree of implementation of lean, resilient and green strategies. Their corresponding practices have been strongly widespread in diverse sectors [i.e., Govindan et al. (2015)], and particularly in AMSC. The implementation and performance of lean practices significantly differ across its supply chain tiers of aerospace manufacturing sector (Bortolotti et al. 2016). In the same vein, it has been highlighted that contextual variables such as the company's size, collaboration level between entities, and the time length of these practices should be considered when adopting them (Bortolotti et al. 2016; Marodin et al. 2016; Tortorella et al. 2017). Accordingly, we carried out a multilevel analysis of the aerospace manufacturing supply chain. Level 1 brought together the OEM and Tier 1 suppliers. Indeed, these large firms maintain a higher collaboration and integration level. Level 2 included Tier 2 suppliers and Tier 3 suppliers. These small and medium size enterprises (SMEs) present a lower collaboration and integration level.

With the goal of evaluating marketing strategies, the Importance-Performance Analysis (IPA) method was proposed (Martilla & James 1977). Then, it allowed evaluating specific attributes of customers' satisfaction considering both importance and performance dimensions. The ratings achieved were plotted in a two-dimensional

importance-performance matrix, and thus four strategies could be defined from each of the four areas. Together with the valuable information that this visual representation of results can provide, the IPA method is considered a simple and effective way to evaluate strategies basing on multiple attributes (Hansen & Bush 1999; Abalo et al. 2007). Hence, it had been successfully applied in evaluating technological innovations (López et al., 2019), tourism (Frauman & Banks 2011), project risk management (López and Salmeron, 2012), e-government services (Wong et al., 2011), among other many issues.

Accordingly, the IPA method was chosen to measure managers' perceptions on both the importance and performance dimensions of each lean, resilient and green practices identified in the literature (See Tables 1, 2 and 3). Those dimensions were conveniently adapted. On the one hand, performance dimension (x-axis) measures in which degree each practice has been implemented in the AMSC (DI). On the other hand, importance dimension (y-axis) shows the importance of each practice for the AMSC (I).

In order to estimate the corresponding pair of ratings (x_i, y_i) for each practice (p_i), two panels of aerospace manufacturing managers were created (one for each identified supply chain level). In this way, we firstly built a database which contains information on active aerospace manufacturing firms operating in Spain. After two rounds contacting these companies by phone, 39 managers agreed to participate in the research. The first panels was formed by 11 managers pertaining to enterprises in the first level of the aerospace manufacturing supply chain, whereas the second panel was made up of 28 managers of the second level. Subsequently, we designed an online questionnaire and sent it to participants via email. Both importance and degree of implementation dimensions were measured on a 5-point Likert scale, where 1 means "not important" or "not implemented" and 5 means "very important" or "completely implemented". Basing on the replies received, we built the IPA grids, one for each strategy (lean, resilient and green) and supply chain level (Figures 1 to 6). Finally, six grids were generated plotting each corresponding practice according to its importance rating and degree of implementation rating. These ratings were calculated using mean values of managers' perceptions. Both y-axis line and x-axis line were computed using the global of importance and degree of implementation values for the total of practices in lean, resilient and green strategies, respectively.

Each quadrant in the IPA grid depicts a specific cluster of practices. Hence, different strategies must be followed for individually managing them in a more effective way:

Quadrant A (Concentrate here). Practices present a high level of importance and a low level of degree of implementation. This is known as the preferential improvement area and the recommendation would be to prioritize the practices in this quadrant.

Quadrant B (Keep up the good work). Practices show a high level of importance and a high level of degree of implementation. The managers ought to maintain current efforts and resources allocated to them.

Quadrant C (low priority). Practices achieve a low level of importance and a low level of degree of implementation. Therefore, practices do not provide enough improvements to justify additional efforts.

Quadrant D (possible overkill). Practices reach a low level of importance and a high level of degree of implementation. Managers ought to cut down excessive efforts and resources addressed to developing these practices.

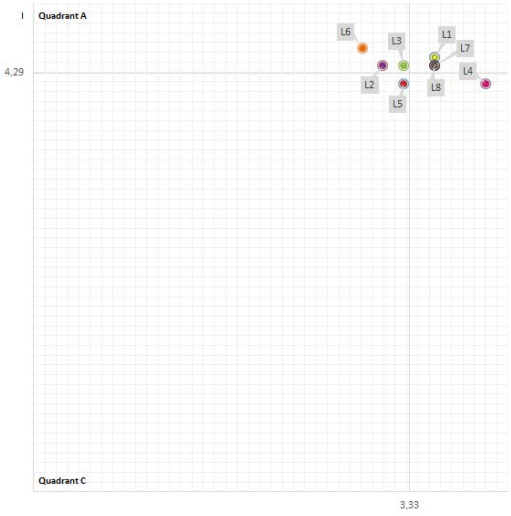

Figure 1 – IPA grid of the lean SC strategy (Level 1)

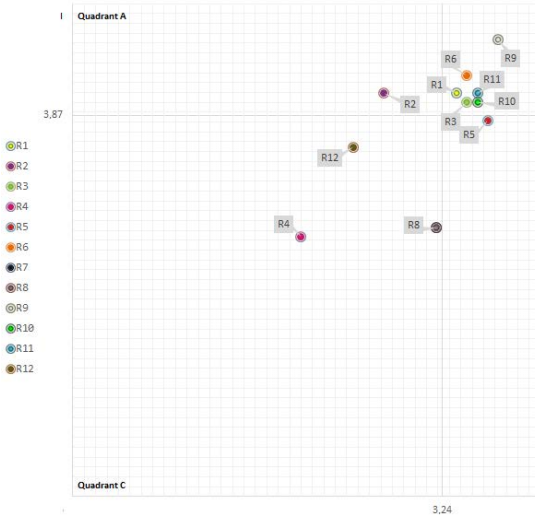

Figure 2 – IPA grid of the lean SC strategy (Level 2)

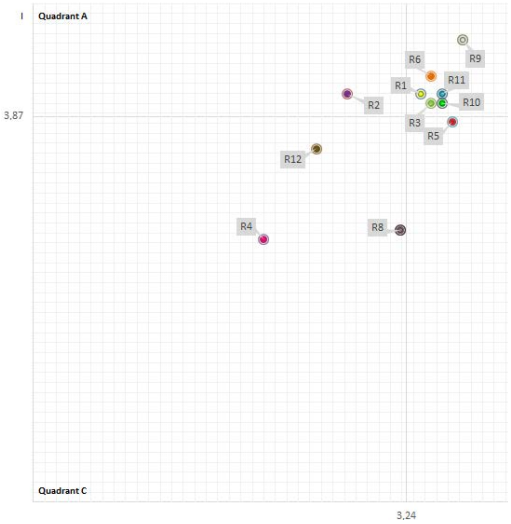

Figure 3 – IPA grid of the resilient SC strategy (Level 1)

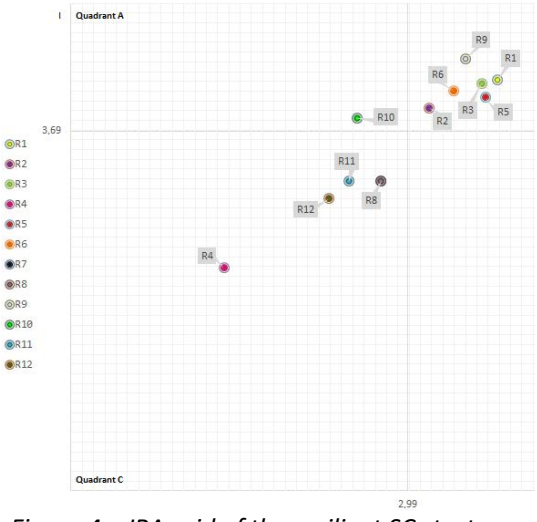

Figure 4 – IPA grid of the resilient SC strategy (Level 2)

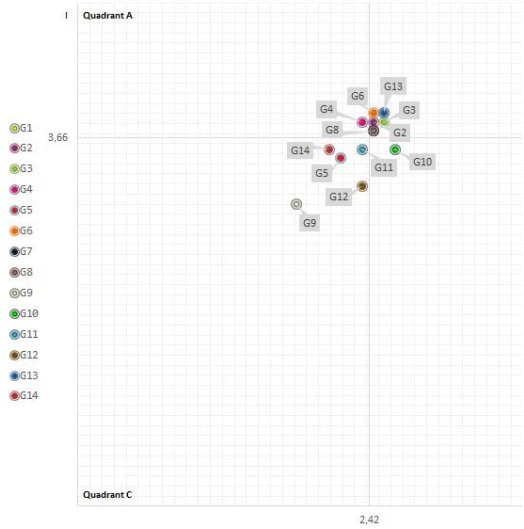

Figure 5 – IPA grid of the green SC strategy (Level 1)

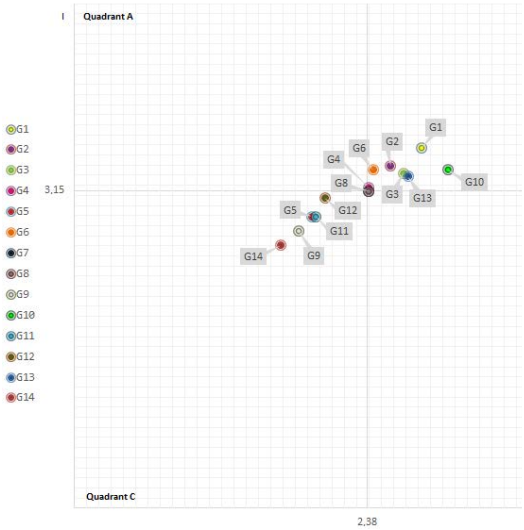

Figure 6 – IPA grid of the green SC strategy (Level 2)

Results

In this section, results on the managers' perception of each strategy in different levels of the SC are presented. The degree of implementation (DI) and importance (I) of each practice are evaluated and the quadrant containing each practice is determined.

Results reveal strong differences in the perception of the lean SC strategy importance/implementation between managers in different levels of the SC as tables 4, 5 and 6 show.

For the lean SC strategy, there is discrepancy on the managers' perception in 6 out of 8 practices between different levels of the SC. In terms of the strategy's importance for the sector, Level 1 companies perceive a higher importance level of lean practices than Level 2 companies. However, there is a perception of higher implementation of lean practices for Level 2 companies, although those companies are the ones that hardly implement such practices into their operations. Additionally, the practices perceived as more important for Level 1 companies do not coincide with the practices that have more importance for Level 2 companies. Therefore, it should be expected some resistance by Level 2 companies to implement the practices that Level 1 companies are pushing down the SC as the perceived importance substantially differ. Furthermore, only Level 1 managers identify lean SC practices in the preferential improvement area (quadrant A), concentrating though into the development of such practices meanwhile Level 2 managers do not identify any of the lean practices as preferent to improve.

Table 4 – Perception ratings for the lean SC strategy

	DI		I		Quadrant	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
L1	3.55	3.39	4.45	4.00	B	B
L2	3.09	3.18	4.36	3.71	A	D
L3	3.27	3.71	4.36	4.32	A	B
L4	4.00	3.32	4.18	4.25	D	B
L5	3.27	3.57	4.18	4.04	C	B
L6	2.91	2.71	4.55	3.46	A	C
L7	3.55	2.54	4.36	3.54	B	C

L8	3.00	2.04	3.82	3.11	C	C
Global mean	3.3295	3.058	4.2841	3.8036		

In the case of resilient SC strategy, the discrepancy level is lower than in the previous case. Only 5 out of 12 practices present different managers' perception on the degree of implementation and importance and being therefore in different quadrants. However, for most of the practices both levels perceive a similar degree of importance and implementation level. The perception of the degree of implementation of resilient practices is high for both levels (7 out of 12 present a high implementation grade). Regarding the importance, again, managers at both levels perceive that resilient practices are important for the SC. Nonetheless, when deciding on the particular practices that are really important for the sector, there are still some discrepancies (R1, R5 and R11). In comparison with lean SC strategy, there is more consensus in managers' perception of the importance and degree of implementation in the case of the resilient SC strategy.

Table 2 – Perception ratings for the resilient SC strategy

	DI		I		Quadrant	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
R1	3.36	3.79	4.09	4.21	D	B
R2	2.73	3.18	4.09	3.93	A	B
R3	3.45	3.64	4.00	4.18	B	B
R4	2.00	1.36	2.64	2.29	C	C
R5	3.64	3.68	3.82	4.04	D	B
R6	3.45	3.39	4.27	4.11	B	B
R7	3.18	2.75	2.73	3.18	C	C
R8	3.82	3.29	4.45	3.93	B	B
R9	3.73	3.50	4.64	4.43	B	B
R10	3.55	2.54	4.00	3.82	B	A
R11	3.55	2.46	4.09	3.18	B	C
R12	2.45	2.29	3.55	3.00	C	C
Global mean	3.2424	2.9881	3.8636	3.6905		

Finally, for the green SC strategy, companies in both levels coincide on the perception of degree of implementation and importance. Only 2 out of the 14 practices considered within the strategy show a different perception and therefore different quadrants in the IPA analysis. Therefore, there seems to be unanimity of managers' perception in terms of the importance and the degree of implementation of the green SC strategy in the AMSC.

Table 3 – Perception ratings for the green SC strategy

	DI		I		Quadrant	
	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
G1	2.55	2.82	3.91	3.57	B	B
G2	2.45	2.57	3.82	3.39	B	B
G3	2.55	2.68	3.82	3.32	B	B
G4	2.36	2.39	3.82	3.18	A	B
G5	2.18	1.93	3.45	2.89	C	C
G6	2.45	2.43	3.91	3.36	B	B

G7	2.45	2.39	3.73	3.14	B	B
G8	3.00	2.79	4.09	3.25	B	B
G9	1.82	1.82	3.00	2.75	C	C
G10	2.64	3.04	3.55	3.36	D	B
G11	2.36	1.96	3.55	2.89	C	C
G12	2.36	2.04	3.18	3.07	C	C
G13	2.55	2.71	3.91	3.29	B	B
G14	2.09	1.68	3.55	2.61	C	C
Global mean	2.4156	2.375	3.6623	3.148		

Conclusion

Even though there are some strategies that have proven to be beneficial for companies, their implementation is still scarce and not uniform along the SC in certain sectors. That is the case of the lean strategy in the aerospace sector. The implementation of lean practices is not uniform along the supply chain, being the OEM and tier 1 companies, the ones heavily implementing lean strategies meanwhile tier 2 and tier 3 companies rarely implement such strategies (Bortolotti et al., 2016).

The results in the present study are aligned and reinforce the ones in Bortolotti et al. (2016). Companies in lower levels (tier 2 and 3) of the SC perceive a lower importance of the lean strategy and therefore their incentive for lean implementation is low. Additionally, the lean strategies perceived as highly important for the OEM and tier 1 companies are not the same as the ones perceived as important for tier 2 and 3 companies. Therefore, this calls for a different approach in the efforts of OEM and tier 1 companies to propagate lean practices along the SC as previous studies hinted (Marodin et al. 2016, Tortorella et al. 2017).

Additionally, in the case of resilient and green SC strategies the perception of the importance and degree of implementation is very similar for companies in different levels of the SC. These strategies are perceived as important for companies along the SC and therefore, all levels of the SC make efforts to correctly incorporate both strategies into their operations.

This is an exploratory study with the aim of analysing the perception of managers belonging to companies in different levels of the SC on the different SC strategies. Further investigation needs to be done in order to understand the reasons behind the difficulty of strategy propagation along the SC found in some sectors.

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Investigating the moderating role of employee's learning intent in creation of supplier driven innovation: Multi perspective analysis capturing employee's reflections through social media

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Abstract

This study attempts to answer the question why certain buying firms tend to leverage suppliers' input better than the others in creating innovations. Using theory of planned behaviour and embeddedness, this paper seeks to shed a light on this by investigating the moderating role of buying firms' employee's intent to learn in facilitating efforts in mobilising input from the buying firm's supply network. The results suggested that the strong moderation of employee's intent to learn, meaningful work and work-life balance with the two dimensions of embeddedness such as between degree centrality and betweenness centrality on the buying firm's innovation creation.

Keywords: planned behaviour theory, innovation, supplier network, structural embeddedness, text mining.

Introduction

It is obvious that the supply network is an importance source of innovations for buying firms. There have been a number of studies investigating the link between the buying firm's reliance on suppliers for innovation creation (Narasimhan and Narayanan, 2013) and there have been a constant stream of research investigating the place of suppliers in buyers' innovation creation (Wagner 2012; Henke and Zhang, 2010; Wagner and Bode, 2014). However, there is lack of research investigating this from the perspective of a supplier network, which is characterised by interactions and different actors, resources and processes (Bellamy et al., 2014), influence on buying firms innovation performance. A innovation research from the supply network view, however, is still relatively rare. The main reason for this is the difficulty in obtaining a real-life supply network data, therefore, the majority of such studies analysed firm level ego networks (e.g., Kim et al., 2011). In addition, a study by Lawson and Potter (2012) explains how closeness with supplier can uncover protectiveness in knowledge transfer across firms. However, learning intent scale used in the study reflects only the knowledge capture but didn't say anything about employee's learning intent. Buying firms extraction of knowledge depends on employees' intention to invent. There are also studies that support the well-being of

employees and firm's innovation (Bryson et al., 2009). However, it is still not clear how employees' intention to learn within a firm helps to derive innovation from supplier.

The literature review revealed three major gaps. Firstly, there is a scarcity of studies integrating planned behaviour theory with embeddedness theory for explaining how a buying firm leverages contributions from external organizations in its supply network towards its own innovation. Secondly, "intent to learn" construct was mostly done through a survey instrument, which many not be sufficient in reflecting "collective intent to learn". It is obvious that using anonymous platforms, such as a social media review, to measure a construct of this nature would alleviate this issue, however, not widely used in academic literature. It is well established that higher levels of engagement will lead to higher profitability Thirdly, there is a contradictory argument that innovative culture will lead to lack of attention in work-life balance and causes time-based stress, depletion of resources, including psychological and physical energy (Sok et al., 2014).

Given the above background, we seek to answer the question why a certain buying firms tend to leverage suppliers' input better than the others in creating innovations by considering the firm's employees' collective intent to learn as a moderator.

Literature Review

This paper uses multiple theoretical lens (i) social network theory and (ii) planned behaviour theory the answer the above research question.

Embeddedness of a Buying Firm in its Supply Network and its Innovation Creation

The social network theory is based on the idea of embeddedness (Kim et al., 2011). Embeddedness refers to non-economic factors, motivating various economic exchanges (Moran, 2005; Barden and Mitchell, 2007; Cowan et al., 2007; Kim, 2014). One notable example of embeddedness is "a social tie" (Koufteros et al., 2007; Dong et al., 2015), since economic activities are often embedded in them (Uzzi and Lancaster, 2003). The link between a firms' performance and its embeddedness has been scrutinised by the scholars to find out how the embeddedness would explain how different levels of embeddedness are related to the variations in the firm's performance (Adler and Kwon, 2002; Kim, 2014).

Firm's embeddedness has been investigated from two distinctive perspectives, which are (i) configurations of social ties and (ii) quality of social ties, (Gulati, 1998; Uzzi and Lancaster, 2003; Moran; 2005; Autry and Griffis, 2008; Dong et al., 2015; Kim and Henderson, 2015). As such, even though there are some variations of conceptualisation of the embeddedness (Tsai and Ghoshal, 1998; Min et al., 2008; Kim, 2014), two salient forms of embeddedness are (1) relational and (2) structural (Granovetter, 1985, 1992; Uzzi, 1996, 1997; Gulati, 1998; Rowley et al., 2000). Relational embeddedness refers to the strength of dyadic ties (Granovetter, 1992; Moran, 2005; Kim, 2014) that is an extent to which a firm develops close and personal relationships with other members in its network (Barden and Mitchell; 2007; Autry and Griffis, 2008; Landoli et al., 2012; Dong et al., 2015). On the other hand, structural embeddedness, which is the main focus of the investigation of this paper, refers to configuration of linkages/relationships among actors (Nahapiet and Ghoshal, 1998; Gulati and Gargiulo, 1999; Moran, 2005; Barden and Mitchell, 2007; Dong et al., 2015).

Accumulation of knowledge assets for a firm's innovation creation has two main sources, those are (1) internal knowledge generation and (2) knowledge with an external origin (Cooper and

Edgett, 2007; Bellamy et al., 2014). For a buying firm, its supply network is an important external source for its knowledge assets (Autry and Griffis, 2008; Bellamy et al., 2014) such as knowledge and resources held by its supplier. Such resources can provide a firm with external information necessary for idea generations as well as improving its process (Tsai, 2001) as well as an opportunity to combine their knowledge for innovation creation (Ahuja, 2000). Therefore, a buying firm's structural embeddedness in its supply network indicates its ability to access the knowledge and information held by its imminent suppliers and beyond (Uzzi, 1996; Tsai, 2001; Cowan et al., 2007; Greve, 2009; Bellamy et al., 2014). The implications of different aspects of a buying firm's structural embeddedness on its innovation creation has been investigated mainly from the perspective of the buying firm's centrality in its network. The centrality of a buying firm reflects its relative importance in its supply network (Kim, 2011; Dong et al., 2015).

A company occupies in a central location, it will get access to information and knowledge more easily helping them to create knowledge assets for its innovation creation (Tsai 2001; Bell, 2005; Greve, 2009; Autry and Griffis, 2008; Bellamy et al., 2014). Moreover, the level of centrality of a buying firm would signal its reputation to its suppliers (Borgatti and Foster 2003), alleviating their fear of failing to protect their knowledge as a result of a buyer opportunism (Mayer, 2006) and would result in more information sharing activities.

Buying Firms' Employees' Intent to Learn

A theoretical aspect to exploit employee's learning intent in leveraging supplier input for its own innovation creation is the Planned Behaviour Theory, which is used to understand individual behaviour and it is a function of attitude, subjective norms and control (Ryan, 2010). Using the above analogy, in our case, employees' intent to learn depends of three dimensions such as meaningful work, subjective wellbeing and work life balance.

Meaningful work capture individual's attitude towards work using four dimensions such as developing the inner self, unity with others, expressing full potential and service to others (Lips-Wiersma et al., 2012). A study by Pradhan and Jena (2019) unfolded the lack of studies that explored the role of meaningful work on the relationship between transformational leadership and innovative work behaviour. Since meaningful work construct is relatively a new term and its usage is limited in the literature. However, subjective wellbeing is a psychological factor that is defined as individual's cognitive and affective evaluation of the experience in terms of pleasant emotions, negative mood and life satisfaction (Wang et al., 2017). An individual's subjective wellbeing depends on complex array of contextual factors including individual determinants, socio-demographic, economic, situational and institutional factors (Binder, 2013). Self-esteem or other personality traits are examples of individual determinants, likewise gender, age, education or marital status are examples of socio demographics. Similarly, income or unemployment corresponds to economic status, health and social relationship corresponds to situational factors (Binder, 2013). In addition, it is rare to find the integration of planned behavior theories within and external organization's contribution to innovation. A study by Binder (2013) states the individual's preferences are dynamic and the measurement of affective experience is very difficult in practice to capture that reflect the preference changes of individuals over time. To overcome this global corporations are relying on anonymous platforms to measure the satisfaction of employees and fixing them on a swift basis to improve engagement. The companies are keen to do this because it is well know that higher levels of engagement will lead to higher profitability and improved employee's commitment (Bonnici, 2018).

Employees are juggling with multiple commitments at work and home where the successful people are good at balancing the two. Conceptually, offering work life balance through flexible working hours will enable employees to perform better and stay in a single company for a longer duration. However, in practices employers are not ready to do so until they see a bottom line economic advantage (James, 2014). However, there are a few evidences that illustrates flexible working hours benefits all staff irrespective of caring staff. Besides this generalist view of benefits, there are several dis-benefits such as increased workloads, understaffing, heightened fear of job loss, dramatic change in labour and demands. In addition, from the organisation's perspective continuous innovation to meet consumer demand and pressure to increase work-life balance of employees to retain them and satisfy customers are the tricky challenges posing those (Malhotra et al., 2016).

Conceptual Model and Hypotheses

In this paper, we seek to investigate the impact of a buying firm's structural embeddedness in its supply network in its innovation creation and how an endogenous organisational factor "employee's intent to learn" of the employee of a buying firm would moderate this relationship.

First, we investigate the link three centrality dimensions of a buying firm's structural embeddedness and its innovation output measured in the number of patents it holds.

The first dimension, degree centrality refers to the number of direct links an organisation maintains with others in its network (Provan et al., 2007). Degree centrality can be interpreted as the amount of knowledge, resource and information coming into the buying firm (Provan et al., 2007; Borgatti and Li, 2009). The following is, therefore, hypothesised:

> H_1: Buying firm's degree centrality in its supply network is positively related to the number of patents it has

The second dimension, betweenness centrality refers to how often the node lies on the shortest path between all combinations of pairs of other nodes (Borgatti and Li, 2009; Kim, et al., 2011). An organisation with high level of betweenness can act as a gatekeeper to other members in its network (Borgatti and Everett, 2006, Provan et al., 2007; Borgatti and Li, 2009; Kim, et al., 2011). In supply network, this means a firm with high-level of betweenness centrality would act as a hub for material (Kim, et al., 2011) and information flows (Bellamy et al., 2014) enables it performance benefits such as access to novel information. The following is, therefore, hypothesised:

> H_2: Buying firm's betweenness centrality in its supply network is positively related to the number of patents it has. The following is, therefore, hypothesised:

The third dimension, closeness centrality refers to how close an organisation is to all other members in its network including those without direct connections (Provan et al., 2007; Kim, et al., 2011). A buying firm can acquire knowledge indirectly through spill-over from its tier 1 suppliers, with its origin back to its interactions with the supplier's own tier 1 suppliers (Gulati and Garguilo, 1990). Considering this, a buying firm with higher closeness centrality can access information, knowledge and resources from indirect suppliers beyond tier 1 more easily, therefore, it is related to the network effectiveness of knowledge access (Bellamy et al., 2014).

H_3: Buying firm's closeness centrality in its supply network is positively related to the number of patents it has. The following is, therefore, hypothesised:

As per planned behaviour theory, the influence of three dimensions of employees' intent to learn from suppliers is discussed in the following section. Typically, our intention is to explore to what extent the three dimensions enables employees to better exploit supplier inputs for its own innovation creation. A study by Pantea (2018), it is obvious that the relationship between supplier input and the buying firm's innovation creation would be stronger if employees' collectively perceive their works more meaningful. This is because,
Meaningful work refers to a place with autonomy, less-tension, spirituality and reduced level of absenteeism.

H_{1a}: As perception of meaningful work among employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger
H_{2a}: As perception of meaningful work among employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger
H_{3a}: As perception of meaningful work among employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger

Studies explored the rationale for the positive relationship between subjective wellbeing and better work performance, knowledge sharing and achievements (Russell, 2008; Wang et al., 2017). Previous studies have found that satisfaction degree and positive emotions helps individual to remember and boost creative problem solving (Koveshnikov et al., 2014; Hashim and Tan, 2015). Other than performance, positive emotions, such as feeling of joy and pleasure, one among the subjective wellbeing factors will enhance individuals to share tacit and explicit knowledge (Henttonen et al., 2016). The following is, therefore, hypothesised:

H_{1b}: As perceived well-being of employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger
H_{2b}: As perceived well-being of employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger
H_{3b}: As perceived well-being of employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger

Very few studies attempted to understand the relationship between work life balance and organization culture represented as innovative and supportive culture (Sok et al., 2014). There is a contradictory arguments that innovative culture values behaviours teamwork including solution-oriented, communicative and quick in terms of decision making. The overall understanding is innovative culture will lead to lack of attention in work-life balance and causes time-based stress, depletion of resources, including psychological and physical energy (Sok et al., 2014). However, this is not applicable to all contexts and needs to be investigated further. Based on the above arguments we propose the following sub hypothesis to test the moderation of three dimensions of employees learning intent. The following is, therefore, hypothesised:

H_{1c}: As perceived work life balance of employees of a buying firm increases, the association between its degree centrality and the number of patents becomes stronger

H_{2c}: As perceived work life balance of employees of a buying firm increases, the association between its closeness centrality and the number of patents becomes stronger
H_{3c}: As perceived work life balance of employees of a buying firm increases, the association between its betweenness centrality and the number of patents becomes stronger

Methodology

This paper investigates if of a buying firm's employees' intent to learn would moderate the relationship between the structural embeddedness of a buying firm in its supply network and its innovation output. For this, we used the data of 182 companies from the S&P 500 list by discarding non-manufacturing sectors such as financials and real estate as well as those companies with excessive amount of missing data.

Data

The data set for this study was built using following databases. For the embeddedness of a buying firm, the list of its suppliers was collected from Bloomberg SPLC database and Factset. As for a firm's innovation performance, the number of patents held by a buying firm was collected using Orbis database. For the intent to learn, employee reviews of their current and previous companies for 182 S&P 500 companies posted in Glassdoor between 2015 and 2017 were collected (475,910 sets of a positive and a negative review). Glassdoor is a social media website, where current and past employees can rate various aspects of their companies such as leadership, work environments and pays (Associate Press, 2013). Glassdoor is the oldest (founded in 2017) and the largest online resources in terms of the number of firms covered and the reviews (Ji et al., 2017).

Measures

In this study, we use social network analysis (SNA) to measure different dimensions of structural embeddedness of a buying firm. Considering a matrix A_{ij}, with a set of nodes and a set of edges, degree centrality is defined as the number of edges tied to a node. It is usually interpreted as the size of a node's direct network. Closeness centrality, in contrast, considers the node's wider network by measuring the distance of a node to all others in within the network. Moreover, betweenness centrality captures the importance of a node for the network by measuring the number of shortest path that rely on that node (for a more detailed overview on network measures, please be referred to Borgatti et al., 2018).

Variable	Measure	Normalised Measure
(In-)Degree centrality	$C_D(i) = \sum_j A_{ij}$	$C_{DN}(i) = \frac{1}{n-1} C_D(i)$
Closeness centrality	$C_C(i) = \frac{1}{\sum_j d(i,j)}$	$C_{CN}(i) = (n-1) C_C(i)$
Betweenness centrality	$C_B(i) = \sum_{s \neq t \neq i} \frac{g_{st}(i)}{g_{st}}$	$C_{BN}(i) = \frac{2}{(n-1)(n-2)} C_B(i)$

Table 1: Description of network measures.

Intents to learn

In order to measure employees' intent to learn of a buying firm, content analysis was used to code the textual reviews from the social media site, Glassdoor. Content analysis is "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use," (Krippendorff, 2013; p.24). As mentioned earlier, a user can leave

two separate textual review about a company, one for the positive and another one for the negative and these unistructural parts of the reviews were coded using content analysis. Due to the sheer volume of the textual data (475,910 sets of a positive and a negative review and around 17 million words), a computer-aided content analysis (CATA) was selected over manual coding. For this, WordStat 8 from Provalis Research was used. Due to the lack of a pre-made dictionary, a set of new dictionaries for the positive and negative were created from scratch using the dictionary building method suggested by Sodhi and Son (2010). Using these dictionaries, the percentages of positive and negative reviews containing specific words or phrases from the total reviews of a specific company were calculated and then, standardised. The difference between the positive and the negative was used to measure each dimension of employees' intent to learn. The assumption is that the greater the difference is the more positive employees' intent to learn.

Innovation Output

In order the measure the innovation performance of a buying firm, the number of patents the firm was used. Use of the number of patents to measure a firm's innovation output has been wildly used by the previous studies (for an example, see: Tsu, 2009; Bellamy et al., 2014; Isaksson et al., 2016).

Analysis and Results

We conducted hierarchical regression analyses using SPSS version 25 to test our hypotheses. Our main models examined if the level of 3 centrality dimensions of a buying firm is related to its innovation output (the number of patents). The results of the analyses provided support for H_1 (degree centrality => patents, $\beta = 0.31$, $p < 0.01$) and H_2 (betweenness centrality => patents, $\beta = 0.27$, $p < 0.01$). H_3, where the relationship between closeness and the innovation output was postulated, was not supported. In the interaction models, the results supported that wellbeing and work life balance positively moderate the relationship between two centrality dimensions (degree centrality and betweenness) and the buying firm's innovation, the number of patents.

Conclusion and Discussion

To the best of the authors' knowledge, this paper is one of the first to combine social network theory and planned behaviour theory to uncover the role of an organisational factor, employee's intent to learn, in leveraging input from its supply network for its own innovation creation.

Our results for the first set of hypotheses are in line with the findings of Bellamy et al., (2014) that the structural embeddedness a buying firm is related to its innovation creation since it determines (1) the amount of knowledge held by its direct suppliers and (2) how easily it can access it. Also, our results suggested that if a buying firm has high level of betweenness, this means the firm acts as hub (Borgatti and Everett, 2006, Provan et al., 2007; Borgatti and Li, 2009; Kim, et al., 2011) and would enable them to acquire novel information by playing a gate keeper role. On the other hand, H_3 for close centrality was not supported suggesting that the value of the indirect ties in a supply network for innovation creation may not be that significant as previously thought. Or findings on the second set of hypotheses on the moderating roles of employee's intent to learn suggested that their subjective wellbeing as well as work life balance do matter in fully utilising suppliers' contribution in its own innovation creation. However, our findings suggested that 'meaningful work' does not increase the efficacy of supplier inputs and uncovering the reasons behind this require further research.

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The role of international NGO in sustainable supply chain management: a conceptual framework

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Abstract

By reviewing 47 peer-reviewed papers between in international NGO (INGO) and sustainable supply chain management (SSCM), this paper developed a conceptual framework to offer a new perspective on understanding the SSCM. More specifically, after reviewing the related theoretical frameworks in existing study, we identified four types of drivers building on social movement theory in the process for INGOs to improve SSCM, which are relative deprivation, political opportunities, resource mobilization and collective action. Relative deprivation and political opportunities provide motives and possibilities for INGOs to mobilize resources, in which process, collective identification can be achieved and collective actions can be implemented.

Keywords: International NGO, Sustainable Supply Chain Management, Social Movement Theory

Introduction

Different from corporate organizations, NGOs have more localized knowledge on society, which makes NGOs more efficient at micro level (Frantz, 1987). In prior studies, e.g., Hyatt and Johnson (2016) and Rodríguez et al. (2016), NGOs are considered as a supply chain members to deal with sustainability issues. NGOs are self-governing, private, not-for-profit organizations that aim to improve social and natural systems (Vakil, 1997). It was acknowledged that NGOs are better at addressing many social sustainable issues and managing supply chains to do so (Rodríguez et al., 2016). To better capture the dynamics of this phenomena, social movement theory (SM theory) was adopted by scholars in sociology, political study and other disciplines in order to analyze why and how SMOs initiate social changes. Indeed, SM theory is a rich perspective to explain how organizations successfully mobilize resources to conduct reform and reach their political goals (Stallings, 1973; McAdam et al., 2003). Since we have focused on international NGOs, institutional perspective is adopted in this study.

In this study, we seek to systematically analyze the related works in the existing study and provide a conceptual framework in the context of sustainable supply chain management (SSCM). By doing so, we reviewed 47 papers from 1970 to 2018. After reviewing the existing literature, we proposed a conceptual framework for our study. Thereby, this paper aims to answer the following questions:

RQ1: What is role of NGOs in changing sustainable practices across supply chains?
RQ2: How do relative deprivation, political opportunities, resource mobilization and collective action affect NGOs' role in sustainable supply chains?
RQ3: How do institutional pressures influence NGOs' works in sustainable supply chains?

The Review Process

In this section, the overview of research approach has been provided in the following section.

Generally, there's little overlap between supply chain management, NGO and sustainability literature. Following SLR method, first, to identify the research scope (Figure 1), we divided these fields into four groups: supply chain, NGO and sustainability; supply chain and NGO; supply chain and sustainability, and NGO and sustainability. To identify the scope, we search the relevant literature in the groups above respectively on Scopus. Second, we use the "advance search" on Scopus database to search following keywords for each group. More specifically, we "translate" SCM as ("supply chain management" OR "value chain" OR "commodity chain" OR "global production network"), NGO as ("international NGO" OR "social responsible stakeholder" OR "social auditor" or "activist stakeholder") and sustainability as ("corporate social responsibility" OR "CSR" OR "triple bottom line"), and adopt these keywords on the database to search the literature for each group respectively to identify the articles. During this process, we choose English articles, peer-reviewed journals as the primary criteria to search articles. In terms of subject, articles are selected in "Business, Management and Accounting", "Economics, Econometrics and Finance" or "Multidisciplinary". Finally, the initial search result showed 44,742 related articles on the database. Then, we conducted an evaluation by scanning the title and abstract and adopting the inclusion and excluding criteria in Figure 2, which identified 393 potential articles. Finally, we read and analyze the full text and identified 47 papers to be discussed in this review Broadly, this process is displayed in figures below:

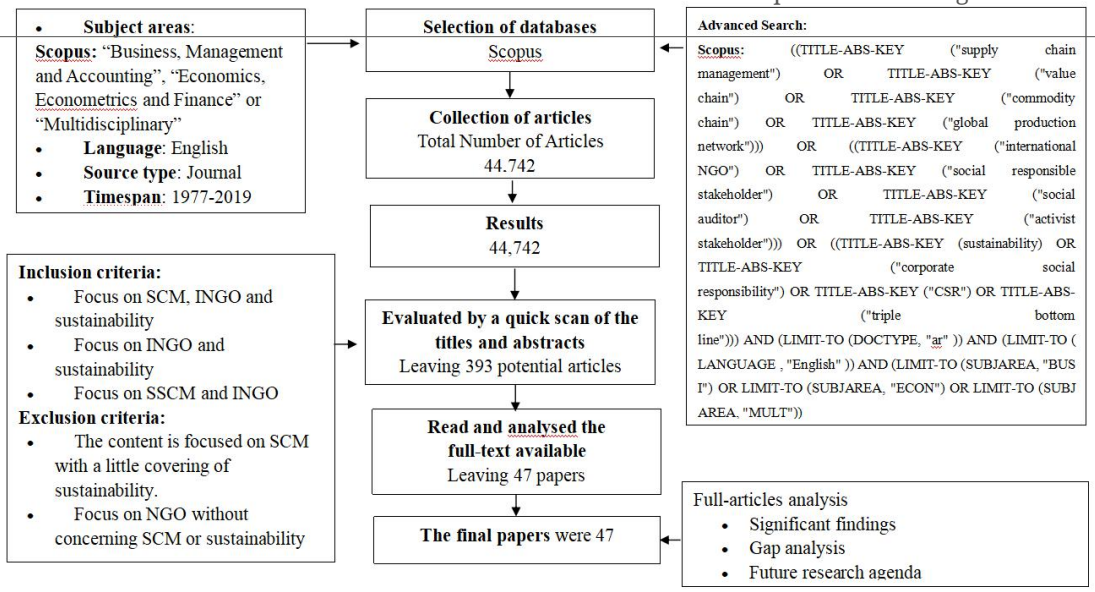

Figure 1 Review Methodology

Construct of Theoretical Frameworks

Relative deprivation

The concept of relative deprivation (RD) was first introduced by Stouffer (1962) in psychology. He claims that satisfaction is relative to available comparison around individuals (Stouffer et al., 1949). Later, scholars such as Pettigrew (1967), Smith et al. (2012) and Walker and Smith (2001) further developed this concept and argue that social judgments are shaped by both absolute standards and standards set by social comparisons. More recently, Pettigrew (2015: p. 12) defined RD as "a judgement that one's in-group is disadvantaged compared to a relevant referent and that this judgment invokes feelings of anger, resentment, and entitlement". In sum, RD refers to the absolute level of deprivation of individuals, or partly, the feeling of dissatisfaction and injustice (Pettigrew, 2015). In a similar vein, such comparison occurs not merely at personal level, but also at organizational level. In sociology, RD illustrates the process of intra-group inequity in order to explain the motivations and implications of social behaviors (Flippen, 2013). In social movement, RD experience has been considered as an essential element. It was acknowledged by resource mobilization theory that RD plays a role as background or motivation in social movements (Oberschall, 1973; McCarthy and Zald, 1973). That said, the outcome of interpersonal or inter-organizational comparisons is the reflection that may finally leads to the strong motivation of changing current situation. Given the fact that individuals or organizations are motivated to rearrange the current settings when emotional reflections arises, successful movements can not be ensured if little opportunities exist prior to the actions being conducted. Thereby, after obtaining motivations, opportunity-seeking behaviours are following after RD experiences.

Political Opportunities

Orwell (1990) argues that social movements cannot emerge when people are not able to associate with others for political purposes. In other words, the foundation of social movement relies on "the chance for people to act together" (Goodwin and Jasper, 1999). Tarrow (1983) indicates that political opportunity is a multidimensional concept which includes "the openness of the political system to potential challengers", "the stability of political alignments" and "the availability of potential alliances". Further, Rucht (1996) addressed "policy implementation capacity of the state" as another dimension of the political opportunities. In other works, political opportunities were considered as the

non-political factors or processes that affect "the chance to act together", such as availability of elite allies and access to political authorities (Goodwin and Jasper, 1999). In sum, opportunities for organizing movement might exist when openness is existing in the current institutional settings when stability is relatively weak. In these regards, "political opportunities" is suitable to be used to explicitly explain INGO-organized "movements" in business operations (e.g., supply chain management). And we therefore argue that political opportunities is the second construct to be adopted in our study.

Resource Mobilization

Resource mobilization contains societal support and constraint of social movement, which examines the variety of resources that must be mobilized, the linkages between social movements and other groups, the dependence of movements on external support and the strategies used by authorities to control movements (Jenkins, 1983). Different from political opportunity approach, the resource mobilization theory focus on the role of internal resources and mobilization efforts (Tarrow, 2011; Tilly, 1979). As discussed earlier, the basis to survive in the society is legitimacy, which allows organizations to collect resources in the society (Meyer and Rowan, 1977). To further pursuit successful works, however, they must not only achieve legitimacy but also try to obtain more resources from the public (McCarthy and Zald, 1977). In this regard, Tilly (1978) proposed resource mobilization theory (RMT) and suggested that resource mobilization plays a key role for the emerging of social movement and sustaining collective action. As a SMO, the success of INGOs' work also requires sufficient resources. To mobilize sufficient resource for collective actions, scholars have proposed the process of Resource Mobilization (RM). In these senses, after access was secured, INGOs' capacity of collecting resources plays a fundamental role in organizing movements. Therefore, resource mobilization perspective is adopted in this study.

Collective Action

In prior studies, scholars in sociology mainly concerns mobilization and collective action are based upon the interactions of like-mind networks (McAdam, 2010) and further analyzed the collective action during movement gatherings and campaigns (Benford and Snow, 2000). Alone this line, three components were proposed including identity, injustice and agency (Wojcieszak, 2011). More specifically, identity component emerges when individual identifies his or her group and recognizes that other groups have different interest and values (Wojcieszak, 2011). In other words, this component defines the concept of "we", which is in opposition to the concept of "they". In addition, injustice component arises when a situation was considered as "unfair" under a certain social setting (McAdam, 2010). Finally, the agency component concerns individual or group recognition that collective action is the solution of unjust situations (Van Stekelenburg and Klandermans, 2013). In this context, INGOs are seen as the social actors that bring about social transformation by utilizing their resources and networks to provide motivations and mobilize people to raise their voices against dominant social settings (Pattnaik and Panda, 2005). Hence, alone this line, INGOs can be considered as social movers or SMOs. This linkage is discussed in the following section.

Institutional Theory

Once again, INGOs' roles as SMOs extend across national boundaries. Davis et al. (2008) argue that in an increasingly global economy, social movements are growing more transnational. It was also mentioned in the previous section that INGOs are expanding their operations in the global business environment, which are challenged by several institutional

pressures. Hence, institutional perspective is employed in this study to better analyze the impacts of INGOs in supply chains.

According to Keim (2003), institutional forces are formal (e.g., government's regulations) and informal (e.g., national culture and values). In prior works, the theory of institution contains three drivers that change organizational strategies, structures and decision-making processes including coercive, normative, and mimetic isomorphic driver (DiMaggio and Powell, 1983). Normative isomorphic driver emphasize the operating mechanism of mind, which includes national or regional culture, shared values, logics of action and mental model. Moreover, coercive isomorphic driver refers to the formal rules that regulate behaviors, which include laws and constitutions. In addition, mimetic isomorphic driver includes informal rules and norms that influence organizational behaviors between competitors. In this study, INGOs are not the ones operating in their home countries. In this sense, institutional environment is seen as the external pressures influencing INGOs' participation in movements. In INGO literature, the most-frequent discussed institutional issue was legitimacy. In other words, external institutional environment making impacts on "movement" carried out by INGOs. Such "movements" can be the ones improving sustainability in firms' supply chains. Thereby, in our study, institutional theory is adopted to analyze how INGOs operate to improve sustainability in supply chains.

Discussion and Development of Conceptual Framework

Based on the constructs above, in this section, we develop 5 propositions and conceptual framework.

As mentioned earlier, relative deprivation theory describes the occurrence of social movement. Pettigrew (2015: p. 12) defined RD as "a judgement that one's in-group is disadvantaged compared to a relevant referent and that this judgment invokes feelings of anger, resentment, and entitlement". In addition, the resource mobilization theory emphasizes both societal supports and constrains of social movements, which argues that the resources related to social movements must be mobilized to ensure the success of movements (McCarthy and Zald 1977). Thereby, in social movement study, these theories have linkages. In prior works, RD experience has been considered as an essential element. In McCarthy and Zald (1973)s' work, RD is the trigger of resource mobilization in social movements. In other words, individuals and groups begin mobilizing resources to prepare for the possible movement when they are motivated by the feeling of unfairness or injustice (i.e., relative deprivation). Hence, based on the discussion, the first proposition is hypothesized as follow.

P1: INGOs' possibility to mobilize resources is positively influenced by relative deprivation in supply chains;

According to Watanabe (2007), the greater gap between people's level of expectation and level of actual fulfillment, the greater is their dissatisfaction. In response to this, people would be more likely to participate social movements.

Theoretical bases of the RD perspective. The link between RD and SM's is grounded in longstanding principles of social psychology. Generally, RD was considered as an essential cause of collective action in prior studies. Justino (2009), for example, argues that individuals are driven to join collective actions in order to improve extremely low living standards, rather than making profit. In other words, individuals are motivated by deprivation in collective protests. However, RD is positively related to the engagement in protests when it occurs in the environment with an open political opportunity structures. That is to say, despite RD is able to encourage individuals to participate collective protest,

it is not a sufficient cause of SM activities (Davies, 1962; Geschwender et al., 1969; Gurr, 1969).

Beaton and Deveau (2005) found that RD based on inter-group comparison may be associated with certain type of collective actions. The impact of economic variables of RD, for instance, depends on the structure of current political opportunities. In this sense, different degrees of efforts required by collective actions have to be identified. In this study, INGOs' motivation to conduct further works is considered as relative deprivation. Furthermore, as INGOs have local knowledge in different regions, we argue that INGOs' RD is based on inter-group comparison. Therefore, we suggest that RD is associated with collective actions.

According to the discussions above, we propose the second proposition as follow.

P2: INGOs are more likely to conduct collective actions in supply chains when they have more relative deprivation.

Tarrow (1983) indicates that political opportunity is a multidimensional concept which includes "the openness of the political system to potential challengers", "the stability of political alignments" and "the availability of potential alliances". Support from authority or openness of institution, for instance, would provide important resources and reduce the autonomy of the SMO as well as threaten its stability, which can impact on the development of SMO. Similarly, the working relationship or political alignment would enhance public recognition in order to access to decision-making procedures and public subsidies with more resources (Goodwin and Jasper 1999). The third proposition is formulated by considering the discussion above, which is presented as below.

P3: political opportunities of an INGO is positively related to INGOs' ability to mobilize resources;

It was acknowledged that organizations have to gain political opportunities and control sufficient resources prior to conducting collective actions (McCarty and Zald, 1977). Khawaja (1994) suggest that the possibility of collective protest depends on the availability of resources. In other words, the more resource people have, the more risk they can take and conduct or participate collective actions. In contrast, individuals with less resources would had a lower possibility to participate in protests. Similarly, Klanderrnans (1997) found that grievance alone cannot formulate collective action without preparing resources at the individual, social and political level. In sum, in this study, we argue that INGOs have better ability to take risk in protests, which motive them to conduct collective actions in supply chains.Based on the discussion above, we propose the following proposition.

P4: INGOs' are more likely to enable supply chains to conduct collective actions when more resources were mobilized;

As mentioned earlier, political opportunity assumes that the political structures, such as the degree of openness and closeness of institution, influence the occurrence of social movements. Although political opportunity is not significantly necessary for the occurrence of collective action or social movement, social movement would not be able to occur "if the political opportunity structure is closed" (Watanabe, 2007: p. 811). This situation also occurs when relative deprivation is high or resources are sufficient. For INGOs, more political opportunities provide more access to resources. Hence, we argue that INGOs tend to be more active in collective actions when more political opportunities were available. Therefore, according to the discussion above, we develop the last proposition as follow.

P5: More political opportunities provide more possibilities for conducting collective action.

In sociology, scholars mainly concern resource mobilization and collective action are based upon the interactions of like-mind networks (McAdam, 2010) and further analyzed the collective action during movement gatherings and campaigns (Benford and Snow, 2000). In supply chains, collective action is required to pursuit higher goals. Ring and Van de Ven (1994: p. 96) suggested that the collaboration of supply chain numbers can be understand as "a form of cooperative inter-organizational relationships, which are `socially contrived mechanisms for collective action". In other studies, participants in supply chains are together to accept specific roles to perform functions and pursuit common goals when each participant's role is believed to be effective to build better supply chains (Ketchen and Giunipero, 2004). Therefore, we develop the last proposition as follow.
P6: Collective actions improve sustainability in supply chains.

By employing both institutional theory and social movement theory to develop a conceptual framework and model for proposed propositions as illustrated below:

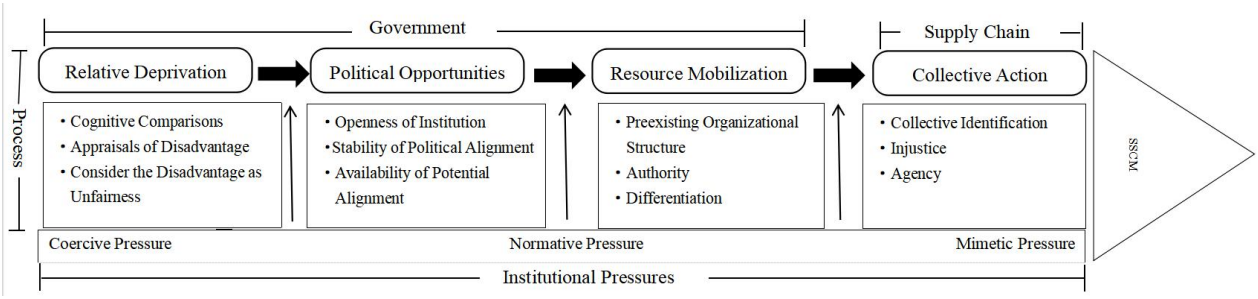

Figure 2 Proposed Conceptual Framework

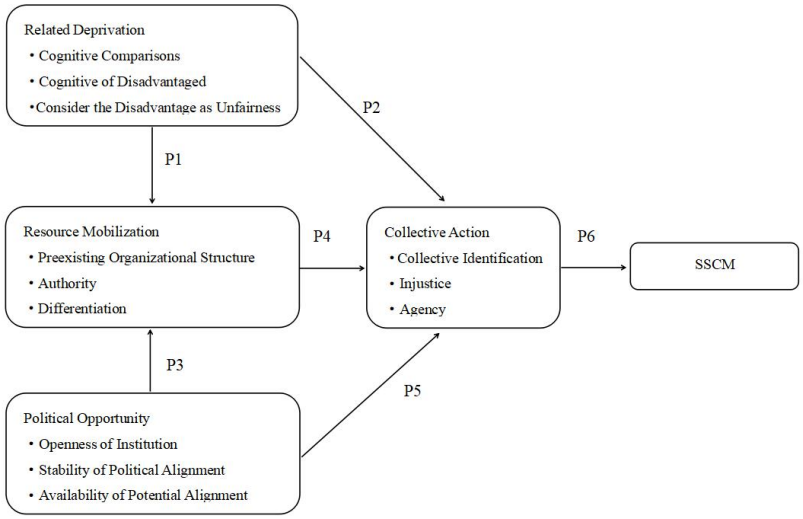

Figure 3 The Motives for NGOs Engaging Social Movement

Conclusion

Overall, the contributions of this study can be threefold. Firstly, this may be the first study which provide a systematic review of INGOs' role on improving social sustainability in supply chains. Secondly, by introducing and adopting social movement perspective from sociology, we opened a possibility to build a new theoretical framework in SSCM study in

the future. More specifically, we argue that relative deprivation, political opportunities, resource mobilization and collective action perspective in social movement theory and institutional pressures should be taken into account in order to understand INGOs' work across supply chains. Third, as this study is not free of limitations, we also provided a number of directions for further studies.

In this paper, we discussed INGOs' role on improving social sustainability in supply chain. Meanwhile, after reviewing the existing literature, we proposed a conceptual framework for our study. Our study, however, is not free of limitations. In response to this, we provide the gaps in the current study and open avenues for the research in the future.

First, NGO can be classified as operational NGO (i.e., the NGO that directly involve in service delivery or participation in self- or development-oriented projects) and advocacy NGO (i.e., the NGO that defend or promote a cause by lobbying and activist events) (Nonprofit Expert, 2017). Therefore, NGOs are complex and adopting different methods to achieve their goals. Our study, however, didn't discuss a particular type of NGO, which is a limitation of this paper. Therefore, the first suggestion is that future research can specifically discuss each type of NGO and provide different types of insights base on the classifications in NGO literature.

Second, as mentioned earlier, social movement theory is a rich perspective to understand how organizations successfully mobilize resources to conduct reform and reach their political goals (Stallings, 1973; McAdam et al., 2003). Indeed, we identified a certain number of constructs under this perspective and selected the related ones for the conceptual framework. Yet, as we reviewed a limited number of relevant literature, the knowledge regarding the social movement perspective is still limited. Thus, the investigation of other constructs of social movement perspective, such as rational choice, may be the second direction for study in the future.

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Do the good die young?: Worker safety and organizational survival

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Abstract
This research asks whether protecting the safety of operational workers offers organizations survival advantage or disadvantage. We address this question because there are conflicting predictions on the relationship between worker safety and organizational performance, making it difficult to create effective safety and policy recommendations. The results, based on a unique longitudinal database covering 386,179 organizations across 25 years are unequivocal: organizations significantly ***decrease*** their odds of survival by protecting the workforce, especially for older and larger organizations. The result suggests that the market is unlikely to enforce workplace safety, and that current regulations are not sufficiently protecting operational workers.

Keywords: Supply Chain Sustainability, Operational Health and Safety, Quantitative Research

Introduction
The pursuit of profit can lead to job creation, innovation, and enhanced prosperity. But when organizations cannot or will not provide a safe workplace, there are costs to the workers, the communities they live in and society at large. This research exploits unique longitudinal data to address a fundamental question: Does providing a safe workplace improve or hinder organizational survival? Otherwise stated, are organizational goals compatible with societal goals?

We address this question because there are conflicting predictions on the relationship between operational worker safety and organizational performance, making it difficult to make coherent policy recommendations or create safe operations. The policy implications if it is profitable to protect the workforce are very different than if it is more profitable not to protect the workforce.

Managerial research posits that improving worker safety will improve profits (e.g. Pagell et al., 2015). Providing a safe workplace is proposed to increase profits as follows. First, the processes recommended for effective safety management systems such as OHSAS 18001 are highly similar if not identical to the processes recommended for effective operations management systems, such as ISO9000 (e.g. Lo et al., 2014; Pagell et al., 2015). Second, these highly similar systems are both primarily aimed at and performed by operational workers. Organizations can create parallel management systems for operations and safety, but this will

likely lead to confusion on the shop floor as operational workers are given duplicate and often conflicting messages about safety and operational management. Hence, organizations can become safe and productive by creating a single integrated management system for safety and operations, which provides workers a coherent message on how to perform their work.

Further, safe workers do not have to dedicate their resources to self-protection and can be motivated to engage in improving the organization's operations; safety provides a necessary condition to leverage human capital into the development of unique capabilities and long-term competitive advantage (Das et al., 2008). Organizations that harm their human capital cannot build these capabilities and will be less likely to survive. This suggests that market mechanisms alone should eliminate poor safety.

However, classical economics suggest that that safety regulation exists because organizations would not provide a safe workplace on their own volition. The supposition that regulation that provides a communal good (in this case a safe workforce) is burdensome or costly for employers is often referred to as the 'costly regulation hypothesis' (Palmer, Oates and Portney,1995; Levine, Toffel and Johnson, 2012). From this perspective, organizations that do not protect the workforce gain an economic advantage by avoiding these burdensome costs and being able to push the workforce further, which may explain why even proponents of "it pays to be safe" provide evidence that numerous organizations are not safe (Pagell et al., 2015).

Similarly, many studies in the managerial literature linking workplace safety to improved organizational performance have been hamstrung by cross-sectional analyses, small and biased samples, and poor proxies. For instance, the sample in Pagell et al., (2015) was limited to manufacturing facilities with at least 100 employees. While there is compelling evidence to support the perspective of either the costly regulation hypothesis or the managerial literature concluding it pays to be safe, neither is conclusive.

We further this discussion by directly exploring organizational survival and safety outcomes across 25 years of quarterly data on all organizations in a U.S. state. Directly exploring safety is important because many organizations have accidents and harm their workers without facing regulatory sanctions (Bureau of Labour Statistics, 2018a); safety is the desired outcome of regulation; and worker safety, not regulatory compliance is what leads to the development of human capital or unique capabilities (Pagell et al., 2015). Our data include the cost of all safety-related claims for each organization, as well as its entry date and how long it survived. Additionally, the data allow us to explore the role of factors such as industry, organization size, organization age, and organization growth. Our research explores these competing predictions:

1. Providing a safe workplace reduces organizational survival, in line with the costly regulation hypothesis.
2. Providing a safe workplace increases organizational survival, in line with the managerial literature on safety.

The results are unequivocal and consistent with the costly regulation hypothesis. Organizations significantly ***decrease*** their odds and length of survival by protecting the workforce. This effect is most pronounced for older and larger organizations and for organizations in industries where accidents are relatively more common. From a policy standpoint this suggests that relying on the market to make workplaces safe does not work. Beyond that, it implies that current regulations are not sufficiently protecting workers. Given our results, we assert that there is a need for greater and more targeted inspections as well as larger non-compliance penalties.

Data and Methods

The Oregon Department of Consumer and Business Services (DCBS), which administers laws and rules governing workplace safety and health in Oregon, provided data on the cost of all disabling claims made in the state from 1989-2014. Disabling claims are those where a worker

suffers temporary disability, defined as requiring three or more days off work, or the expectation of permanent disability.

DCBS also provided employment data for all organizations operating in Oregon, which originally came from the U.S. Bureau of Labor Statistics' Quarterly Census of Employment and Wages (QCEW). The QCEW complies quarterly employment and wage data for 8.9 million U.S. organizations, representing 98% of non-farm, payroll organizations. While this data is publicly available in aggregate form, individual organizational records are not publicly available due to privacy concerns (Bureau of Labour Statistics, 2018b). DCBS provided unique IDs allowing us to anonymously link the QCEW and claims data.

The population included 386,179 organizations with establishments in the state between 1989 and 2014. Two samples of organizations with over 5 employees and sufficient data were constructed. To examine the relationship between short-term claims costs and the risk of failure, a sample of 103,906 organizations was constructed.

We focus on claims costs, not a count of claims, because cost is a better indicator of severity (Lebeau, Duguay and Boucher, 2014). Our primary measures, described below, are short-term claims costs (STCC), organizational survival, and failure. The supplement provides additional detail on measurement, and information on the control variables included in the analyses.

STCC were captured in each quarter as a time varying covariate. Defined as the mean cost of claims per 100 workers per quarter per organization in the past two years, STCC was log transformed due to extreme positive skew. To avoid losing 0 values in the transformation, a 1 was added prior to transformation. STCC was top-coded at the 99^{th} percentile to reduce the influence of very large claims. Mean STCC after top-coding was $ 4,264 (SD= $ 16,014), or 1.95 (SD=3.71) log STCC. The average claim costs $13,910, meaning on average an organization of 100 employees has .304 average sized claims per quarter.

Organizations are considered to have been founded either on their first appearance in the QCEW data (Knaup and Piazza, 2007) or, for organizations present in the first quarter of the dataset (1989 quarter 1), on the date of initial liability provided by the DCBS. The latter organizations are left truncated. Organizations "exit" the dataset at their last record (Phillips and Kirchhoff, 1989) with those making their exit in the last quarter of the dataset (2014 quarter 4), considered right censored. Organizations were considered to have "failed" at a given time point if they left the data set and did not return. To examine effects of STCC on risk of failure, organizations were dummy coded as "failed" or "ongoing" in each quarter. To examine effects of LTCC on length of survival in quarters (survival), organizations were dummy coded as "failed" or "ongoing" at the last time point of the QCEW dataset (2014 quarter 4), with survival calculated as exit time minus entry time in quarters.

We examined the relationship between log STCC and risk of failure in the current quarter employing sample A (103,906 organizations) using a conditional cox proportional hazards model that deals with left truncation (Guo, 1993; Yang and Aldritch, 2012). Results are presented in table 1 and figure 1. The relationship is non-linear; log STCC squared is significant (table 1 Main effect). Increases in STCC ($\log STCC + \log STCC^2$) are associated with a reduction in quarterly risk of failure by up to 30.46% (21.10%, 38.67%) relative to an organization with zero STCC. Only at very high levels of STCC is there a predicted increased

risk of failure; for an organization with 100 employees, this occurs when they average more than 6.68 average sized claims per quarter 6.68*13,910 = 92, 966. The largest reduced risk of failure occurs above the 75th percentile of log STCC, and claims do not relate to an increased risk of failure until they reach the 90th percentile of log STCC. The reduced risk of failure associated with increased STCC is amplified with age while holding employment and other covariates constant (Table 1 Age; Fig. 1B). Similarly, the reduced risk of failure associated with increased STCC is amplified with organizational size (Table 1 Size; Figure 1C).

To summarize the results: Increased STCC predicts a reduction in the risk of failure in the current quarter and this effect is curvilinear. The largest reduced risk of failure occurs above the 75th percentile of log STCC, and claims do not relate to an increased risk of failure until they reach the 90th percentile of log STCC. This pattern is consistent, but strongest for older and larger organizations.

Table 1- Conditional cox proportional hazards models show that increasing STCC reduces hazard but the effect is non-linear. The dependent variable for all models was risk of failure at time t (hazard). Model 1 tests the effects of control variables on hazard (risk of failure at time t). Model 2 tests the effect of STCC. Model 3 tests for polynomial effects of STCC. Model 4 examines the polynomial effects of STCC grouped by organization age. Model 5 examines the polynomial effects of STCC grouped by organization size. Coefficients are rounded to 4 digits, and p<.001 unless otherwise specified.

Independent Variable Specification	Model 1 Controls	Model 2 Linear effect	Model 3 Main Effect	Model 4 Age	Model 5 Size
Entry year and quarter	-0.0031 ± 0.0017 p= 0.0646	-0.0025 ± 0.0017 p= 0.1288	-0.0023 ± 0.0017 p= 0.1675	1e-04 ± 0.0017 p= 0.9322	-0.0015 ± 0.0017 p= 0.378
Year and quarter	-0.0118 ± 0.0013	-0.0129 ± 0.0013	-0.0137 ± 0.0013	-0.0154 ± 0.0013	-0.0142 ± 0.0013
Mean employment per quarter in the past 2 years	-0.0042 ± 2e-04	-0.0035 ± 2e-04	-0.0029 ± 2e-04	-0.0027 ± 2e-04	-0.0014 ± 2e-04
Industry dummies	Included	Included	Included	Included	Included
Log STCC		-0.0203 ± 0.0013	-0.127 ± 0.0071		
Log STCC^2			0.0111 ± 7e-04		
Log STCC: 3-7 years				-0.0843 ± 0.01	
Log STCC: 8-12 years				-0.1129 ± 0.0151	
Log STCC: 13-17 years				-0.1487 ± 0.0194	
Log STCC: 18-22 years				-0.2004 ± 0.0261	

Log STCC: 23-27 years Log STCC: 28+ years				-0.2239 ± 0.0327 -0.2571 ± 0.0248	
Log STCC^2: 3-7 years Log STCC^2: 8-12 years Log STCC^2: 13-17 years Log STCC^2: 18-22 years Log STCC^2: 23-27 years Log STCC^2: 28+ years				0.0085 ± 0.001 0.0095 ± 0.0015 0.0119 ± 0.002 0.0159 ± 0.0027 0.018 ± 0.0033 0.0216 ± 0.0025	
Log STCC: < 10 workers Log STCC: 10-30 workers Log STCC: 30-100 workers Log STCC: 100+ workers					-0.0334 ± 0.0111 , p= 0.0026 -0.0402 ± 0.0116 -0.1687 ± 0.0182 -0.2935 ± 0.0358
Log STCC^2: < 10 workers Log STCC^2: 10-30 workers Log STCC^2: 30-100 workers Log STCC^2: 100+ workers					0.0033 ± 0.0011, p= 0.0029 0.0044 ± 0.0012 0.0151 ± 0.0019 0.0188 ± 0.0039
Likelihood Ratio test	$\chi^2(25)$= 3976.86	χ^2 (26)= 4221.24	χ^2 (27)= 4460.61	χ^2 (37)= 4726.29	χ^2 (33)= 3869.39
Summary Findings	Controls predict hazard.	A one unit increase in log STCC results in a (2.01%) reduction in risk of failure.	The relationship between log STCC and risk of failure is curvilinear.	The protective effect of recent claims costs is larger for older	The protective effect of log recent claims costs is present only for organizations with >10 workers, and is greater

				organizations than younger ones.	for larger organizations than smaller ones.

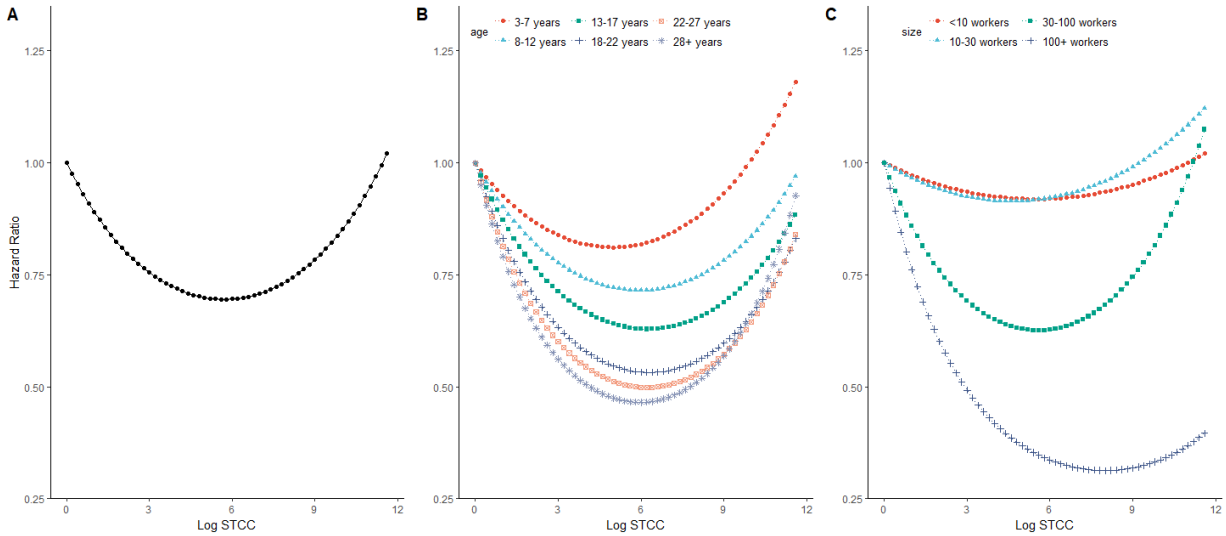

Figure 1- Graph depicting predicted values of Hazard Ratio (risk of failure relative to employers with $0 STCC, with all covariates held constant) vs. log STCC, for all organizations (A, Table 1 Main effect), grouped by organizational age in years (B; Table 1 Age) and grouped by organizational size (C; Table 1 Size). There is a substantial non-linear effect (A), which is greater for older (B), and larger organizations (C).

Discussion

The research asked if providing a safe workplace for operational workers improved or hindered organizational survival. The results are unambiguous and indicate that providing a safe workplace hindered survival; organizational goals are in conflict with societal goals. Organizations with claims are more likely to survive than their peers without claims. These results and other recent research (e.g., Kirchhof, Omar and Fugate, 2016) suggest that, for the many organizations who prioritize organizational goals over operational safety, enhanced survival will conflict with societal goals.

The data set is both the key strength and key limitation of the research. The dataset captures almost all organizations that engaged in economic activity in Oregon over 25 years, but the dataset provides no information on actual managerial practices. Hence, the analysis is predictive not explanatory. Still the analysis does provide some direction both to start to explain the results and to guide future research.

One area to explore is alternative measures of harm to the workers. Disabling claims require at least three days off work, and as such are quite severe. Time away from work is linked to negative outcomes for the worker; illness days, medication use, and job and life dissatisfaction (Wright, Beard and Edington, 2002). The assumption that near misses and minor accidents can predict future severe accidents is prevalent in the safety literature (Manuele, 2011). However, the links are tenuous (Bellamy, 2015; Manuele, 2011; Marshall, Hirmas and Singer, 2018). By focusing on only severe disabling claims, we hopefully eliminated noise from minor incidents, which allows us to target only serious harm to workers. In addition, while under-reporting is a possibility (Pransky et al., 1999), it is less likely with disabling claims, relative to non-disabling claims due to their severity. Someone (typically an insurance company for the organizations in this data) needs to cover the wide range of medical and non-medical costs associated with these claims, and that can only happen if they are reported. Hence, worker compensation databases are viewed as providing a robust measure of work injuries (Oleinick and Zaidman, 2004). Future research needs to test this supposition by exploring the same questions with alternative measures of harm, which could include all accidents (disabling and non-disabling), near misses, and regulatory sanctions.

A related area for future research involves the perceptions of accidents of operational workers and how these perceptions feed into developing human capital and organizational survival. High claims costs eventually harm organizational survival (above $92, 966 per 100 workers per quarter), although at levels which are well above the average injury rates reported by the BLS. The result may occur because after a certain point, accidents are demoralizing to workers or other stakeholders. However, the current research does not decompose the impact of accident frequency vs. severity, as high costs could be attributed to either. Future research should explore how operational workers react to accident frequency and severity as well as how industry norms influence these reactions. Exploring these issues may help to explain when / if organizations build human capital on the foundation of a safe workforce.

These results do not necessarily mean that research concluding it “pays to be safe” (e.g. Pagell et al., 2015) is wrong. We instead suggest that previous research mainly focused on limited samples of primarily large manufacturing organizations that invested in integrated safety management systems; for these organizations it likely *does* pay to be safe. Future research needs to explore how smaller organizations not engaged in manufacturing can create the same outcomes. In raising this question we are really highlighting the much wider issue that most managerial research does not capture small and medium enterprises and is often biased to manufacturing; making many of the literature’s conclusions suspect (Kull et all, 2018). Our results suggest that one way to

make research more relevant and useful will be to target a much wider range of economic actors.

Similarly, this research does not invalidate previous work linking inspections to improved safety with no harm to the organization (e.g. Levine, Toffel and Johnson, 2012) - quite the opposite. Many organizations are presently benefiting from externalizing their costs of poor safety on society, driving a need for increased enforcement. The likelihood of an organization getting inspected in developed countries such as the USA or UK is very low *(*Porter and Van der Linde, 1995) and resultant fines tend to be minimal. Organizations seeking to maximize survival are unlikely to actively put workers in harm's way. But they are also correct in concluding that the costs of protecting operational workers or complying with regulation are higher than the costs of not doing so. This must change, which will require much higher levels of enforcement and higher penalties for organizations that violate regulations. This increased enforcement need not harm competitiveness, but it likely will rebalance the odds of survival in favor of the organizations that seek to prevent all harm to operational workers.

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Crowd delivery: what types of supply chain entry strategies?

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Abstract

In recent years, many crowd delivery initiatives have developed, using a connected crowd of private individuals to carry out delivery. The aim of this research is to understand the supply chain entry strategies used by such firms. Based on secondary data from thirty crowd delivery websites, the article introduces a typology of entry strategies followed by these firms: service, intermediation and integration strategies. These results show that such firms use different business models to enter supply chains. Finally, the article discusses the impact these firms have on distribution, and makes recommendations for crowd delivery firms and players in the channels.

Key words: retailing, last-mile, delivery, crowdsourcing

Introduction

In recent years, a new type of delivery to end users has sprung up: crowd delivery. As a crowd practice (Howe, 2006), crowd delivery consists in using a crowd of private individuals to take charge of the final delivery to the consumer. These initiatives have been developed in urban centres for the distribution of meals (e.g., Foodora, Deliveroo), to deliver supermarket food products (e.g., Instacart, Amazon Fresh), or consumer goods in general (e.g., Postmates). Such schemes rely on the universal connection of people through Internet and Smartphones. This new connectivity enables to benefit from the crowd's physical and logistics resources (Carbone et al., 2017): motive power, the use of private vehicles, the use of public transport, etc.).

Supply chain management academics have so far paid little attention to such initiatives. Yet, crowd delivery may upset the competitive balance in supply chains, superimposing a delivery approach to the complex omnichannel (Verhoef et al., 2015) network. Some crowd delivery actors have reached impressive proportions. Instacart was valued at $3.4 billion in 2017 [The Wall Street Journal, 7 March 2017]. Postmates, with an estimated value of $460 million, raised an additional $140 million in October 2016 [Techcrunch, October 31, 2016] and uses 25 000 private individuals who make 1.3 million deliveries per month in 40 cities in the United States [Time, July 11, 2016]. In several activities (accommodation with AirBnB) those digital, collaborative player are decidedly disruptive.

This paper investigates the booming field of crowd delivery. We propose to answer the following research question: what supply chain entry strategy do crowd delivery firms follow? Given the lack of previous work, the methodology is inductive and exploratory, as suggested by Ketoviki and Choi (2014). The analysis is based on thirty case studies of crowd delivery firms, examined via their websites and secondary information sources.

First, we review the crowd delivery boom, and define it as crowd practice. Then we present the results of our research, developing a typology of supply chain entry: *services*, *intermediation*, and *integration*. In the third section, we highlight the theoretical contribution of our research, and in the fourth section, we assess the potential impact of delivery on these

supply chains and make managerial recommendations for crowd delivery players and existing members of those chains. In conclusion, we underline the limits of our work and suggest avenues for future research.

Crowd delivery, using the crowd to make deliveries to consumers

The term crowdsourcing, based on the words "crowd" and "outsourcing," was popularised by Howe (2006). He refers to firms outsourcing activities to the crowd of private individuals. The boom in crowd practices relies on the idea, widespread in marketing (Vargo & Lusch, 2008), that individuals possess resources (financial, intellectual, material, etc.) that can be activated thanks to the development of digital technologies. As a result, individuals undertake a range of activities that had previously been the responsibility of the company.

Crowd delivery, a form of crowd logistics

Research on the use of crowd resources has stressed two main types of individual resources: financial and intellectual. The crowd funding practices (Ordanini et al., 2011) exist in the field of creation, and many platforms have developed to fund cultural projects (e.g., Kickstarter, KissKissBankBank). Intellectual resources enable the development of crowd innovation services (Collm & Schedler, 2012) used for example to create advertising slogans.

In recent years, several scholars have insisted on the idea that it is possible to activate the crowd's physical resources. Chen et al. (2014) mention the development of a paradigm of urban logistics based on the crowd. Mladenow et al. (2015) note that it is possible to deliver logistics services by mobilising the crowd and Mehmann et al. (2015) propose that the principles of crowd sourcing apply to logistics. Carbone et al. (2017) distinguish in more detail between four types of crowd logistics practices: crowd storage (for warehousing), crowd freight shipping (outsourcing continental transport operations), crowd freight forwarding (international transport based on air travel by individuals), and crowd delivery (the use of the crowd for local deliveries). Ultimately, the latter can be considered as a form of crowd logistics that consists in using the crowd of private individuals to carry out a necessary logistics operation within any supply chain: final delivery of the product to the consumer.

Crowd delivery, a boom in initiatives but little academic research

Crowd delivery initiatives appear very recently (Ghajargar et al., 2016), and develop rapidly in many urban centres. Punel and Stathopoulos (2017) note that in the United States, on average one crowd delivery start-up is currently launched every week! Some authors (Rougès & Montreuil, 2014) present this phenomenon as a response to increasing consumer expectations with regard to delivery (deadlines, cost, and service). The crowd delivery boom is also based on the development of digital and mobile technologies, which provide new opportunities for organising last-mile delivery (Arslan et al., 2016), considered to be the most expensive link in the supply chain (Frehe et al., 2017). Thus, it is now possible to connect with private individuals and transform ordinary citizens into couriers (McKinnon, 2016), and to recruit urban 'crowd workers' (Chen et al., 2014) to carry out parcel deliveries – in exchange for a small payment. Finally, the crowd delivery boom is also a response to the needs of retailers, particularly small operators (Schreieck et al., 2016). It enables them to offer their customers rapid delivery of purchases made at a sales outlet (Ghajargar et al., 2016).

However, the management literature on crowd delivery is for the moment underdeveloped. Most publications on the topic are technical (Frehe et al., 2017), dealing with algorithms or geolocation systems (Mehman et al., 2015). While the managerial literature describing crowd practice strategies is now substantial (Carbone et al., 2017), research in the field of crowd delivery is in its early stages (Frehe et al., 2017).

Methodology: multiple case studies of 30 crowd delivery firms

Ketoviki and Choi (2014, p. 134) recommend that when *"the research context is new and unfamiliar,"* as in this case, a theoretical framework should not be chosen. Our exploratory methodological approach is thus based on multiple case studies that make possible *"to explore a contemporary phenomenon in depth and in its actual context"* (Yin, 2014, p. 16), and fit with theory development. Multiple case studies allow for *"a broader examination of the research questions"* (Eisenhardt & Graebner, 2007, p. 27).

Identification of crowd delivery initiatives

To constitute our series of cases, we used lists drawn up by professionals (Rachel Botsman, Ouishare collective), and extended them with Internet searches. The boundaries of this activity are still blurred, and listing firms is not easy. Like others (Schor, 2014), we identified crowd delivery initiatives pragmatically, using the fact that the various players know each other. In late April 2017, we established a sample of 30 firms (list available upon request).

The crowd delivery initiatives we studied operate in many sectors, although catering and food take the largest share. Such initiatives develop in a variety of countries, including the USA (Deliv, Doordash…), Germany (Foodora,Volo), and Australia (Suppertime)... France is also well represented (Popchef, Colisweb…), which is certainly due to "nationality" bias (some French language sites we consulted mostly belong to French start-ups). However, it is only to be expected that a great number of crowd delivery start-ups should be launched in Paris: the density of the population, the number of restaurants, and the French love of good food clearly favour the development of these initiatives. Finally, the crowd delivery initiatives we studied are led by start-ups, established distributors (Amazon Flex), logistics services providers (DHL MyWays), and new economy companies that have diversified by extending collaborative practices to other sectors (Ubereats).

We first examined the firms' websites. These secondary data "*exists prior to formulation of research objectives"* (Rabinovich & Cheon, 2011, p. 303), and limits artefact bias (Herbert, 2007). In addition, using websites data is particularly appropriate, since initiatives are by definition based on a website (Schenk & Guittard, 2011). Analysing these websites requires several tasks: carefully reading all the material available (pages, general conditions, documents downloadable documents, etc.), watching any videos, and exploring links to the initiative's blogs, forums, Facebook page, and Twitter account. In addition to this data, we collected secondary data from the professional press.

Analysis of the data collected

We used content analysis; its is applicable in a qualitative context, and on a many different types of data, including internet data (Seuring & Gold, 2011), and appropriate for exploratory research. Content analysis is also preferable when the data is unstructured and irregular, and may contain ambiguities (Aureli, 2017). Overall, this method appears particularly appropriate for website content, which undeniably include "propaganda" and extremely varied content. Content analysis enables the classification of raw data by identifying categories and dimensions by a combination of interpretation, subjectivity, and objectivity (Manuj & Pohlen, 2012). Here, we coded the data manually, which is particularly recommended for immersion in emerging phenomena (Thomas, 2006).

During the first "descriptive coding" stage (Miles et al., 2013), we carefully read the content of a dozen websites, alone and then together in order to develop a descriptive coding table (Maas et al., 2014). The objective of the following analytical coding phase was to go beyond description and to develop a conceptual approach. This led us to develop a typology of the supply chain entry strategies followed by crowd delivery firms. Typologies have been a common form of theorisation in the human and social sciences since Weber. In accordance with Doty and Glick's (1994) recommendations, we described each type with regard to the same set of variables. We identified nine key variables to describe each of the three types.

Three types of supply chain entry

Our analysis of 30 crowd delivery initiatives reveals three major supply chain entry strategies. The first one, followed by "Urban logistics service providers" offers existing distributors a crowd delivery service to the final consumer thus enhancing brand's delivery offers. The second one followed by "Online urban retailers" develops an e-commerce platform including a crowd delivery service thus operating direct intermediation between producers/distributors and consumers. The third entry strategy is followed by "crowd delivery based companies". The dominant features of these ideal-types (in Weber's sense) are summarised in Table 1.

	Urban logistics service provider	Online urban retailer	Crowd delivery based company
Entry choice	Service	Intermediation	Integration
Physical operations insourced	Delivery	Order preparation, delivery	Procurement, production, order preparation, delivery
Role of the crowd	Transport	Picking, handling, transport, consumer relationship	Transport, consumer relationship
IT resources	Planning interface (API) with distributors	Planning interface (API) with retailers + mobile application	Dedicated ERP + mobile application
Position in the supply chain	Logistics services provider for distributors/ producers	Intermediary between retailers and consumers	Competitor of other producers/distributors
Direct clients	Retailers (or producers)	Retailers and Consumers	Customers
Product offer	Multi-sectorial	Specialised	Variable
Pricing logic	By the kilometre	Depending on the order	Fixed or included in the price
Benefit for client	New or improved offer of last-mile delivery	Commercial visibility (retailer), on-demand delivery (consumer)	Differentiation and accessibility of the offer, on-demand delivery
Risk for client	Brand image, dependence	Disintermediation (retailer), stock shortages (consumer),	Lack of variety
Examples	Stuart, Uberrush	Postmates, Instacart	Nestor, Popchef

Table 1: types of supply chain entry strategy followed by crowd delivery firms

The crowd delivery firm as a logistics services provider

The first strategy identified is that of urban delivery services provider. These firms' clients are retailers rather than the consumers who benefit from the delivery service. These crowd delivery firms provide a home delivery service for retailers (independent or subsidiaries, with physical sales outlets and/or e-commerce websites, incorporated in a commercial centre, etc.), from their warehouses or points of sale at a reasonable cost. The role of the crowd is to transport goods on behalf of a third party. The principal risk for the retailer is that the quality of the service may not be high enough. On the other hand, if the services work well, the retailer can become dependent on the provider, and see the price charged for the delivery rise. The delivery service proposed, based on the crowd, is extremely flexible (single-unit delivery, flexible delivery times, etc.). This crowd delivery service does not generally target a particular sector, it can be used by independent sales outlets, large distribution networks, (for example, Leroy Merlin has tested the You2you model), large stores (BHV with Deliver, for example), or even manufacturers (Addresses of distinction, a mailbox manufacturer, uses Kanga). The crowd delivery service can be part of a wider range of logistics solutions, including collection from the store or pickup points, exchanges between sales outlets, e-commerce returns, etc. Usually, such firms invoice by distance; the retailer decides whether to pass the delivery cost on to the consumer. These systems are based on dedicated software designed by the crowd delivery firm, interfacing with the retailer's information system. The software can use the internet or sales point interface. A mobile application is also provided for the couriers, but is not usually available for consumers. The key point here is the IT interface with the distributors. Typical examples of such firms include Deliv, Stuart, UberRush, and Zipments.

The crowd delivery firm as an online urban retailer

The service offered by these firms is only available on line and in urban areas. Players target both consumers, who pay the crowd delivery firm for the service provided, and retailers, whose products are listed online. These crowd delivery firms use the retailers in an urban area as suppliers, and position themselves as a visible intermediate, an online marketplace, between the consumers and the retailers. They offer consumers quick delivery and low-cost access to a wide variety of products. The main risk faced by consumers is that the products they buy on line may not be available on the shelves due to stock shortages. As for the retailer, their advantage is based on commercial visibility. The risk they face is that they create a new intermediary between themselves and the consumer. In such a strategy, the crowd is responsible for the transport and for the picking at the point of sale. The crowd constitutes a key actor that can also take on a marketing role, promoting the crowd delivery firm to consumers. Firms often offer a food-oriented product range: catering (e.g., UberEats), cakes and pastries (e.g., citycake), or food retailing (e.g., Instacart, see Box 2). The giant Postmates, adds alternative products (gifts, stationery etc.). The pricing system depends on the features of the order, and can vary with the overall cost of the shopping, its volume, and/or the delivery distance. The service is based on a mobile app that consumers download, and from which they may select the suppliers and/or products they wish. These crowd delivery firms can also offer to set up special partnerships with retailers, both in IT (e.g., integration of the solution within the information system, reception of digital orders in real time by a restaurant) and physically (e.g., dedicated checkouts at Costco stores for Instacart). This ability to set up overall IT and logistics interfaces appears to be crucial for these crowd delivery firms. Typical examples of such firms include Deliveroo, Instacart, and Ubereats.

The crowd delivery based company

These firms target customers exclusively, that can be individuals or companies. Outsourcing delivery to the crowd is used to deliver products designed by the firm itself. From its central kitchen in the suburbs of Paris, the catering firm Nestor delivers a single menu on weekdays to addresses in the west of Paris using a fleet of independent couriers. Similarly, Amazon, is developing crowd delivery, under the name Amazon Flex, to guarantee express deliveries of products sold as part of its offer Prime Now. In this strategy, the crowd undertakes delivery, but also plays a key marketing role as ambassador for the firm. Here, the crowd delivery service is a key feature of the company's offer to its customers, rapid availability and low cost being considered as key success factors. The principal risk for customers is that the offer may not correspond to their need, due to the difficult for the firm to offer its clients sufficient variety. Pricing is either fixed (as in the case of Amazon Prime), or integrated in the price charged to the customer (as in the case of Nestor). Such a strategy is based on a dedicated IT solution interfaced with a mobile application via which consumers place orders. The key competences required for success appears to be developing a marketing offer well-adapted to the target. This type of crowd delivery is much less common than the two other strategies, and is used particularly in catering, with typical examples like Nestor and Popchef. It also reflects the desire of certain retailers (such as Amazon) to create their own distribution channel.

Crowd delivery, several business models to enter supply chain

Our results suggest that crowd delivery firms pursue three major types of strategy to enter supply chains, each of which is based on a different strategic logic: outsourcing, intermediation, or integration.

The diversity of crowd delivery business models

Our findings reveal that crowd delivery firms implement different business models (Zott et al., 2011) to enter supply chains. A firm's business model designates the means it uses to create

and distribute value. Any business model is materialised by different choices (Lecoq et al., 2006): 1) its resources and competences; 2) its internal and external organisation; 3) its value proposition. Figure 1 describes the different choices around which crowd delivery firms build up their business model (Figure 1).

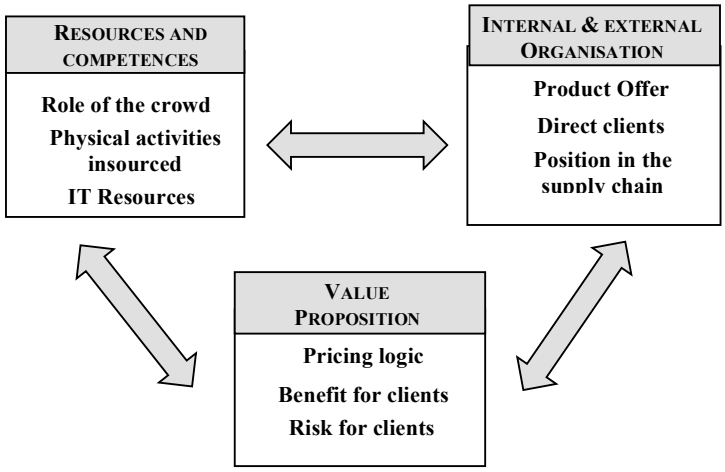

Figure : the diversity of crowd delivery business models

The resources and competences on which the start-up are based can be divided into three areas: the role of the crowd, whose latent logistics competences are mobilised (Carbone et al., 2017), the physical activities insourced by the crowd delivery platform, and the IT resources it mobilises. Our results underline the contrast between the three strategies identified with regard to these parameters. This is true of the crowd, which in each case plays a more or less comprehensive role: this role might simply involve delivering, or include other operational roles such as picking, or even commercial roles. This is also true of the physical activities controlled by the crowd delivery firm, that can be restricted to transport or include other operational activities such as order preparation. Finally, this is true of IT resources, which may include a mobile application, a planning interface, or dedicated ERP software.

The firm's internal and external organisation are based on choices made with regard to the offer, clients, and positioning in the supply chain. The offer may target a single or multiple sectors. The clients can be retailers, the final consumer or both. The firm's position in the chain varies, as the start-up positions itself as a service provider, marketplace, or competitor.

Finally, the value proposition includes the pricing policy, the customer benefits highlighted, and the associated risks. Here again, the choices made by the start-ups are clearly different. Delivery charges can be based on distance or on the service provided, be fixed, or included in the product price. The customer benefits can relate to the features of home delivery (speed, flexibility, etc.), to the breadth or accessibility of the product range, or the uniqueness of the offer. The risks also differ, and include image, dependency, stock shortages, disintermediation, and signing up to a limited offer.

Ultimately, crowd delivery start-ups must find a logical compromise between the three components any business model comprises. Their challenge is to design a model that uses and links the resources and competences developed, the internal and external organisation selected, and the value proposition made to the client. Our finding suggest that the key to success for these "digital" companies is to integrate these technologies within a much larger structure of organisational, marketing, and logistics components. The key issues are those of strategically aligning their IT resources with the other non-digital components (Henderson & Venkatraman, 1993), and beyond this, of successfully interfacing them with both traditional market players and other 'mobility web' start-ups (Rougès & Montreuil, 2014).

Crowd delivery to gain power in the supply chain

Our findings show that the crow delivery firms try differently to disturb the political and strategic balance that governs any supply chain (Cox, 1999). A *services strategy* leads crowd delivery firms to take the place of existing logistics service providers (LSP) and position themselves as third-party for retailers (Punel & Stathopoulos, 2017). Crowd delivery can offer cost saving and more flexible services, adapted to consumer behaviour (McKinnon, 2016). They may threaten LSPs (express couriers, local transporters, courier firms, etc.) but their long-term profitability is dependent on a critical mass of distributors and individuals.

The *intermediation strategy* can also alter the balance. Crowd delivery firm endeavour to manage both delivery and consumer transactions. As brokers (Miles et Snow, 1986), they replace existing retailers by reorganising the channel. As Vétrois and Rimbault (2017) stress, this model both renews and disrupts traditional players. Crowd marketplaces act as integrators (Moati, 2016) by mediating between the producers or retailers and the end consumer, to whom they propose a 'package'. This positioning confirms the observable convergence (Moati, 2016) *"between players of very different origins towards the position of integrator"* (p. 116), which lead distributors to adapt.

Finally, crowd delivery firms following the *integration strategy* design and control the production and transactions of their own offer, and ensure its distribution via the crowd. This model does not appear particularly disruptive when it takes the form of catering. However, it may change the rules when implemented by Amazon, the world's largest source of parcels and last-mile delivery player (McKinnon, 2016)!

Potential impact of crowd delivery on supply chains

Many crowd practices have impacted a wide range of sectors (AirBnB in the hotel sector, Uber in taxi services, etc.). So far, the turnover of crowd delivery start-up firms, whilst difficult to estimate, has often been insignificant. But what does the future hold?

Urban online retailers: the possibility of disruption remains to be confirmed

In our opinion, the strategy with the greatest potential for disruption is that of urban online retailer. The marketplaces listing retailer's products, offer the latter substantial visibility, but they do not restrict themselves to picking up some of their margin. Their arrival is liable to result in the retailer losing direct contact with consumers. If thousands of American consumers keep on using Instacart, nothing will prevent the player from putting traditional distributors in competition by negotiating discounts for its users. This danger is all the greater given that crowd delivery start-ups are no longer the anonymous service providers they initially were, but implement aggressive marketing strategies. Their aim is to target individuals who are a dual target for them, as potential employees and as potential clients.

For the start-ups, the challenge is to reorganise the chain and to substitute retailers "by stealth." For the moment they have by no means succeeded, because of the weight of retailers, and the fragility of their own employment model raising serious questions about their long-term viability. The challenge for the retailers is to avoid losing their crucial direct contact with consumers and to prevent their shops from becoming warehouses where crowd shoppers go to pick up what their clients require. They can consider developing their own crowd delivery services, buying up a crowd delivery player, or emphasizing experiential marketing!

Service providers, between crowd and industrial delivery

These start-ups threaten traditional LSPs operating in supply chains (express parcel deliverers, local transporters, courier firms). The threat is a real one for these firms, particularly as end consumers are demanding with regard to delivery times (less than an hour in urban areas) and expect to benefit from the latest innovations (secure systems, etc.). With their intelligent use of digital technologies and their agility in mobilising simple resources available to everyone, crowd delivery players may establish themselves in this field.

To succeed, such start-ups must be able to provide the customer with a flawless service, which is far from easy when using a crowd of individuals whose logistics skills cannot be guaranteed! Many crowd delivery firms begin by using individuals, but later employ a large proportion of professional couriers…Thus, they are no longer crowd delivery firms, but more like traditional transport firms! It seems to be very likely that LSP's will see some opportunities in these new initiatives. This is the above all the case for 4PL providers, who are used to taking on the role of orchestrator (Zacharia et al., 2011) and are seeking to benefit from crowd delivery by including it in their own range of integrated services.

Firms with integrated crowd services and niche strategies

In the long term, it seems that the impact of firms that deliver their products using their own crowd delivery on supply chains will be limited. Such a strategy requires firms to rethink their products and services, adapting them to the conditions of crowd delivery in line with the principles of *design for logistics* (Mather, 1992). These firms are thus usually forced to limit the assortment they offer. In addition, this restricted offer is only available via a single distribution channel, that of internet orders and delivery (by the crowd or professionals), at a time when the multiple demands of their clients are pushing many players towards omnichannel distribution.

Thus, such a strategic model is likely to follow a niche strategy, in Porter's sense, insofar as it is only possible to target a restricted group of customers. The potential of these strategies seems particularly limited given that in general, these start-ups only offer their services in clearly restricted areas, major city centres such as Paris, New York, London, etc.

Conclusion

In this research we have described the supply chain entry strategies followed by crowd delivery firms. Based on a study of the websites of thirty of these firms and other documentary sources, we have highlighted that these actors use three typical strategies. The first consists in positioning themselves as logistics service providers, aiming to enhance the services of existing retailers by offering them a delivery service. The second consists in considering the firm as an urban online retailer, offering consumers the possibility of buying products from various existing retailers and having them delivered by the crowd. The third consists in producers or retailers developing their own system of collaborative delivery, which they outsource to the crowd.

This research is not free from limitations. These lie in the methodology selected and in our data collections strategy based on analysing crowd delivery initiatives via their websites. These are of course commercial sites, designed to attract users, and this can mean that our data is not objective. In addition, we were unable to measure the commercial and financial results of these initiatives. An examination of the financial statements together with face-to-face interviews, or perhaps targeted in-depth case studies (for example studies of representative firms of each of the three types), would help establish definitively the validity of the typology we introduce here.

But beyond these limitations, our research opens up several interesting research perspectives. A first avenue would be for future research to approach this subject from the standpoint of crowd delivery targets services (retailers and consumers). What are their motivation leverage or brake? Is it possible to identify typical profiles of user companies or consumers?

Another future research avenue would consist in studying human resource management practices in crowd delivery firms. This model offers flexible working, available to all without the need for qualifications or investment apart from the need for a bicycle, and often takes advantage of the limits of the current legal framework. Such human resources management raises multiple, highly-debatable political and societal issues, currently very much in the

public eye. It also raises questions with regard to performance. How can it be possible to guarantee the quality and reliability of the delivery services on offer? How should this new type of work be regulated, to avoid unfair competition between some courier firms subject to strict legislation and others working in the legislative vacuum of the collaborative economy? How can we avoid these new practices leading ultimately to a new kind of exploitation of the crowd?

Hopefully, future research will be able to answer these questions. The development of crowd delivery initiatives raises complex problems that require to consider technical, social, and economic factors, and shape an exciting research field in both logistics and marketing.

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Operational Risk Prioritization in Transport of Fruits and Vegetables

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Abstract

Operational risks are associated with unexpected events which can affect the regular performance of activities. Colombia has a food supply for human consumption of 28 million tons per year; however, it is not fully exploited, as losses and wastes are generated all along the food chain. This risk may occur in the transportation of fruits and vegetables, in which their damage and loss may take place. Therefore, it is important to manage risks, in order to take necessary actions. A proposal is presented to identify and prioritize operational risks in transportation of fruits and vegetables by road in Colombia.

Keywords: Operational risk, Transportation, Fruit and vegetable products

Introduction

Colombia has a food supply for human consumption of 28 million tons per year (FAO, 2014); however, it is not fully exploited, as losses and wastes are generated all along the food chain.

Operational risks are associated with unexpected events which can affect the regular performance of activities, and it has its origins in machines, workforce, processes or external events. This risk may occur in transportation of fruits and vegetables in which their damage and loss can take place. Therefore, it is important to manage risks by identifying and prioritizing them, in order to take necessary actions towards their mitigation or elimination.

The supply chain of fruits and vegetables is complex compared to other supply chains, due to the seasonal nature of its manufacturing processes, the limitations on raw materials' lifespan (Lang and Ding, 2013), the perishable time of products, and their transportation and storage requirements, as the products need to be provided with excellent quality, correct quantity, and at the right place in the delivery time established at a competitive cost (Siegel *et al.*, 2010). Given the pervasiveness of risks and massive structural changes in global and national agri-food systems, farmers, agribusiness firms,

and governments face new challenges in the design of risk management strategies (Siegel *et al.*, 2010).

Figure 1 shows a supply chain configuration for fruits and vegetables, which was built based on the papers presented by (Dani, 2009; Siegel *et al.*, 2010; Lang and Ding, 2013; Yeboah *et al.*, 2014; Rebolledo, 2015)

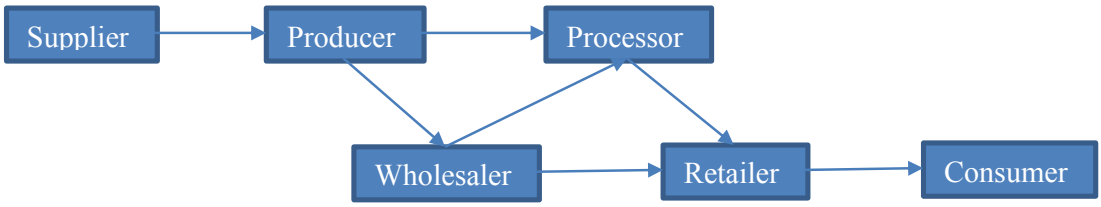

Figure 1. Supply chain structure for horticultural products

A ground transportation activity dominates most of the food supply chain systems, especially towards their final consumer (Ackerley et al, 2010). In Colombia, road transport is one of the most outsourced logistical activities; in 2018, according to (Departamento Nacional de Planeación, 2018) the coverage of this logistical service was near to 45%.

A high participation of road transport in a supply chain, and the inherent tendency of horticultural products to deteriorate due to physiological reasons, as invasion of pests, infections and diseases (FAO, 2014), leads to adopting strict measures to control temperatures and adapt standards for vehicles to be used In order to preserve their safety and quality of products that will reach final consumers (Procolombia, 2014).

To achieve this, it is important to identify and prioritize operational risks present in the transport of horticultural products which directly may affect food safety.

Methodological approach

The methodological approach proposed has two stages as shown in Figure 2:

- Stage 1: Identification of risks present in outsourced transport of fruits and vegetables.
- Stage 2: Prioritization of risks in accordance with strategic objectives of the supply chain

For risk identification, questionnaires and experts are required. A digital questionnaire was designed in which each operational risk identified in the literature had three questions:

- Does it apply as an operational risk?
- What is its probability of occurrence?
- What is its magnitude of impact?

The scale to answer questions 2 and 3 was set out as follows: Very low (1), Low (2), Medium (3), High (4) and Very high (5). With the results, the probability – impact matrix will be built, and risks within the red and orange zones will be prioritized according to stage 2.

For risk prioritization, Fuzzy Quality Function Deployment (FQFD) is applied (Osorio-Gomez *et al.*, 2018). In this case, the linguistic scale showed in table 1 was used to apply FQFD. The complete methodology to FQFD application in risk prioritization might be consulted in (Osorio-Gomez *et al.*, 2018).

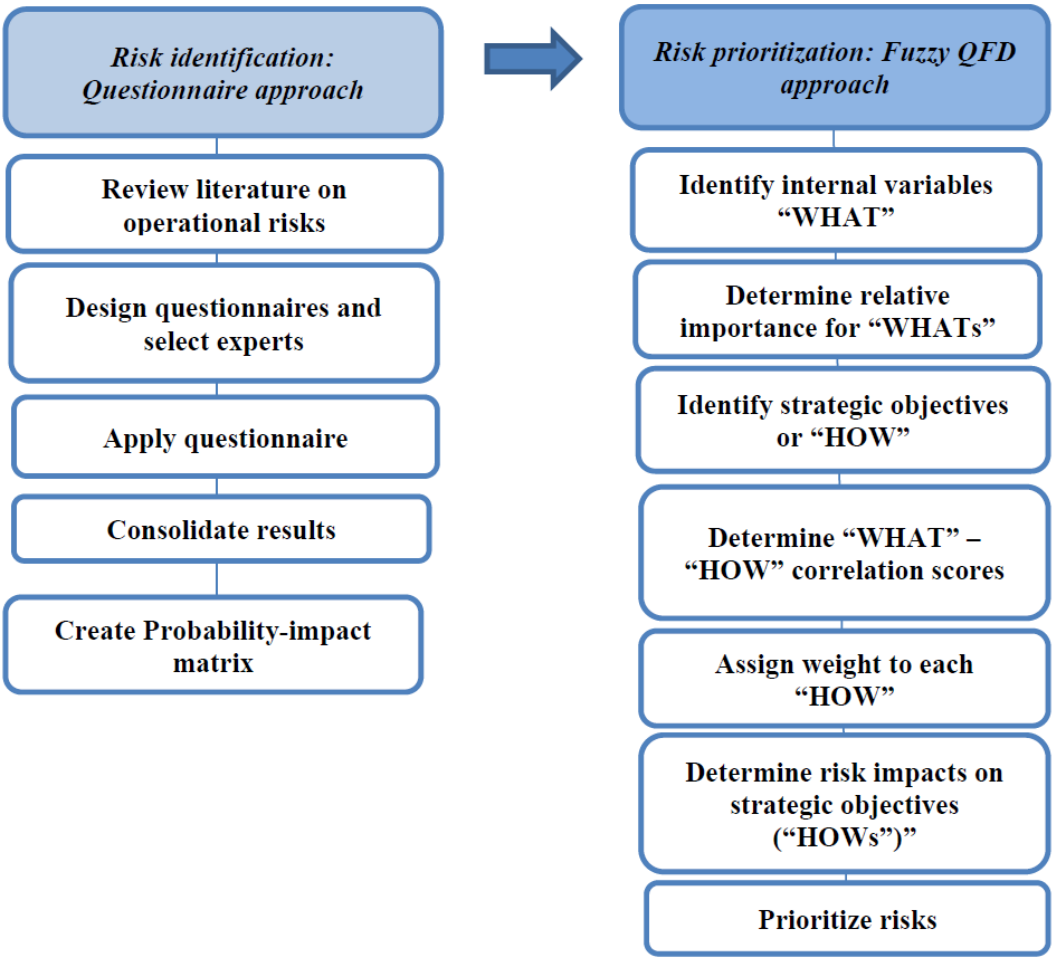

Figure 2. Methodological scheme proposal.

Table 1. Linguistic scale and equivalent triangular fuzzy numbers

Linguistic Variable	Triangular Fuzzy Number
Very Low (VL)	(0, 1, 2)
Low (L)	(2, 3, 4)
Medium (M)	(4, 5, 6)
High (H)	(6, 7, 8)
Very High (VH)	(8, 9, 10)

Source: (Bevilacqua et al, 2006)

Results

The previous methodology was implemented to identify and prioritize operational risks related to outsourced transportation of fruits and vegetables products, and their impact on some performance indicators. This proposal focus on mitigating and reducing these impacts.

First of all, following this methodological approach, operational risks were identified according to the literature review as shown in table 2. Then, using questionnaires the experts chose operational risks that applied to the study case, and defined an impact and

likelihood of each of them. Whit this information, the probability- impact matrix was built as showed in figure 3. The selection of experts was made based on contacting people closely related to the horticulture sector and their knowledge in logistics; for example, industrial engineers, food engineers, and workers in horticultural entities.

Considering the probability - impact matrix, risks located within the red and orange zones are to be prioritized by using FQFD approach. In this particular case, the most important risks are R2 (Bad road conditions), R3 (Strikes, public demonstrations), R5 (Inappropriate practices, conditions or equipment for loading and unloading), R4 (Disruptions in the cold supply chain), R9 (Vehicles breakdowns), R10 (Improper fleet), R11 (Deficient packing of products), R12 (Inadequate hygienic conditions of personnel and vehicles) and R14 (Cross contamination).

Once the FQFD was applied, a final prioritization was obtained taking into account the final risk priority index (FRPI), which is the highest mean value of the most critical risk. The results are presented in table 3.

Finally, the results show that the most critical risk is R11 (Deficient packing of products) followed by R2 (Bad road conditions). They are the most important risks; therefore, the actions taken are to be oriented to mitigate or eliminate these risks.

Once R11 and R2 are mitigated or eliminated, the next risks to consider are (in strict order) R10, R9, R5, R14, R4, R3 and R12.

According to this prioritization, action plans should be defined to help reduce or mitigate their impact on performance indicators.

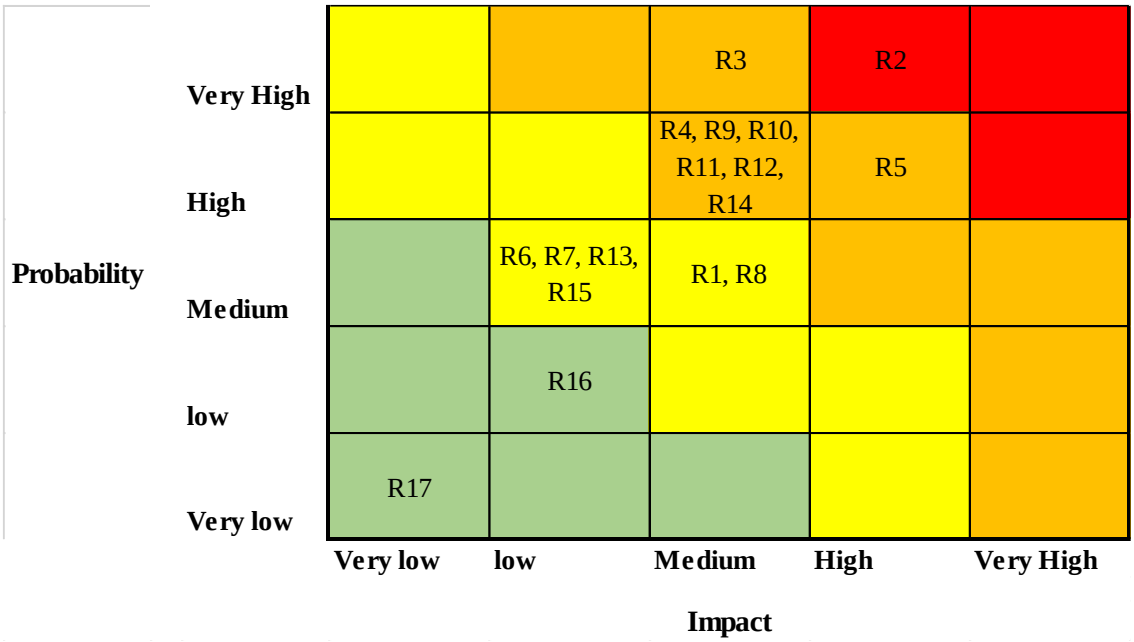

Figure 3. Probability – Impact Matrix

Table 2. Operational risks found in literature review.

Operational Risks	Authors
Bad road conditions	(Siegel *et al.*, 2010) (Yeboah *et al.*, 2014) (Liu and Fan, 2011) (Xu and Huang, 2010) (Louw and Jordaan, 2016)
Strikes, public demonstrations	(Siegel *et al.*, 2010) (Yeboah *et al.*, 2014) (Liu and Fan, 2011) (Xu and Huang, 2010) (Louw and Jordaan, 2016)
Disruptions in the cold supply chain	(Osorio et al, 2017)
Inappropriate practices, conditions or equipment for loading and unloading	(Siegel *et al.*, 2010) (Yeboah *et al.*, 2014) (Liu and Fan, 2011) (Xu and Huang, 2010) (Louw and Jordaan, 2016) (Prakash *et al.*, 2017) (Ackerley et al, 2010) (Tummala and Schoenherr, 2011).
Improper fleet	(Osorio et al, 2017)
Inadequate hygienic conditions of personnel and vehicles	(Osorio et al, 2017)
Variation in transportation costs	(Siegel *et al.*, 2010) (Yeboah *et al.*, 2014) (Liu and Fan, 2011) (Xu and Huang, 2010)
Deficient packing of products	(Louw and Jordaan, 2016) (Prakash *et al.*, 2017) (Ackerley et al, 2010) (Tummala and Schoenherr, 2011).
Lack of traceability of products during transport	(Louw and Jordaan, 2016) (Prakash *et al.*, 2017) (Ackerley et al, 2010) (Tummala and Schoenherr, 2011).
Vehicles breakdowns	(Osorio et al, 2017)
Crimes, thefts and terrorist acts	(Osorio et al, 2017)
Cross contamination	(Louw and Jordaan, 2016) (Prakash *et al.*, 2017) (Ackerley et al, 2010) (Tummala and Schoenherr, 2011).
Poor pest controls in transport units	(Louw and Jordaan, 2016) (Prakash *et al.*, 2017) (Ackerley et al, 2010) (Tummala and Schoenherr, 2011).
Drivers' lack of skills	(Osorio et al, 2017)
Shipping errors	(Osorio et al, 2017)
Incorrect documentation	(Osorio et al, 2017)
Absence or bad communication between drivers and owners	(Osorio et al, 2017)

Table 3. Risk prioritization

Risks		Risk Priority Index (RPI)			Final RPI
Very High					***466***
R11	Deficient packing of products	231	363	538	374
R2	Bad road conditions	224	355	529	366
High					***364***
R10	Improper fleet	219	348	520	359
R9	Vehicles breakdowns	209	335	503	345
R5	Inappropriate practices, conditions or equipment for loading and unloading	209	335	502	345
R14	Cross contamination	189	306	464	316
R4	Disruptions in the cold supply chain	187	303	460	313
R3	Strikes, public demonstrations	179	294	449	304
R12	Inadequate hygienic conditions of personnel and vehicles	171	282	433	292
Medium					***262***

After prioritization risks, some interviews were conducted with experts responsible for the logistic operation, such as logistic coordinators and people in charge of receiving fruits and vegetables products in main market places and supermarkets located in Cali - Colombia. In order to know the main causes of these risks and thus to establish actions oriented to mitigate or eliminate each one of them.

Conclusion

Identifying and prioritizing operational risks in the transport of fruits and vegetables is essential to detect risks which may have greatest impacts on supply chain indicators. In this way, companies could make decisions aimed to reduce damage and prevent early disposal of their products. The latter, generate not only economic losses but also affect the quality of life in many societies.

Damage and early disposal of fruits and vegetables increase significantly throughout the entire food supply chain. For this reason, it is highly important that all SC participants ensure an effective interaction with each other, and look forward to maintaining the highest quality of their products.

Among the main weaknesses found in this study for the outsourced transport of fruits and vegetables products are: bad practices in manipulation horticultural products, poor standards of transport and lack of standards in internal policies.

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Modelling the causes of food loss and waste in fresh food supply chains: An integrated ISM-MICMAC analysis

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Abstract

To design and implement effective food loss and waste (FLW) prevention strategies, a good understanding of its causes is necessary. In this paper, the interrelationship between 14 causes of FLW in fresh food supply chains (FSC) were analysed using an integrated ISM-MICMAC methodology. The causes were divided in different levels and categorized into four clusters, regarding their driving and dependence powers. The most influential causes are the logistics related causes of food loss and waste, since most of these comprise the top levels of the ISM-based model and the independent cluster, containing the root causes of FLW in fresh FSCs.

Keywords: Food Loss and Waste, Food Supply Chain; Interpretive Structural Modelling

Introduction

Although the prevention of FLW has gained greater attention in recent years, the pattern and range of FLW along FSCs is not yet well understood (Bagherzadeh et al., 2014). There is a clear need to improve the knowledge on the drivers of FLW and on their environmental, social and economic impacts, since this knowledge is crucial for the "design and implementation of effective prevention policies at EU, at national and local level" (Fusions, 2016; Priefer et al., 2016). Hence, the identification of the different sources of FLW should be taken as the first step to study the phenomenon of FLW in FSCs and to establish where and how the efforts should be applied towards FLW prevention or mitigation (Priefer et al., 2016). This first step is crucial for the study of FLW, because food is lost or wasted from its production to its consumption (Martínez et al., 2014; Bräutigam et al., 2014) and the causes of FLW differ significantly, for example, with the type of food and the geographical region.

The study of FLW is even more complex because the majority of the results reported by researchers is not comparable due to different definitions of what is being regarded as

FLW. No consensus has been reached as to what should be the definition of the terms food loss or food waste, but, in several studies, food waste is defined as "any food, and inedible parts of food, removed from the FSC to be recovered or disposed, but not including food, or inedible parts of food, sent to animal feed or used for the production of bio-based material/biochemical processing" (Fusions, 2016). Food loss is used if the discarding of food occurs at the upstream stages of the food chain; if, on the other hand, the food is discarded at the retail or consumption stages, then it is usually referred to as food waste. For the purposes of this paper no distinction between food loss and food waste will be used, therefore, FLW will be used to address all food products being discarded from the fresh FSC.

The main contribution of this paper lies in addressing these shortcomings by focussing on the interactions between the causes of FLW within fresh FSCs. Therefore, the research question guiding this paper is:

How are the causes of FLW along FSCs interrelated from a holistic point of view?

To address this question, the research analyses the main causes of FLW along fresh FSCs and then assesses the interrelationships between them. Interpretive structural modelling (ISM) is used to help develop a more effective understanding of the causes of FLW. Since one cause might lead to other causes of FLW to be noticeable, resulting in a domino effect, then it is very important for the practitioners to understand the relationship between causes of FLW. A group of stakeholders was carefully chosen to aid in the selection of the main causes of FLW in FSCs and to develop the ISM model to draw the relationships between them. The results from the ISM methodology was complemented with a MICMAC analysis to identify the driving and dependence power of each of the causes under study.

The paper consists of other four sections. The next section outlines the theoretical background to the study. The section after that describes, step by step, how to implement the ISM-MICMAC analysis and reports the different outcomes. The following section provides a detailed discussion of the results and the final section summarizes the main conclusions of this paper, highlighting the theoretical and managerial implications of the research and suggesting future research opportunities.

Literature Review

Food products have to be transported, cooled, processed, traded, treated and packaged before reaching the final consumer. Because of the variety of activities food products have to endure, it is easy to understand why the products get deteriorated and ultimately discarded from the FSC. So, to fully understand why food products are discarded from FSCs, an analyses at the level of the different stages of the food chain is necessary (Martínez et al., 2014).

Several authors attempted to classify and establish relationships and priorities between the different causes of FLW, instead of only assessing the sources of FLW and where these occurred in FSCs. For example, Willersinn et al. (2015) tried to classify the causes of FLW into four categories: technological, institutional (business and economy), institutional (legislation and policy) or social drivers. Mena et al. (2011), while analysing the causes of FLW in the supplier–retailer interface, started to realise that several causes had interdependencies, but that they were part of a complex web. So, the author used causal maps to study the web, creating a tree where the top nodes, representing the symptoms, were linked to the bottom nodes, representing the root causes of FLW. The root causes of FLW were then classified into: mega-trends, natural constraints and management root causes, the latter being the ones practitioners should tackle.

Even though some efforts are being made to better understand why FLW is generated, Diaz-Ruiz et al. (2018) emphasises that little attention has been devoted to understanding the core of the FLW problem by applying multidimensional approaches with a holistic perspective of the FSC. In this direction, some authors have recently started to use multi-criteria decision-making (MCDM) tools to evaluate different variables in FSCs. The majority of the studies on the causes of FLW in FSCs focuses on the study of the fruit and vegetable supply chain in India (Balaji and Arshinder, 2016; Gardas et al., 2017; Gardas et al., 2018; Raut and Gardas, 2018; Raut et al., 2018). Only one of those studies target other country, namely UK and Spain (Mena et al., 2011). Also, the majority of the articles do not describe the boundaries of the FSC in study and for the ones that do, the focus is clearly on the downstream stages of the food chain (Mena et al., 2011; Raut et al., 2018).

While previous findings provide valuable information for this research, they have limited value in identifying and evaluating the relationships between the causes of FLW across the fresh FSC, because they tend to examine the dyadic relationships between buyers and suppliers rather than the more complex interactions amongst all the participants in the FSC (e.g., Mena et al., 2011).

In conclusion, most of the literature that assesses the causes of FLW focus on the downstream stages of the FSC and often use data taken from the literature itself, without resorting to practical or industrial data (Priefer et al., 2016). The focus is mainly on the identification of material flows and the origin of FLW, without trying to prioritize or to analyse the relationship between the different causes. Even though we have seen that some researchers took a step in this direction, they did so mainly in the context of the Indian fruit and vegetable supply chain and no emphasis is given to what are the boundaries of the FSC under study. Hence, it is the key objective of this paper to model the causes of FLW for the fresh FSC and to establish the interrelationship among these using an integrated ISM and MICMAC analysis, from the agricultural production up until retail, since the causes of FLW in household consumption are more of a behavioural nature and harder to relate to the rest of the stages of the food chain.

Methodology and Results

Interpretive Structural Modelling (ISM) can be used to identify the structure of the relationships among elements related to a particular complex research problem (Kwak et al., 2018). It is a process that transforms unclear and poorly articulated mental models of systems into visible and well-defined models (Venkatesh et al., 2015). It helps in understanding a complex system by considering the hierarchy and relationships among the variables of the system (Kwak et al., 2018). ISM was used in this research to identify and evaluate interactions among the causes of FLW along FSCs. The findings present a graphical structural map of the causes, highlighting the connections between them and the most critical types of causes requiring mitigation. The hierarchical model developed by the ISM methodology will feed the MICMAC analysis to further determine the driving and dependence powers of each variable, in order to assess which are the most influential causes of FLW along fresh FSCs (Gardas et al., 2017).

To apply the ISM methodology efficiently, one must possess in-depth knowledge of the method and be sufficiently trained to interpret the obtained data. Albeit these limitations, ISM is capable of capturing dynamic complexities, while other methodologies from MCDM, like AHP or Analytic Network Process (ANP), have trouble dealing with complex real life problems and have lower ability to capture dynamic behaviours (Shahabadkar et al., 2012).

Steps to implement the ISM methodology

ISM comprises a set of well-defined steps for its successful implementation and in this research, the works of Venkatesh et al. (2015), Mishra et al. (2017) and Kwak et al. (2018) were used to guide the implementation of the ISM methodology. Therefore, to implement ISM, firstly, the key variables of the system are identified and listed. Secondly, the contextual relationships are identified among each pair of variables identified before. These contextual relationships are registered in the form of a matrix called structural self-interaction matrix (SSIM) and can be of four different types: V, A, X or O (see sub-section Structural Self-Interaction Matrix (SSIM) for more info). Next, the SSIM is converted into a binary matrix, called initial reachability matrix, by substituting V, A, X and O with 1's and 0's, following the rules described in sub-section Reachability Matrix. After the development of the initial reachability matrix, the matrix is checked for transitivity. After computing the final reachability matrix, this is then converted into the canonical matrix format by arranging the elements according to their levels, performing the so-called level partitioning. After that, the ISM-based model is drawn by connecting the variables in each level, based on their relationships as defined in the structural self-interaction matrix.

Identification of variables

Magalhães et al. (2019) assessed the major causes of food loss and waste for the different stages of the FSC. That work was used as a basis to build a list that summarized where the different causes of FLW occur in the FSC, from agricultural production up until retail. That list was then presented to relevant stakeholders from the FSC (namely, producers, distributors and retailers), and to prominent academics with expertise in FSC management, and it was reduced to incorporate the FLW causes most relevant to the problem. Fourteen causes of FLW were chosen to be the starting point of the ISM methodology: (1) inadequate demand forecasting; (2) overproduction and excessive stock; (3) poor handling and operational performance; (4) storage at wrong temperature; (5) inadequate or defective packaging; (6) non-conformance to retail specifications; (7) product quality; (8) short shelf-life or expired products; (9) climate change and weather variability; (10) lack of storage facilities; (11) pricing strategies and promotions management; (12) lack of coordination and information sharing; (13) inadequate transportation systems; and (14) inefficient in-store management.

Structural Self-Interaction Matrix (SSIM)

The contextual relationships were summarised into one SSIM, where the relationship between each (i, j) pair of variables was classified into four different types:

- V: variable i leads to achieve or influences variable j;
- A: variable j leads to achieve or influences variable i;
- X: variable i leads to achieve or influences variable j and vice versa;
- O: there is no relationship between the variables i and j.

The panel of experts was asked to assess the contextual relationships between causes and, after reaching a consensus, the interrelationships were converted into the SSIM matrix, as shown in Table 1.

Reachability Matrix

Given the SSIM, an initial reachability matrix was developed by substituting V, A, X, O with 1's and 0's, according to the following rules:

- If the (i, j) entry in the SSIM is V, the (i, j) entry in the initial reachability matrix becomes 1 and the (j, i) entry becomes 0.
- If the (i, j) entry in the SSIM is A, the (i, j) entry in the initial reachability matrix becomes 0 and the (j, i) entry becomes 1.
- If the (i, j) entry in the SSIM is X, the (i, j) and (j, i) entries in the initial reachability matrix becomes 1.
- If the (i, j) entry in the SSIM is O, the (i, j) and (j, i) entries in the initial reachability matrix becomes 0.

After the development of the initial reachability matrix, seen in Table 2, the matrix is checked for transitivity. In summary, the transitivity means that if variable i is related to variable j and if variable j is, in turn, related to variable k, then the variable i is indirectly related to variable j, and if the entry (i, k) of the initial reachability matrix was 0, then it should be replaced by a 1. Transitivity was checked resorting to Matlab, to avoid human error, and was incorporated into the final reachability matrix, shown in Table 3, by assigning 1* to the identified indirect relationships. Driving and dependence power were also calculated in this step to assist the MICMAC analysis.

Table 1 – Structural Self-Interaction Matrix (SSIM)

C[i/j]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	-	X	O	O	O	O	O	V	O	O	X	A	O	O
2		-	O	O	O	O	V	V	O	A	X	A	O	O
3			-	O	A	V	V	V	O	O	O	O	O	V
4				-	O	V	V	V	O	A	V	A	A	A
5					-	V	V	V	O	O	O	O	A	O
6						-	X	V	A	A	O	A	A	O
7							-	V	A	A	V	A	A	A
8								-	O	A	V	A	A	A
9									-	O	V	O	O	O
10										-	O	O	O	V
11											-	A	O	O
12												-	O	O
13													-	O
14														-

Note: C[i/j] represents the cause in line i or in column j.

Level Partitioning

After the development of the final reachability matrix, level partitioning is conducted. For each variable, the reachability set, the antecedent set and the intersection set are found, to assess the levels of the variables. The reachability set is the sum of the entries equal to 1's for each line (indicating that variable i influences variable j), the antecedent set is the sum of the entries equal to 1's (indicating that variable i is influenced by variable j) and the intersection set is the intersection between the variables present in the reachability set and the ones from the antecedent set. When the intersection set is equal to the reachability set, then the variable is attributed to the level of that iteration. The variables assigned to one level are then removed from the remaining reachability and intersection sets for the next iteration and the same process is applied until all the variables are partitioned into levels. Four causes are considered the top-level of the ISM-based model: inadequate demand forecasting; overproduction and excessive stock; short shelf-life or expired products; and pricing strategies/promotions management. After removing these causes from the remaining reachability and intersection sets, then the next level causes are causes

6 and 7, non-conformance to retail specifications and product quality, respectively. After seven iterations, the bottom level of the ISM-based model was found and the results of the level partitioning can be consulted in Table 4.

Table 2 – Initial Reachability Matrix

C[i/j]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	1	0	0	0	0	0	1	0	0	1	0	0	0
2	1	1	0	0	0	0	1	1	0	0	1	0	0	0
3	0	0	1	0	0	1	1	1	0	0	0	0	0	1
4	0	0	0	1	0	1	1	1	0	0	1	0	0	0
5	0	0	1	0	1	1	1	1	0	0	0	0	0	0
6	0	0	0	0	0	1	1	1	0	0	0	0	0	0
7	0	0	0	0	0	1	1	1	0	0	1	0	0	0
8	0	0	0	0	0	0	0	1	0	0	1	0	0	0
9	0	0	0	0	0	1	1	0	1	0	1	0	0	0
10	0	1	0	1	0	1	1	1	0	1	0	0	0	1
11	1	1	0	0	0	0	0	0	0	0	1	0	0	0
12	1	1	0	1	0	1	1	1	0	0	1	1	0	0
13	0	0	0	1	1	1	1	1	0	0	0	0	1	0
14	0	0	0	1	0	0	1	1	0	0	0	0	0	1

Note: C[i/j] represents the cause in line i or in column j.

Table 3 – Final Reachability Matrix

C[i/j]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	DVP
1	1	1	0	0	0	1*	1*	1	0	0	1	0	0	0	6
2	1	1	0	0	0	1*	1	1	0	0	1	0	0	0	6
3	1*	1*	1	1*	0	1	1	1	0	0	1*	0	0	1	9
4	1*	1*	0	1	0	1	1	1	0	0	1	0	0	0	7
5	1*	1*	1	1*	1	1	1	1	0	0	1*	0	0	1*	10
6	1*	1*	0	0	0	1	1	1	0	0	1*	0	0	0	6
7	1*	1*	0	0	0	1	1	1	0	0	1	0	0	0	6
8	1*	1*	0	0	0	0	0	1	0	0	1	0	0	0	4
9	1*	1*	0	0	0	1	1	1*	1	0	1	0	0	0	7
10	1*	1	0	1	0	1	1	1	0	1	1*	0	0	1	9
11	1	1	0	0	0	1*	1*	1*	0	0	1	0	0	0	6
12	1	1	0	1	0	1	1	1	0	0	1	1	0	0	8
13	1*	1*	1*	1	1	1	1	1	0	0	1*	0	1	1*	11
14	1*	1*	0	1	0	1*	1	1	0	0	1*	0	0	1	8
DPP	14	14	3	7	2	13	13	14	1	1	14	1	1	5	

Note: C[i/j] represents the cause in line i or in column j.

Development of the ISM-based model

A direct graph, or digraph, is built by arranging the variables vertically and horizontally according to the level partitioning and, if variable i influences variable j in the initial reachability matrix, than an arrow is used, pointing from i to j, to show the direct influence between these two nodes.

The ISM-based model, shown in Figure 1, demonstrates the hierarchical structure of the causes of FLW and highlights their interrelationships. The digraph was generated by arranging the 14 causes according to the level partitioning (Table 4) and by connecting the causes according to the initial reachability matrix (Table 2).

The levels of the different causes of FLW in the ISM-based model (Figure 1) provide an understanding of their impact in the reduction of FLW in fresh FSCs. The figure shows that inadequate demand forecasting, overproduction and excessive stock, pricing strategies and promotions management and the short shelf-life or expired products are the causes of FLW at the top level (level I) of the ISM-based model. The following level (level II) comprises the non-conformance to retail specifications and the product quality. Given the ISM methodology, if practitioners implement actions to eliminate the causes from level II, these actions will also aid in the elimination of the causes from level I. At the bottom of the ISM hierarchy is the inadequate transportation systems (level VII), which is the cause that has most influence over the other causes of FLW considered. This is the most influential cause under study, and since the hierarchy has seven different degrees of influence, than management actions taken towards level I or II, for example, will have little or no repercussion at all at higher levels.

Table 4 – Level partitioning results

Causes	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,6,7,8,11	I
2	1,2,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,6,7,8,11	I
3	3	3,5,13	3	V
4	4	3,4,5,10,12,13,14	4	III
5	5	5,13	5	VI
6	6,7	1,2,3,4,5,6,7,9,10,11,12,13,14	6,7	II
7	6,7	1,2,3,4,5,6,7,9,10,11,12,13,14	6,7	II
8	1,2,8,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,8,11	I
9	9	9	9	III
10	10	10	10	V
11	1,2,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11,12,13,14	1,2,6,7,8,11	I
12	12	12	12	IV
13	13	13	13	VII
14	14	3,5,10,13,14	14	IV

After building and assessing the hierarchy of the ISM-based model, we realised that the causes were organized in the model by their origin, i.e. it was clear that the causes were grouped in logistics related causes, quality related causes and retail related causes (Figure 1). The logistics related causes of FLW incorporate inadequate transportation systems, inadequate or defective packaging, lack of storage facilities, poor handling and operational performance, lack of coordination and information sharing, inefficient in-store management and storage at the wrong temperatures. Quality related causes of FLW comprise the climate change and weather variability, the product quality and the short shelf-life or expired products. The retail related causes of FLW include the non-conformance to retail specifications, the pricing strategies and promotions management, the overproduction and excessive stock and the inadequate demand forecasting.

It became noticeable that the logistics causes are the most influential ones and that if some actions were taken to mitigate these causes, then it would have a major influence under the quality and retail related causes. Therefore, practitioners should focus their efforts to fight the logistics related causes of FLW first. After appropriate actions are implemented and the logistics related causes are eliminated or mitigated, then other strategies to fight the quality driven causes should be sought and implemented. Retail related causes should be tackled last.

A MICMAC analysis was used to further assess which causes of FLW are most prominent to be tackled in the fresh FSC.

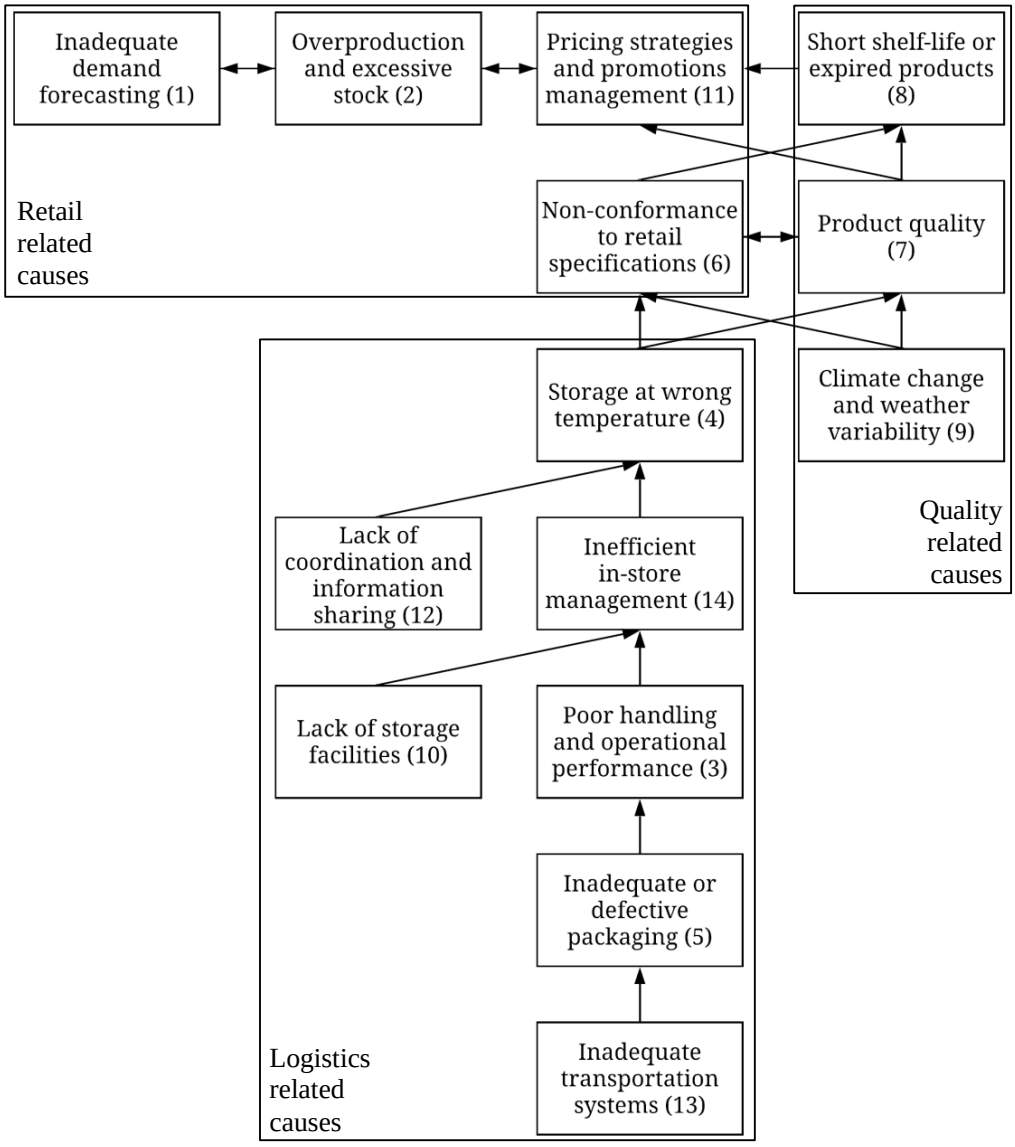

Figure 1 – ISM-based model of the causes of FLW in FSCs

MICMAC analysis

The MICMAC analysis examines the driver and the dependence power of the variables (Charan et al. 2008). The driving and the dependence powers of each cause under analysis is shown in Table 3. In the final reachability matrix, every 1 in the rows of the table indicates that the cause i influences cause j. Therefore, the sum of the row from cause i determines the driving power of that cause. The same logic reasoning is applied to calculate the dependence power. Every 1 in the columns of Table 3 indicates that cause j is influenced by cause i. Therefore, the sum of the column from cause j determines the

dependence power of that cause. Subsequently, the driving-dependence power diagram is constructed and the causes are classified into four clusters, as shown in Figure 2.

The first cluster consists of the autonomous variables, which have weak driving and weak dependence powers. The causes in this cluster are relatively disconnected from the system, with which they have only few links. The second cluster consists of the dependent variables, which have weak driving, but strong dependence, and comprises the causes that only influence some of the others, but that are influenced by the majority of the causes from the system. Third cluster has the linkage variables, which have strong driving and strong dependence powers. The causes in this cluster are quite unstable given the fact that any action on these causes will have an effect on the others and also a feedback on themselves. Fourth cluster includes the independent causes having strong driving, but weak dependence power. Since these are the causes that have a strong influence on the majority of the other causes, but are almost not influenced by any other, then these are considered the key or root causes of FLW in FSCs.

From Figure 2, we can conclude that the root causes of FLW in fresh FSCs are the independent causes, namely: poor handling and operational performance (cause 3); inadequate or defective packaging (cause 5); lack of storage facilities (cause 10); lack of coordination and information sharing (cause 12); and inadequate transportation systems (cause 13).

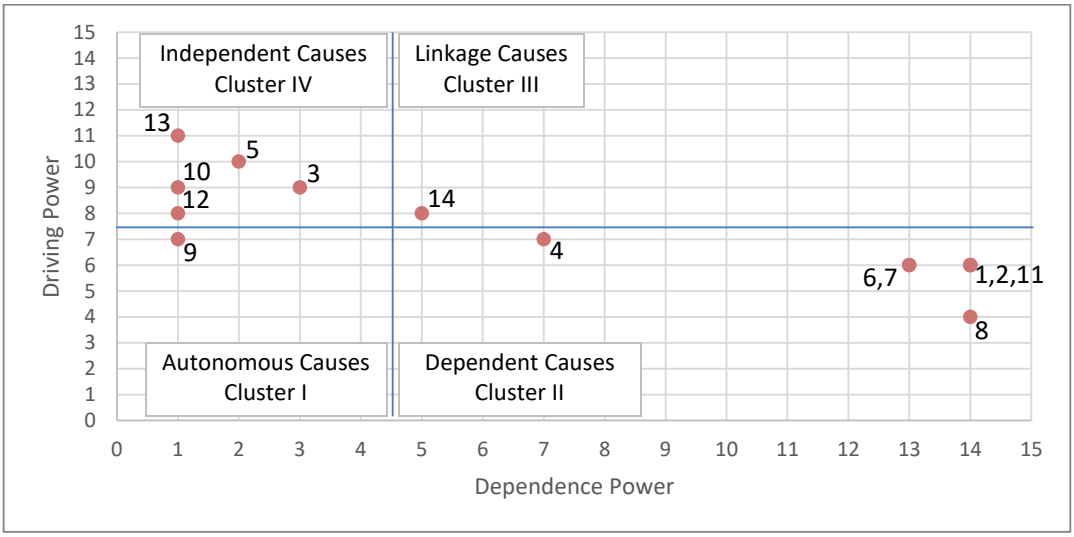

Figure 2 – Cross-impact matrix multiplication applied to classification (MICMAC) analysis of the causes of FLW

Conclusion

In this paper, fourteen causes of FLW in the fresh FSC were selected and their interrelationships was modelled using an integrated ISM and MICMAC analysis approach. This integrated approach established that the most influential causes of FLW in fresh FSC are: inadequate transportation systems, inadequate or defective packaging, lack of storage facilities, poor handling and operational performance and lack of coordination and information sharing, which are exclusively logistics related causes of FLW.

Although this research provides critical insight about the issues regarding the supply of fresh foods, from the moment they are produced until they reach the shelves of the supermarkets, the present results should be interpreted with caution, since the ISM and

MICMAC analysis rely on the subjective judgment of a set of experts. FLW prevention is the most sustainable option to feed the growing world population and, therefore, the proposed model should be used in the future to assess which mitigations strategies the various supply chain members and decision makers should implement for reducing FLW.

Acknowledgements
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Diagnosing the vulnerability of food supply chains: An unstructured data analytics approach

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Abstract
Even when a food-safety problem occurs at only one point in a food supply chain, the probability that it will disrupt the entire chain is high. Nonetheless, despite the potential of unstructured big data to help resolve such issues, few attempts have been made to use such data in this context. Accordingly, this study aims to explore food risk management issues and to assess the food supply-chain vulnerability. The proposed unstructured data analytics approach reveals that the essential vulnerable phases of food supply chains are caterers, food processors, and food producers.

Keywords: Food supply chain, Vulnerability, Risk management

Introduction
Effective supply-chain management is pivotal to meeting growing consumer demand for food in appropriate ways (La Scalia et al., 2017). However, the operation and management of supply chains involving multiple countries are increasingly complicated, and especially so in the case of food (Ahumada and Villalobos, 2009; Singh et al., 2018), as fresh food's key characteristic of perishability necessitates technological approaches to traceability and management (Ala-Harja and Helo, 2014). Unfortunately, food-safety crises have gradually increased in frequency due to the globalization of trade in food, and the food industry has struggled to cope with challenges including bovine spongiform encephalopathy, dioxin during chicken feed, foot-and-mouth disease, as well as various outbreaks of foodborne illness (Aung and Chang, 2014).

In every industry, managers seek valuable insights about their rivals from within their own databases. Although one study (Barton and Court, 2012) has suggested that enterprises could enhance their productivity and profitability by using data-driven analytics, decision-makers – notably, in the food industry – still often make questionable decisions according to merely small data samples through market surveys (Singh et al., 2018). Despite a surge in interest in big data and analytics in the sphere of business

strategy more generally, few firms have actually been using them to strengthen their supply chains, arguably due to a lack of knowledge about how to manage and analyze big data (Ross et al., 2013; Yu et al., 2018). Approximately 80% of the world's vast amount of business-relevant textual information is in an unstructured form that cannot be readily understood by traditional databases (Abrahams et al., 2015; Lavalle et al., 2011; Ur-Rahman and Harding, 2012). Hence, research that facilitates understanding of the content of this unstructured data is of potentially huge value to industry.

A food-safety problem can cause serious supply chain problems. Specifically, even when a food-safety problem occurs at only one point in a food supply chain, the probability that it will disrupt the entire chain is high. Nevertheless, huge unstructured textual data has seldom been included in such investigations. To fill this gap, therefore, this study aims to explore food-safety issues associated and to diagnose the vulnerability of food supply chains through the proposed unstructured data analytics approach.

An unstructured data analytics approach

The researchers' comprehensive survey of potentially relevant websites identified 12 as repositories of extensive knowledge about the crucial food-safety issues that are most frequently discussed in the context of food supply chains. These included Food Safety Magazine; Food Safety News; IFIC Foundation – Your Nutrition and Food Safety Resource; USDA Blog – Food Safety; Keep Food Safe Blog; US Food Safety; The CAMBRO Blog; Food Safety – National Sustainable Agriculture Coalition; Mérieux NutriSciences – Food Safety & Quality Blog; FoodLogiQ Blog; Unsafe Foods; and Food Logistics.

During the essential text pre-processing stage of the text-mining process, the present study followed Wu and Huang's (2018) recommendation, based on extensive experience, that data cleaning and data integration be conducted repeatedly via a process of trial and error so as to add value to the output and ensure exceptional results. It is also worth noting in this context that the results acquired from each method often gets back to this stage. In the present study, the principal pre-processing steps were 1) removal of stop words, 2) stemming, and 3) term frequency/inverse document frequency (TF/IDF). The purpose of the first is the removal of uninteresting words as well as deletion of terms that emerge commonly, but are not of value to the intended approach. This study relied, in the first instance, on the default stop word list for data standardization, i.e., the removal of most pronouns, prepositions, and conjunctions, along with numbers, website urls, punctuation, and times. Moreover, the most commonly used word in a given language will happen roughly k times as frequently as the kth most recurrent word (Gerlach and Altmann, 2013).

Stemming is an important step of the unstructured data analytics approach, as it identifies the numerous morphologies that infer disparate forms onto some occurring word-form, especially via suffix changes. Following stop-word removal and stemming, the data were systematically processed using TF/IDF. The overall weight of a term is calculated as the recurrence of that term in a single textual file, as well as the inverse recurrence of the term in the corpus (Zamani et al., 2014).

The present study used text clustering with an expectation-maximization (EM) algorithm (Li and Zhang, 2008; Rigouste et al., 2007) to explore food risk management issues.

Empirical results of unstructured data analytics

Text-mining analytics was conducted using SAS Enterprise Miner 14.1. Based on the analytical results of text clustering, the researchers divided the corpus' main food-safety

issues into six categories. These categories were named according to both the weights of their keywords and the associations between the documents and keywords. The paramount issues of food supply chains include food-safety inspection, food cleaning, food traceability, food recall, food biotechnology and the environment, and foodborne illness as shown in Figure 1.

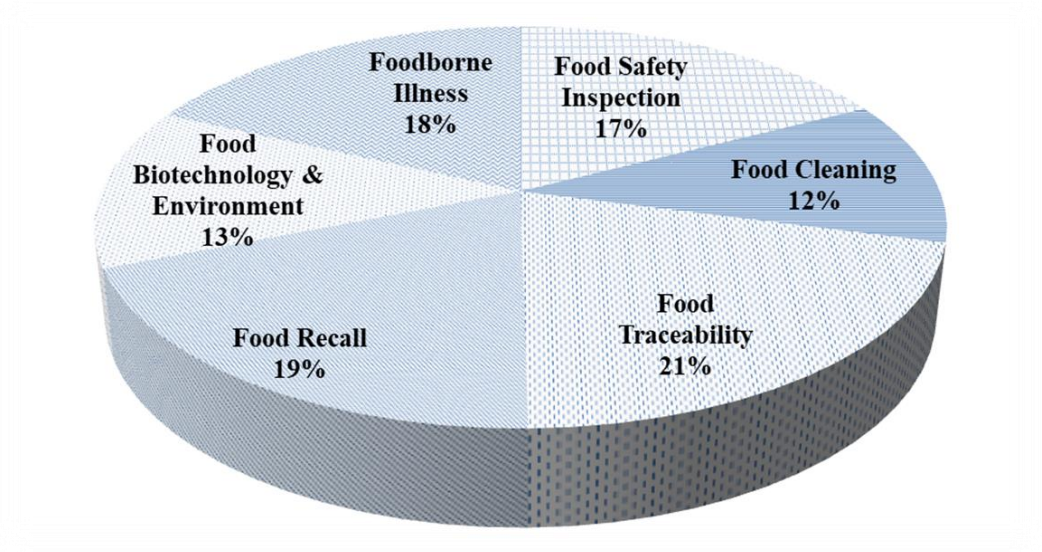

Figure 1 Food-safety issues

To comprehend the circumstances that engender the vulnerability of food supply chains, this study inspected the original unstructured data to extract documents which indicate food incidents and their level of severity regarding food safety problems. Figure 2 exhibited the vulnerability of food supply chains. Consequently, the top three vulnerable phases of food supply chains mentioned according to the most vulnerable were caterers, food processors, and food producers.

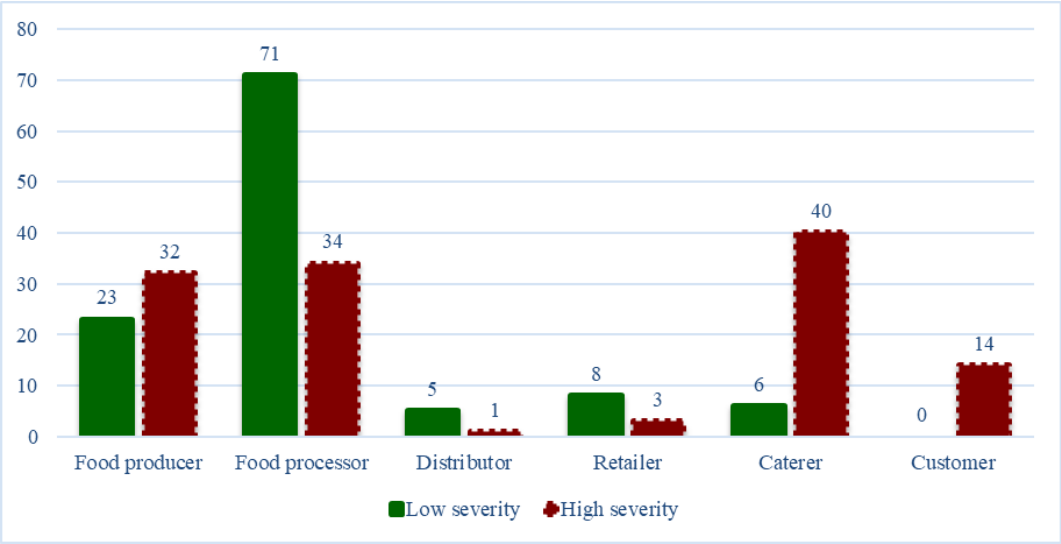

Figure 2 The vulnerability of food supply chains

Conclusion

This study proposes an unstructured data analytics approach to effectively tackle the crucial issues of food supply chain risk from a great number of unstructured data. Food supply-chain vulnerabilities can be identified through the proposed analytics.

The proposed unstructured data analytics approach identifies essential food chain themes involving food-safety inspection, food cleaning, food traceability, food recall, food biotechnology and the environment, foodborne illness. Furthermore, caterers, food processors, and food producers are the critical vulnerable phases of food supply chains.

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Incentive alignment, collaborative carbon reduction in supply chains and performance

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Abstract

The purpose of this study is to explore the antecedents and consequences of incentive alignment in performing collaborative carbon reduction in supply chains (CCR-SC). To fulfill the research objective, an empirical study was carried out in China, an emerging economy that has in recent years started to undergo a transition towards a low-carbon economy. The statistical technique of structural equation modelling (SEM) was used to analyze the questionnaire data collected from 120 Chinese companies. The research results reveal that incentive alignment has a positive impact on CCR-SC, which is instrumental in the improvement of both financial and environmental performance.

Keywords: Incentive alignment, Collaborative carbon reduction, Supply chain.

Introduction

Incentive alignment refers to the extent to which an organization is able to achieve its goals whilst meeting the requirements of the partner at the same time (Theißen *et al*., 2014). In the context of supply chain management (SCM), it is recognized as an important factor that motivates the chain members to create value that benefits all members in the supply chain (Simatupang and Sridharan, 2008), ensuring that collaboration outcomes are quantifiably beneficial to all, and securing sufficient levels of cooperation and minimize opportunistic behaviour (Harland, 2004). Given its significance in managing and operating supply chains, particularly its essential role in supply chain collaboration, incentive alignment has received considerable attention from academia. For example, Simatupang and Sridharan (2002, 2005, 2008) recognized incentive alignment as one of the five main elements of the architecture of supply chain collaboration. Chao and Zhang (2011) defined incentive alignment as one of the seven interconnecting components of SCC in a study of the nature of supply chain collaboration and its impact on firm performance. Hinkka *et al*. (2013) were aware of the role of incentive alignment between buyers and suppliers in supply chains and

explored this issue with reference to inter-organizational system implementation projects.

As awareness of carbon reduction management in supply chains has increased, concern has been raised about the role of incentive alignment in supply chain members performing collaborate carbon reduction. For example, based on a multiple case study, Theißen *et al*. (2014) ascertained that incentive alignment is one of the five determinants influencing an organization' readiness to engage in collaborative carbon reduction management. Nevertheless, a close examination of the existing literature finds that the issue remains conceptualized and empirical investigation remains scarce. To fill this gap, this study intends to examine the antecedents and consequences in the setting of collaborative carbon reduction in supply chains (CCR-SC).

The paper proceeds as follows. Section 2 provides a review of the literature on incentive alignment and CCR-SC. The conceptual model and hypotheses of antecedents and consequences of CCR-SC are then presented in Section 3. Section 4 describes the research design for the investigation. Finally, the results and the conclusions of the study are presented. The paper concludes by discussion the limitations of this study and the future research agenda.

Literature review

Incentive alignment

Incentive alignment is described as the motivation to fairly share the benefits of collaboration among members, and to enable members within the supply chain to self-enforce, aligning their individual decisions with the common goal of increasing total profits (Simatupang and Sridharan, 2002, 2005). According to Simatupang and Sridharan (2005), incentive alignment works as a scheme that motivates chain members to act in a way that is consistent with mutual benefit, including making optimal decisions, revealing accurate private information and calculating costs, risks and benefits. It is necessary to be aware of the effect of incentive alignment in reducing anxiety and uncertainty and increasing the prevalence of trust. Sahay (2003) pointed out that it can be seen as a way of initiating increased trust in supply chain relationships. Sierra (2013) ascertained that in the process of greening suppliers, providing suppliers with incentives is an important approach to the improvement of firm performance. Some studies report the results of misaligned incentives. For example, Narayanan and Raman (2004) reveal that misaligned incentives are the main cause of excess inventory, incorrect forecasts, and poor customer service. Voigt (2014) claimed that credible information-sharing cannot be established if misaligned incentives exist. In addition, Lee and Whang (2004) argued that a well-designed mechanism is needed to align incentives across the supply chain; this should enable chain members to commensurately share gains in terms of their investment and risk. Simatupang and Sridharan (2005) suggested that pay-for-effort and pay-for-performance are two major reward mechanisms.

In initiating CCR-SC, firms often estimate whether they can achieve incentive alignment by assessing the congruence of goals. Incentive alignment can only be built on the basis of identical goals among members in order to achieve shared objectives. Goal congruence is referred to "the extent to which firms perceive the possibility of common goal accomplishment" (Lejeune and Yakova, 2005, p.18). Goal congruence can enable firms to interact synchronously (Angeles and Nath, 2001) and reduce the incentives for opportunism. It is identified as an estimator when calculating the degree of alignment throughout the supply chain. Goal congruence is in conjunction with trust

and information sharing, a low rate of exchange of information will result in behaviour invisibility and thus lead to an absence of goal congruence.

Lejeune and Yakova (2005) considered that the degree of goal congruence varied and assumed it to have three levels, namely absence of congruence, moderate goal congruence, and true goal congruence. In the first two levels, goal congruence is weak or even non-existent in the supply chain. The deficiency of goal congruence can be attributed to an inadequate formulation of supply chain incentives (Narayanan and Raman, 2004). In the context of collaborative supply chains, Lejeune and Yakova (2005) also noted that goal congruence is weak to moderate, mainly because the trust in the collaborative supply chain is limited to its openness component. In the third level, i.e. true goal congruence, firms believe that they can achieve their goals by working simultaneously towards the objectives of the whole supply chain.

Collaborative carbon reduction in supply chains (CCR-SC)

CCE-SC has been recognized as an effective way for supply chain members to reduce carbon reduction. For example, Theißen *et al*. (2014) identified collaborative carbon reduction management as offering firms the ability to establish unique value-added processes through organizational boundaries that better match customer needs. Based on observation and investigation, many researchers support the view that collaboration is a more advanced approach in environmental management. Seuring and Müller (2008) emphasized that cooperation between buyers and suppliers is the only way to achieve an environment-oriented supply chain. Sustainable practices such as carbon reduction require the participation of all members in the supply chain. Chiou *et al*. (2011) suggested firms solve environmental problems by building a close relationship with their supply chain partners and creating competitive advantages through innovative environmental products. Through joint efforts in the supply chain, firms can simultaneously minimize carbon emissions and climate impacts, reduce waste and energy costs, meet the standards set by policy-makers and improve corporate reputations. To be specific, this includes the process of sharing data, knowledge, assets and other resources related to carbon reduction.

In addition, prior studies also ascertained that CCR-SC is more effective than enforcement under legal compliance, and more likely to produce benefits such as improved public reputation (Sundarakani *et al*., 2010). Carballo-Penela *et al*. (2017) demonstrated the effectiveness of CCR-SC through the measurement of carbon footprints. The results of their study show that the lack of mandatory legislation for measuring carbon footprints leads to an unsuccessful CCR-SC. Giurco and Petrie (2007) found that many opportunities for carbon reduction at the supply chain level have been ignored, since most of them focus on the organizational level. To better understand the environmental impacts of products and increase environmental performance, Sharfman *et al*. (2009) suggested that it is crucial for firms to conduct CCR-SC across supply chains.

Conceptual development and hypothesis development

Incentive alignment and CCR-SC

Many studies have classified incentive alignment as an important dimension of supply chain collaboration (Simatupang and Sridharan, 2005; Cao *et al*., 2010; Cao and Zhang, 2011). In order to be effective, an incentive alignment mechanism needs to be designed to correlate overall and partial performance, enabling members to consciously make individual decisions under the overall profit target, thus ensuring the successful implementation of the project (Hinkka *et al*., 2013; Chen and Lee, 2017).

Chen and Lee (2017) found that a well-defined incentive contract design can effectively avoid incentive misalignment by constructing a two-level supply chain game model. Drawing on the viewpoint on trust, Harland (2004) argued that incentive alignment is a sufficient guarantee for supply chain collaboration and commitment while minimizing the opportunism of members. Simatupang and Sridharan (2008) demonstrated that the effective implementation of incentive alignment can increase the enthusiasm and productivity of supply chain members and create value and benefit for the entire chain. Gunasekaran *et al*. (2015) highlighted the importance of incentives for green supply chain collaboration.

As such, this study argues that incentive alignment ensures the equitable sharing of costs, risks, and benefits, increases trust in the supply chain, and effectively avoids misalignment and opportunism. This should make companies willing to trust their partners and participate in initiating CCR-SC. Therefore, the first hypothesis in this study is as follows:

H1: Incentive alignment is positively related to CCR-SC.

Goal congruence and incentive alignment

Goal congruence encourages companies to implement incentive alignment to ensure that their members continue to move in the same direction and avoid misalignment. It requires a degree of mutual understanding and consistency in terms of a firm's attributes, values, beliefs, and practices, which is strongly linked to the scheme of incentive alignment. According to Theißen *et al*. (2014), the first step when building an effective partnership in supply chains is setting a consistent goal. Lambert *et al*. (1999) argued that supply chain members should reach an agreement on the management of goals and the key processes to be employed in supporting them. Inconsistent goals can lead to an unreasonable division of work among members, thus reducing efficiency and leading to incentive misalignment. Rossetti and Choi (2008) maintained that incentives work as an intermediation of goal congruence and buyers should consider aligning goals through incentives with their partners. Samaddar *et al*. (2006) stated that, in the absence of common goals, firms have no incentive to participate in activities such as information-sharing or supply chain collaborations. To a large extent, incentive alignment requires a high degree of information sharing. Governance mechanisms such as goal congruence can mitigate opportunism in incentive alignment. The greater the goal congruence between firms, the greater the strategic nature of their work, and the closer their incentive alignment.

Congruence can lead members to coordinate with each other under the guidance of an overall goal that contributes to the efficiency of incentive alignment. This study therefore argues that goal congruence is an important enabler of incentive alignment if firms are to initiate CCR-SC, hence the following hypothesis:

H2: Goal congruence is positively related to incentive alignment.

CCR-SC and firm performance

Bowersox (1990) pointed out that collaboration can bring economies of scale to firms whilst simultaneously reducing costs and increasing profits. Vargo and Lusch (2004) emphasized the importance of collaboration for a firm's business strategy and considered collaboration to be a source of competitive advantage. Cao and Zhang (2011) noted that partnerships can increase profits and reduce risk. Effective supply chain collaboration can reduce conflicts and uncertainties, resulting in collaborative advantages and better financial performance. Kalwani and Narayandas (1995) agreed that a long-term collaborative relationship is a unique resource that enables companies

to achieve a higher profit. From a relational perspective, Priem and Swink (2012) elaborated that supply chain relationships between suppliers and buyers can be viewed as intangible resources for value creation. In general, the higher the level of supply chain collaboration, the better the firm's financial performance. In addition, supply chain collaboration can increase the efficiency of operations management, allowing companies to better respond to market opportunities.

In the context of environment-oriented supply chains, collaboration is also recognized as an effective approach for improving firm performance. For example, some studies have clarified that strategic collaboration among supply chain members allows firms to move beyond organizational boundaries and find new ways to reduce environmental management costs, thereby improving environmental performance (for example Giurco and Petrie, 2007; Theißen *et al*., 2014). The results of their study confirmed the positive effect of CCR-SC on firms' performance.

In addition, there is a correlation between environmental performance and financial performance. Carbon reduction has been observed to improve a firm's environmental performance, which in return strengthens the firm's financial performance. For example, a reduction of transportation costs in the firm's logistics will also enhance its financial performance. Previous studies have shown that sustainable management practices, especially supply chain collaboration, contribute to the financial performance of firms (Hollos *et al*., 2012). On one hand, improving environmental performance can reduce costs and waste, improve resource utilization and operational efficiency, and further improve financial performance. On the other hand, improving environmental performance helps to increase corporate social responsibility and reputation, leading to a growth in market share.

CCR-SC allows firms to obtain economies of scale through resources and knowledge-sharing, both internally and externally. Firms can gain competitive advantages and reduce costs whilst simultaneously improving their environmental performance and financial performance. Thus, three hypotheses were formulated:

H3: CCR-SC is positively related to a firm's financial performance.

H4: CCR-SC is positively related to a firm's environmental performance.

H5: A firm's environmental performance is positively related to its financial performance.

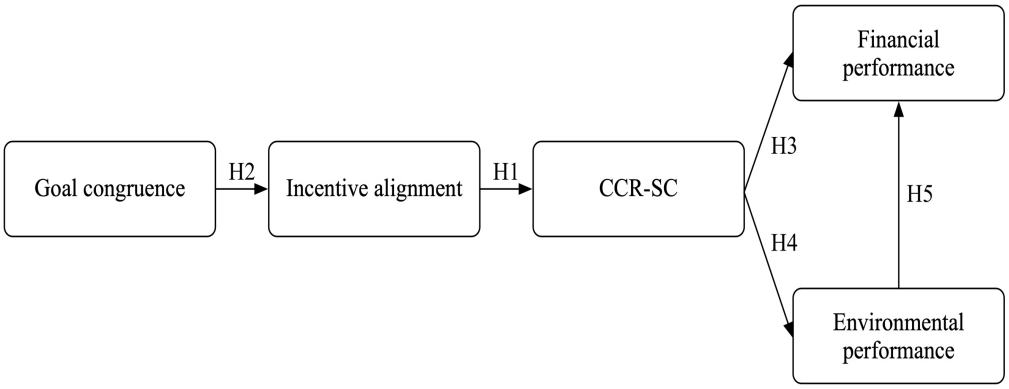

Figure 1- Research framework of incentive alignment in CCR-SC

Instrument development

Item generation

To achieve the content validity of constructs when generating items, a critical review of the relevant literature, such as research streams regarding CCR-SC (Theißen *et al*., 2014) and green SCM (Doran and Ryan, 2014) was carried out. After consulting with both academic and industrial experts, 32 measurement items were created for five constructs, namely, CCR-SC, incentive alignment, goal congruence, financial performance and environmental performance. A 5-point Likert scale was used to indicate the extent to which managers agree or disagree with each statement (1=strongly disagree, 2=disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

Sampling design and data collection

A data sample was collected from 900 Chinese companies engaged in SCM and operations. An online survey was used to administer the delivery of the questionnaire. After eliminating invalid questionnaires with blanks and deletions, 120 valid samples were obtained with a response rate of 13.3%.

The target respondents of this study were middle and senior managers in the company, particularly those involved in SCM practices. The sample respondents were expected to have a comprehensive acknowledge of collaborative and carbon reduction management in supply chains.

The non-response bias of samples was examined using the method recommended by Armstrong and Overton (1977). After comparing those responses returned early (80) with those returned late (40), the result of t-test shows there was no significant difference between early samples and late samples when randomly selecting samples, which means that non-response bias is not a problem with a 95% confident interval.

Table1- Respondents' profile

Type of owner ship		Number of employees		Firm size (million yuan)	
State-owned enterprise	27	<100	14	<5	13
Private company	61	100-200	10	5-10	5
Joint Venture	14	200-500	22	10-20	6
Foreign-funded enterprise	18	>500	74	20-50	12
				50-100	9
				>100	75
	120		120		120

Data analysis and research results

Reliability and validity analysis

In terms of the creation of measurement items, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were employed to assess the reliability and validity of the scales developed. The indicators used for assessment include Cronbach's α, normalized factor loading, composite reliability (CR) and average variance extracted (AVE). All indicators were significant at $p<0.01$, and all five constructs identified exhibited acceptable fit. The results demonstrated that the model fit indices meet the recommended criteria. Cronbach's α has a minimum number of 0.821 and a maximum of 0.952; all have alphas greater than 0.70 and are therefore considered reliable. Discriminant validity was tested using the approach recommended by Fornell and Larcker (1981); that is, the AVE of each construct is higher than the shared variances between each of the constructs, as shown in Table 2. Overall, the results show that the scales used had good reliability and validity.

Table2- Exploratory and Confirmatory Factor Analysis

Constructs	Items	Factor loading	CR	Cronbach's α	AVE
Incentive alignment	SCIA-1. Co-develop systems to evaluate and publicise each other's performance	0.776	0.887	0.885	0.611
	SCIA-2. Share cost among supply chain partners	0.752			
	SCIA-3. Share benefits among supply chain partners	0.808			
	SCIA-4. Share risks among supply chain partners	0.782			
	SCIA-5. Have incentives commensurate with investment and risk	0.788			
Goal congruence	SCGC-1. Agree on supply chain goals	0.821	0.903	0.902	0.652
	SCGC-2. Agree on supply chain collaboration	0.867			
	SCGC-3. Recognize the importance of improving overall interest of the supply chain	0.802			
	SCGC-4. Agree to achieve personal goals and satisfy the requirements of the supply chain at the same time	0.795			
	SCGC-5. Collaborate to develop plans in order to achieve supply chain goals	0.747			
CCR-SC	CCR-SC-1. Develop carbon reduction plans in conjunction with supply chain partners	0.843	0.947	0.952	0.783
	CCR-SC-2. Share carbon reduction technology with supply chain partners.	0.870			
	CCR-SC-3. Joint procurement of carbon reduction equipment with supply chain partners	0.887			
	CCR-SC-4. Work with supply chain partners to achieve common goals for reducing carbon emissions	0.906			
	CCR-SC-5. Collaborate with supply chain partners to develop carbon reduction methods	0.915			
Financial performance	SCFP-1. Increase in sales revenue	0.875	0.939	0.945	0.721
	SCFP-2. Increase in net profit	0.875			
	SCFP-3. Decrease in total cost	0.817			
	SCFP-4. Increase in return on investment (ROI)	0.860			
	SCFP-5. Increase in market share	0.859			
	SCFP-6. Increase in market competitive position	0.807			
Environmental performance	SCEP-1. Reduce emissions	0.860	0.931	0.927	0.728
	SCEP-2. Reduce effluent emissions	0.898			
	SCEP-3. Reduce solid waste emissions	0.869			
	SCEP-4. Reduce the use of dangerous, toxic, hazardous materials	0.814			
	SCEP-5. Reduce energy cost	0.823			

Results of hypothesis tests

To test the hypotheses proposed in this research framework, structural equation modelling (SEM) was used to assess the model fit with the data. The path coefficients

for the SEM model were shown in Table 3. The fit indices for the model were χ^2 = 495.035, df = 293, normed = 1.690, CFI = 0.926, IFI = 0.927, RMSEA = 0.076, indicating that the model was of good fit.

The results of the hypothesis tests were shown in Table 3. The path coefficient was 0.34 and was statistically significant at the level of 0.001, which supports Hypothesis 1. This result showed that incentive alignment was significant and positively related with CCR-SC. Hypothesis 2 was also supported with a path coefficient of 0.64, which was statistically significant at the level of 0.001. The finding indicated that goal congruence was positively related to incentive alignment. Hypotheses 3, 4 and 5 were also supported.

Table 3 - Results of hypothesis testing

Hypothesis	Path	Path coefficient	p-value	t-value	Results
H1	SCIA→CCR-SC	0.34	< 0.001	3.427	Support
H2	SCGC→SCIA	0.64	< 0.001	6.082	Support
H3	CCR-SC→SCFP	0.58	< 0.001	5.814	Support
H4	CCR-SC→SCEP	0.57	< 0.001	6.232	Support
H5	SCEP→SCFP	0.22	0.016	2.417	Support

Conclusion and limitation

The present study provides an empirical analysis of the antecedents and consequences of incentive alignment in the setting of CCR-SC, a topic that has been under-researched in previous studies. It verifies the enabling role of incentive alignment to CCR-SC and its antecedent, namely, goal congruence. The resulting CCR-SC can however affect environmental and financial performance. From a research perspective, this study advances empirical investigation in the research areas of low-carbon SCM and supply chain collaboration. From a practical perspective, this study is of interest to managers involved in initiating CCR-SC. As shown by the empirical analysis, managers should collaborate with their supply chain partners, developing common goals and designing aligned incentives, in order to ensure that CCR-SC has a positive effect.

While the research has made significant contributions to the existing literature, there are still limitations that need to be avoided in future study. First, because of the difficulty of data collection, the sample size used in this paper was relatively small. Future research could increase the sample size in order to improve the effectiveness of reliability and validity. Furthermore, this research is based on questionnaire data, which means that the conclusion might reflect the current status of firms, although environmental management practices are dynamic under sustainable development. Future research should consider using a longitudinal study in order to incorporate the changing dynamics of CCR-SC.

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Antecedents of a Firm´s Supply Chain Agility: The Roles of a Transactive Memory System and Supply Network Flexibility

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Abstract

This paper describes how firms can develop Firm Supply Chain Agility (FSCA) and its benefits for operational performance (OP). The purpose of this research is twofold. First, to analyze the role of transactive memory system (TMS) and supply network flexibility (SNF) as potential antecedents of FSCA, also evaluating the moderating role of TMS; and, second, to evaluate the relationship between FSCA and OP, also examining the possible mediating effect of FSCA. The relationships are tested with survey data from 190 Spanish high-tech firms using structural equation and linear regression models.

Keywords: Firm's supply chain agility, transactive memory system, supply network flexibility.

Main subject text

Theoretical background

Today's hypercompetitive environment – characterized by demanding customers, short product life-cycles, volatile supply and demand, global supply chains, and rapid advances in technology – has pushed firms towards finding new ways of competing (Swafford et al., 2006; Chiang et al., 2012). Indeed, research suggests that developing a firm's supply chain agility (FSCA) can be key to improving competitiveness in the current environment (Christopher, 2000; Gligor et al., 2015; Kim and Chai, 2017). FSCA has been conceptualized variously as a comprehensive strategy, a paradigm, a management system or practice, and even as a capability (Shin et al., 2015). In this study, we adopt

Braunscheidel and Suresh's (2009, p. 126) definition of FSCA as *"the capability of the firm, internally, and in conjunction with its key suppliers and customers, to adapt or respond in a speedy manner to a changing marketplace, contributing to the agility of the extended supply chain".*

Given the importance of FSCA, an investigation of how such a capability can be built and the performance outcomes is of utmost importance (Blome et al., 2013; Gligor et al., 2015). The literature has identified some antecedents of FSCA by recognizing, for example, that FSCA depends on: the flexibility of the procurement/sourcing, manufacturing, and distribution/logistics processes (Swafford et al., 2006); internal and external integration of the firm (Braunscheidel and Suresh, 2009); coordinating, cooperative, and communicative mechanisms in the supply chain (Gligor and Holcomb, 2012); and the development of supply- and demand-side competences (Blome et al., 2013). Research has also identified outcomes associated with FSCA. For example, FSCA enables a firm to be more market-sensitive, have greater capacity to synchronize supply with demand, better manage disruption risks, achieve shorter cycle times, ensure uninterrupted service to customers, and accelerate the introduction of new products (Braunscheidel and Suresh, 2009; Blome et al., 2013; Gligor et al., 2015). However, due to limited research in this field, there have been a number of recent calls to explore new antecedents of FSCA and to further scrutinize the effect of FSCA on performance (Chiang et al., 2012; Blome et al., 2013; Gligor et al., 2015; Chan et al., 2017; Fayezi et al., 2017). Swafford et al. (2006) indicated that agility requires competitive strategies based on both the development of knowledge and the generation of flexible processes so firms can respond to changing circumstances in the environment. Building on this, our study evaluates a variable related to knowledge – transactive memory system (TMS) – and a variable related to flexibility – a firm's supply network flexibility (SNF) – as potential antecedents of FSCA.

Our first variable, TMS, *"is the shared division of cognitive labor with respect to the encoding, storage, retrieval, and communication of information from different domains that often develops in close relationships"* (Lewis and Herdnon, 2011; p. 1254). This variable, related to the creation, maintenance, transfer, and coordination of knowledge in work teams (Argote and Guo, 2016; Heavey and Simsek, 2017; Huang and Cheng, 2018). has been applied to various types of dyadic relationships (Hammedi et al., 2013; Argote and Guo, 2016), work groups (Liang et al., 1995; Argote and Guo, 2016), organizations (Heavey and Simsek, 2015; Huang and Cheng, 2018), and even contexts that transcend organizational boundaries, such as the development of TMSs between supply chain partners (Obayi et al., 2017). Although TMSs have received little attention in the operations management field, this variable could contribute greatly to the development of FSCA. For example, it has been recognized that uncertain environments require the rapid generation and coordination of new knowledge (Gligor et al., 2015; Argote and Guo, 2016). Further, firms like Honda, Apple, Zara, and Amazon have all succeeded in developing supply chain agility because they have teams that are motivated to develop creative solutions to unexpected problems (Gravier, 2016).

Our second variable, SNF, is related to an organization's ability to effectively and efficiently reconfigure its supply base (Liao et al., 2010), enabling the firm to maintain a sufficient set of alternatives and responses to possible changes in the environment (Liao and Marsillac, 2015). Although the extant literature has recognized the importance of different types of flexibility in achieving FSCA (Chan et al., 2017), SNF is a relatively new concept that remains underexplored in the FSCA literature (Liao et al., 2010; Purvis et al., 2014; Liao and Marsillac, 2015). As Lummus et al. (2003) argued, supply chain design must take change into account. When the market changes, competitive priorities

also change, making it necessary to find new supply chain partners with the required capabilities. Finding such partners is necessary for high levels of flexibility in supply networks (Purvis et al., 2014). Cisco, for example, uses three different supply networks to manufacture its products (depending on the type, volume, and customization required). When the need arises, it can switch manufacturing from one network to another, achieving rapid response to changes in the environment (Lee, 2004). It is thus reasonable to expect that having different strategic options for product supply would facilitate higher levels of FSCA.

Given the need to further evaluate the effect of FSCA on performance (Gligor et al., 2015), we also examine the relationship between FSCA and a firm's operational performance (OP). Supply chain managers must know what results to expect from the implementation of FSCA-focused strategies, yet prior studies have evaluated only some measures of operational performance (e.g. Gligor and Holcomb, 2012; Blome et al., 2013; Eckstein et al., 2015; Gligor et al., 2015). Our study expands these measures by exploring the relationship between FSCA and OP in four specific areas – delivery, production cost, product quality, and production flexibility – that reflect the four key capabilities of a focal firm in responding to competition (Wong et al., 2011).

Based on the above, our study has two main goals. First, to analyze the role of TMS and SNF as potential antecedents of FSCA, evaluating the moderating role of TMS in the SNF-FSCA relationship; and, second, to evaluate the relationship between FSCA and OP, examining the possible mediating effect of FSCA on the relationship between SNF-OP. These goals are summarized in the following two research questions:

RQ1. What is the relationship between TMS, SNF, and FSCA?

RQ2. How does FSCA affect OP, either directly or by mediating the relationship between SNF and OP?

The relationships to be empirically investigated are illustrated in the theoretical model in Figure 1.

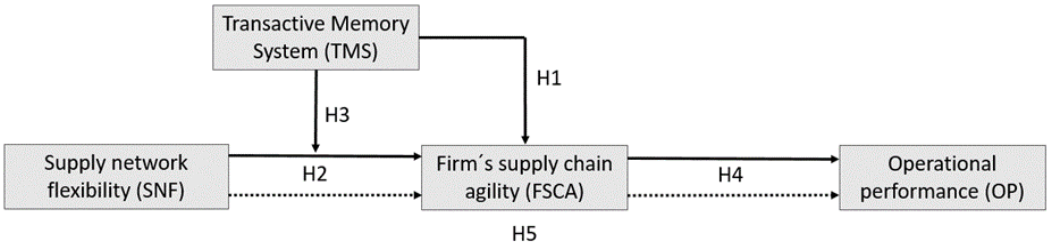

Figure 1. Theoretical Framework of the Study

Design/methodology

In order to provide empirical evidence for the proposed research hypotheses, Spanish companies belonging to the high technology sector were selected from the Iberian Balance Sheet Analysis System (SABI) database. Once the total population was defined, a survey was conducted to obtain specific information for our research, following Dillman's (2000) prescriptions. The unit of analysis was the firm, and the preferred respondents were senior managers with knowledge of the processes and activities of the firm´s operations department and who had the capacity to make decisions in that department. The procedure for data collection was through the computer-assisted telephone interview (CATI) system. Finally, we obtained a final sample of 190 usable surveys and a final response rate of 12.45 percent.

The main constructs used in our model were: TMS, SNF, FSCA, and OP. The measurement scales for these variables were adapted from prior studies: TMS (Lewis,

2003), SNF (Liao et al., 2010), FSCA (Swafford et al., 2006), and OP (Wong et al., 2011). A seven-point Likert scale survey was designed to capture managers' perceived levels of these variables (1 = maximum disagreement; 7 = maximum agreement). Moreover, we considered other contextual factors that might have an influence on operational performance such as firm age and firm size.

We examined the reliability and validity of the measurement scales following the procedure developed by Kaynak and Hartley (2006). We also studied all indicators of the measurement scales' goodness of fit by analyzing the absolute and incremental goodness of fit and the model's parsimony. In all cases, the indicators are within the levels recommended as acceptable in the literature (Hair et al., 2010).

The theoretical model was tested using the methodology of structural equations and regression analysis. In order to test H1, H2, H4 and H5, we employed structural equation modeling (SEM) to estimate the proposed research model. Results indicate a good fit for the measurement model with a Chi-square of 862 and 549 degrees of freedom, CFI of 0.90, IFI of 0.90, BBNNFI = 0.90 and RMSEA of 0.05. The standardized coefficient weights for each causal path are provided in Figure 2 for the main effects, being all factor loadings significant. The analytical approach outlined by Hayes (2013) was used to test the hypothesis related to moderation (H3). A summary of the moderation analysis results is available in Table I. In addition, Figure 3 presents the moderating effect of TMS in the SNF-FSCA relationship, for low, moderate and high TMS values. The empirical evidence suggests FSCA achieves its optimum when companies have high values of TMS and SNF. However, higher values of TMS weaken the relationship between SNF and OP. In other words, the existence of a highly developed TMS leads to SNF becoming less important in the consecution of FSCA.

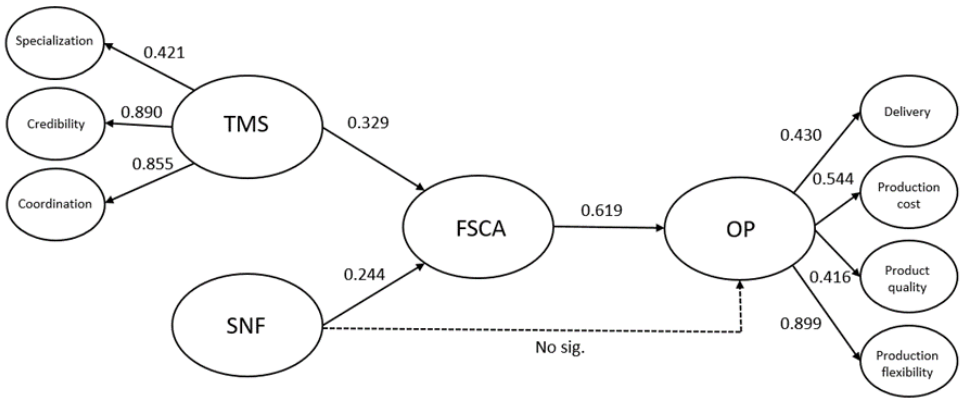

Figure 2. Main Effect Results

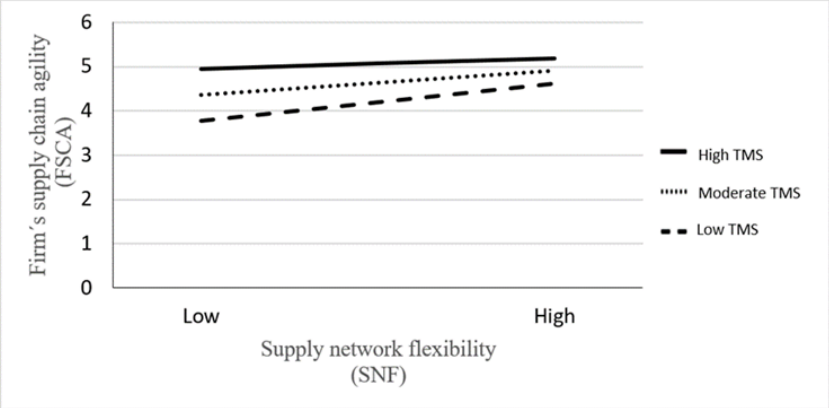

Figure 3 - Moderating Role of Transactive Memory System

Table 1. Moderation Results

	Firm´s supply chain agility		
	Coefficient β[a]	SE	95 percent CI
Constant	4.611***	0.084	4.444; 4.779
Independent variable			
SNF	0.230***	0.066	0.099; 0.361
Moderator			
TMS	0.507***	0.087	0.335; 0.680
Interaction			
SNF × TMS	-0.011**	0.054	-0.215; -0.002
R	0.468		
R^2	0.219		
F	17.424		
p	0.000		

Notes. Confidence intervals (CI). Significance *** p < 0.01; ** p < 0.05; * p < 0.10

Findings

The study makes three important contributions to Operations Management research, Supply Management Orientation and the Resource-Based View (RBV). First, in response to suggestions by Swafford et al. (2006), it contributes to the literature on Operations and Supply Chain Management by evaluating the role of TMS and SNF as possible antecedents of FSCA. These antecedents have not been considered before in the literature on agility. On the one hand, finding evidence of a positive relationship between TMS and FSCA (H1) supports the conclusion that the presence of high levels of TMS in the operations department encourages FSCA. This is a novel contribution to the literature in the field. Although the benefits of TMS and the use of knowledge in other areas of the organization are recognized (Zheng and Mai, 2013; Peltokorpi, 2014; Argote and Guo, 2016; Heavey and Simsek, 2017), there has been almost no exploration of these benefits in operations management. Therefore, our study adds to pioneering studies like that of Obayi et al. (2017), which have begun to explore the role of TMS in the field of operations, supply chains and their role in OP. Obayi et al. (2017) considered the TMS generated among the partners in the supply chain. Our study extends the knowledge of the area, by considering the TMS in the firm's operations department and exploring the benefits that this can have on the FSCA. On the other hand, evidence of a positive relationship between SNF and FSCA (H2) reinforces the need to reconfigure the supply

base in the face of changes in the environment. This finding is not only consistent with the operations management literature that recognizes the importance of different types of flexibility to achieve FSCA (Swafford et al., 2006, Swafford et al., 2008, Braunscheidel and Suresh, 2009, Chan et al. al., 2017), but also improves our knowledge on the flexibility-agility relationship, by exploring a particular type of flexibility, practically unexplored in this field: SNF. Firms that have different strategic options for product supply and can properly reconfigure their supply base will have a better position to develop the FSCA.

Both antecedents, in turn, highlight the need to develop intra- and inter-organizational competencies to achieve FSCA. FSCA depends on issues related not only to internal management of the firm (such as the presence of high levels of TMS in the operations department) but also to external management of the firm, such as relationships with suppliers (SNF). This need has been suggested by prior studies such as those performed by Braunscheidel and Suresh (2009), Gligor et al. (2015), and Fayezi et al. (2017). This study empirically confirms these assumptions.

Evidence of the moderating role of TMS in the relationship between SNF and FSCA (H3) is also important. In contrast to previous proposals, we find a negative moderating effect of TMS. That is, when the firm has high levels of TMS in the operations department, the relationship between SNF and FSCA weakens. One possible explanation for this finding may lie in the firm's capability for internal management. A high level of TMS grants the firm greater internal management capability, which facilitates its adaptation or response to market changes using its own mechanisms. Thus, based on survey data collected from 137 start-ups in China, Zheng and Mai (2013) found that forming teams of start-ups that were operating in highly uncertain environments and that had high levels of TMSs did not have to resort to external sources when responding to surprises in their environments. Rather, they responded to surprises by improvising using their own knowledge. Improvisation requires integrating and applying new and preexisting knowledge in real time, and the existence of a high level of TMS in the team facilitated this task.

As a firm's operations department develops its TMS, the probability of resorting to its supply base to improve FSCA decreases. In other words, the solutions for managing rapid changes can be forged internally. The ability to create, maintain, transfer and coordinate knowledge in operations departments with high levels of TMS enables the firm to draw on its own abilities instead of consulting external players to solve problems (Carney et al., 2008). Further, improving FSCA through the firm's internal processes encourages quick response and eliminates the costs associated with seeking new suppliers and generating commercial transactions (Williamson, 1975). SNF involves finding the best strategic combination for product supply. Such searches require not only the presence of suppliers available on the market but also the time, cost and knowledge necessary to perform a search and to select suppliers effectively and efficiently. Firms with a high level of TMS in the operations department will thus be more inclined to invest in themselves to respond to uncertainty instead of delegating this responsibility to external agents.

Second, the study makes a key contribution to the agility literature by examining the association between FSCA and OP. The evidence of a positive relationship between FSCA and OP (H4) confirms the importance of developing FSCA to improve the firm's operating measures. Consistent with prior research (Gligor and Holcomb, 2012; Eckstein et al., 2015; Gligor et al., 2015; Chan et al., 2017), this finding also enables us to extend knowledge in the field by considering four key dimensions of OP: delivery, production cost, product quality and production flexibility. To the extent of our knowledge, prior studies that explore the relationship between FSCA and OP have considered only some

of these dimensions (Blome et al., 2013; Eckstein et al., 2015; Gligor et al., 2015; Chan et al., 2017). Our study provides a more complete view of the operating measures improved by FSCA.

Finally, the study contributes to developing the literature supporting the relationship between flexibility and agility as a competency-capability relationship (Swafford et al., 2006; Braunscheidel and Suresh, 2009; Swafford et al., 2008; Chiang et al., 2012; Blome et al., 2013). However, this study extends past research considering an aspect of external flexibility, related to supply management. Normally, the studies have evaluated the flexibility relative to the internal processes of the firm. There is few research that extend the flexibility beyond the limits of the focal firm. Our findings suggest that the variable FSCA mediates the relationship between SNF and OP (H5). That is, while SNF is a competency, FSCA is a capability. According to the RBV, competencies in themselves do not lead to sustainable competitive advantage. Rather, they must be combined and managed to develop capabilities. Thus, SNF in itself does not generate greater OP per se, but requires FSCA to obtain operational benefits.

This study also has important implications for managers. The empirical evidence obtained highlights the value of investing in FSCA as a tool to build a sustainable competitive advantage. FSCA enables the firm to compete in an increasingly dynamic and changing environment by improving some of the firm's operational aspects, such as increasing product quality, decreasing production costs, improving issues related to product delivery and/or encouraging production flexibility.

At the same time, the study allows managers to understand how FSCA can be strengthened. We stress that FSCA depends not only and exclusively on internal aspects of the firm but also on parties external to it, which involve different agents in the supply chain. Managers should thus develop both intra- and inter-organizational resources to encourage FSCA. First, managers could focus on the intra-organizational possibility of developing a solid TMS in the operations department. That is, they could build work teams that prioritize collaboration and trust among the group's members, with members who specialize in a specific area and are willing to share and coordinate individual knowledge. Such teams not only enjoy greater response capability but can develop creative solutions to unexpected problems (Akgün et al., 2006) in the area of operations, increasing FSCA. Second, managers could develop the inter-organizational possibility of SNF by building a network of suppliers flexible enough to adapt to changes in the environment and thus able to respond quickly to new demands from the firm's customers. For example, in environments with highly competitive and dynamic markets, short product lifecycles and rapid new product introductions, maintaining these flexible networks reduces the firm's dependence on its suppliers and increases its capability to adjust supply and demand.

However, it should be noted, in the face of the need to prioritize one option over the other, investment in internal resources in the firm seems to be the more effective response when developing FSCA. Specifically, developing TMS in the operations department could be especially valuable when uncertainty is high as with the high-tech industry, because TMS provides a knowledge base that can be coordinated to better address uncertain conditions in the environment (Argote and Guo, 2016) without facing the costs associated with the search for new suppliers and the generation of new commercial transactions.

It is also important to note that while managers can develop SNF to strengthen FSCA, SNF does not improve the firm's operational aspects directly. A firm that has different strategic options for product supply, has a greater capability to adapt to changing market

requirements which increases its FSCA. This FSCA will lead to improvements in operational measures.

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Finding common ground: a systematic literature review and categorization of the causes of the bullwhip effect

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Abstract
This paper aims to facilitate the understanding of the causes leading to the bullwhip effect. Therefore, causes that have been scattered across many publications so far are brought together and structured in a systematic way. To do so, a systematic literature review of the bullwhip effect causes is conducted and identified causes are assigned to inductively derived categories. A comprehensive overview of the causes leading to the bullwhip effect is generated by this procedure and can be used as a starting point for further research as well as by professionals.

Keywords: bullwhip effect, demand variance amplification, systematic literature review

Introduction
Working together in a supply chain rather than exclusively focusing on local interests can benefit everyone (Barratt, 2004). However, to be competitive as a supply chain, it is inevitable to address inefficiencies within the supply chain and familiarize with their causes. By doing so, researchers as well as practitioners repeatedly observed a phenomenon which is nowadays known by the term “bullwhip effect”. The bullwhip effect is characterized by an increase in order variance as one moves upstream the supply chain. This implies that orders issued to a supplier have a larger variance than sales to a customer (Lee et al., 1997). Among other things, this phenomenon causes excessive inventories, low capacity utilization and poor customer service along a supply chain (Disney & Lambrecht, 2008). Since the first academic study conducted by Forrester (1958) who drew attention to underlying mechanisms of this effect and addressed the problematic implications attached to demand variance amplification, one stream of literature has focused on researching the causes of demand variance amplification. A vast number of publications resulted from these research efforts: however, there have been few efforts so far to compile a comprehensive overview of causes for demand variance amplification in a systematic way. This has led to a situation, where quantity and nature of listed causes for the bullwhip effect vary from study to study. This spread makes it difficult to perceive a comprehensive picture and develop a deep understanding of the

causes. Without this understanding, however, it is difficult to design and implement appropriate remedies. This view is supported by McCullen & Towill (2002) stating that the bullwhip effect is often either misunderstood or ignored.

This paper aims to simplify the understanding of the causes behind the bullwhip effect for scholars and professionals. This is done by pursuing the research objective of bringing together and structuring all the causes of the bullwhip effect which are discussed in literature.

Methodology

To surface all known causes of the bullwhip effect in the literature, we conduct a systematic literature review, following the steps proposed by Thomé et al. (2016). Thereby, this literature review is not exclusively focusing on primary sources. It is also built upon secondary literature, utilizing existent knowledge that can be drawn from literature review sections that papers usually contain. Thus, our systematic review can be understood partly as a review based on primary sources and partly as a review of reviews.

Keywords were defined according to the research objective and combined in the following search string: ((“bullwhip" AND "cause*") OR ("bullwhip" AND "review*")). The search string was used to identify relevant articles in four different databases: Web of Science, Science Direct, Business Source Premiere and Academic Search Premiere. A first set of articles was retrieved by searching titles, abstracts and keywords of all papers within these databases with the search string. In a subsequent step, duplicates were removed. Abstracts of the remaining articles were analyzed. Based on predefined inclusion and exclusion criteria (Table 1), articles were either discarded or qualified for the full text analysis.

Table 1: Exclusion and inclusion criteria

Exclusion Criteria	**Rationale**
Non-English or non-German language papers	Corresponds to the languages of the authors
Papers published outside peer reviewed journals	Quality of the paper cannot be guaranteed if it is not peer-reviewed
Inclusion Criteria	**Rationale**
Papers primarily concerned with the bullwhip effect	Only causes of the bullwhip effect are of interest for this study
Papers discussing a variety of different causes	Only papers not focusing on specific single causes are of interest for this study

The same inclusion and exclusion criteria were applied to the remaining full texts. Overall, 31 papers relevant for the literature review were identified through this procedure. Figure 1 illustrates the article selection process.

As for the quality assessment of the retrieved papers, the exclusive consideration of peer-reviewed articles minimizes the risk of including low-quality or unreliable studies in the analysis. However, the exclusion of publications outside peer-reviewed papers, e.g. the grey literature, makes this systematic literature review susceptible for publication bias. Furthermore, the search term “bullwhip” limits the time period covered, since this designation for order variance amplification had not been used until Procter&Gamble coined this term in the early 1990s (Wang & Disney, 2016).

A qualitative content analysis approach was applied to analyze the selected articles. To assess all text passages in which causes of the bullwhip effect were discussed, the articles were reviewed line-by-line. Listed causes were coded in-vitro and then consolidated inductively into categories. The inductive categories were derived by following the approach outlined by Mayring (2008). First, codes were paraphrased and in a second step, related paraphrases were consolidated to form categories.

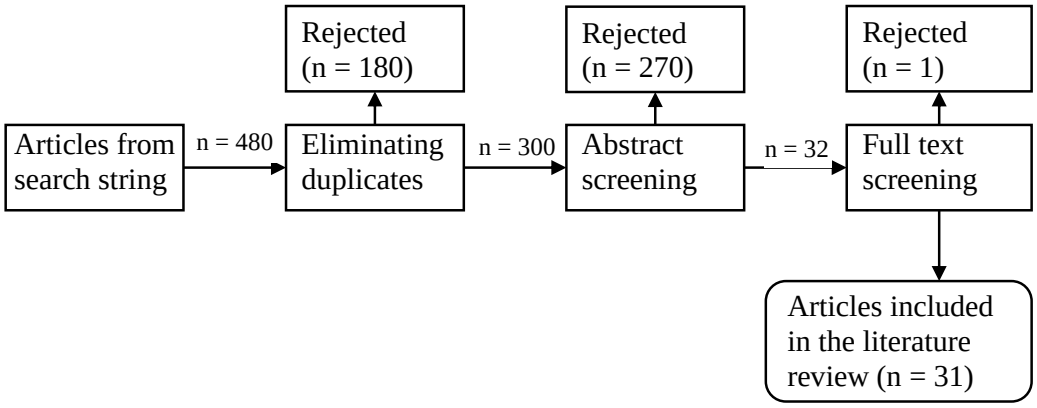

Figure 1: Article selection process

Descriptive findings

The 31 selected articles are published in 22 different journals. Most strongly represented are papers from the "European Journal of Operational Research" and the "International Journal of Production Economics" with 3 publications each. The distribution of the publication over years ranges from 2004 to 2018 and is relatively uniform which indicates a constant interest in reviewing the causes of the bullwhip effect over time.

Thematic findings

Through the qualitative content analysis of the selected articles, four categories were inductively derived in which the causes can be classified: underlying structural factors, uncertainty due to insufficient information availability, misaligned incentives as well as human and process errors.

Underlying structural factors

The review of causes for the bullwhip effect by Miragliotta (2006) identifies complexity, feedbacks and non-linearities in supply chains as important factors influencing demand variance. Complexity of a supply chain stems, for example, from the involvement of a high number of individuals and diverse practices as well as policies, which in turn lead to a high degree of uncertainty (Paik & Bagchi, 2007). Furthermore, complexity is increased by feedback loops. This is illustrated by an example, Miragliotta (2006) gives by referencing Forrester (1980) who wrote that "symptoms, action and solution are not isolated in a linear cause-to-effect relationship, but all change takes place within the control of feedback loops. Growth, goal-seeking and oscillation are consequences of feedback loops dynamics" and, thus, also introduces non-linearities as a factor of concern. The systemic point of view also builds the basis for the recognition that lead times, which describe the time span between initiation and execution of an order, play an integral role for the bullwhip effect. This claim can be found in many of the reviewed papers (e.g. Csık

& Földesi, 2012; Devika et al., 2016; Gilbert, 2005). The following example illustrates the influence of lead time on the bullwhip effect: Assumed, a company faces a 5% increase in demand rate. To meet the 5% increase in demand, the company must not only increase its ongoing weekly order rate by 5% but also places additional orders to increase the inventory level by 5%. In case of a 2 weeks lead time, the order placed to bring the inventory to the new desired level is equal to 10% of the weekly demand rate. Hence, demand variance is amplified. Another factor causing demand variance amplification, which is similar but driven by equipment liftetime instead of inventory lead-time, is called "investment accelerator effect". Multiple studies in the review sample mention this factor and point out the peculiarity that this effect occurs usually between product manufacturers and their capital equipment suppliers (e.g. Bhattacharya & Bandyopadhyay, 2010; Geary et al., 2006; Kouvelis et al., 2006). Kouvelis et al. (2006) explains the investment accelerator effect by referring to Anderson et al. (2000) as follows: "a plant may use 100 machine tools and replace 5% of them in a typical year. If this firm anticipates a 5% increase in sales, it may plan to buy 10 machine tools this period; 5 new and 5 replacements. Thus, a 5% surge in expected sales at one level becomes a 50% surge for the supplier" (Kouvelis et al., 2006, p. 450).

Complexity, presence of feedback loops, non-linearities and time dependencies are presented as underlying factors in several reviewed papers. For example, according to Paik and Bagchi (2007) complex feedback loops combined with time delays render it very likely that decisions result in demand variance amplification, even if not intended. A similar view is represented by Miragliotta (2006). By pointing out to Sterman (1989a), Miragliotta blames feedbacks created by the interactions between companies for the fact that decisions that were locally rational bring unwanted and dysfunctional results on the global level. Based on these examples and the above explanations, we propose that complexity, feedbacks, non-linearities and time dependencies give rise to a system prone to uncertainty due to insufficient information availability, misaligned incentives and human and process errors. As shown in the following, order decisions made in presence of insufficient information, misaligned incentives as well as human and process errors in turn are causing demand variance amplification.

Uncertainty due to insufficient information availability

Not all the necessary information is always available to everyone in a supply chain. Furthermore, information is often not only missing, but can also be incorrect. Scukanec et al. (2007) even considers the "insufficient flow of real information" as the main cause of the bullwhip effect. Information can be withheld on purpose, for example, the likelihood of sharing point of sales data is greatly reduced, if there are any concerns that a supply chain partner is going to utilize the shared information for opportunistic behavior (Svensson, 2001). However, lack of information sharing can also result from an underestimation of the value information potentially could have for other supply chain partners (Nienhaus et al., 2006). Missing or wrong information leads to a state of uncertainty where no definite answers to pressing questions like "What will be the demand next week?" or "Is the supplier capable of fulfilling my orders?" exist.

To cope with uncertainty in demand and supply, companies usually forecast demand and maintain a safety stock to absorb unforeseen events to a certain extent. In case of new information, parameters of the applied inventory replenishment rule are adjusted accordingly. For example, new demand information may result in an update of the demand forecast, target stock level and/or safety stock level. This behavior is mentioned by all reviewed papers as possibly causing demand variance amplification and most often called demand signal processing. This designation goes back to Lee et al. (1997). Thereby, order variance becomes, for example, amplified by adjusting safety stocks due

to a changed customer demand pattern (Braz et al., 2018). In such a situation, the change in orders is not equal to the change in customer demand but exceeded by the quantity ordered to adjust safety stock. If, in return, other upstream supply chain members decide to change their safety stock level as well, the original demand signal becomes further distorted at each decision point. Furthermore, the forecasting technique can have an influence on demand variance amplification. Multiple authors (e.g. Devika et al., 2016; Hassanzadeh et al., 2014) draw attention to a study by Dejonckheere et al. (2003) who proved that forecasting demand by using exponential smoothing and moving average within an Order-Up-To-policy always results in an order variance amplification, regardless of the demand process (unless the demand is always constant). Hence, the uncertainty about future demand and the necessity to order based on forecasts, can contribute to the bullwhip effect.

The state of uncertainty because of insufficient information about the future also provokes interventions by managers in order quantity decisions (Ancarani et al., 2013). This gives room to behavioral biases distorting the demand signal. Exemplary for this, Disney & Lambrecht (2008) cite overoptimistic attitude and overaction to demand changes or customer complaints. Such exaggerated adjustments of quantitative demand forecasts generally result in higher forecast errors, hence, higher demand variance amplification. The extent to which an order is adjusted also depends on the risk attitude of a decision maker. A risk averse decision maker might overorder out of the fear of facing stock-out situations (Bhattacharya & Bandyopadhyay, 2010). The inflation in orders resulting from overordering itself increases order variance. However, order variance becomes even more amplified due to the necessity of upstream supply chain partners to adjust their orders as well to avoid stock-out situations (Nienhaus et al., 2006). However, a risk seeking individual which is willing to deplete its safety stock can also cause a bullwhip effect. This was demonstrated by Nienhaus et al. (2006) who observed a reoccurring behavior of individuals in supply chains they called “panic strategy”. This strategy refers to the reaction of individuals who emptied their inventories during constant demand and then start panicking because of stock-out situations as soon as the demand rises. Decision makers following this strategy have no safety stock left and do not only face high stock-out costs and the necessity to order more than in a situation with safety stock left, but also force upstream stages to order more and cause possible stock-out situations in upstream stages as well.

Uncertainty, however, does not only exist in respect to future demand and supply quantities, but also regarding supply chain members’ behavior. Even though all supply chain members superficially work towards a collective outcome, there may be reservations regarding supply chain partners’ trustworthiness, motives or cognitive abilities (Croson et al., 2014). Croson et al. (2014) call the risk resulting from this uncertainty “coordination risk”. In the existence of coordination risk, individuals create a so-called coordination stock to be prepared in case of decisions of other supply chain members which are disadvantageous for the own company. Coordination stock can be seen as a type of safety stock which “buffers against strategic uncertainty in orders or delivery due to coordination risk”. A similar observation was made by Nienhaus et al. (2006) who analyzed the decision makers’ behavior in a four-tier supply chain and found a strategy they named “safe harbor”. Individuals following a safe harbor strategy order more than actually necessary resulting in an excessively high safety stock level. Croson et al. (2014) hypothesize that the tendency of accumulating excessive safety stock could be in response to stress resulting from orders or unexpectedly long delivery times. Also, Shee & Kaswi (2016) observed mangers’ intent to order higher quantities than actually necessary which they call “extra days of order” and define it as “additional stock amount

being added up on top of the incoming orders received from downstream partner while ordering up to upstream partner". Shee & Kaswi (2016) see the extra days of stock not only as a buffer against business uncertainties but also because of the pursue of achieving higher service levels, reducing stock-out situations and the objective to boost customer demand.

Misaligned incentives

Incentives, i.e. the rewards and punishments associated with different actions, can have a great influence on decisions. However, the creation of incentives can not only be unintentionally, but can also have unintended consequences (Carter et al., 2007). An example of an incentive that unintentionally leads to demand variance amplification is the exploitation of price fluctuations. This cause of the bullwhip effect can be found in all reviewed papers with reference to Lee et al. (1997). In theory, customers ramp up their inventories in periods of low prices to avoid the necessity to place orders during periods of high prices. This kind of forward buying does not realistically reflect the immediate needs in the supply chain. As a result, variability of orders exceeds the variability of the consumption rate (Klug, 2013). Price fluctuations can be attributed, among other things, to promotional campaigns or dynamic pricing (Kouvelis et al., 2006). Furthermore, Kouvelis et al. (2006) draw attention to the so-called called hockey stick phenomenon, where the effect of price fluctuations becomes particularly vivid. The phenomenon is characterized by a steep increase in orders e.g. at the end of a financial year or quarter. Among other things, this can be traced back to sales targets that have been set. In order to boost demand and to meet sales targets, many suppliers offer price discounts at the end of the financial year or quarter. Companies, anticipating this behavior from their suppliers, aggregate customer demand over time and wait for the special offers to buy at a lower price. Thus, demand variance is amplified. The action of aggregating customer demand over time, which is then forwarded in an aggregated form to the suppliers is in literature mostly called order batching or lot sizing. By referring to Lee et al. (1997), this behavior is also listed in all the reviewed papers as a cause of demand variance amplification. The literature review brings various possible reasons for companies' motivation to batch orders besides the already mentioned advantage taking of price fluctuations to light. Kouvelis et al. (2006) cite the impact of fixed costs and further considerations of economies of scale as examples. Fixed costs can be associated to the costs of ordering, e.g. because an employee must fill out an order form, but also with costs of transportation. For example, the fix costs per unit are less in case of a full truck load compared to an only half-filled truck (Paik & Bagchi, 2006). As stated by Kouvelis et al. (2006), order batching can also stem from the applied inventory policy. A company following a periodic review ordering practice serves as an example. If the company faces a daily demand but places orders to their suppliers every fourth week, i.e. batches the demand, the order variance is increased. As pointed out by Miragliotta (2006) financial deadlines can also trigger order batching. For example, the common payment term of 30 days from the end of an invoicing month incentivizes companies to buy at the beginning of a month and thereby delay the payment by a month. Holland & Sodhi (2004) cite orders issued according to the economic order quantity as an additional cause of order batching.

All articles bring attention to another business which potentially causes demand variance amplification, most often called "rationing and shortage gaming", following in the footsteps of Lee et al. (1997). In case of a shortage of supply, suppliers ration their products according to specific rules. Very common is the division of available goods in such a way that each customer receives a certain percentage of the ordered quantity. Customers are aware of the supplier's course of action and consequently artificially inflate their order if they expect a situation of shortage in order to receive a quantity which

is closer to their actual demand (Scukanec et al., 2007). It can be concluded that the supplier's policy has unintentionally created an incentive for the customers to exaggerate their orders. As soon as the shortage of supply is eliminated, customers cancel their artificially inflated orders (Nienhaus et al., 2006). What remains is a completely distorted picture of end customer demand for the supplier.

Human and process errors

Complexity of a system and its components, combined with feedbacks, non-linearities and time dependencies create an environment susceptible to human and process errors which in turn amplify demand variance (Paik & Bagchi, 2007). In such a system, for example, faulty assumptions regarding actual stock or actual supply line level can arise (Goodarzi et al., 2017). Misperceptions about the actual stock level can occur, for instance, in presence of inventory inaccuracies. Bruccoleri et al. (2014) points to the problem that even large retailers experience inventory inaccuracy, meaning that the inventory records differ from the number of products which are actually available for customers to buy. During physical stock counts, which are periodically performed, discrepancies between actual inventory for sale to customers and book inventory are detected. Subsequent orders take these discrepancies into account and the order quantity is adjusted accordingly. This adjustment of order quantity is not reflected in customer demand. Thus, order variance is amplified. Inventory inaccuracies can not only be traced back to inventory misplacement by customers or inventory shrinkage due to theft or damage but also to the reaction of individuals to work pressure. Bruccoleri et al. (2014) demonstrate that the more the level of workload pressure deviates from the ideal value for the specific employee, the more inventory data entry errors arise, contributing to inventory accuracies.

Decision makers' tendency of faulty assumptions about the supply line was observed by Sterman (1989). Based on experiments he demonstrated the tendency of individuals to underweight the supply line. This means that individuals playing a supply chain simulation game base their order decisions to a higher extent on the discrepancy between desired and actual stock than on the discrepancy between desired and actual supply line. In many cases, this amplifies the demand variance. Different theories exist, why decision makers underweight the supply line. Paik & Bagchi (2007) say it occurs because the supply line is ignored, whereas Wang & Disney (2016) justify it with the argument that decision makers overlook the supply line. On the other hand, Udenio et al. (2017) state that decision makers under-estimate the quantity of the order in the supply line and Disney & Lambrecht (2008) attribute the behavior to the problem that decision makers "do not have a clear idea of what is available in the pipeline".

Not only human shortcomings give rise to demand variance amplification, but also process errors can evoke responses amplifying order variance. Several reviewed articles (e.g. Klug, 2013; Paik & Bagchi, 2007) point out to Taylor (1999) who demonstrated the impact of variability in machine reliability and in process capability on demand variance amplification. Taylor (1999) illustrates this with an example of a press shop which relies on input from blanking. Assume the press shop has an average demand for blanks of 1000 units per week. However, due to reliability problems, the blanking machine only produced 800 units instead of 1000 units in week 1. In the subsequent week, this shortfall must be compensated, hence, a production of 1200 units in week 2 is required from the blanking machine. This shows that although press shop's demand was constant at 1000 units, members upstream the blanking machine faced a demand of 800 units in week 1 and of 1200 units in week 2.

Variability in process capability results in fluctuations of service quality. Hence, the inability to produce constantly perfect products leads to varying quantities of units which can further processed downstream in the supply chain. Suppose the demand of the press shop is again 1000 units per week. If in week 1 blanking only delivers 800 units which can be further processed, the press shops' demand in week 2 is 1200 units to cover last weeks missing quantity. After the press shop received an incomplete shipment, i.e. less faultless goods than expected, it may anticipate potential service quality shortfalls for subsequent weeks and exaggerates the order even more to proactively balance them out (Taylor, 1999).

Discussion and conclusion

The conducted systematic literature review combined with a qualitative content analysis surfaced a variety of causes of the bullwhip effect from literature. Based on the identified causes in literature, we argue that there are four underlying structural factors, namely complexity, feedback, non-linearities and time dependencies that give rise to a system in which (1) not all necessary information is always available where it is needed, (2) incentives for decision-makers are often misaligned, and (3) human and process errors can occur. Thereby, identified causes can often be combined to form a causal chain. For example, the complexity and lead times in supply chains result in a situation, where most likely not all information is available to everyone. This lack of information results in uncertainty which in turn makes it necessary to forecast demand. However, as explained above, demand forecasting techniques are susceptible to induce amplification in order variance.

The inductively derived categories of factors and causes influencing demand variance amplification differ significantly from existing categorizations. Usually, causes of the bullwhip effect are divided into two categories: operational causes and behavioral causes. Operational causes refer to structural characteristics that lead rational decision makers to amplify the order variance, whereas behavioral causes refer to the existence of bounded rationality of individuals and the resulting problems thereof (Croson et al., 2014). Typically, the four causes identified by Lee et al. (1997), i.e. price fluctuations, demand signal processing, order batching as well as rationing and shortage gaming, constitute the category of operational causes. Causes like supply line underweighting or coordination risk are, on the other hand, usually attributed to the category of behavioral causes. Our proposed new categorization allows a more targeted classification of causes. Furthermore, our categorization does not put such a strong emphasis on the question if a demand variance amplification results from rational decision or from a decision under bounded rationality. This opens up new perspectives that may for example be helpful in researching mitigation strategies.

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The contribution of artificial intelligence to supply chain management - a systematic literature review

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Abstract

Artificial intelligence (AI) is a technology which focuses on enabling machines to communicate with and imitate the capabilities of humans. The recent hard- and software advances opened plenty of new application fields for this technology, among them the field of supply chain management (SCM). While different industrial and engineering potentials of AI has been discovered and used, the contribution of AI to SCM, both theoretically and practically, has yet to be explored. The aim of this study is to reduce this gap and provide a systematic and comprehensive review uncovering research gaps and the contribution of AI to SCM.

Keywords: Supply chain management, Artificial intelligence, Marketing, Logistics, Production, Systematic literature review

Introduction

Among the currently upraising technologies that are shaping our lives, AI is going to change business and economics more than others (Dirican, 2015). Due to its ability to recognize business patterns, learn business phenomena, seek information, and analyze data intelligently (Min, 2010a), AI has become a game changer for organizations by creating new business opportunities, accelerating processes and improving the human decision-making processes (Martínez-López and Casillas, 2013; Jarrahi, 2018). In addition, AI has created a wide field for scholars to research and explore the nature and potentials of AI from a scientific point of view.

The concept of AI, defined as the computational study of intelligence (Korf, 1991) has been around for more than two decades (Huin et al., 2003) and many studies have been conducted revolving around this concept due to its broad range of applications in engineering, business, manufacturing, SCM and many other fields (Saidi Mehrabad and Fathian Brojeny, 2007).

In spite of the large number of studies around AI, literature reviews on this topic are scarce; especially in the field of SCM. Attempting to curtail the aforementioned gap, this work provides a Systematic Literature Review (SLR) answering the following research questions:

How can AI contribute to SCM?

To be more focused and explore this topic in detail, we took four main steps: (1) identifying the most influential and commonly used AI techniques in SCM studies, (2) identifying the potential techniques of AI that can be employed in SCM, (3) identifying the subfields in SCM that were already improved using AI, and (4) implications of this study for academics and practitioners.

Methodology

This study follows the five SLR steps suggested by Denyer and Tranfield (2009) plus an additional pilot search. These steps are:

In the first step, between May and July 2018, we conducted a pilot search that enabled us to identify a research gap and establish the inclusion and exclusion criteria as follows: studies need to be published: (1) within the time span between 2008 to 2018 since the majority of the papers and a large number of new ideas, trends and applications, contributing to AI have emerged in the last ten years. (2) in peer-reviewed journals or conferences in order to achieve the highest level of relevance and quality. (3) in the SCM and AI fields.

We also defined a bespoke article inclusion protocol to mitigate the performed opinions that could have biased our assessments of relevance of articles (Orwin et al., 1994). To this end, we, firstly, used our predefined pilot search string. Secondly, articles with relevant keywords but irrelevant topics were excluded. Thirdly, we excluded pure engineering articles that did not have a strong connection or attachment to SCM studies. Due to broad nature of SCM discipline and our aim to conduct an inclusive yet practical literature review, we furthermore focused our search on SCM subfields with the strongest literature background including: supply chain, logistics, production and marketing; based on the SCM definition of Stock and Boyer (2009).

In the second step, we formulated the research questions. In the third step, the selection of suitable identified studies took place. Bearing in mind that we required databases that cover a great variety of journals; we selected ScienceDirect, Emerald Insight, JSTOR, Wiley Online Library and Taylor & Francis.

Table 1- Search results

Databases	Emerald	Science Direct	JSTOR	Taylor & Francis	Wiley	**Total**
Keywords	Artificial intelligence					
Marketing	22 (1)	16 (7)	75 (1)	3 (1)	44 (1)	**160 (11)**
Logistics	5 (2)	44 (3)	41 (0)	2 (1)	13 (0)	**105 (6)**
Production	23 (6)	209 (14)	94 (1)	5 (2)	112 (0)	**443 (23)**
Supply chain	5 (2)	25 (18)	15 (1)	4 (3)	1 (0)	**50 (24)**
Total	**55 (11)**	**294 (42)**	**225 (3)**	**14 (7)**	**170 (1)**	**758 (64)**

Containing millions of peer-reviewed articles, these databases are credible and scientifically renowned. The search protocols used to explore these databases are mostly similar with minor modifications due to the search system of each database. The general structure of this protocol was: “artificial intelligence” AND “keyword1” NOT “keyword2” NOT “keyword3”. Keywords are: marketing, supply chain, production,

logistics. Table 1 shows the results of the third step in relation to the number of the articles extracted and in brackets the number of articles selected for the review. The fourth and fifth step were dedicated to the analysis, synthesis and reporting of findings.

Analysis and synthesis

In the subsequent sections, we present a categorial analysis of the 64 papers reviewed. Afterwards, we summarize the identified AI techniques and assign them to the individual SCM fields. Finally, we present the outcomes of our study.

Categorical analysis of the literature according to SCM fields

In total 14 articles are related to the marketing field. Lee et al. (2012) propose an Artificial Neural Network (ANN)-based system for sales forecasting in convenience store industry. Ketter et al. (2012) present an agent-based model for sales management and O'Donnell et al. (2009) use Genetic Algorithm (GA) to present an online system that helps sales promotion. In segmentation, Casabayó et al. (2015) combine cluster analyses and fuzzy models for a novel market segmentation approach, while Sarvari et al. (2016) use ANN and K-means clustering for customer segmentation. The papers of Bae and Kim (2010) and Martínez-López and Casillas (2009) are focused on consumer behavior. While the former uses association rule and tree-based, the latter uses a genetic fuzzy system. Shakya et al. (2010) use various AI techniques and suggest a pricing system for diverse products and services, while Peterson and Flanagan (2009) use ANN for a pricing model with lower errors and greater precision. Stalidis et al. (2015) also apply ANN to develop a marketing decision support framework. Rekha et al. (2016), in turn, explore the use of support vector data description to facilitate the selection of contacts. Using GA and fuzzy models, Kwong et al. (2016) propose a methodology to integrate affective design, engineering, and marketing for defining the design specifications of new products. Taratukhin and Yadgarova (2018) use multi-agent systems and thereby suggest an approach for product life cycle management, whereas Martínez-López and Casillas (2013) present a historical literature review of AI-based systems applied to marketing.

Seven articles revolve around logistics, from which Salido et al. (2012) and Cardoso et al. (2013) employed heuristics and automated planning. Whereas Salido et al. (2012) offer a Decision Support System (DSS) for calculating the number of reshuffles needed to allocate the containers in the appropriate place, Cardoso et al. (2013) present a system for container loading problem. Knoll et al. (2016), developed a predictive inbound logistics planning approach. In order to distinguish between more or less performing human–artificial collaboration systems in logistics, Klumpp (2017) introduce a multi-dimensional conceptual framework. Eslikizi et al. (2015) address an inter-organizational lot-sizing problem which is solved by a set of self-interested and autonomous agents. Lee et al. (2011) examines how AI techniques and RFID can enhance the responsiveness of the logistics workflow and Wang et al. (2012) propose an intelligent system for industrial robotics in the logistic field.

23 studies were on production. Martinez-Barbera and Herrero-Perez (2010) as well as Heger et al. (2016) are concerned with manufacturing systems using Fuzzy Logic (FL) and Gaussian models. Kasie et al. (2016) address manufacturing decision support using Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR). Camarillo et al. (2018) suggest a production-oriented approach and use CBR for manufacturing problem solving. Kucukkoc and Zhang (2015) offer a GA-based model for the parallel two-sided assembly line balancing problem, while Sanders and Gegov (2013) review some of the applications and examples of AI tools for assembly automation. In quality control and improvement,

Taylan and Darrab (2012) propose an approach for the design of fuzzy control charts. Brandenburger et al. (2016), in turn, suggest a system for quality monitoring and data representation. All three production forecasting articles employed ANN; Gligor, et al. (2018) propose solution for forecasting the electricity production of a photovoltaic power plant, Li et al. (2013) propose a comparison of three AI approaches and Sheremetov et al. (2013) describe different models for forecasting time series. In production systems, both Küfner et al. (2018) and Ennen et al. (2016) suggest a concept for the realization of a decentralized data analysis integration and a self-learning production ramp-up system. In the subfield production planning and scheduling, Sousa and Tavares (2013) present a study of different planning approaches, while Ławrynowicz (2008) propose an AI-based methodology to support production planning and scheduling. Gámez and Velázquez (2011) developed an AI-based classification methodology for the validation of production data based on ANN, GA and data mining. Olsson and Funk (2009), present a CBR-based system for production monitoring. The rest of the articles target various subfields of production. Tsafarakis et al. (2013) suggest a HPSO (Hybrid Particle Swarm Optimization) approach for product line optimization, Bravo et al. (2011) implemented a distributed AI architecture to approach the problems of integrated production management, Ma et al. (2018) present an AI-based workflow framework for oil reservoirs, Trentesaux and Thomas (2012) introduce the concept of product-driven control, Munguia et al. (2011) propose a tool for the assessment and selection of rapid prototyping/manufacturing systems for low-volume production using ANN and FL, and at last, Mayr et al. (2018) identify and present exemplary application scenarios for knowledge-based systems.

In the last field, SCM, 20 articles were identified from which Amirkolaii Nemati et al. (2017), Ahmadi et al. (2017), Efendigil et al. (2008), Bala (2012) and García et al. (2012) worked on forecasting methods using AI techniques. Regarding consumption forecasting, Yu et al. (2017) present an online big data-driven oil consumption forecasting model that uses Google trends, which finely reflects various related factors based on a myriad of search results. Ferreira and Borenstein (2012) suggest a fuzzy-bayesian supplier selection model, while Vahdani et al. (2012) propose a neuro-fuzzy supplier selection model for the cosmetics industry. Pino et al. (2010) worked on a multi-agent supply chain system and Merlino and Sproģe (2016) explored the main technological changes and the most advanced cases in sustainable supply chains. Vargas Florez et al. (2015) proposed an AI-based humanitarian facility location Decision Support System that can adequately manage the response to a disaster despite failures or inadequacies of infrastructure and potential resources. By means of agent-based and multi-agent systems, Ferreira and Borenstein (2011) present a simulation framework for supply chain planning, Zgaya et al. (2009) suggest a negotiation model and Dias et al. (2009) forecasts the use of RFID integrated into an ICT framework. The literature review of Min (2010) explores different subfields of AI that are suitable for solving practical problems relevant to SCM. Chong and Bai (2014) examine the predictors of open inter-organizational systems adoption by using Rosetta Net as a case study. Regal and Pereira (2018) present an ontology for conceptual modelling of intelligent maintenance systems. Zhang et al. (2017) proposed an efficient bio-inspired algorithm for design of optimal supply chain networks in a competitive oligopoly market. Tsang et al. (2018) propose a risk-monitoring system by means of the IoT (Internet of Things) and AI techniques. And finally, Sinha et al. (2012) suggest an algorithm to solve the problem of inventory replenishment in distributed plant–warehouse–retailer. Table 2 assigns the exemplary articles to the respective SCM fields and subfields.

Table 2 - Assignment of the exemplary studies to the respective SCM fields and subfields

Fields	Subfields	Exemplary Studies
Marketing	Sales forecasting; Sales management; Sales promotion; Market segmentation; Customer segmentation; Consumer behaviour; Pricing; Marketing decision support; Direct marketing; Industrial marketing; New products specification design; Product life cycle management	Lee et al. (2012); Sarvari et al. (2016); Stalidis et al. (2015); Rekha et al. (2016); Kwon et al. (2016); Taratukhin and Yadgarova (2018)
Logistics	Container terminal operations and management; Inbound logistics processes; Logistics systems automation; Lot-sizing; Logistics workflow; General	Salido et al. (2012); Cardoso et al. (2013); Knoll et al. (2016); Klumpp (2017); Eslikizi et al. (2015); Wang et al. (2012)
Production	Assembly lines; Assembly automation; Production monitoring; Production forecasting; Production systems; Production planning and scheduling; Production data; Integrated production management; Manufacturing systems; Manufacturing decision support; Manufacturing problem solving; Quality control and improvement; Quality monitoring; Product line optimization; Workflow; Product-driven control; Low-volume production; General	Kucukkoc and Zhang (2015); Gligor et al. (2018); Küfner et al. (2018); Ennen et al. (2016); Heger et al. (2016); Kasie et al. (2016); Camarillo et al. (2018); Taylan and Darrab (2012); Brandenburger et al. (2016); Tsafarakis et al (2013); Ma et al. (2018); Trentesaux and Thomas (2012); Mayr et al. (2018)
Supply chain	Demand forecasting; Facility location; Supplier selection; Supply chain network design; Supply chain risk management; Inventory replenishment; Crisis management; Consumption forecasting; Global value chains; Supply chain process management; Supply chain integration; Supply chain planning; Maintenance systems; General	Amirkolaii Nemati et al. (2017); Vargas Florez et al. (2015); Ferreira and Borenstein (2012); Zhang et al. (2016); Tsang et al. (2017);Yu et al. (2017); Merlino and Sproǧe (2016); Chong and Bai (2014); Regal and Pereira (2018); Min (2008)

AI techniques and their distribution

From another perspective, we analyzed the literature based on the AI technique that the articles use or revolve around. In doing so, we followed Chen et al. (2008) and Bundy (1997) comprehensive list of AI techniques. In addition, we assigned, counted and ranked the articles that referred to the identified AI technique (Table 3).

We found the highest variety of AI techniques in the field of production. We assume that this is primarily due to the practical nature of this research field which mostly encompasses experimental research, case studies and real-life problem-solving studies. ANN, FL and CBR are the most frequent AI techniques in this field. With 12 AI techniques used, marketing has the second highest variety, in which ANN, GA and FL are the most popular techniques. The third most diverse field is supply chain with ten AI techniques. ANN and FL hold the top ranks in this field. Finally, logistics has the least variety of techniques with only seven AI techniques used.

The most popular AI technique is ANN. It was used 18 times. The second frequent technique is fuzzy logic/models with 11 applications. Intelligent agents are in the third place with nine repetitions. This is presumably due to their wide range of application. GA is the next popular technique with seven repetitions. Both DM and CBR are used four times each in the literature, whereas SI and SVM were identified three times. Simulated annealing and automated planning are used two times each. The rest of the techniques are used once.

Study outcomes

Generally, research papers are unique and they usually develop unique results. If papers produce models, systems, frameworks, approaches, algorithms, methods and

methodologies they have a more experimental or practical nature. Whereas, if they produce literature reviews, examples, concepts ontologies, comparisons, forecasts and explorations, they can be classified as conceptual or philosophical studies. Based on our review, we found that the majority of papers in all fields have an experimental or practical orientation. The results are predominantly modelling and systems.

Table 3 - AI Techniques counted and ranked according to the number of mentions

AI Technique	**Usage count**	**Distribution and ranking of AI techniques in subfields**			
		Marketing	**Logistics**	**Production**	**Supply chain**
Artificial Neural Networks (ANN)	18	$4_{(1^{st})}$		$8_{(1^{st})}$	$6_{(1^{st})}$
Fuzzy logic/models	11	$3_{(3^{d})}$		$4_{(2^{nd})}$	$4_{(2^{nd})}$
(Multi) agent-based systems	9	2	1	3	3
Genetic algorithm (GA)	7	$4_{(1^{st})}$		3	
General forms of AI	7	1	1	1	$4_{(2^{nd})}$
Data Mining (DM)	4		1	2	1
Case-Based Reasoning (CBR)	4			$4_{(2^{nd})}$	
Swarm Intelligence (SI)	3	1		1	1
Support Vector Machines (SVM)	3	1			2
Simulated annealing	2	1	1		
Automated planning	2		1	1	
Association rule	1	1			
Tree-based models	1	1			
Hill climbing	1	1			
K-means	1	1			
Expert Systems (ES)	1			1	
Heuristics	1		1		
Robot programing	1		1		
Stochastic simulation	1				1
Bayesian networks	1				1
Physarum model	1				1
Rule-Based Reasoning (RBR)	1			1	
Decision trees	1			1	
Gaussian models	1			1	

Discussion

As mentioned, we took four steps in order to answer the research question. In this part, we strive to discuss each of them.

Most influential and commonly used AI techniques in SCM studies

There are various AI techniques that can be applied to SCM, however, the results of our study show that ANNs are the most influential techniques in these studies; mainly because they are capable of solving data-intensive problems where the rules or algorithms for solving the problem are unknown or difficult to express (Chen et al., 2008). Moreover, they can be applied to several categories of problems including pattern classification, optimization, clustering, prediction and process control. The second technique is FL which According to (Bundy 1997) are on the border between AI and non-AI with a rapid growth in recent years. The reason for this rapid development is that it addresses qualitative information perfectly as it resembles the way humans make inferences and decisions (Bundy, 1997). Results show that fuzzy logic is widely used as a modeling tool and an element in hybrid intelligent systems. Another group of techniques that are

frequent in SCM studies, are (multi) agent-based systems. An agent is a piece of software containing code and data. A multi-agent system comprises a network of agents interacting to achieve goals. These agents are capable of modelling, designing, and implementing complex systems, and that is the reason behind its wider use in SCM. Results revealed that GA is also one of the most frequently used AI techniques in SCM that mimics natural selection. This algorithm evolves until it solves the problem adequately.

Potential techniques of AI that can be employed in SCM

There are many AI techniques that have been employed in SCM studies but there still ones with more potential. While robotics (robotic programming) is not a new topic in SCM, the vast potentials of this area is not fully utilized. Our study indicates a limited use of it in the literature and subfields of SCM. For instance, packaging and container terminal operations are liable for more robotic influence. This could be in the form of more automatic facilities or faster intelligent robots. Another AI technique that has great potential for use in SCM is the Expert Systems. It emulates the decision-making ability of a human and therefore has a great potential in reasoning and decision-making and can be employed in DSSs, especially for lot-sizing and supplier/buyer selection.

Subfields in SCM that were already improved using AI

All major SCM fields are currently improved using AI techniques. However, the concentration on subfields is not equally distributed. In particular, marketing, sales and segmentation have received more attention than fields such as pricing, consumer behavior, marketing decision support or direct marketing. In logistics, container terminal operations, logistics systems automation, lot-sizing or logistics workflow already utilized AI techniques, but there are other topics that need to be covered. In production, the subfields of assembly, manufacturing and forecasting are more equipped with AI. Other subfields such as product line optimization, workflow, product-driven control and low-volume production are less improved by AI techniques. At last, in the field of supply chain, demand forecasting is the leading AI-equipped subfield, while other subfields received less concentration.

Implications of this study for academics and practitioners

There are potential SCM subfields that can be improved in the future by using AI techniques both in research and practice. Our results reveal that most of marketing articles that employed AI, are revolving around sales and segmentation. Therefore, other members of the marketing mix like promotion, product and place can be candidates for AI applications. Sales promotion, advertising, public relations and direct marketing are consequently the subfields that can be improved dramatically with deeper use of AI. In logistics, distribution and transportation, logistic hub management and logistics risk management can be improved by using AI. Fields such as mega project management and advanced project process management are important fields for consideration in the area of production. In supply chain, buyer selection, automated replenishment, smart warehousing and green supply chain are the fields which need more focus.

Conclusion

This paper provides a systematic literature review on articles published from 2008 to 2018 regarding the contribution of AI to SCM. We analyzed and synthesized the data from 64 articles in marketing, logistics, production and supply chain. The results were presented through a tabulation of analyzed data and outcomes. Future practical and experimental

studies are highly encouraged to contribute to the expansion of the knowledge base of AI in the SCM field.

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Lean and Agile Supply Chain strategies: A systematic literature review

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Abstract

The present hostile economic conditions highlight the need for organizations to integrate various supply chain (SC) strategies to compete favourably. Lean and Agile are two critical strategies because the former ensures efficient use of resources while the latter involves matching supply with demand in unpredictable markets. This paper aims at advancing their understanding by conducting a review to unravel the state of art of Lean-Agile SC by examining the procedure of knowledge conceiving, transfer and development via the application of "Systematic Literature Network Analysis". The investigation enabled unravelling research directions/emerging themes thereby supporting researchers/newcomers to target specific theme to explore.

Keywords: Lean strategy, Agile Strategy, Systematic Literature Network Analysis

1.0. Introduction

Market competition is gradually tilting towards the supply chain (SC) level rather than focal company. This is due to diverse and erratic customer behaviour among others as the world becomes a global village. A conglomerate of companies collaborating together is simply SC. It is "a system whose constituent parts include material suppliers, production/manufacturing facilities, distribution services and customers linked together via a feed forward flow of materials and feedback information flow" (Naylor *et al.*, 1999; Soltan and Mostafa, 2015). For SC to survive, adoption of strategies and business models considering overall organizational objectives need be carefully specified.

Various strategies of SC exist in literature among which are Lean, Agile, Resilient and more recently added due to the need to incorporate sustainability measures into SC operations is the Green SC strategy. Lean and Agile are critical strategies because of their abilities to maximize the efficiency by eliminating non-value adding elements, stock control & centralized management as well as optimizing distribution and production activities (in case of lean strategy). Agile strategy on the other hand proffers

advantage by its capacity of response and flexibility to variable market needs plus risk hedging means.

Lean approach is traced to have originated from the Toyota Production System with main spotlight on "efficient use of resources via level scheduling" (Ohno, 1988). It basically works fine in reasonably stable and foreseeable demand scenario and where variety is low. Conversely, agility, whose principal concern is responsiveness, is suited for situations with volatile demand and high variety requirement. It strives "to match supply with demand in turbulent and unpredictable markets" (Christopher *et al*, 2006).

The present hostile economic conditions highlight the need for organizations to integrate various SC strategies in order to compete favourably. According to Krishnamurthy and Yauch (2007), "there are three general positions with respect to lean and agile: those who believe that they are distinct and cannot co-exist (e.g. Harrison, 1997), those who believe that they are mutually supportive strategies (e.g. Naylor et al., 1999), and those who believe that leanness must be a precursor to agility (e.g. Hormozi, 2001)". In reality the two approaches can complement each other.

Hence, careful adoption of both strategies no doubt will lead to organizational performance improvement. This work thereby aims to advance the understanding of lean and agile SC strategies by conducting a scientific review through the adoption of the "dynamic literature review" method named "Systematic Literature Network Analysis (SLNA)" introduced by Colicchia and Strozzi (2012). The method combines both the "Systematic Literature Review (SLR)" and "Bibliographic Network Analysis (BNA)". Adopting the SLNA approach is considered a supreme choice as its application in other settings (e.g. Strozzi et al., 2017) has proven successful at unravelling state of art of dynamic body of knowledge through identification of research trends and evolutionary paths.

2.0. Materials and Methods

The SLNA has two phases, the "Systematic Literature Review (SLR)" and the "Bibliographic Network Analysis (BNA)". The SLR phase involves scope definition to carve a niche for the study; studies location to retrieve articles from databases using predefined keywords or search strings; study selection and evaluation to filter out the most applicable articles. The second phase, BNA, on the other hand considers the selected articles in the first phase and applies bibliographic network analyses and network visualization tools.

Articles were retrieved from the Scopus database which alongside "Web of Science" (WoS) is the most popularly used scholarly citation database. Both are similar but the former however has advantage of nearly 60% coverage over the latter (Zhao and Strotmann, 2015). Vosviewer software (http://www.vosviewer.com/) was used for building the citation network as well as preparing input file for another software package, Pajek. Pajek software is a Social Network Analysis tool and was deployed in building the main path.

3.0. First phase of SLNA methodology: SLR

3.1. Scope of the analysis

As stated earlier, this work focuses on lean and agile SC strategies. A structured literature review on both strategies could help both practitioners and academia at unravelling the trend and most developed practices of lean and agile which proves a great deal at improving the performance of the organization.

3.2. Locating study

Keywords definition is essential for locating the study. From literature, the following sets of keywords are identified for lean – 'lean' and 'leanness'; for agile – 'agile' and 'agility' as well as 'leagile' that combines the two. The query applied on Scopus database is as follows: 'lean' and 'agile' OR 'leagile' OR 'leanness' and 'agility'. This step is considered crucial as outcomes might change with any change in the applied query. We chose not to incorporate the specific terms connected with supply chain in the chosen keywords at this stage so as not to limit the number of papers to be retrieved. Also, going through literature, we discovered some authors do not relate lean and agile to the whole supply chain, but were specifically related to manufacturing. Hence, the chosen keywords allow us to see lean and agile both directly connected with manufacturing or the entire SC.

3.3. Study selection and evaluation

The identified keywords were used as search query in Scopus database at the end of December 2018 in the 'Title' field because we are interested in papers that have lean and agile as the main goal of their analysis. Time restriction was not placed while filtering papers and only papers published in English language are considered. Also, only articles published in journals, conference and review papers were considered in the document type, while the subject areas include engineering; business, management and accounting; decision science as well as computer science. 210 works were retrieved.

3.4. General characteristics of selected studies

As stated in the study selection section, this review work is based on the 210 papers obtained from the SLR phase. In this section, we briefly analyse the features of the selected papers. Firstly, the retrieved articles show that the last decade has witnessed increasing growing trend towards this research area as significant amount of literature revolved around lean and agile strategies. Figure 1 shows how there is a growing trend from 1 article published in 1994 up to 10 in 2009 and 23 in 2018.

Interesting to note is the diverse geographical spread of the papers as they comprise contributions of authors from 42 countries. It is however worthy to note that authors from UK, US, India, Finland and Portugal constituted majority. Distribution of authors by countries is depicted in figure 2.

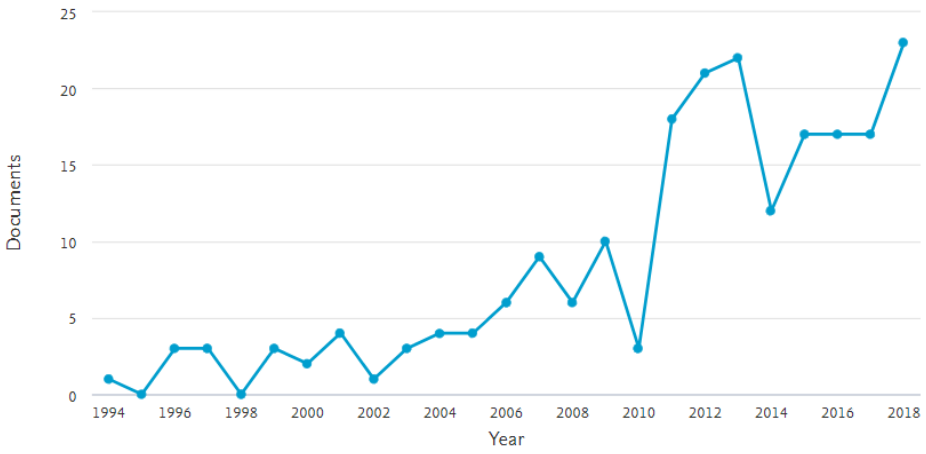

Fig.1: Distribution of articles by publication year

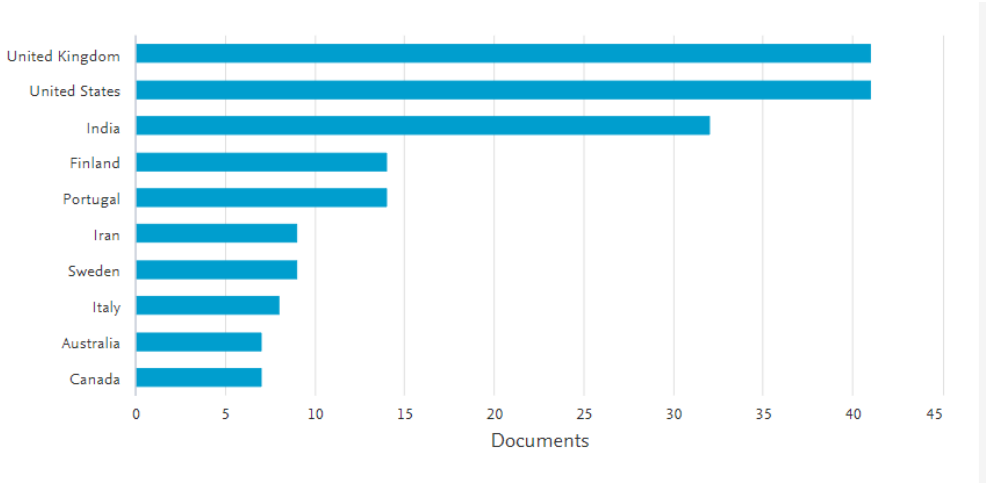

Fig.2: Distribution of authors by Country

4.0. Second stage of SLNA methodology: BNA

The 210 articles resulting from the SLR phase constitutes the input for the BNA phase. These were considered as relevant works for the analysis at hand and hence, were included in the citation network analysis.

4.1. Citation Network Analysis (CNA)

In order to perform the CNA, the isolated nodes need be excluded in the network. Isolated nodes are articles which are neither cited nor citing any article in the network. Out of the 210 papers, the only connected component consists of 122 papers while others are isolated; hence, we extract the connected ones for further analysis.

4.2. Analyzing the Connected Component

The connected component is shown in figure 3. To analyse the component, the Main Path (MP) algorithm is deployed. The MP extracts main streams in the evolution of articles by identifying papers that constitute a hub of research realm. Indeed, as Strozzi et al. (2017) pointed out, "the main path underscores the papers that build on prior articles but continue to act as hubs in reference to subsequent works".

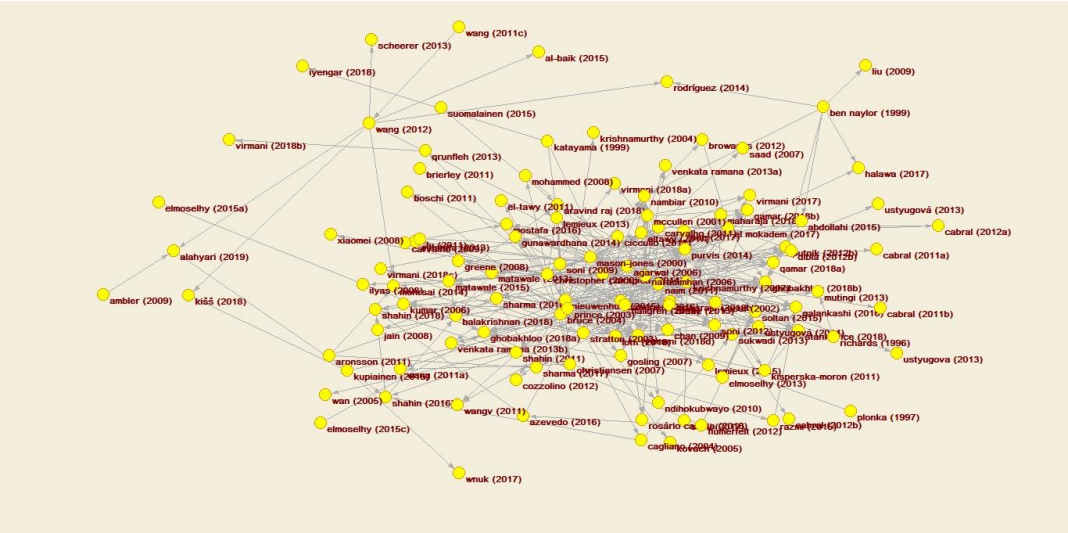

Fig. 3: The connected component of the citation network

The main path of the connected component is depicted in figure 4. The papers range from 1996 to 2018 and their main subjects concern how the lean and agile strategies are associated for better organizational performance as well as the strategic combination of the two paradigms to form leagile. Also covered are frameworks covering their drivers (both internal and external) as well as for measuring their impacts on organizational performance.

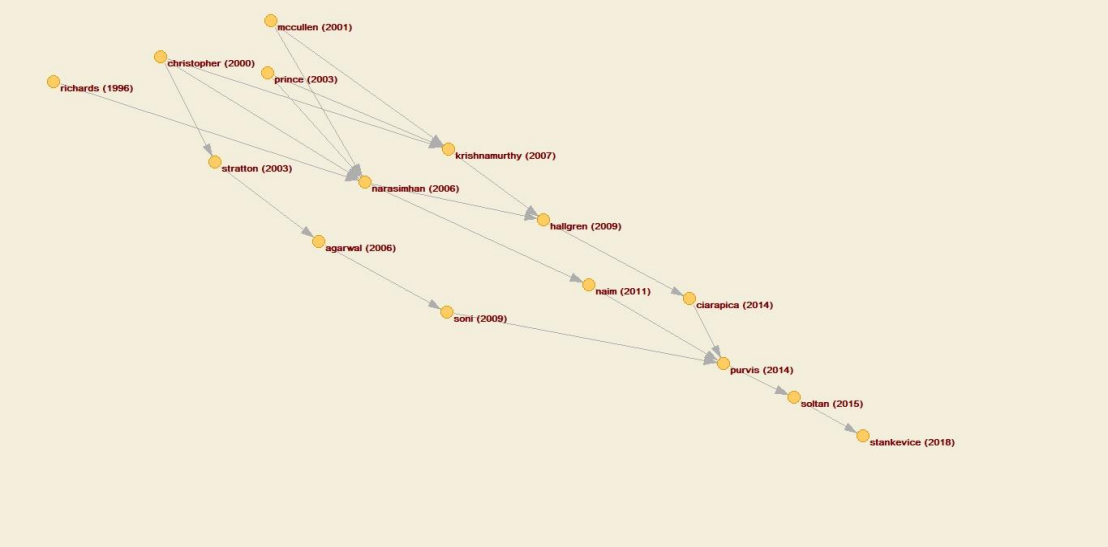

Fig.4: The Main Path of the connected components

The oldest paper of the path, Richards (1996) relay how the term '*agility*' was initially coined by the US Air Force strategists which to them means ability to change manoeuvre rate of aircrafts before subsequently becoming acceptable strategy to the entire military as the ability of friendly forces to be more proactive and reactive faster than the enemy. He stressed how the notion of agility applies to the business concept where the strategy is for the competitors to fight for customers. He defined *agility* in manufacturing as "the ability of an enterprise to thrive in a competitive environment of continuous and unanticipated change by responding quickly to rapidly changing markets driven by customers' valuation of products and services" Richards (1996). He further emphasized how the *lean production concept* is associated with *agility*. For instance, he argued that *inventory elimination* which is a concern of Just-in-Time pillar of *lean* is also required of *agility*. He further submitted that *value creation*, which is the centre of *lean* strategy, can not be determined within the four walls of an organization without considering the ever changing needs of customers who alone can ascertain if any value was added in a production process - This is part of what *agility* preaches. In the same vein, an agile enterprise also needs to produce products and services that customers want to buy, more than they want to buy those of the competitors in order to avoid stockpiling of inventories – This is one of the preaching of *lean* philosophy. On overall, the paper stresses the link and association between *leanness* and *agility*. Also tolling this line, Christopher and Towill (2000) used the notion of "*market qualifiers*" (criterion to enter any competitive arena) and "*market winners*" (particular competencies to win an order) to stress the criticality of the connection between *lean* and *agile* strategies. The winning criterion for the former being cost while it is service and customer value enhancement for the latter. In real life, these criteria are essentially corroborative in a competitive environment, hence, buttressing how the association

between the two paradigms could be beneficial to organizational SC. They also added that *leanness* might be an element/portion of *agility* in specific situations; it will not on its own allow the organization meet the exact needs of the customers rapidly. The authors however stress the role of *decoupling points* for the connection between the two strategies. Accordingly, correct positioning of *decoupling points* for information and material flows allow a *hybrid SC* to be engineered. "This encourages *lean (efficient) supply upstream* and *agile (effective) supply downstream*, thus bringing together the best of both paradigms" (Naylor et al, 1999; Christopher and Towill, 2000). The paper ultimately proposes a "*cyclic migratory model*" that depicts the PC supply chain qualities while evolving from its *traditional SC* to its current personalized *leagile* operation.

Similarly, McCulen and Towill (2001) while drawing on the result of their SC modelling and dynamic simulation of a case study on a precision engineering factory in the UK indicate a connection between the two approaches. They concluded that viewing manufacturing within SC as a whole makes it possible to perceive how *agile manufacturing* can include the *lean paradigm*. Other authors e.g. Stratton and Warbutton (2003) also investigated the strategic integration of agile and lean paradigms by exploring the *role of inventory and capacity* at accommodating the growing demand and variety uncertainty. Narasimhan et al. (2006) on the other hand discussed *leanness* and *agility* as *manufacturing paradigms* and *performance competencies*. Their empirical research attempted to verify whether *lean* and *agile* strategies occur with any form of uniformity in production plants

Agarwal *et. al* (2006) on their part analyse the relative impact that different *pre-identified enablers* have on *lean, agile* and *leagile* SC strategies. Specifically, the paper develops a framework, using "*Analytic Network Process*" (ANP) approach, for modelling performance of lean, agile and leagile SC on the basis of interdependent variables. The ANP methodology allows the authors to assess the impact of various identified performance dimensions on the specified supply chain objectives like prompt response to customers' demand. It also shows the influence and interdependency of the determinants. For the case study adopted in the study, the framework suggested better performance weighted index for *leagile* supply chain as compared to mere *lean* or *agile* strategy. This favours the policy of combining the 2 strategies as against adopting either uniquely. However, the authors noted that the results can not be generalized yet as the only sector considered is a Fast Moving Consumer Goods (FMCG). Similarly, Hallgren and Olhager (2009) examined factors (both internal and external) driving the selection of lean and agile operations capabilities with corresponding impact on operational performance. The result of their analysis via structural equations modeling shows that *the two strategies are unique in drivers and outcomes*. While the adoption of *cost leadership strategy drives the lean approach, operational flexibility in terms of product mix and volume drives the agile approach* (Hallgren and Olhager, 2009). This again confirms the work of previous researches earlier reported; hence, adopting the two strategies prove a great deal at improving the performance of organization.

Furthermore, Krishnamurthy and Yauch (2007) on their part tried to build on the notion of *leagility* as discussed among scholars with respect to supply chains and focal manufacturing plants. Specifically, they tried to find out whether *leagility* concept can be useful to a multi-unit corporate enterprise by investigating one that displayed both *lean* and *agile* qualities and whether a *decoupling point* would be evident. The results of their simple case study in form of "theoretical model of leagile organizational infrastructure" show how *leagility* as a concept can be applied to a multi-unit corporate enterprise. According to them, akin to previous *leagile* models devised for SCs and

manufacturing facilities, calling a manufacturing system *leagile* is hinged on the *boundary location* around the system or sub-units within the system – This is *decoupling point* and affirms its necessity when combining lean and agile characteristics to form leagile strategy.

Soni and Kodali (2009) in an attempt to justify the *leagile* SC strategy developed a "multi attribute decision model" in form of "performance value analysis" which was demonstrated and validated with an auto component SC case study. The result of the case study showed that *leagile strategy* outperformed the *traditional SC* as well as *lean* and *agile* considered singly for all the fields of performance measurement considered. Naim and Gosling (2011) conducted a literature review specifically on articles citing Naylor et al. (1999) in order to ascertain the degree at which the *leagility* concept is receiving assent and adoption among scholars. They highlighted the *broadening of the leagility* notion to contain not only the *decoupling point*, which signifies the possibility of having different *leagility* types. Subsequent upon this, Purvis et al. (2014) extended the *leagility* concept outside the material flow decoupling point by proposing "*leagile with vendor flexibility systems* (i.e. one that combine use of agile vendors with lean sourcing)" and "*leagile with sourcing flexibility systems* (i.e. one that combine use of lean vendors with agile sourcing)".

Soltan and Mostafa (2015) on their part noticed little researches on performance measurement at the plant level as regards the lean and agile strategies. Thus, they proposed a framework to assess the *general performance of a manufacturing organization* at the enterprise level based on lean and agile strategies. Stankevice et al. (2018) while realizing the era of *innovative capabilities and advancement in manufacturing and the SC* as a whole (e.g. *era of smart factory; industry 4.0; smart logistics* etc.) expressed the need to include *innovation into the discussion of leanness and agility*. They proposed an integrated theoretical framework that links different *innovation practices* with low performing, *lean and agile enterprises*. In more detail, the paper attempts to align innovation practices with enterprises' capabilities development trajectories towards leanness and agility and conceptualizes an integrated theoretical framework of innovation-based capability development sequence.

As noted in the citation network, some papers among the retrieved set of scientific works constitute outliers because there are no citations linking them; hence, they could not be included in the analyzed connected components in the CNA phase. To compensate this drawback, we performed additional analysis - Global Citation Score (GCS) - on the whole data retrieved from Scopus.

4.3. Global Citation Score Analysis

GCS analysis is useful for detecting seminal works in a particular research field. Papers having high GCS on the concerned database (Scopus in our case) are usually recognized as seminal or prominent papers in a field of knowledge (Knoke and Yang, 2008; Strozzi et al., 2017). However, there is possibility of having seminal papers with significant amount of citations on the Scopus database that will not appear in the citation network. This can be observed by comparing the GCS with the CNA. The top 5 most cited papers as shown in table 1 are ordered in line with their GCS signifying their entire citations in Scopus.

In table 1, we can see that some of the papers belonging to the man path are indeed significant in their topic - not just within the citation network. Also, the two additional papers (# 1 and 4) confirm the increasing considerations for lean and agile SC integration for improved organizational performance.

Table 1: GCS of the 5 most cited Papers

Rank	Title	Author	Journal	Year	GCS	Main Path
1	"Leagility: integrating the lean and agile manufacturing paradigms in the total supply chain"	Ben Naylor J., Naim M.M., Berry D.	International Journal of Production Economics	1999	817	
2	"Supply chain migration from lean and functional to agile and customized"	Christopher M., Towill D.R.	Supply Chain Management	2000	403	x
3	"Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach"	Agarwal A., Shankar R., Tiwari M.K.	European Journal of Operational Research	2006	370	x
4	"Lean or agile: A solution for supply chain management in the textiles and clothing industry?"	Bruce M., Daly L., Towers N.	International Journal of Operations and Production Management	2004	317	
5	"Disentangling leanness and agility: An empirical investigation"	Narasimhan R., Swink M., Kim S.W.	Journal of Operations Management	2006	308	x

5.0. Conclusions and Research Agenda

This study presents a quantitative bibliometric analysis on the lean and agile SC paradigms, counting on software tools and their algorithms that enable us to perform a dynamic demonstration of knowledge evolution over time. In so doing, we provide a big view of the knowledge on the subject in order to identify some research trajectories and present agenda for future research. From the analysis, some interesting research agenda are identified and a few of them are discussed as follows.

While acknowledging works describing the relationship between SC paradigms and the performance outcomes via frameworks/conceptual model, most of them were anecdotally established from literature review without empirical/statistical validation (e.g. Carvalho et al., 2011; Galankashi and Helmi, 2016 etc.). Even where such models are validated with real-life case studies, bulk of them is on automotive SC (e.g. Cabral et al., 2012; Elmoselhy, 2015 etc.). Hence, more studies where the SC paradigms and relationship with performance outcomes would be empirically/statistically validated on other case studies are recommended.

Ghobakhloo and Azar (2018) obtained that advanced manufacturing technology (AMT) enhances development of lean and agile manufacturing strategies. We submit that these technologies alongside pillars of industry 4.0 technologies capable of acting as enablers to lean-agile strategies should be explored while their impact on SC performance outcomes modelled and subsequently tested and validated. Recall that the era of innovative capabilities and advancement in manufacturing and SC was realized from our main path (Stankevice et al., 2018). Hence, it will be a "hot cake" for future research to move towards identifying innovative capabilities and AMT/ industry 4.0 technologies capable of driving various SC paradigms for improved SC performance.

From methodological point of view, it could be interesting to apply and compare different methods of modelling relationship between SC paradigms and performance outcomes. Methods like "Analytical Network Process (ANP)"; "Analytical Hierarchy Process (AHP)"; "Interpretive Structural Modelling (ISM)" and "fuzzy approach" could be combined in a single case to see the result of the relationship from each method. This perhaps could reveal the firmness of one method over another or to solidify researchers' output if different methods reveal similar results.

As we cannot discountenance the potential demands that lean-agile strategies will place on workforce of organizations who are at the beginning of adopting the strategies, it will be interesting to include human factor consideration, viz-a-viz change management perception from the workers' perspectives into future researches. Also, contributions that management can make at improving their workforce capability in lean-agile environment should be studied.

Conclusively, this study is not without limitations with the main one being that citation data are retrieved from a single source. Albeit, Scopus has coverage of 60% larger than WoS as stated earlier, it still doesn't represent all scientific contributions in the studied field. Future studies may select articles from other databases to compare the results on the research trends that will evolve.

Notwithstanding the drawback, this systematic review could give an outlook of the most established study areas in lean and agile SC paradigms thereby assisting newcomers to aim and adopt any of the identified themes as their research focus. Lastly and holistically, a stimulating output of this research is the demonstration of the utility of SLNA as a research means to aid dynamic analyses for unravelling agendas and themes for upcoming research in the realm of lean and agile strategies.

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The use of Autonomous Guided Vehicles in Flexible Manufacturing Systems: A Systematic Literature Review

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Abstract
This study aims to examine the impact of AGVs on Flexible Manufacturing Systems (FMS) using a systematic literature review of published articles. The initial keyword search in management and business literature produced 1066 articles of which 75 articles were finally included in the analysis representing 59 academic journals and conference publications. Thematic analysis revealed the following key themes: Smart and Flexible Manufacturing Systems; Scheduling and Routing of AGVs; Synchronizing RFID with AGVs; Human-Machine Interface; Sustainability (Economic, Environmental, Social and Employment) Impact of AGVs; Reshoring–Nearshoring phenomenon; Internet of Things (IoT).

Keywords: Autonomous Guided Vehicles, Flexible Manufacturing Systems, Systematic Literature Review

Introduction
Industry 4.0 represents a new industrial paradigm based on the adoption of disruptive technologies such as Autonomous Guided Vehicles (AGVs) and the Internet of Things (IoT) (Wagner and Walton 2016). Industry 4.0 connotes the increasing digitisation and automation of the manufacturing environment: Advanced robotics, autonomous systems, smart and additive manufacturing are expected to revolutionize traditional ways of producing and delivering value (Wieland, Handfield, and Durach 2016; Koenigsberg and McKay 2010). This is the first time in industrial history that such a paradigm shift has occurred at such an unprecedented degree and pace, creating the Fourth Industrial Revolution (Schwab 2016).

However, despite the hype, few empirical studies have synthesized and evaluated the impact of disruptive technologies such as AGVs on warehousing of existing manufacturing systems and, particularly, flexible manufacturing systems. An FMS in general consists of (Buzacott and Yao 1986): (a) a set of machines or work stations, which have some degree of flexibility, such as that they do not require significant set-up or change-over time; (b) a Material Handling System (MHS) that is automated and flexible, so jobs can move between any pair of machines in flexible job routing; (c) a network of supervisory computers to manage job routing, track job status and communicate instructions among relevant parts; (d) monitoring operational performance and alerting

problems; (e) the jobs to be processed by the system; typically there is a constrained number of jobs an FMS can process simultaneously.

This study aims to examine the impact of AGVs on flexible manufacturing systems using a systematic literature review of published articles. The research questions were: in what ways do AGVs influence the performance of FMS? What are the key areas of research in AGVs in relation to flexible manufacturing and what are the practical implications of these findings? What is the role of AGVs in smart, flexible manufacturing? The study uncovered the following thematic areas: (i) Scheduling and routing (ii) human-machine interface, (iii) smart manufacturing, and (iv) sustainability. This study discusses the first two areas.

Methodology

This study conducted a systematic literature review of AGV studies in relation to flexible manufacturing. The primary information source for this study was journal databases. Two databases were used, Business Source Complete (EBSCO) and ABI Inform Complete (ProQuest), with Google Scholar contributing other articles via snowballing in order to enhance the research. The keyword search strings were divided into four main categories that contributed to the efficient search of the articles related to this study. After running a considerable amount of trial-and-error testing, the keyword search strings were completed.

The identified articles were assessed related to the title and abstract screening criteria. Then, the authors conducted a full-text review assessment in two steps: full paper screening and quality assessment. Full paper screening involved analysis and evaluation of the theoretical and empirical papers, not only by screening the title and abstract, but also the full text, based on the following criteria to ensure the most appropriate papers. Theoretical articles had to involve: (i) detailed information on the theory (e.g., impacts and counter-views related to AGV technology); (ii) a theoretical review of AGV-associated trends and implications which can be used to understand better the current position of this technology; and (iii) discussion on future developing scenarios in warehousing and other industries. Empirical papers had to involve: (i) relevant discussion practices, including trends and future developments, impacts, and changes that have come across in AGV applications in warehousing; and (ii) collecting empirical evidence to enhance the knowledge in different AGV implication aspects involved in warehousing and logistics. Full articles were reviewed based on quality evaluation such as the author's contribution, theory, methodology and data analysis. After quality evaluation, 75 articles were included in the review, 41 of which were directly derived from the keyword search (*Table 1*).

Findings

The 75 articles were derived from 59 academic journals and conference publications. The top journals, ordered by number of articles in brackets, included: International Journal of Production Research (8), International Journal of Production Economics (3) and IEEE Transactions on Industrial Electronics (3).

The number of publications depict the diversity of AGV disciplines, however, the most relevant disciplines that appear to relate to AGV implementation in the warehousing industry include: (i) industrial engineering; (ii) supply chain management and logistics; and (iii) computer-data communication/automation.

Table 1 AGV Articles thematic mapping

Key themes	Topics	Articles
Current Developments of AGVs	Smart and Flexible Manufacturing Systems	Abdelmaguid et al. (2004) Ali et al. (2010) Buyurgan et al. (2007) Farling, Mosier, and Mahmoodi (2001) Lee, Tangjarukij, and Zhu (1996) Mahadevan and Narendran (1993) Maughan and Lewis (2000) Seo and Egbelu (1999)
	Scheduling and Routing of AGVs	Bose (1986) Co and Tanchoco (1991) Draganjac et al. (2016) Koff (1987) Narasimhan (1999) Qiu et al. (2002) Rubrico et al. (2006) Rubrico et al. (2008)
	Synchronizing RFID with AGVs	Akerlof (1978) Cho and Cho (2013) Lu, Xu, and Zhong (2016) Park and Lee (2013) Zecca et al. (2009) Zhou et al. (2017)
	Human-Machine Interface	Cardarelli et al. (2015) Michalos et al. (2016) Pan et al. (2012) Villani et al. (2018)

The number of publications depict the diversity of AGV disciplines, however, the most relevant disciplines that appear to relate to AGV implementation in the warehousing industry include: (i) industrial engineering; (ii) supply chain management and logistics; and (iii) computer-data communication/automation. Most publications appear during the last five years, particularly in 2013 and 2015. The studies in the context of AGVs began in America in 1953, with Europe following a few years later, while the first AGV was successfully installed in 1954. However, the current research focuses on the "third era" of AGVs from 1991 to 2010, which was mostly using AGVs for intralogistics, followed by the "modern era" from 2010 to 2018. Additionally, it is clear from the chart that before the 2000s the journal articles were limited due to the small growth of AGVs to certain years, namely 1991, 1993, 1996, 1999 with only six journal papers in total. During the third era, academics and managers started to change their views because new technological standards were set and new markets established (Ullrich and Kachur 2015). The majority of the journals used in this research come from the UK (23%) and the USA (23%), together comprising almost 50% of the total research articles, while most of the remaining journals come from Switzerland (8%). A number of internationally highly ranked and reputed journals were published in these two countries (UK & USA) and contributed valuable insights into the research.

AGV applications in warehouses have been widely studied in different regions around the globe. Europe and North America comprise a major part of the research

conducted on this topic. This occurred because both of these parts of the world have flourishing industries, highly developed and expanded economies with balanced business environments and they are considered to be global business leaders. Additionally, despite the fact that some of the articles' location sources come from Switzerland, the location of the studies took place in the Netherlands. This change of location indicates a potential rise in the country's economy which led to a boost in the amount of research. However, the AGV industry remains a relatively new topic in this region and the studies of AGV applications remain immature. Finally, India, South Korea, Italy, and Poland contribute to the research with a small number of articles, which indicates that this field is in its infancy in these countries and is about to increase in the near future. Regarding sectors and industries researched in the AGV studies, manufacturing comprises the highest percentage (55%) followed by wholesalers/retailers (21%). Within the manufacturing industry, the sectors with the most interest from the publication point of view are: (a) industrial machinery (b) computer &communication and (c) electronics.

AGVs and Flexible Manufacturing Systems

AGVs impact FMS systems in terms of design, control, communication requirements and technologies. In FMS design, the criteria and method to integrate AGVs into the system has received considerable attention. Farling, Mosier, and Mahmoodi (2001) introduce a tandem configuration to minimize the common congestion and system control issues. By using simulation techniques to correlate the performance of three AGV configurations under diverse experimental settings, the study found that the system size, load/unload time, and machine failure rate factors have critical effects on the operations performance of the system. Um, Cheon, and Lee (2009) combine a multi-objective non-linear programming and evolution strategy to determine the design parameters of the FMS in terms of including the number, velocity, dispatching rules of the AGV, part-types, scheduling, and buffer sizes. Azimi and Alidoost (2011) use a number of the same criteria for planning issues, such as fleet sizes, buffer levels, processing times and control strategies to estimate the appropriate AGV load, resulting in an integrated approach which binds the material handling system to the FMS. Lee, Tangjarukij, and Zhu (1996) examine different heuristics rules in the operation of multiple-load AGVs in a flexible manufacturing system where AGVs can carry two or more loads, and found that the variable-route-part-priority (VP) rule and fixed-route-part-priority (FP) rule generated significantly higher throughput than their counterparts, while the 'pick-all-send-nearest' (PN) rule outperformed the other rules in part flow-time and work-in-process. Seo and Egbelu (1999) conducted a study concerning the material processing and transportation functions and showed that by simultaneously decomposing the integrated planning model into two sub-problems - machine selection and operation sequencing and flexible guide path design - led to enhanced flexibility in operational processes.

Furthermore, related to the operation dynamics of the production system, another important factor is the estimation of the number of vehicles in the FMS. Vivaldini et al. (2016) extend the work of Mahadevan and Narendran (1993) by developing an analytical method to estimate the minimum number of AGVs required to execute a given transportation order within a specific time-window. Regarding FMS control, the literature proposes two approaches for the routing of AGVs in the FMS: real-time routing and the hybrid model. Buyurgan et al. (2007) modelled real-time routing in a random FMS to use an evolutionary algorithm-based intelligent path planning model and found that this model outperforms the traditional dispatching rules for real-time routing of AGVs in many cases. Similarly, Abdelmaguid et al. (2004) used evolutionary algorithms to address simultaneous scheduling the machines and the AGVs in the FMS while Corréa, Langevin,

and Rousseau (2007) presented an hybrid method to to solve scheduling and conflict free routing of up to six AGVs. Abdelmaguid et al. (2004) used a hybrid GA/heuristic method while Corréa, Langevin, and Rousseau (2007) used a decomposition method. Maughan and Lewis (2000) note that in FMS design, an AGV can be used as both the materials handling unit and the communications line linking each station to the host controller and demonstrated that a control software can allow real-time communication between the AGV and peripheral equipment using a standard infrared data link, eliminating hard-wiring and network protocols.

Scheduling and Routing of AGVs

In the past few decades, scheduling and routing of AGVs has drawn considerable attention. Scheduling and routing methods are often mutually connected to achieve the best results within warehouses, such as applications that involve many actions (Qiu et al. 2002). Routing is described as the AGV's ability to make decisions according to the given guidance paths in order to identify the optimum routes to definite destinations (Martínez-Barberá and Herrero-Pérez 2010). Scheduling involves the allocation of resources to assignments over time and it is a decision-making process that connects the diverse operations, time, costs and goals of the company (Rubrico et al. 2006).

The AGV's controlling algorithms rely either on centralized or decentralized warehousing design architectures (Martínez-Barberá and Herrero-Pérez 2010). Centralized control is when one central AGV executes various intricate assignments, like mission scheduling, path planning, and movement coordination, while decentralized methods are described as distributed network systems with high levels of AGV autonomy. Based on these two warehousing control architecture systems, the scheduling and routing of AGVs can be programmed. An AGV network can be described as a map including nodes linked with a set of arcs. Each arc is linked with a cost or the related time required by an AGV to cross it. This map acts as the main input to the routing algorithm (Co and Tanchoco 1991). However, these general path topology algorithms consider the routing problem as the shortest path issue, which confuses the trace of nodes and arcs, especially when the time is limited (Qiu et al. 2002). Additionally, the optimal solution may be omitted due to certain imposed limitations. This may lead to failure in identifying a feasible route or induce delays. These algorithms are more appropriate for the small number of AGVs and small size of path networks (Qiu et al. 2002). On the other hand, specific path topologies give acceptable solutions, such as single or multi-loop, segmented path and mesh (collision and bottlenecks, etc.), are easily removed and routing control is simplified. Although these algorithms have been highly implemented in the manufacturing industry, they do not permit many AGVs to be routed simultaneously. Routing can be static or dynamic (Hodgson et al. 1985). Static routing is when the AGVs' path between any two nodes is determined, while in dynamic routing AGVs can select different paths from one node to another. An essential routing issue is when collisions occur during processes. Rear-end collisions should be prevented and the flow of AGVs into an intersection should be regulated (Egbelu and Tanchoco 1982). Koff (1987) recommends zone control as the most reputed and trustworthy method, preventing AGVs from entering a zone already taken by another AGV.

Additionally, by implementing heuristic rules and diminishing the frequency of AGVs encountering an intersection could decrease AGV waiting time. The optimal situation with zero intersections is the circular or single-loop layout (Co and Tanchoco 1991). In regular systems with few intersection points, AGVs can trace their routes autonomously; however, in complicated layouts, traffic management control is more

effective (Bose 1986). As far as routing interruptions are concerned, Narasimhan (1999) conducted analysis for re-routing AGVs and used route databases to acquire previously created paths in order to quickly re-route the AGVs when interruptions occur.

Martínez-Barberá and Herrero-Pérez (2010) used topological and grid-based maps for routing and showed that the adoption of these tools assists in obstacle avoidance and is recommended for small zones and fast planning. On the other hand, scheduling AGV movements are beneficial for projecting traffic flow, congestion and in making predictions when a busy AGV will be set free from its last assignment. Taghaboni and Tanchoco (1988) point out that two AGVs should not be employed in the same node simultaneously and thus routing should be dynamic to avoid collision. Scheduling of multiple-picking AGVs for warehouse management is also addressed in the literature (Rubrico et al. 2008). For example, Rubrico et al. (2006) suggested a hierarchical decomposition of the multi-AGV-picking problem and found that by decreasing the total time needed to pick a given batch of orders favourably influenced both throughput and due-date satisfaction.

Another area of research is the synchronization of contactless technologies such as RFID with AGVs. RFID is a contactless automatic identification technology (Yamano et al. 2004) extensively used, among other applications, in warehousing to track and trace items and provide supply chain visibility in real-time (Ahmad and Mohan 2014). Within an FMS environment, RFID provides real-time inventory tracking at shelf level (Lu, Xu, and Zhong 2016); however, when AGVs also operate in the same space, there is a need to coordinate and synchronize them to achieve smooth flow inside the warehouse. Zecca et al. (2009) recommend a coordination algorithm to achieve synchronization and collaboration efficiency within a swarm of robots by linking both RFID-tags and robot-to-robot intelligence to harmonize and regulate the swarm and achieve autonomous collaboration without a pivotal framework or global network time.

Human-Machine Interface

Human-Machine Interface (HMI) is described as the contrast between safety, harmony, and cooperation among humans and robots (Villani et al. 2018). Even though there is a high degree of automation in FMS, human interference always exists, i.e., in a lean environment where the merits of the automation (high accuracy, velocity, and repeatability) are combined with the flexibility and intellectual skills of the workers. However, HMI, in the case of AGVs in FMS, imposes several challenges in terms of safety, collaboration, and coexistence (Cardarelli et al. 2015). A safe interaction should be assured to avoid the injury of operators when directly contacting the AGVs. It is essential that intuitive user interfaces are correctly outlined so that the programming and physical or cognitive interaction with the AGVs can be easy (Villani et al. 2018). Three safety standards have to be addressed in HMI: T*ype A* that include the fundamental safety prerequisites for common requirements that apply to machinery, *type B* that are related to generic safety standards, and *type C* that involve personal safety measures against particular machinery types.

Collaborative operative modes, as stated in *ISO 10218-1/2*, are also important for the co-existence of humans and robots (Dietz et al. 2012). Certain challenges make pre-requisite the risk assessment, particularly for those operations that involve dynamic collaborations(Knoop, Pardowitz, and Dillmann 2007) One of the main issues identified in the HMI literature is when the operator is required to have specialized knowledge to interact with the AGV which necessitates intuitive user interfaces and specialized AGV programming (Zoliner et al. 2005). The first method to robot programming is the

conventional lead-through programming, which is based on the usage of a teach pendant for moving the robot via the required motion cycle, by nudging (Villani et al. 2018). However, this method requires programming for each new task, it is only suitable for programming simple tasks and it is time-consuming and expensive (Dietz et al. 2012). To overcome these limitations off-line programming (OLP) is used, by programming the robot from a computer rather than on the robot itself. Modelling and simulation are used to depict graphical representation and the possibility to identify possible collisions (Villani et al. 2018). Nevertheless, according to Pan et al. (2012) employing an OLP system is very expensive and demands great programming effort.

A new approach is a multi-modal interface in which sensing is used to improve the human-machine interface (Roitberg et al. 2015). Sensors enable robots to imitate workers and behave more like humans. Thus, the communication gap between user and machine is diminished and workers do not need previous experience to interact with robots (Cardarelli et al. 2015). Another method is vision-based programming, in which the robot recognizes human gestures and facial expressions and transfers them to the robot for motion imitation (Zhang and Yu 2018). Cardarelli et al. (2015) implemented a 3D visual representation to manage the fleet of AGVs with a centralized data fusion system called Global Live View. This system updates visually both static and dynamic elements in the environment, is very simple to use and does not require the operator ti have special knowledge. Similarly, the vocal commanding method appears to be very useful when hands-free intervention is needed. The main advantage of this method is that it does not restrict the operator's movement. However, misrecognition of the voice instructions and the possible peril of delaying production, efficiency and safety is the reason for the lack of such systems in the industry (Rogowski 2012). Finally, analysis around the augmented and virtual reality programming methods revealed that productivity is increasing and human safety is enhancing (Michalos et al. 2016). The difference between the two methods is that in the former user retains a sense of presence in the real world, while the latter enables a fully engaging environment where the operator's senses are captivated by the system.

Discussion

This study has conducted a systematic literature review of AGV applications in warehousing and particularly in flexible manufacturing systems, which can be considered as complex systems consisting of people, technology and operational processes (Geels 2004). Industry 4.0 connotes the increasing digitization and automation of the manufacturing environment to higher levels of productivity and competitiveness (Koenigsberg and McKay 2010). The design and integration of Industry 4.0 technologies requires novel business models that integrate these innovative technologies with existing manufacturing practices and engineering processes to increase performance in terms of efficiency, productivity and competitiveness. The literature review has revealed the following key areas: (i) flexible manufacturing including improved scheduling/routing of AGVs and the human-machine interface, (ii) smart manufacturing, and (iii) sustainability. Studies have examined the scheduling and routing of AGVs from many different perspectives and the results indicate that the scheduling and routing should be in-sync on either centralized or decentralized warehousing environments (Draganjac et al. 2016; Martínez-Barberá and Herrero-Pérez 2010). Certain studies highlight the necessity of minimizing the waiting time with zero intersections of AGVs. For simple warehouse layouts, the circular- or single-loop layout is recommended while, in complex layouts, traffic management control is found to be the most suitable (Bose 1986; Co and Tanchoco 1991). However, most of the articles focus on collision, interruptions and bottleneck

avoidance (Koff 1987; Narasimhan 1999; Qiu et al. 2002). The most important solutions to those issues involve reputed methods such as single- or multi-loop, segmented path, mesh, topological and grid-based maps, the zone control method and certain rerouting algorithms that have resulted, also, in better AGV performance (Co and Tanchoco 1991). Lastly, heuristic and metaheuristic methods for the scheduling of multi- picking AGVs in warehousing are introduced to regulate the delay issues, diminishing the make-span and enhancing throughput and due date satisfaction (Rubrico et al. 2008). Related to the RFID-based tracking technologies, its purpose is multi-dimensional when it is linked with the AGV system inside a warehouse. A method is illustrated for controlling and tracking the randomness of inventory located in a warehouse environment (Akerlof 1978). It is also found that RFID improves AGVs and shelf-positioning inside a warehouse (Zhou et al. 2017). The foundation on which human-machine cooperation is relied upon is the combination of the terms safety, coexistence and collaboration (Villani et al. 2018). Additionally, various safety standards and collaborative operative modes were illustrated in the study that highlighted the necessity for the operators to follow the legislation rules (Dietz et al. 2012; Pan et al. 2012). Regarding smart manufacturing, AGVs help manufacturing systems become more agile and flexible by: (a) reducing production bottlenecks and deploying the workers more effectively through the tandem system configuration (Farling, Mosier, and Mahmoodi 2001); (b) combining new sensor and software technologies which are ideal for unpredictable or changing production layouts and dynamic work environments. The proposed solution is by simultaneously decomposing the integrated planning model into two sub-problems, namely machine selection and operation sequencing and flexible guide path design (Seo and Egbelu 1999); (c) operating the AGV controller independently with the Manufacturing Work Order on board. Hence, better manoeuvrability of the system is achieved without causing interruptions (Maughan and Lewis 2000).

Limitations and Recommendations

This study conducted a systematic literature review which has several limitations. Firstly, despite the adoption of an extended systematic literature review the data collection process accomplished depended upon three databases, namely ABI, EBSCO and Google Scholar, which restricted the study to articles accessible via these platforms. Secondly, AGV adoption in flexible manufacturing is considered as an emerging practice, thus the academic literature is relatively limited compared to other sectors, such as the shipping industry. Lastly, in the field of the AGVs' engineering parts, the literature is still evolving, and it was not included in this review. Future studies on the topic of AGV usage should go beyond flexible and smart manufacturing and examine lean manufacturing too. Although this study demonstrates the developments and effects of AGVs in the warehousing industry, studies of the effects of AGVs on sustainability, particularly social and economic, such as and reshoring-nearshoring are scare.

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Economic evaluation in decision models: a critical review and methodological propositions

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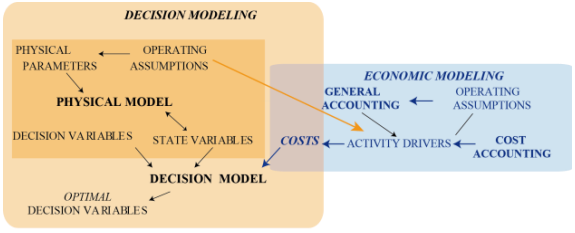
Abstract

Decision models of industrial management articles are often based on an economic criterion to find the proposed solution. They use economic parameters that are generally imported from the firm cost accounting system. When cost information is not adapted to the decision, the obtained solution of the model may be invalid. In this article, we deal with a critical literature review to report the methodological problems encountered in industrial management articles vis-à-vis the used costs. Finally we suggest methodological propositions to be kept in mind by authors when they are using costs in decision models.

Keywords: Industrial management, mathematical model, economic model

Introduction

We are interested in the management of a supply chain (SC) or a sub-system of a SC. It concerns strategic, tactical and operational decisions taken to design, and run production units. To improve their decision making process, managers call in decision models that attempt to reproduce, through a simplified physical model, the functioning of the studied productive sub-system. In these physical models, decisions to take are represented by *decision variables* that determine, through a number of causal relationships, their impact on some physical characteristics of the studied system (flow, stock, resource use …). Decision variables may be quantitative (capacity of a new plant, reorder points…) or qualitative (opening or closing facilities, production orders assignment…). Across a modelling, we focus more particularly on certain physical quantities calculated by this model and linked to the decision variables, because they condition the performance of the studied system. In modelling, these physical quantities are generally called



state variables and are used with costs to obtain an economic evaluation of the considered alternative decisions (Giard, 2017).

The physical model is bounded to a studied physical subsystem exchanging flows of goods and/or services with its environment. In a decision model, evaluation of alternative decisions lays on a criterion in relation with the global performance of the studied subsystem. Such criterion may be physical (machines utilization rate, % of unsatisfied demand…) and, in this case, it's supposed that the variation of the company financial performance (cost or margin) is linked with the one of the considered physical criteria and is assumed to vary always in the same direction (or in the opposite one). The decision criterion may be economic and called on costs information provided by a cost model. In that case, the relevance of the solution provided by the decision model depends on the compatibility of the implicit assumptions of the physical system functioning, used by the cost system with the one used in the decision model. A significant discrepancy invalids the relevance of the proposed solution. Most often, authors focus on the physical model development techniques and resolution methods, without paying attention to the consistency of the implicit functioning assumptions of the used cost model with the one of the physical model used by the decision model. It is assumed that the modelling teams can work independently of those of management accounting. The costs regularly provided by a firm management accounting system, cannot be suitable to any type of use.

This paper present a critical literature review to see to what extent authors check the adequacy of the used cost model with their developed decision model. In each article we dissect the economic function to highlight the considered costs, the way they were defined vis-à-vis the considered time and space horizons and whether the authors studied under which conditions, the proposed solution remains valid, especially when the given solution impacts the system design and the use of its productive capacity.

The rest of this paper is organized as follows, we begin with the theoretical framework, next we present the adopted methodology of the review. Subsequently we report the encountered methodological issues. And finally propositions of contributions and the conclusion are presented.

Theoretical framework

We focus here on a description and a literature review of the main theoretical concepts, that are necessary for the discussions dealt in the present paper. Firstly, we deal with highlighting the decision model characteristics, thereafter, we present some cost accounting approaches and briefly some economic concepts and costing theories.

Decision model underlying characteristics

Decision models are developed under the assumption that we can explain and capture the behavior of a physical system and/or a decision making process dealt by managers. Causal relationships exist between the considered variables of the model. These causal relationships enable the model to predict the future state of the modeled physical system (Bertrand and Fransoo, 2002).

A decision model has two key characteristics, they are space and time granularities (Giard, 2017). The space granularity concerns the covered perimeter of the studied productive system and the degree of details considered which in turn, determines the granularity of information provided for the user. The time granularity, defines whether the model deals with an operational, tactical or strategic issue. Space and time granularities are not independent; in general, the granularity is fine in operational decisions analysis and more aggregated in other cases. Granularity conditions bill of

materials, production routings, product ranges and the definition of resources used in the physical model. It has an essential impact on the relevance of costs to be mobilized.

Concerning decision models development approaches, we can distinguish two main approaches, mathematical (operation research (OR)) and simulation modelling. The first one refers to *i*) optimisation that gives the best solution for a particular issue, it's a very visible and influential topic in the field of operations management and, *ii*) heuristics which are intelligent rules leading to "good" solution and are used when optimization is impossible or too expensive. The second approach refers to all simulation techniques (discrete event simulation, agent-based simulations, system dynamics).

Cost accounting

A cost system refers to means by which organizations calculate costs of products and services to make sales profitable. Moreover, cost system concerns the modeling of costs of organizations resources and operations in order to support internal decision making process. Cost information should be useful to help managers in managing the performance and the profitability of products, customers, productions processes… (Lawson, 2018). Here we distinguish the *traditional cost accounting* and the *Activity Based Costing* (ABC) approaches:

The traditional cost accounting system in a company aims to allocate, at the end of each month, costs to products and services. It's oriented toward a retrospective calculation of historical costs. It's based on a succession of spills of analysis centers expenses to other cost centers by means of volume key distribution. ABC is a cost accounting approach developed from the eighties. It's based on the principle that activities consume resources, and products and services consume activities. ABC focuses on the activities that take place within the company, the cost of carrying out each activity and the factors generating these activities. It goes beyond the traditional system by allocating resources, based not only on volume units, but also on the diversity and degrees of complexities of the products (Cooper and Kaplan, 1998). Hence, the ABC approach distinguishes different cost pools (activity drivers): *unit-level activities* are performed each time a unit is produced, *batch-level activities* are performed whenever a batch is processed, *product-level activities* (process engineering, design, etc.) are costs which come into play whenever a particular product (order) is manufactured and *facility sustaining activities* concern costs related for example to rent, utilities, maintenance, and facility management.

Furthermore, an activity cost may evolve in the long run. Value chain analysis is the way to analyse activities in order to achieve competitive advantages by performing these activities better than competitors. Each activity has its structure and behavior, which determine its cost. Porter calls these determinants "cost drivers". He distinguishes ten possible causes of an activity cost evolution: *i*) economies or diseconomies of scale (costs sensitive to volume), *ii*) learning phenomenon (unit costs depend on time), *iii*) capacity cost utilization (impacts the fixed unit costs), *iv*) the linkage between activities that makes an activity cost dependent of other activities costs, *v*) interrelationships (resources share between different strategic units), *vi*) the degree of vertical integration (impacts transaction costs), *vii*) the timing (first-mover reward), *viii*) discretionary policies that refer to products or services design, *ix*) localisation and *x*) change in institutional and regulatory factor that may affect unit costs. (Hergert and Morris, 1989) (Bouquin, 1997).

The absence of the concepts of activity drivers and cost drivers in the traditional cost system is one the reasons that make it inappropriate for the study and analysis of operational and strategic decisions respectively. The traditional system is characterised by a lack of cause and effect traceability (Stratton et al., 2009), that makes it inadequate to understand how activities are performed and makes it weak in cost traceability.

Cost concepts

There is a multitude of cost concept whose use relevance depends on the studied context:

- *Opportunity cost* is a concept that dates back to the nineteenth century. It is proposed by Friedrich von Wieser, (1851-1926) who was interested in determining the production factors value (Burch and Henry, 1974). He defined the opportunity cost as the net income generated by this factor of production in its best use. (Andreani, 1967) linked it to the existence of a conflict between opportunities that could lead to a shortfall. Opportunity costs are the revenues to be gained from possible actions, but lost because other actions have been taken to achieve a particular goal, (Andreani, 1967), (Vera-Munoz, 1998).
- *Marginal cost* is the cost incurred for the production of an additional unit. The marginal cost differs according to whether it is decided to momentarily increase the volume of production by one unit, or if it is decided to increase it durably by one unit (Boiteux, 1951). In the first case, the additional unit is satisfied by the current capacity, but the second case may require an increase in capacity.
- *Variable costs:* the traditional system accounting defines variable costs as those who change with production volume and fixed costs those who do not change with volume. Cooper and Kaplan propose to use short-term variable cost, they vary with production volume, long-term variable costs which do not vary with production volume but do vary with other activity measures (handling, setup…) and fixed costs that do not vary; in a given period; with any activity driver.
- *Capacity costs* are defined by the set of resources (facilities, staff...) in which the company is committed to achieve a given level of performance. This latter is linked to the estimated maximum demand, the intended degree of flexibility to respond to unforeseen demand and the desire to ensure products diversity. These capacity costs, also called fixed costs, are generated form strategic decisions defining the company's strategy and vision (Bouquin, 1997). "*Investments in resource capacity are made based on the expected demand because instantaneous adjustment of capacity is impossible and/or extremely costly*" (Balakrishnan et al, 2007). The difference between the maximum capacity and the actual activity level is called unused capacity.

Different economic criterions in decision models

Several economic criterions may be used to assess decisions, their relevance depends on the studied decision nature. Here we retain the three criterions of costs, profit and discounted cash flows (DCF) through Net Present Value (NPV). Investment decisions refer to long-run decisions which focus on studying different alternatives of investment (outflows) in one or several periods to generate returns (inflows) in one or several future periods. They differ from operational decisions in the way that their study requires the consideration of the value of money evolution over time (Shillinglaw, 1963) (Lucey, 2003). Hence, the NPV is the appropriate measure to study investment decisions, it calculates the present values of expected inflows and outflows. Operational and tactical decisions study is based on the anticipated current cash flow only. The profit is the sum of revenues minus costs. When the revues are constant (sales and prices are independent of decision variables), profit maximization can replaced by costs minimization. Accounting profits are not suitable for investment decisions, they are period oriented (quarter, year…) (Lucey, 2003).

Costs and spatial perimeter

Issues dealt by decision models may belong to any SC activity: production, inventory management, transportation, pricing, design, relationship management… We note then

that a decision perimeter may either belong to the internal firm perimeter (production scheduling, investment, transportation…) or extends the firm boundaries (interrelationships management). The former case settles for the firm system accounting (intra costing) whereas the latter one necessitates an inter-organizational costing (inter costing). In fact a cost system is contingent to the studied physical system characteristics. Cost accounting systems of two cooperating companies are seldom similar. The difference between the two approaches creates inaccurate costs and ineffective practices (Kulmala et al 2002). Thus, creating relevant approaches for partnership relations is one of cost accounting challenges. Furthermore cooperation between a supplier and customer is based on trust and their readiness to open their book cost accounting. But this willingness to share information (reliability) is not enough, there should be dedicated approaches to generate relevant cost information (Kulmala et al 2002).

Costs at service of SC professionals

Previous research works has pointed out that often SC managers are not satisfied by the cost information provided by their firm accounting system. (Gurowka and Lawson, 2007) presented a road map to help mangers in choosing the appropriate costing approach. When cost information is not correct and accurate, the accounting system has no value for the company, worst it can damage the organization decision making.

According to a survey done on 2003 by the Institute of Management Accountants (IMA)/Ernst and Young, only 23% of the interviewed mangers are satisfied by their accounting information, 92% of them state that this information is distorted. (Gurowka and Lawson, 2007) say that if cost information still irrelevant, decisions are irrelevant and over time, departments managers may stop relying on financial criterion and make decisions based solely on non-financial data (more accurate).

The results of a recent survey (Lawson, 2017) shows that supply chain professionals often view their company's managerial costing system as being only slightly useful for generating questions and for making managerial decisions. According to (Lawson, 2017), three main causes explain this result: *i*) many organizations rely on externally oriented financial accounting systems to produce the information supporting internal business decision making; *ii*) many organizations use outdating cost models; these latter are not appropriate for the current organizations challenges and environment; *iii*) the third cause is the finance and accounting professionals resistance to change. This is amplified by little pressure from managers; who use costs; to improve data accuracy and relevance (Kilcarr, 2018).

In this paper, we complete this previous works, by a critical literature review of articles dealing with decisions models to highlight methodological problems related to the used costing models. It's to our knowledge, the first article that fully addresses this literature review.

Methodology

The adopted methodology leads to the selection and the evaluation of selected sources. We followed the same methodology adopted by (Maestrini et al., 2017). We first *i)* identify articles *ii)* we select articles, and finally *iii)* we evaluate and analyze them.

Articles identification

For the sources search we relied on the Business Source Complete base (BSC). Since we are interested in the study of the coherence between the developed decision model and the used economic model, we used the key words "industrial management", "mathematical model", "simulation model" and "economic model". To broaden the search range of articles, we used two key words combinations, in the first one we used

"industrial management", "mathematical model" and "economic model", and in the second combination we replaced "mathematical model" by "simulation model".

The use of two key words combinations gave a total of 1225 articles. We relied on SJR site, we investigate the journal scope and *H Index*. We considered only IJPE, IJPR, POM, OMEGA and PPC whose *H Index* varies between 61 and 141. We also limited the period of publication, we focused on the period between 2013 and 2018. We therefore get a sample of 202 articles.

Articles selection

We set boundaries to select the relevant articles to be considered in the present review. We select articles in which a decision model is developed to help users in making decisions related to a sub-system of the considered SC, hence there should be explicit variables that determine characteristics (functioning or design) of this system. The selection criterions are discussed and defined by authors of the present paper, and the task is done by two authors based on the abstract, the conclusion and eventually the introduction. Consequently, we selected a sample of 113 articles.

Articles evaluation and analysis

To evaluate the selected articles we started with an analysis grid. This grid attributes were defined based on previous literature review works (Maestrini et al., 2017), a SC taxonomy developed by (Capar et al., 2004) and additional attributes deduced from the theoretical framework above.

We begin with articles journal of publication. In the second stage we present the modelling approach on which the decision model is based (Bertrand and Fransoo, 2002). Thereafter, we highlight the considered time granularity in each article (Anthony, 1965), (Ansoff, 1980) and the considered perimeter that implicitly determines whether it's an inter or intra costing. We additionally mention the considered objective function physical or economic and whether it's costs, profit or NPV and the mobilized cost concepts. A grid summary is presented in table 1 bellow.

Findings

In this section we will present the mains results obtained from the reviewed articles analysis. We begin by reporting the articles journals of publication. In the second stage, we report the decision criteria. And finally, we focus on articles in which an economic model is used, in order to highlight the main encountered methodological issues.

Publication journal

The final number of the reviewed articles is 113. The largest percentage 49% of articles belong to IJPE, succeeded by 40% that bong to IJPR , and succeeded by 7%, 3% and 2%, that belong to OMEGA, PPC and POM respectively.

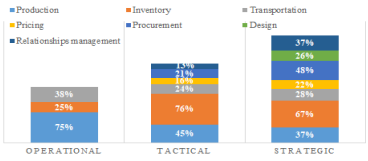
Decision criteria

13 out of 113 articles deal with problematics in which the developed decision model gives the solution based on the minimization or the maximization of a physical criteria. Most of these articles (11 out of 13) deal with operational and tactical levels issues

12% of articles consider both an economic and physical criteria. In the rest (76 %), the choice of the proposed solution is based solely on an economic criterion. Hereafter, we will exclude articles which are limited to the study of a physical criteria, we retain 100 article.

Encountered methodological issues

In this stage we based on the grid analysis to report the widespread methodological problems encountered in each article.



This figure presents for each decision level the SC activities dealt with. Bellow, we discuss issues related to cost content explanation (activity drivers), costs traceability, inter or intra costing nature, appropriateness of used economic criteria, capacity costs, cost drivers in the long run and finally the eventual impact of the obtained solution.

In the quasi totality of the reviewed articles, the authors gave no explanation about the used economic model parameters. These latter, are considered as given parameters provided by an external source which is generally the firm accounting system. They do not discuss the relevance of the used cost content according to the spatiotemporal perimeter. This suppose the assumption that modelling and accounting teams can work independently, as if costs could be absolute. No article uses activity drivers to define the relevant content of the used cost parameters. In some articles the authors give details about some used costs, for instance in [90] the unit transportation cost "*includes costs of fuel, salaries, wages, operating supplies, insurance, and depreciation*", [62] explain that the unit inventory cost is due to "*inventory obsolescence costs and capital costs related to slow-moving parts*", and that the unit manufacturing cost excludes all capacity costs (e.g. machines depreciation).

Generally a firm system accounting has its standards, it regularly calculates costs at the end of a predefined period (month). When a decision model is developed, it may necessitate the introduction of some specific costs that the firm system accounting is regularly not interested in. So here we identify a problem of traceability. In [69] and [105], the salvage value is difficult to be determined a priori, elsewhere there should be a sufficient data to can to estimate it. [37], [66]…models use penalty cost of unsatisfied demand, [103] developed a model for a retailer replenishment under supplier prices discount, and he uses a penalty cost induced whenever the retailer change his order quantity. [12], [33] mobilize the opportunity costs which are future costs that need to be known a priori. In [98] costs of non-conformity and rework cost are considered. Furthermore, some papers deal with batch or order level costs, if the firm system accounting is not based on ABC approach, these costs are not provided. Here then, we mention that there are several costs that are needed by the developed decision models in a company but for which there is no traceability in the system accounting.

The objective in [69] is the comparison between different relationship scenarios between a manufacturer, a distributor centre (DC) and a retailer (i) not using contract, ii) using buyback contract or iii) revenue sharing contract). [105] developed a model to coordinate between a supplier and retailer, it determines e-concession as a decision variable (a concession that both retailer and supplier need to make to maximize the whole system profit). Their model mobilizes the following economic parameters the supplier production cost, the retailer wholesale price, retailer salvage value and the retailer shortage penalty. [21] focus on the comparison between centralized and decentralized strategies between a retailer and its supplier. These examples of articles and others that compare different relationship strategies between different SC players imply that the applicability of the presented models is conditioned by the involvement and willingness of the considered firms to collaborate and share their costs information with other firms, which is not evident in practice. Through this inter costing necessity we signal the problem of the model perimeter which presents a new methodological issue.

In several of the reviewed articles, the authors deal with some top strategic issues. [37] developed a decision model for a network design, it determines facilities (production plants, warehouses and DC…) to be opened, the supplier selection. [66] models defines production and inventory capacities in a correctional institution… [92] presents a model

to compare different strategies to meet demand satisfaction, one of which consists on capacity investment. Even if all these issues imply investment with long term impact, the authors used costs rather than the NPV. They mix in one economic function costs related investment decisions and recurrent costs related to operating decisions. Here we identify the problem of discounting that should be considered when we deal with investment decisions whose impact is recorder along several periods. In the strategic level costs aren't the relevant to solely be considered, but they still the criteria adopted by the majority of authors. Only 3 of all reviewed articles [41], [34] and [104] consider NPV as the choice criteria.

In this paragraph we are interested in reporting the methodological issues related to capacity costs. We separate strategic form operational and tactical levels:

- Strategic level: in 85% of the studied articles consider full costs. However, since the activity levels are not necessarily the capacity level, they are decision variables of the model, the use of full costs leads to sank costs that penalizes the considered cost objects (products, orders…). [37] , [79], [78]… determine the production level in each plant and the inventory level in each SC node (e.g. DC, warehouse). [21], [109]…present models that determine economic order quantity (EOQ). Full costs include capacity costs that are not generated by the chosen activity level but rather by the firm strategy. These sunk costs are due to unused capacity. One article [93] considered unused capacity costs concept.
- Operational and tactical level: capacity costs are not controlled in the operational and tactical levels. Decisions related for example to week production planning, or orders scheduling during a month don't affect this category of costs. [106] model determines products scheduling in production machine. [71], [67] developed a model that define the orders distribution planning, they consider as decision variables, each product start and end dates, number of storage days… In [58] the model determines the production orders scheduling in parallel machines. In all these examples, the authors consider full costs, which are not relevant to all kind of uses as the case for operational decisions. Only 6 out of 16 articles consider variable or marginal costs rather than full costs to evaluate operational decisions. This full costs lead to biased economic evaluation.

Concerning cost drivers, none of the reviewed article considers cost drivers implying the eventual evolution of unit costs on the long run.

A new methodological problem is related to the impact of the obtained solution on the productive system. [93], [97], [37], [78], [26]… present developed models that define SC network designs. [1] developed a model for cellular manufacturing design, in each plant the model determines installed capacity in terms of machines number of workers… This kind of models, start from an initial physical system from which we deduce a cost model, and then the model use these information to obtain an optimal solution. The decision variables in these cases may affect the physical system, which calls into question the used cost parameters and then the obtained optimal solution. None of studied articles, studies the impact of the obtained solution on the used cost parameters.

Table 1: Grid summary

Decision level	Operational level				Tactical level				Startegic level						
	16				38				46						
Modeling approach	Math	Simulation		Combined	Math	Simulation		Combined	Math	Simulation				Combined	
	12	2		2	31			7	37	5				4	
Economic criteria	Costs	Profit		NPV	Costs	Profit		NPV	Costs	Profit				NPV	
	16				26	12			27	17				3	
Cost concepts	Variable costs	Full costs	Marginal costs	Opportunity costs	Variable costs	Full costs	Marginal costs	Opportunity costs	Variable costs	Full costs	Patial cost	Direct cost	Marginal costs	Opportunity costs	
	6	12			7	28	1	4	4	39	1	1	2	2	
Methodological issue	Explanation	Traceability	Inter costing	Capacity costs	Explanation	Traceability	Inter costing	Capacity costs	Explanation	Traceability	Inter costing	Capacity costs	discounting	Cost drivers	
	16	14	4	12	38	27	14	24	45	24	36	17	17	11	

Contributions

The presented results reveal that indeed authors neglect the costs relevance which leads to the reported methodological issues that affect the relevance of the proposed solution. In this section, we suggest some methodological guides that industrial management researchers need to keep in mind when they define costs in their decisions models

- *Need of reprocessing the firm accounting system information*: One of the main revealed findings, is that authors consider costs as given parameters without any explanation. A cost calculation makes sense if it is only adapted to the decision-making system that will use it. As a result, a decision model cannot take the output of full cost calculation without analysis and reprocessing. This means that decision models need to be provided by an ad hoc economic evaluation adapted to their spatiotemporal perimeter. If not, these decision models do not really improve the decision making, since the solution search relies on this economic evaluation. Therefore, the costs introduced in the decision models cannot be considered as valid physical parameters regardless of the physical system that they seek to improve. They are contingent to physical and functioning characteristics.
- *Costs specification and appropriate cost approach*: To ensure a relevant economic evaluation, the one need to determine charges that are impacted by the studied decision and exclude from the evaluation all charges that do not steam form this decision. The understanding of costs behaviour; through the use of relevant activity drivers; and the use of appropriate cost concepts help to establish incremental cash flow report that measures the *real impact* of each scenario on the company income statement. Our findings also explore the use of specific costs (nonconformity costs, product or batch level cost…) or specific contexts (inter costing) which generally are not included in traditional system accounting. The companies need to change or complete their cost accounting by new costing approaches. If not, an inappropriate costing system will produce distorted information leading to a poor decision making (Gurowka and Lawson, 2007).
- *Collaboration between cost accounting and production management*: As a result of the two previous points, cost accounting, modelling and SC managers cannot be independent. They need to collaborate in order to determine and calculate the adequate costs to each studied context. This can help to overcome the resistance of accounting professionals to integrate new costing methodologies.
- *Impact of the obtained solution*: Concerning decisions related to production system design, one starts from a basic scenario from which he deduces cost parameters. He feeds a decision model by these cost information to obtain a new design solution. Since, costs are contingent to the organization physical characteristics, the solution of the decision model can lead to inconsistencies between the initial costs used and hypothesis, and the physical system new characteristics. This may make the obtained solution unworkable.

Conclusion

This article is grounded on the question: to what extent authors of industrial management articles study the adequacy between their decision models and the used cost system.

To answer this question we led a critical literature review whose finding reveal several methodological issues encountered when defining costs in decision models. *i*) In almost all articles authors give no explanation about the used economic parameters content, they

assume costs as given parameters provided by an external source; *ii*) the reviewed decisions models use some costs that are not necessary traceable in the firm system accounting; *iii*) some articles suggest models that involve different companies, the applicability of this kind of models depends on the willingness of these companies to share their cost information; *iv*) the majority of search articles which study investment decisions having multi periods impact still base their decision criterion on costs rather than NPV; *v*) the majority of articles use full costs which generate inconsistencies related to capacity costs.

This work is intended to attract industrial management specialists to pay more attention about the relevance of the costs they use in decision models. The full costs of traditional system accounting cannot be used without reprocessing. To provide relevant and accurate costs, accounting professionals need to be open to integrate new costing methodologies. Modelling and cost accounting teams should be interconnected and work together to provide ad hoc economic evaluation for each decision model and finally we emphasize that decision models are a priori decision making oriented they need to integrate relevant costs concepts and to use activity drivers to can compare the existing alternative decisions and measure the impact on the company income statement.

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AI techniques and Intelligent Decision Support System – a structured literature review

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Abstract

Intelligent Decision Support System (IDSS) is a novelty concept that applies Artificial Intelligence techniques to the decision support systems. The purpose of this research paper is to present a systematic literature review at the intersection of IDSS and supply chain integration (SCI), which main focus is the communication between different parties of the supply chain. This research analysed a total of 31 published articles. Moreover, it provides a visual representation of the main industries, methodologies and software, as well as a cluster representation of the keywords used.

Keywords: intelligent decision support system, AI, systematic literature review

Introduction

In today's era of digitisation, more and more companies are revising their current strategies and approaches to business, in order to be able to maintain a competitive position on the market. One of the difficult tasks that businesses are facing on a daily basis is filtering, analysing and using in an appropriate manner the huge amount of data that is gathered. By having access to effective data management, the companies can strive to enhance the supply chain integration, which can therefore increase the business value (Zhao et al., 2008; Min, 2010; Alfalla-Luque et al., 2013). Decision Support Systems (DSS) have long been used to aid managers in making the most efficient and effective decisions aimed to resolve various problems encountered, however its application has, since then, shifted towards solving more current issues, while using more advanced technologies. With the application of Artificial Intelligence (AI) within DSS, thus creating Intelligent Decision Support Systems (IDSS), a completely new set of issues can be tackled.

Therefore, this paper will attempt to conduct a systematic literature review (SLR) of DSS that uses AI, within the context of supply chain integration. The SLR will aim to provide more clarification into the current uses of DSS and the respective AI techniques that are currently being applied in the supply chain management.

Methodology

Having the aim to identify and analyse the literature of a high scientific value, this paper is applying the systematic literature review approach. By overcoming potential weaknesses of a narrative literature review, the SLR can offer such advantages as: transparency and replicability (Tranfield et al., 2003; Correria et al., 2017). It provides scientific insight into a given topic, while following strict guidelines (Ali et al., 2017). Moreover, it aims to minimise any potential bias by thoroughly researching published and unpublished studies, and provides a following trail of the reviewing decisions (Tranfield et al., 2003). The systematic review is then followed by a meta-analysis, the aim of which is to synthesise the finding through a statistical procedure. Furthermore, the SLR can help practitioners and academic to save time by reviewing the existing literature through a set of predefined filters, which can assure them the quality of the studies (Rousseau et al., 2008).

The process of the SLR is therefore described below, as adapted from Colicchia and Strozzi (2012):

- Defining the research question. As stated by Denyer and Tranfield (2009), the clearly formulated research question helps define the inclusion and exclusion criteria of the review;
- Identifying relevant studies through the use of appropriate tools, such as databases, by selecting the appropriate criteria (keywords, language, publications, time frame, etc.);
- Selecting and evaluating the studies through meta-analysis.

Therefore, for the purpose of this paper, the following research questions were formulated:

RQ1. Does IDSS provide support to supply chain integration?

RQ2. What type of IDSS is best to use for data filtration and sharing in supply chain management in order to obtain a better supply chain integration?

By having formulated these research questions, the following keywords were identified: decision support system, artificial intelligence, supply chain integration, supply chain management, intelligent decision support system, information sharing, information filtration. The databases selected for the purpose of this study were: Scopus, EBSCOhost, and Emerald Journals. These databases have been selected due to their extensive libraries of peer-reviewed academic literature, as well as their availability at the author's academic institution (Ali et al., 2017; Qaiser et al., 2017).

The initial keywords were introduced as corresponding in either keywords, title or abstract section of the articles. The initial search result returned a total of 39 articles (20 from Scopus, 13 from Emerald Journals and 6 from EBSCOhost). It has to be mentioned that among these 39 results, there were 8 conference papers. A following search of the identified keywords, by using different types of combinations, revealed additional 27 articles. The search results were then reduced by excluding any articles that were in any

language other than English, published before 2010, and belonging to the Engineering or Computer Science fields. The latter was decided due to this paper aiming to analyse the managerial implication of IDSS in the supply chain, and the papers with extreme technical focus would not provide much understanding to the target public. After introducing this exclusion criteria, the search returned a final number of 31 academic and conference papers. The reason for taking the conference papers into consideration is the fact that, with IDSS being such a new topic, there are more chances to present a conference paper than to publish an academic paper, which can take longer time.

After the articles were gathered and thoroughly studied, they were evaluated applying a literature mapping process, as well as by using tables, graphs, and charts, that show the frequency of publications, location, and methodologies used.

Data analysis

The data analysis focused mainly on the literature mapping and text network visualization, in order to produce a clear image of the current state of the literature, as well as identify the possible gaps.

Firstly, in order to determine the reoccurrence of the published articles within literature, the statistical data is presented in Figure 1. Therefore, since 2010, there were 31 academic and conference papers related to the area of intelligent decision support system and supply chain integration. It can be observed that there was an interest regarding these topics in the 2010, where 3 of the articles were presented at a research conference. The interest spiked again after 2015, however the number of articles is still low.

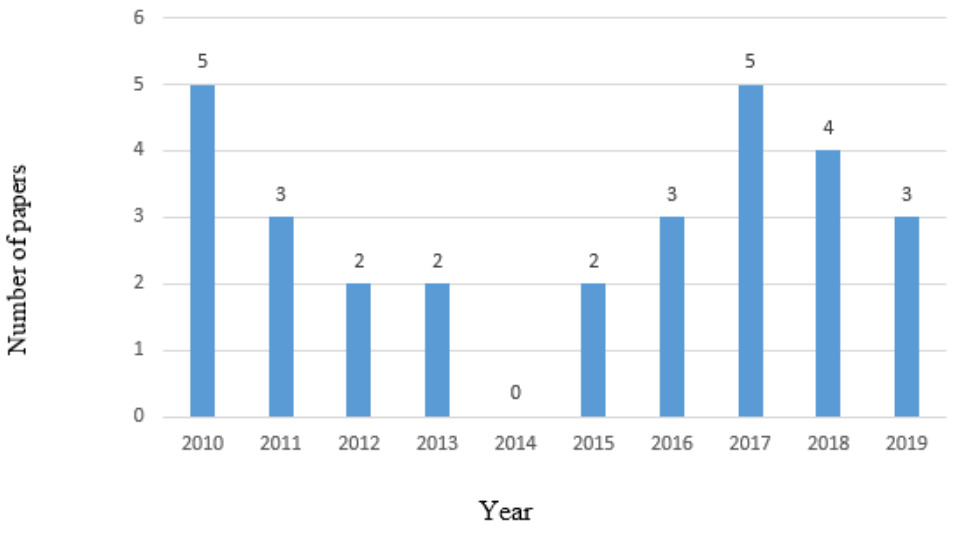

Figure 1. Number of published papers per year

The following set of analysis is literature mapping, created with the help of Creately website, which classifies the existing literature. Therefore, the main topic of the literature is Decision Support System. The next step of classification is the methodologies used in

the identified articles, which were defined as follows: Simulation, Coding/algorithms, Modelling, and Others (literature review). Moreover, the articles were then classified into the associated industry for each study. It can be noticed that there are a number of articles that focus mainly on the food and manufacturing industry, with a total of 5 and 8 articles respectively. Moreover, for each of the articles, the appropriate used software was identified. It can be observed that the methods used differ for every study, suggesting that the research topic can be approached from various angles.

Furthermore, one of the initial conclusions that can be drawn from this study is that there is a scarcity of literature that tackles the area of information value and sharing through IDSS in the supply chain integration. Thus, it is suggested that there is an existing gap in literature that can be further approached.

This type of literature mapping permits the assessment of all the existing methods of analysis available. It can be observed that some of the existing articles have a combination of methods, such as modelling and simulation, or modelling and coding. Moreover, by identifying the used software, the scholars can determine the most appropriate to use for future research in different domains. It can be noted that for simulation the software Anylogic was used twice, while for modelling the loop diagrams are more popular. In the coding area, there are a number of programming languages to choose from, and it can be observed that all the examined articles have adopted different approaches to designing the programs.

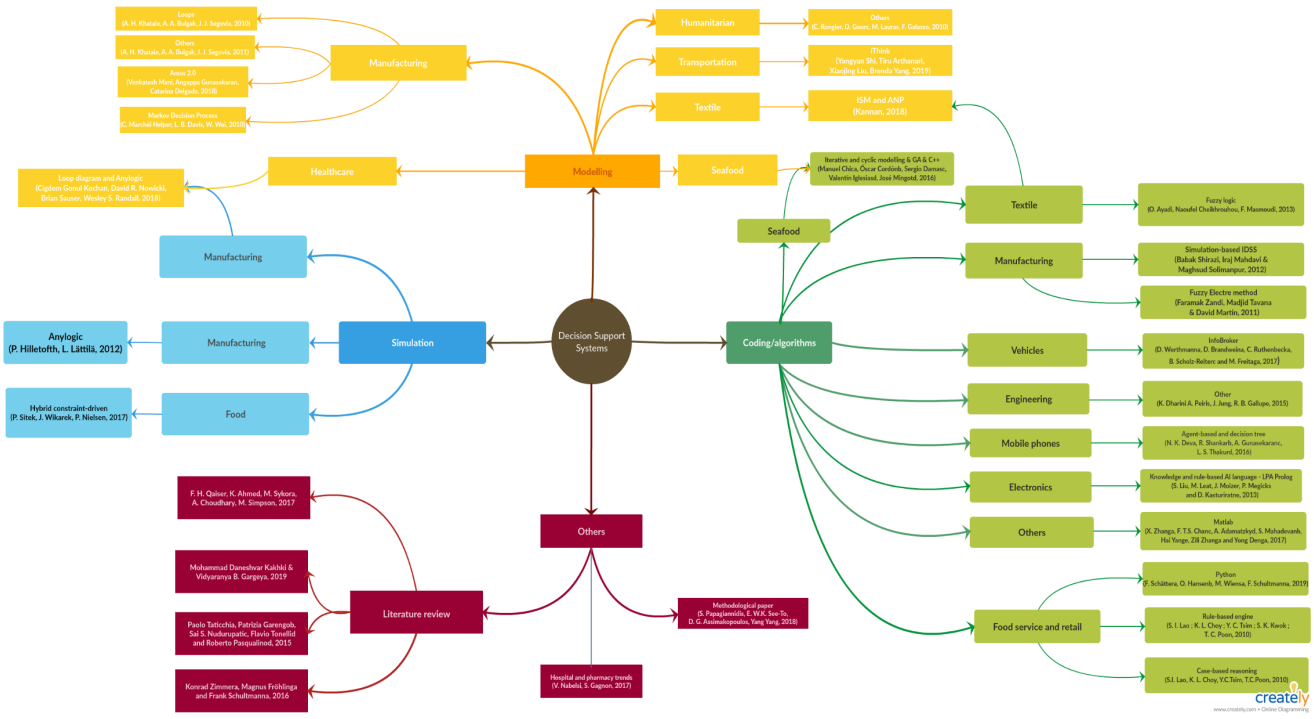

Figure 2. Literature mapping

For the text network visualization, the software VOSviewer was used. The software extracts keywords from the titles and abstracts of the selected articles, and maps them into a network. The program identified a total of 1,018 terms, and 78 of them were selected for the visualization process, based on the minimum number of occurrences – 3. It can be noticed that some words and circles are more prominent than others, which is dictated by their occurrence in the texts. An additional feature of the text visualization is the observable link between various terms.

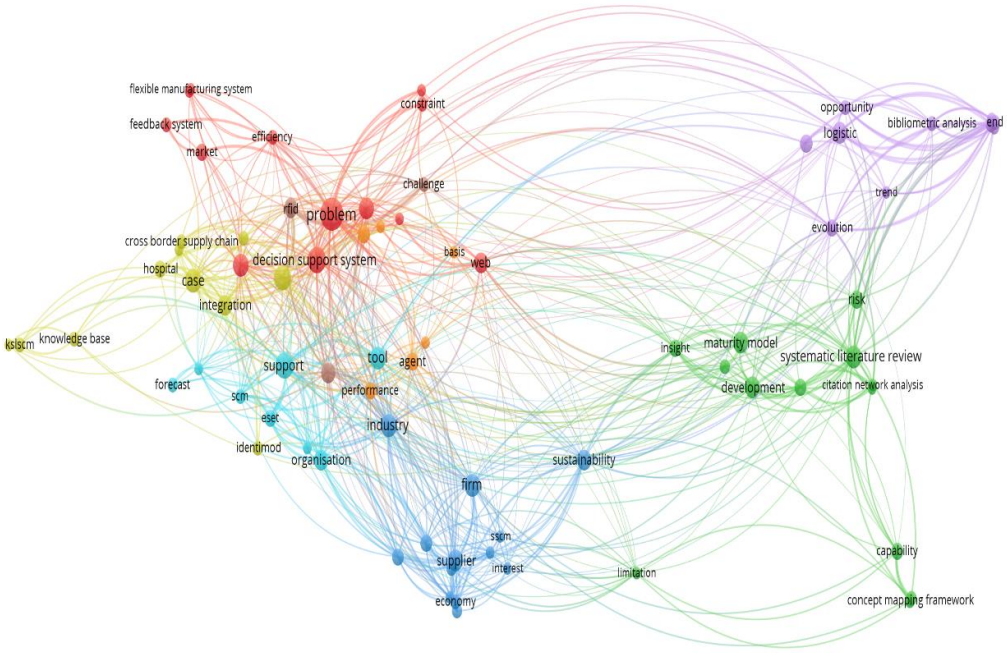

Figure 3. Text network visualization

Although, there is observable noise in this representation, an initial analysis of the keywords can be made. Most of the papers were concerned with developing a decision support system or framework, with the main focus on efficient supplier selection or sustainability. Furthermore, such topic as performance measurement and feedback systems were prioritized. A number of papers were more theoretical, and offered systematic literature reviews and bibliometric analysis of the existing literature.

By combining these two forms of analysis, it can be observed that there are two types of published papers: the theoretical papers and the practical papers. The first set of papers are primarily concerned with identifying the main theories behind decision support systems and supply chain integration. They also revise the need for DSS implementation and possible applications within SCI. It has to be considered that there are not many articles that combine these two major topics. However, a number of articles mention that DSSs can influence the

SCI, provide an opportunity for more sustainable logistics, and improving the communication between different parties of the supply chain.

On the other hand, the practical papers offer different models of DSSs which are compiled and tested in different settings. Another statement that can be made is that the developed systems are either tested in case studies, at various companies, or simulated using different software. Nevertheless, all the proposed systems are validated through testing and comparison with previous results from the companies. This in turns demonstrates the functionality and performance of the decision support systems.

Contributions

This research aims to contribute to the young growing IDSS body of knowledge by identifying the gaps and making suggestions for future research. The possible implications of DSS in the supply chain context are massive and understudied. The recommendation for future research can vary from investigating the usefulness of DSS in SC context (Hilletofth & Lattila, 2012) to comparison of different Artificial Intelligence types for suitability in the SC context (Deva et al., 2016) to providing empirical studies of trust, privacy, and security in the information sharing aspects of supply chain integration (Kahki & Gargeya, 2019). While the more practical papers involved the development of the programs themselves, the more theoretical papers were more concerned with issues that are gaining more and more importance such as data trustworthiness and more sustainable processes in the SC.

The graphical representation of the literature offers researchers a better understanding of the industries that are thoroughly studied, at the same time emphasising the gaps. For example, there is limited research in car manufacturing or textile industries, with the majority focused on manufacturing and food services. Moreover, the representation emphasise the possible methodologies that can be used for future research, as well as different combinations of methods.

This research paper can serve both academics and industry practitioners. For academics, it can provide a good starting point for future research, while for industry practitioners it can serve as a good indicator for their resource investment and company development.

Conclusion

This research presented a systematic and bibliometric analysis of the current state of the literature surrounding the topics of Intelligent Decision Support System and Supply Chain Integration. One point of observation is that the combination of these two research topics is still in its infancy, and the area is understudied. While there are many articles that are concerned only with ‘IDSS’ or ‘supply chain integration’, the combination of these two terms does not provide many results. It is an often occurrence that the term ‘supply chain integration’ is only mentioned once or twice in an article about ‘IDSS’ or ‘DSS’. However, the research shows a trend of papers regarding areas of ‘supplier selection’ and ‘sustainable logistics’. The ‘sustainable logistics’ topic is the latest trend across a number of research fields, and it comes as no surprise that an advanced technology such as IDSS to be used in order to obtain more sustainable processes. Moreover, this research has identified potential gaps in the literature, and provided a detailed overview of the areas and industries that were already researched. Consequently, a representation of potential combination of different methodologies is presented in this paper, which can be of help for future research.

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If Blockchain is the answer what is the question?

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Abstract

The purpose of the paper is to identify the issues and challenges to employing blockchain technology for different operations context. The paper analyses five cases to identify drivers and barriers to adopting the technology. Our findings suggest that interoperability and platform dependency can limit the wide-scale deployment of the technology. Additionally, trust in rule-based software automation and consensus among supply chain actors can inhibit effective adoption. In summary, the paper finds that care should be taken when applying blockchain, since there are many situations where its implementation is not feasible or not beneficial.

Keywords: Blockchain, Challenges, Limitations

Introduction

Blockchain has emerged as a technology that can provide visibility, traceability and transparency in business operations, which will lead to better accountability. The potential usefulness of the technology has been reported in many sectors such as: energy (Adoni et al., 2019); health-care (McGhin et al., 2019); digital supply-chain (Min, 2019); retail (Morkunas et al., 2019); financial services (Tapscott and Tapscott, 2017); and transportation (Lei et al., 2019). The key properties of this technology that makes it a valuable proposition to handle heterogenous transactions in different sectors are discussed below and these have been reported in the pilot studies undertaken by technology providers such as IBM (2017), Capgemini (2017) and in academic research.

- ***Immutability****:* The transactions recorded in a blockchain cannot be tampered, deleted and revised, i.e. the process and information stored in each block is irreversible, thus providing an accurate view of the activities. However, the

authenticity and quality of the information will depend upon the author and source.

- *Distributed:* The blocks and corresponding chain is stored among all the entities in the network participating in the transactions, which increases visibility of the information. However, access restrictions may apply depending on the nature of the information and the rules associated with the creation of blocks.
- *Decentralised:* The transactions occur based on automated rules set in the network (mainly through a process of consensus), which eliminates the need of a central authority, i.e. this potentially will lead to faster transactions, and eliminates the risk of the data being held centrally in a server (as in contemporary information systems). However, as the size of the chain increases the processing time to create or retrieve a block will increase.
- *Automation*: Most processes in the network, i.e. creating a record, processing transactions, are executed automatically by the software codes deployed in the network. The cryptographic verification process ensures authenticity of the transactions and makes the process incorruptible, i.e. devoid of errors (if the software codes do what they are meant to or agreed upon in a suitable manner). It is worth highlighting that the process of rule creation and revisions is a grey area and will depend on the context and purpose of using the technology.
- *Single Unified Ledger:* This helps in aggregating all the records in a single network, i.e. provides the actors with high-level as well as low-level view of all the transactions, linked-information efficiently, thus reducing the information and cognitive overload to some extent. Employing blockchain analytics to provide such a view can be complex and inefficient, due to size of the chain and automated access rights imposed by automated rules.

The existing literature has focussed mainly on the advantages offered by the technology in different business sectors. Though, the merits offered by the technology are demonstrated through pilot projects undertaken by technology providers, it is necessary to understand the challenges to large-scale adoption of the blockchain and readiness of businesses to deploy the technology.

Issues and challenges identified from the literature.

The literature gathered from various business disciplines, information systems and computing science was systematically reviewed to identify the potential challenges associated with the adoption of the technology from a business perspective. Though, the emerging technology has been tipped to transform businesses in a 'positive way', the key issues associated with the technology (usage, implementation and deployment) and organisation needs (value of using the technology, skills and expertise) are yet to be understood and discussed comprehensively. *Table 1* will present the key challenges that can be potential barriers towards the wide-scale adoption of the technology in business domain (in-particular global supply-chains which are increasingly becoming complex). A quick review of the table highlights: the need to understand that will aid in managing and implementing the technology (skills and expertise); agreement between various businesses adopting the technology on the automated rules (process and author), and operational software platform; assessing the long-term benefits of the technology (i.e. consider its efficiency to process multiple transactions and viable integration with the existing operations and processes).

Table1: Summary of key challenges reported in academic literature and business (Y means that the challenge has been briefly discussed/mentioned in the literature)

Challenges	Min (2019)	Morkunas et al., (2019)	Atlam and Wills (2019)	Casino et al., (2019)	Kamble et al., (2018)	Kshetri (2018)	Deliotte (2018)	Capgemini (2017)
Access control/ authorisation						Y	Y	Y
Compliance: legal and regulatory	Y	Y		Y		Y	Y	Y
Computing power	Y			Y		Y	Y	
Data Management			Y	Y				
Efficiency and performance			Y	Y		Y	Y	Y
Skills and expertise	Y				Y		Y	
Platform standardisation		Y	Y					Y
Operational Costs		Y					Y	Y
Organisational Resistance [within firm]	Y	Y				Y	Y	
Organisational Resistance [between firm]	Y					Y	Y	
Privacy	Y		Y	Y			Y	Y
Scalability	Y		Y	Y			Y	Y
Security								
Strategy to			Y	Y				Y
Suitability				Y	Y			
Trust in automated software	Y	Y		Y				Y

Review of industry pilot cases

Blockchain is considered as a valuable solution in different areas because it can record transactions in a secure, transparent, decentralised, efficient, and low-cost way (Schatsky & Muraskin, 2015). It can simplify the transmission of information to eliminate the commonly conflicting layers found in supply chains, making information more reliable,

timely, highly visible and incorruptible. The purpose of this section is to present different instances in which blockchain has been implemented to investigate the themes identified in the literature review and to understand the requirements to leverage the potential of this technology. The five cases selected are looking at the food industry, energy, disaster relief, housing and banking. The findings stemming from the review of the pilot cases is summarised in Table 2.

- ***Food Supply Chain.*** The food supply chain is an excellent example of the potential value of blockchain. Freshness of food, especially meat, is a significant health concern. That was the motivation behind Provenance (Provenance, 2019), a company that has implemented blockchain to provide more certainty and transparency in the food supply chain. The purpose is to allow users/companies to know more about the origin, travel and destination of food. Talking about meat that can allow users to trust the "kill" dates in their meat products, thereby ensuring freshness. In fact, the company implemented a similar idea in Indonesia, in which they used blockchain to track tuna from the moment it was caught until it reached the consumer (Safaryan, 2017). That way, it was possible to add traceability to the supply chain and ensure consumers about the journey of their product. The potential of blockchain in this setting is not only to increase traceability though. It can allow to support commodity management to reduce duplication of certificates and paperwork, allow marketplace creation by connecting suppliers and customers, increase data sharing among different members of the supply chain through collection of information from different sensors at different stages, increasing access to capital investments, and enhancing payments (Noel, 2018).
- ***Energy.*** Introducing a fully decentralised energy system is another potential venue for blockchain. The technology available nowadays allows people to be not only consumers of electricity, but also producers. Blockchain has the potential to support transactions among customers with different roles. Elektrify is a good example of the use of blockchain to allow these interactions (Electrify, 2019). In fact, a project between Busan City, Nuri Telecom, Pusan National University, Busan City Gas, and Korea Industrial Complex Corporation tries to exploit this possibility, to improve power generation and distribution in the region (Marley, 2019). This would also facilitate the creation of a micro-grid in regions of the country, which is a project currently pursued by Korea Electric Power Corporation (KEPCO). Beyond that, also in Korea, Swytch, is partnering with Chuncheon to use smart meter and blockchain technology to incentivise and provide benefits for companies and people looking to reduce carbon emissions (SmartCitiesWorld, 2018). On top of that, blockchain can also be used to allow metering, billing and clearing processes (PwC, 2016), which shows the reason this technology is very promising for other countries as well.
- ***Relief and disasters.*** Collaboration and cooperation are very complicated in situations in which a disaster has affected a region because of the multiple number of organisations involved. Governmental organisations, non-governmental organisations, charities and civil organisations try to provide support for the affected people, but it is complicated to provide a honed response because of the duplication of efforts and the centralised systems used by these organisations. The U.S. government realised that blockchain could be effectively used to enhance collaboration. Blockchain can be used to create a decentralised system through improved information sharing exploiting its traceability, transparency and immutability (Akilo, 2018). In that way, organisations could have more clarity about

the activities of the other stakeholders, helping guide their activities. Moreover, this would allow to pool resources and introduce a coordinated response. This benefit, however, would not be only for the organisations. Transparency and traceability would allow donors to increase trust in NGOs and charities and ensure a more efficient response to the victims. From that perspective, blockchain can allow to provide support for donations and financial transaction in disaster settings (Phil, 2018).

- ***Housing.*** The housing industry represents an area with huge potential for the implementation of blockchain. A very interesting example comes from the intersection of housing and public policy. The Kenyan National Housing Fund provides government-funded housing for families in need. However, the scheme has been criticised because of fraudulent activities and corruption (Aki, 2018). The use of blockchain would allow to ensure the transparent distribution of houses because blocks cannot be altered once these have been added to the chain. The notoriously porous land registry database would be recorded using blockchain to ensure that houses go to the people who need them. Additionally, funds would be more difficult to embezzle, and bribes would be reduced considerably (Sharma, 2018).
- ***Banking.*** The most notorious application of blockchain is related to cryptocurrency. Looking at financial services, blockchain has an incredible potential to improve transactions. The We.Trade platform from HSBC in collaboration with another 9 banks is a clear example (Finextra, 2018). HSBC has been at the spear point of the use of blockchain to improve financial transactions. In 2018, the bank was able to perform the first trade finance transaction using R3's Corda scalable blockchain platform, in the situation of a Cargill shipment of soybeans going to Malaysia from Argentina (HSBC, 2018). The purpose of this test was to use a shared application instead of applications in multiple systems, which reduced the transaction time from days to less than 24 hours. This outcome showed the feasibility of trade digitisation and emphasised the potential to reduce fraud risks in letters of credit, and introducing more efficient procedures (Ganesh, Olsen, Kroeker, & P, 2018).

Research Agenda

An important contribution of this research is to convert the themes identified in the literature and illustrated through analysis of cases, into possible directions for future research. We identify four research questions that demand attention, if blockchain is to be seen as a valuable technology for operations management.

- ***Interoperability.*** Research on blockchain focuses on the benefits and the characteristics, but often overlooks the technical requirements and implications. For example, each actor in the system must possess the required expertise and equipment to effectively share data. Therefore, research should investigate the minimum technical requirements and how big a challenge it may be to bring organisations to the required standard. Additionally, when discussing cases in which individuals also read or write data, this becomes even more complex.

Table 2: Summary of the business cases

Cases	Technical		Social	
	Interoperability	Platform	Rule-based software automation	Consensus among actors
Food SC	Different levels of IT expertise and equipment among different links from supply chain (from fisherman to retailer).	Data recording methods and technology might be inconsistent. Different stakeholders can have multiple platforms.	Rules development and agreement can have a significant effect on the different links in the SC	Permissions for data editing/access need to be properly agreed. Acceptance to technological innovation can be challenging.
Energy	The decentralised system requires similar technology for users/producers and organisations to record/update.	Highly complex system with multiple nodes in which a single platform across all users/producers would be required.	Data protection can be problematic because of GDPR. Data sharing rules would need to be clearly defined.	The level of access to producers/users should be well-established and agreed upon. There is a need to ensure consistency in practice.
Disasters	There is a varying level of technological proficiency and resources among actors, particularly donors.	Multiple platforms should be integrated, and databases consistently prepared.	The different type of participants would need to define who would be making the rules, how/if these can be modified and how are all the stakeholders integrated.	The combination of private and public funding could affect the interests of different stakeholders. Decisions on how much information is shared and what information can be taken should be agreed.
Housing	Technological requirements for data collection and recording need to be defined. The expertise to implement blockchain would be essential.	Different branches of government need to interact through the integration of different systems.	GDPR requirements can be complicated. The level of personal data shared, its use and level of access would need to be carefully stated.	It requires involvement of contractors/suppliers and governmental officials to identify the kind of data shared and who would be the main participants.
Banking	Technological proficiency would need to be consistent across actors.	Multiple platforms should be integrated into a single platform.	Decisions should be made about to what extent should data be shared, who will be defining the rules and how/if these can be modified.	Banks and authorities would need to agree on what data can be taken from the transaction and what access level is required from the different parties.

- ***Platform dependency.*** As with information technology, the extent to which blockchain delivers benefits is affected by the data in the system. This means the platforms used, the way in which they are used by actors and the level of expertise of these actors are all important. In particular, the way that data are captured and communicated could be crucial. For example, if objective data are captured using a standardised approach, the data will be more trusted than data input manually, with implications throughout the lifetime of these data. Research should seek to understand data management, platforms and readiness for blockchain implementation.
- ***Trust in rule-based automation software.*** Rule-based systems, whether electronic, economic or otherwise, are important in enabling business. Trust in such systems, however, is greatly affected by the source of the rules. Whether blockchain rules are set by regulatory bodies or by individual companies and whether they can be modified by individuals or not can affect the trust and hence the adoption or success of blockchain. Research should investigate the behavioural aspects in particular, to understand how and when blockchain can command sufficient trust to be adopted.
- ***Consensus among supply chain actors.*** The adoption of the technology will require an understanding and agreement between all the actors (for example, supply-chain entities) participating in the blockchain network. This will require have an agreement on the rules set-up within the network, using a platform provided by a technology provider, which will require integration with the existing processes, and participating in the transactions (i.e. willingness and mindset to use the technology). The consensus between the firms will be driven by the potential benefits offered by the technology to the individual firms and the awareness/ expertise of the managers about this new and complex technology. The consensus within firm will be driven by the organisation culture to take risks i.e. adoption a technology whose benefits are yet to be validated through long-term usage and technical complexities involved to integrate with existing process in the firm, which will require persuading the management and updating the skill-set of the relevant employees throughout the processes involving technology adoption, deployment and maintenance. Research should understand and investigate various consensus factors within and between firms that will lead to wide-spread adoption of blockchain and eventually make it scalable.

Managerial Implications

Operations Managers in a variety of business contexts may find blockchain being offered as the silver bullet that will solve all problems. Examples, including the cases discussed in this research, demonstrate the breadth of applications, from supply chains for consumer products, to government contracts and from energy to banking. Blockchain can be applied in almost every business context. Before leaping into the unknown, however, managers should question whether it should be used in their specific context. This research outlines four key questions that should be considered before deciding that blockchain offers the appropriate solution.

- ***What kind of expertise is required?*** Implementing a blockchain based solution requires both strategic and technical expertise. The former is to evaluate and

decide on the most appropriate implementation of technological possibilities. The latter must be updated as the technology will evolve, and its complexity increases. This complexity is particularly clear in cases such as the energy one, in which the number of actors contributing energy (and data) is enormous. Ensuring that all of these actors are appropriately connected and that the sources of data are integrated, as well as being certain that the system will remain suitable over time, represents a considerable technical challenge.

- ***Who has the right to input data?*** Assuming the required technical expertise and strategic decision making are in place, one of the key challenges is platform governance. Consider, for example, the case of the food supply chain, in which traceability depends on the information in the system, how it is input and how it is communicated. If false data are input, these will be stored and transmitted through the whole system. While using blockchain should give confidence that fish have been caught legally or food safety standards have been maintained, this confidence would be unfounded if an actor in the supply chain has deliberately or inadvertently supplied inaccurate data. It is essential, to be sure that the right people have the right access and use it appropriately for blockchain to be useful.
- ***Who will decide the rules, and can they be modified?*** Access rights are among the aspects that should be defined in the rules of a blockchain system. For example, in a smart contract, it is important that access is restricted to those affected by the contract and that decisions are made when rule-based conditions are met, e.g. once payment is made by one party, the ownership of a property is transferred to that party. Managers should be aware of which actors can decide the rules, for example, in a supply chain, will suppliers have any say and, should the members of the supply chain make changes, will there be ongoing implications? Moreover, should the situation change, the original rules may no longer be relevant, but if they cannot be changed, blockchain may not be appropriate. For example, if a buyer and seller change their agreement, so that a higher amount is payable at an earlier date (or vice-versa) it is possible that blockchain would limit flexibility and prevent changes.
- ***What level of transparency is good for business?*** Blockchain provides potential benefits in terms of transparency and traceability. An important consideration, however, is whether this is always desirable. In most business contexts, holding back some operational details can be very important. For example, knowing which sources of supply are used or how efficient equipment is can affecting negotiating positions between buyers and suppliers. The transparency offered by blockchain can be of benefit between partners in a supply chain, but managers must consider whether too much transparency may be involved. Consider, for example, a situation where a supplier also supplies competitors, who therefore have access to information. Or an alternative situation in which the agreement with a supplier ends and their access to their own data is restricted. Neither of these situations suggest that the benefits of blockchain should always outweigh the costs.

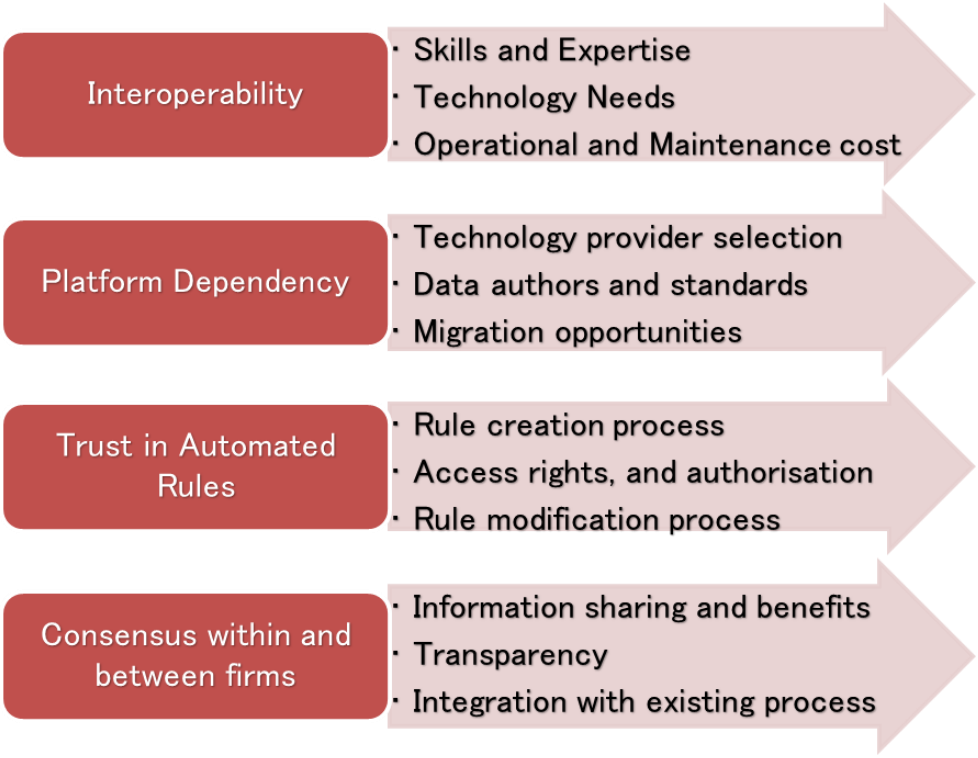

Figure1: Consolidating research agenda and implications for managers

Conclusion

The limitations of the blockchain technology has received less attention, leading to an inaccurate impression that it can address any challenge pertaining to transparency, reliability, effectiveness, efficiency, accuracy, decentralized information storage and distributed information. The paper contributes to theory by developing the understanding of the key challenges of blockchain implementation and proposing a research agenda (Figure 1) that warrants further investigation to understand potential realistic solutions for addressing these challenges. For operations managers, the paper offers a useful starting point to reflect on several key questions that are likely to impact intra-firm relationship, inter-firm relationship and key decisions pertaining to benefits of adopting blockchain (i.e. both short and long-term). However, the key question for the managers *is 'If blockchain is the solution, what is the problem'*.

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Improving manufacturing performance by developing innovative capabilities: the importance of supply chain relationships

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Abstract

This research investigates the relationships between supply chain relationships/integration, innovative capabilities and manufacturing performance. Data was collected from 171 organisations based in three rapidly developing countries – Brazil, India, China. Data was collected as part of the International Manufacturing Strategy Survey (IMSS VI) and analysed using Structural Equation Modelling. The findings indicated that supply chain relationships and integration relate positively to both product and process innovative capabilities. The study also found that there were positive relationships between both product and process innovative capabilities and manufacturing performance. Finally, there was a positive relationship between product innovative capabilities and process innovative capabilities**.**

Keywords: Innovative capabilities, Supply chain management, Developing countries

Introduction

This study investigates the relationships between supply chain relationships and integration, innovative capabilities and manufacturing performance within the context of three rapidly developing countries - Brazil, India and China. Previous studies including those by Back, Parboteeah, and Nam (2014) and Ren, Eisingerich, and Tsai (2015) have highlighted the necessity for more research on innovative capabilities and product development in developing countries. Developing countries such as Brazil, China and

India are increasingly seeking to improve their global economic presence and influence. To this extent, many organisations in these countries focus extensively on the development and exploitation of innovative capabilities. This study seeks to investigate if the supply chain relationships that manufacturers in these countries develop encourage them to develop their innovative capabilities. In addition, the study investigates if the development of these innovative capabilities result in improved manufacturing performance. Hence, the key questions that motivate this research are as follows:

Within the context of manufacturers in rapidly developing countries, do supply chain relationships and integration relate with the development of product and process innovative capabilities?

Do product and process innovative capabilities drive manufacturing performance in these rapidly developing countries?

Literature Review and Hypotheses

According to Tsai and Hung (2016), supply chain performance can be improved by developing a well-integrated supply chain. In essence, organisations that become more integrated or which develop better relationships with their suppliers and customers improve co-dependency and can develop an innovative advantage (Day, 2000; Souitaris, 2001). However, despite increasing evidence that manufacturers are under increasing pressure by their customers to adopt innovative practices and improve their innovative capabilities (Laosirihongthong, Punnakitikashem, and Adebanjo 2013), the relationship between customer relationship and integration and the development of innovative capabilities of manufacturers remains largely unexplored. The key hypotheses investigated in this research are now presented.

The study by Ren, Eisingerich, and Tsai (2015) suggested that within the context of developing countries like China, organisations tend to lag in technology development and are under the control of their western customers. The impact of the control of western customers is that the manufacturers in developing countries are necessitated to tailor their innovation-related activities to meet the needs of their customers (Bullinger, Auernhammer, and Gomeringer 2004). Increasingly, these customer needs include the ability to develop their innovative capabilities (Mishra, Chandrasekaran, and MacCormack 2015). Such innovative capabilities can be either product-related or process-related. Hence the following are hypothesised:

H1. Improvement in supply chain relationship and integration will relate positively with improvement in product innovative capabilities in manufacturing organisations in developing countries.

H2. Improvement in supply chain relationship and integration will relate positively with improvement in process innovative capabilities in manufacturing organisations in developing countries.

Product innovation is important to organisations because it has the potential to deliver new streams of income (Kleinschmidt and Cooper 1991; Teece 2010). However, Martínez-Ros and Labeaga (2009) and Ballot et al. (2015) noted that while product

innovation and process innovation are different, they could have a complementary relationship and could lead to each other. Linton (2015) also suggested that that product innovation is likely to result in process innovation. Therefore, the following hypotheses are proposed:

H3a. Improvement in product innovative capabilities will relate positively with improvement in process innovative capabilities in manufacturing organisations in developing countries.

H3b. Improvement in product innovative capabilities will partially mediate the relationship between supply chain relationship and integration and Improvement in process innovative capabilities.

The main reason why organisations focus on the development of product innovative capabilities is the need for organisations to maintain a competitive edge in the market place (Leskovar-Spacapan and Bastic 2007). This relationship between product innovative capabilities and organisational performance has been explored in previous studies. The study by Yang et al. (2015) concluded that supply chain performance is influenced by innovation capability. This argument also extends to process innovative capability. The potential impact of developing process innovation on the performance of an organisation was investigated by Oke and Kach (2012) and they found that the benefits included improvements in the production process, efficiency and cost. Hence the following are hypothesised.

H4. Improvement in product innovative capabilities will relate positively with improvement in manufacturing performance in developing countries.

H5. Improvement in process innovative capabilities will relate positively with improvement in manufacturing performance in developing countries.

Methodology

The study collected data from Brazil, India and China through the International Manufacturing Strategy Survey (IMSS) version VI between June 2013 and June 2014. For this study, manufacturing performance was measured using a combination of quality and flexibility because these two dimensions of performance should be of major concern for all organisations that are focussed on product and process innovation. The responses for manufacturing performance were assessed using a five-point Likert scale that compared organisational performance to the main competitor. The measures for all other constructs were developed from established scales and were measured on a five-point Likert scale as well. The study collected 171 valid survey responses which were used to test the hypotheses presented above. The dataset comprised of 28 (16.4%) responses from Brazil, 56 (32.7%) from India and 87 (50.9%) from China.

The study performed a principal-component exploratory factor analysis for each survey item to check for the specified constructs. The results showed that all the items of each construct had factor loadings between 0.725 and 0.896, exceeding the recommended coefficient of 0.50 (Hair et al. 2010). The constructs were also examined for internal consistency and the results showed that every construct had Cronbach's Alpha ranging from 0.840 to 0.900, meeting the desirable value of 0.70 (Hair et al. 2010). In addition, the study also checked the composite reliability of all constructs and the results showed

that the values of composite reliability for all the constructs ranged between 0.894 and 0.928, which are above the recommended value of 0.60 (Bagozzi and Yi 1988). The values of average variance extracted (AVE) for each construct were above 0.50, indicating convergent validity. To address the problem of multicollinearity, the study evaluated multicollinearity through the variance inflation factors (VIF) and the values of all variables were between 1.287 and 1.942, lower than the recommended thresholds of 3 (Hair et al. 2010), thereby confirming there was no multicollinearity problem in this study.

The study then used structural equation modelling to test the hypothesized relationships. The SEM results showed a good model fit with normed chi square (χ^2) = 1.114, GFI = 0.923, AGFI = 0.893, RMSEA = 0.026, RMR = 0.053, NFI = 0.928, TLI = 0.990, and CFI = 0.992

Findings

The study found that supply chain relationship and integration had a significant and positive relationship with product innovative capabilities (β=0.682; p-value < 0.001). Supply chain relationship and integration was positively related to process innovative capabilities (β=0.294; p-value < 0.01). There was a positive relationship between product innovative capabilities and process innovative capabilities (β=0.475; p-value < 0.001). Product innovative capabilities was positively related to supply chain relationship and integration (β=0.270; p-value < 0.05). Process innovative capabilities (β=0.305; p-value < 0.05) was found to have a significant and positive relationship with manufacturing performance. The results provided evidence to support hypotheses H1, H2, H3a, H4 and H5. These results are shown in table 1.

The significant positive relationship between product innovative capabilities and process innovative capabilities resulted in the testing of a mediating effect for product innovative capabilities. The bootstrap approach (Preacher and Hayes, 2004) was adopted to test the mediation hypotheses. The indirect effect of product innovative capabilities on process innovative capabilities was calculated as the product of the path coefficients between supply chain relationships and integration and product innovative capabilities (β = 0.682) and between product innovative capabilities and process innovative capabilities (β = 0.475). This indirect effect coefficient was equal to 0.324, which can be validated for significance using a bootstrap approach. The indirect effects were significant given that the lower confidence interval of the bias-corrected bootstrap does not contain zero. As both direct and indirect effects were significant, the partial mediating effect (H3b) was supported for product innovative capabilities.

Conclusion

The study shows that for manufacturers in Brazil, China and India, the ability to develop supply chain relationship and integration will significantly and positively impact on their ability to develop their product innovative and process innovative capabilities. The study also found that, product innovative capabilities have a strong positive relationship with process innovative capabilities. The implication of this finding is that organisations that develop strong product innovative capabilities are also likely to develop process innovative capabilities thereby improving the overall level of innovativeness in the

organisation. Finally, the study found that both product and process innovative capabilities have significant positive relationships with manufacturing performance.
From a theoretical perspective, the findings suggest that institutional pressures that affect manufacturers such as pressure from supply chain customers can lead them to develop new capabilities with respect to product and process innovative capabilities. From a competitive perspective, the findings show that that manufacturers in the countries that were studied are increasingly beginning to focus on product and process innovative capabilities. If and when they develop such capabilities to an advanced level, the impact on global manufacturing and trading relationships could become very significant.

Table 1. Results of Hypotheses testing

Hypo-theses	Causal Path	Standard Path Coefficients	Standard Errors	Critical Ratios	*p*-value
H1	Supply chain relationships and integration → Product innovative capabilities	0.682	0.062	7.876	0.000***
H2	Supply chain relationships and integration → Process innovative capabilities	0.294	0.088	3.034	0.002**
H3a	Product innovative capabilities → Process innovative capabilities	0.475	0.137	4.384	0.000***
H4	Product innovative capabilities → Manufacturing performance	0.270	0.113	2.230	0.026*
H5	Process innovative capabilities → Manufacturing performance	0.305	0.088	2.568	0.010*

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When deviating from standard processes leads to higher performance - How companies can improve complexity management by understanding deviations of process standards

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Abstract

Deviations from predefined process standards often occur in order to reach higher performance levels. Based on a structured literature review and a data analysis of over 1,000,000 data lines, we developed a theoretical framework to understand the characteristics of desired and undesired process complexity. To validate the positive performance impacts of process deviations we present a case study of two production companies and demonstrate the findings of their analyzed end-to-end processes of actual process paths, as opposed to their predefined processes. We conclude with actionable alternatives on how management can use complexity to enhance logistic performance.

Keywords: Process complexity management, business process reengineering, process mining

Introduction

With expanding interlinking activities between business partners and the increasing demand of customers for individual products, complexity management became an integral part of the management agenda. Fulfilling this new market need and simultaneously enhancing logistic and financial performance has become one of the major challenges for top management (Bode, Wagner, 2015).

Complexity can influence performance in both positive and negative ways. For example a larger product variety can help the company to open up new markets and increase revenue (Aitken et al., 2016).

(Marley et al., 2014), (Bode, Wagner, 2015), (Fisher, Ittner, 1999) investigated the negative impacts of complexity on increasing supply chain disruptions, a higher failure rate and increasing need for supervision and control. Aitken et al. (2016) raised the position that there is a difference between necessary and unnecessary complexity: Necessary complexity can be helpful to reach strategic company goals, for instance by accepting a lager product variety to offer customers a wider product range. Unnecessary

complexity can hinder reaching the strategic company goals and thus, must be avoided. However, complexity can also have positive performance impacts when deviating from predefined process standards.

Latest technology developments gave rise to software programs called process mining tools, which help to analyze large data volumes and identify actual taken process paths within a company's business wherever electronic data is available.

In this research we aim to understand the positive aspects of additional process complexity through deviation from standard processes by using the term "desired" and "undesired" complexity. We aim to investigate the characteristics and emergence of desired and undesired complexity and to develop a heuristic framework to illustrate the cause-and-effect-relationships between impact factors and performance effects of desired and undesired process complexity. Further, we show how latest process mining tools can be used to identify process deviations in order to apply this approach to multiple processes by introducing a case study of two companies.

The remainder of the article is structured as follows: First, we illustrate a review of the current state of literature. Second, we present the theoretical background. Third, we expose our heuristic framework and highlight the research gap. Fourth, we present and discuss the main findings of our case study. The paper concludes with some theoretical and managerial implications and gives advice for further research.

Structured Literature Review

In order to investigate the current state of literature and highlight the research gap we did a structured literature review on articles between 1998 and 2017. For the literature review we identified 18 keywords, which were supplemented during the search process, documented in Table 1.

Table 1: Keywords for literature research

Keywords	Added keywords during search
process complexity	process mining
process (complexity) management	measurement of complexity
complexity (management)	complex systems
complexity theory	process variances
complex (adaptive) systems	business process reengineering
complex networks	process deviations
process deviations	transaction cost theory
complexity drivers	cognitive bias
	network indicators

These keywords were combined to research strings resulting in 248 papers. For the subsequently followed forward and backward search relevant criteria were defined. This search resulted in 314 papers. To reduce the number of papers we choose criteria such as focus on process complexity, measurement techniques of complexity and business process improvement methods, resulting in 38 papers. All remaining papers were investigated by using a structured analysis approach. The focus of the article analysis was investigating (1) the used theory, (2) characteristic of complexity, (3) complexity drivers and (4) the impact of complexity on performance to develop a general understanding of complexity and to develop a framework to explain the cause-effect relationship between the different complexity types.

Theoretical Background

We give a brief definition of process complexity. In order to show how process complexity can be analyzed we present several graph theoretical measurements and

highlight the influence of process complexity on performance. Then, we present reasons for deviating from process standards and show how business process reengineering can be solved with the help of process mining tools. Based on this analysis we highlight the research gap.

Process Complexity

A high task variety, a variety of different inputs and uncertainty are characteristics of complex processes (Mani et al., 2010). (Karimi et al., 2014) added to that definition the uncertainty and interdependence between the individual activities of a business process. (Größler et al., 2006) state process complexity also named internal complexity is an answer to the complexity resulting from the outside business environment. (Schäfermeyer et al., 2012) indicates that business processes even need a certain level of complexity to be able to respond to the environment.

Process complexity therefore can be defined as a process characteristic describing the effort which is needed to fulfill the process goal. Task variety, involved parties and subject areas determine the level of process complexity.

As business processes are the core element of a company's operations, it is absolutely important to understand the characteristics and influences on process complexity to be able to respond with the correct management action.

Measurement of complexity

In order to define the level of complexity and therefore respond with the correct action alternative it is necessary to measure the degree of complexity.

In the field of network research there exist several indicators to measure complexity (Boccaletti et al., 2006). For this paper we used the relevant indicators which are necessary to define the level of process complexity. The shortest path length is one of the basic indicators which defines the shortest connection between two nodes within a network. Another quite commonly used indicator is the so called betweenness centrality. This measurement is based on the shortest path length and characterizes a node as important if it belongs to a high value of shortest path lengths. (Boccaletti et al., 2006).

Performance vs. Complexity

The majority of business literature focuses on the negative impacts of complexity.

According to (Bode, Wagner, 2015), (Marley et al., 2014) (Allesina et al., 2009) complexity should be reduced or avoided wherever possible. They argue with the negative impact of complexity on logistical performance, a more complicated decision-making process and increasing supply chain disruptions.

Following the argumentation of the normal accident theory, the likeliness of failures increases with an increasing complexity and tight coupling of processes (Perrow, 1999). This theory was applied in several research field of supply chain management, manufacturing and transportation to explain why failure and process disruptions occur. According to this theory due to the high number of interactions errors will occur in unexpected ways. In combination with the tight coupling, therefore failures can spread easily within the network and it´s "normal" that failures and therefore disruptions will occur (Marley et al., 2014).

(Aitken et al., 2016) questioned whether the only possible impact of complexity is negative and therefore distinguish in their paper between "strategic or necessary" and "dysfunctional or unnecessary" complexity.

According to the authors (Aitken et al., 2016), (Bozarth et al., 2009) strategic

complexity empowers the company to reach their strategic goals like a higher product variety increases the complexity but also enables the company to gain market share. In contrast, dysfunctional complexity in a process impedes its performance. Thus, a healthy level of complexity can have positive performance impacts and even deviations from standard processes can lead to an increase in performance.

Deviation from Process Standards

People often take alternatives to reach their goals despite of predefined standard process steps. They do so actively but sometimes also unconscious.

Deviating from standard processes could mean on the one hand, doing process steps in a different sequence than the standard process pretends. On the other hand deviation could also result in a completely new set of process activities which are not intended in the standard process.

Especially the external factors time pressure and multitude of information encourage the phenomenon of cognitive bias and lead people to deviate from predefined standard processes (Arnott, 2006). The employee has to react fast and there is not enough time to comply with all necessary process steps, therefore the employee seeks possibilities for reaching the process goal as fast as possible in spite of known, standard process requirements (Bendul, 2016).

Additionally, missing knowledge and lack of transparency are reasons influencing why people deviate from process standards. They are just not aware of how the process should be exactly executed and therefore decide on their own what they think is the best way to reach the process goal. Lastly, another reason might also be that employees sometimes get the instruction from their supervisors to do a task in an unique way, which is not in line with companywide defined process standards.

While these are more of an unconscious action, some people also actively deviate from standard process. They are convinced that their process path is better than then defined one to reach the process goal. Moreover, after a process change this is a quite common phenomenon. Accordingly, people also tend to do their task the same way they have carried out in the past, even if new process standards have been implemented by the company´s management. (Marjanovic, 2000).

Business Process Reengineering and Process Mining

As presented in the previous section on normal accident theory, depending on their complexity level, systems contain an inevitable failure potential and the only way to abandon this is to redesign the system. This is also true for the system of business processes. Beside other business process improvement techniques such as Six Sigma, continual business process improvement and core process redesign, Business Process Reengineering (BPR) is one approach to improve business processes (Grant 2016).

BPR is a method used for achieving higher performance through a radical change of current business processes (Hammer, Champy, 1993). Therefore, BPR entails a total rethinking of how processes are currently carried out and how process goals can be achieved. (Murray, et al., 2000).

When selecting which processes should be reengineered, a company should focus on strategic processes. Strategic processes are defined as core processes which are directly related to the company’s business purpose and contribute to reach the strategic goals (Hanafizadeh, Osouli, 2011).

Other than the need to select the right processes to re-engineer, choosing the right

method for their alteration is a key factor for successful BPR. Cheung (1998) suggest two types of appropriate approaches for BPR projects, one is non-digital and the other is software-supported or software enabled.

Process Mining is a young software technology which could be used as a support tool for BPR. Based on the analysis of event-logs within the system of a company this technology enables analyzing really taken process steps. It supports process analysis, process policy conformance and the understanding of process models and is therefore a useful tool to support business process improvements (Polpinij et al., 2015).

Theoretical Framework of Process Complexity and Research Gap

Process Complexity Framework

Based on our structured literature review, we developed a heuristic framework for explaining the emergence of process complexity, taking into account its characteristics and interdependency to other complexity types within a production company.

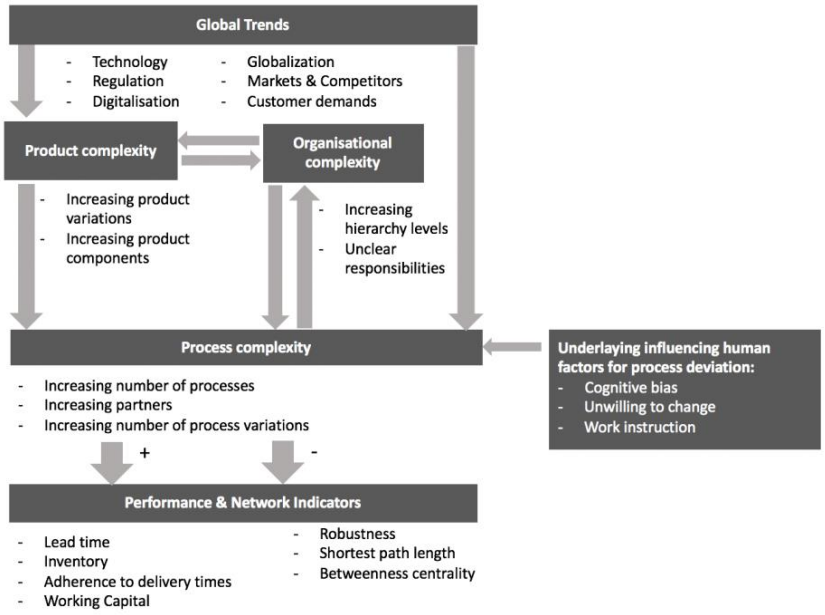

Fig. 1 Process Complexity Framework

In general, there are three categories of complexity within a production company; which are product, process and organizational complexity (Größler et al., 2006).

Different developments such as technical development, market and customer demands Are global trends which have either directly or indirectly influenced product or process complexity (Bode, Wagner, 2015). The different product variations and relevant number of components determine the product complexity.

Process complexity in general is determined by the number of possible process path alternatives and process steps actually taken (Mani et al., 2010). Organizational complexity can be characterized as the structure of hierarchy and delegation levels in an organization. Product complexity as itself also influences process complexity and organizational complexity (Größler et al., 2006). Organizational complexity can be characterized as the structure of hierarchy and delegation levels in an organization (Größler et al., 2006).

Their interdependencies can be exemplified through the following sample; a larger number of product variants and components require a lager number of suppliers which in turn often require different souring processes. Thus, an increase in product variants and therefore complexity, often directly leads to correspondingly higher process complexity. Increasing the number of product components also leads to the need for more employees (for example for product design, construction etc.) and therefore, also to an increasing organizational complexity (Bode, Wagner 2015).

These interdependencies go both ways, product complexity impacts organizational complexity, but organizational complexity can also effect products. Organizational complexity is often characterized by many levels of hierarchy and unclear responsibilities, which can lead on the one hand to higher product complexity due to unclear construction standards for example and on the other hand to a higher process complexity (Aitken et al., 2016).

Human factors are also reasons for deviating from predefined standard processes which influence process complexity (Arnott 2006), (Marjanovic, 2000). It is undisputable that process complexity impacts the performance of processes in terms of their lead times, inventory, delivery reliability and working capital (Bode, Wagner, 2015), (Aitken et al., 2016) as well as on network indictors like robustness, shortest path length and betweenness centrality (Boccaletti et al., 2006), (Meyer et al., 2015).

Research Gap

Aitken et al. (2016) argue that the desirability of different complexity levels should be distinguished, such that an acceptable level is identified depending on the strategic relevance. As only negative impact of complexity on corporate performance has been addressed in literature, there is a need for further research of the positive impact of process complexity on specific key performance indicators like process throughput times.

Furthermore, the reasons for deviation from predefined process standards must be further investigated. To further discussion on this gap, this paper aims to contribute to the research goal; how process deviation increase corporate performance in terms of process throughput times and how people behavior affect deviation from process standards.

Case Study

In order to explore above-mentioned question we present a case study of two German production companies (see table 2) and demonstrate the findings of two analyzed end-to-end processes, with a combined total of 1.794.000 data records of process paths truly taken, as inputted by employees in each respective companies SAP system. The characteristics of the two chosen companies are presented in the table below:

Table 2: Key facts of the companies

	company I	**company II**
branch	metalworking plant engineering	aviation
annual turnover	> 900 Mio. €	> 400 Mio.€
employee	2.000	1.500

The two chosen production companies dispose about all relevant key business processes with a relevant spectrum of attributes and complexity aspects like number of suppliers and customers, invoices in different currencies and delivery routes. The two chosen companies are large corporations. Therefore, also the company size, involved

departments and employees as well as the data and process volume represent the situation of a multitude companies. As both companies are production companies they often deal with all three presented complexity types; of product, process and organizational complexity. Moreover, there are many involved parties which contribute to the complexity, such as various departments, and employee hierarchies within a single process, which allows for an assessment of the underlying human factors on process complexity can be investigated.

For the analysis we used extracted data of one accounting period from the company´s Enterprise Resource Planning (ERP) system of the purchase-to-pay and the order-to-cash process. In total 1.794.000 single data records were analyzed by using a process mining tool, named Celonis.

Table 3: Analyzed data records

process	data record
purchase to pay	1.593.000
order to cash	201.000

Based on event logs within the ERP system and the time stamps of the several process step activities the process mining tool is able to mirror the actually taken process paths. Based on the analysis of the time stamps Celonis is also able to determine the used throughput time. It is possible to define a target process and doing a conformity check if the process path and the specific steps are the same as they were defined in the target process or if there occurred some process violations.

The central measured values from the tool are the throughput time based on the analysis of the time stamps and the cases per step, based on the analysis of the IT-documents per process activity. In the following section we show the process deviations taken, as well as their identified influence on performance indicators.

Findings

Comparison of Planned vs. Actual Process Paths

The standard process predefined by management are first shown for purchase-to-pay (Figure 2) and order-to-cash (Figure 3).

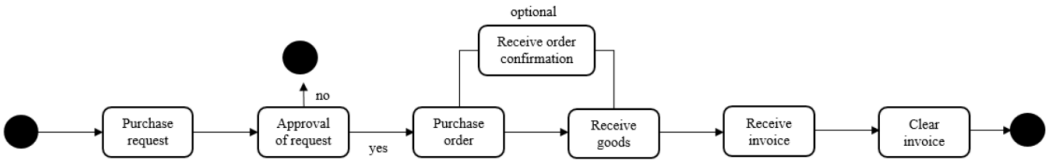

Fig. 2 Standard purchase-to-pay process

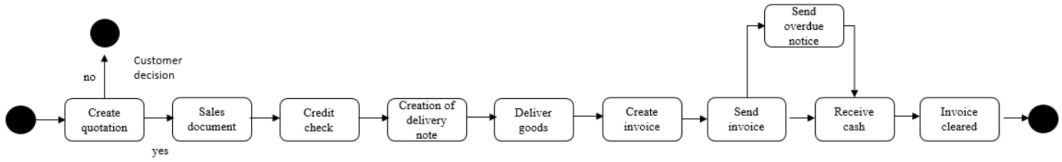

Fig. 3 Standard order-to-cash process

To validate our framework about desired and undesired complexity we present the following example from our analysis of the invoicing part of the order to cash process. We investigated in the order to cash process a normal throughput time of 23 days. For this sub process part a normal throughput time of 8 days is defined as a standard. The activity "send overdue notice" for sent invoices where there is no cash income yet, is defined by the company as a desired activity. Even the throughput time of the whole process increased by 17 days and also the process complexity increased due to the extra loops, it is a necessary complexity increase and certainly also by management a desired process step, from a company strategic point of view.

Figure 4 shows the comparison to Figure 2 of the network topology between the purchase-to-pay standard process with its accepted path alternatives and the process path actually within the company.

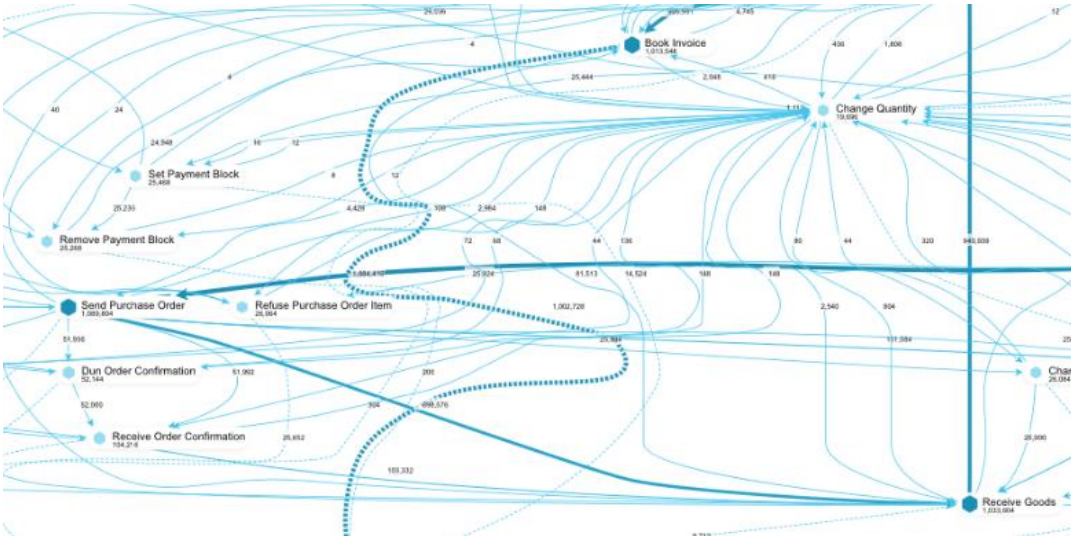

Fig.4 Real-taken process paths within purchase-to-pay process

As also the figure illustrates, we investigated a higher static complexity due to the increase of possible path alternatives. Also, a higher dynamic complexity occurred due to the taken process paths and the deviation from the standard process.

We investigated the shortest path length of the taken process path. *Dij* defines the length between one node i to another node j.

$$L = \frac{1}{N(N-1)} \sum_{i,j \in \mathcal{N}, i \neq j} d_{ij}$$

The shortest path length increased by 7-9%. This means there is a higher effort necessary to reach the process goal and confirms the increase in complexity.

By using a process mining tool process throughput times can be easily investigated. We analyzed the throughput times of the two end-to-end processes in the several taken process path variants. Apart from the standard process there were 655 alternative actions in the purchase-to-pay process of Company I and 11.421 variants in Company II, taken by the employees involved in the process. In the order-to-cash process 636 variants exist in Company I and 76 variants in Company II.

Regularly the throughput times increased when deviating from predefined standard processes. But we also identified between 10% and 20% process variants where the deviation from the standard process has led to a decrease of throughput time by 10-12%.

Further, we found that even when people deviate from predefined standard process within the process activity sequence, the start point and the process end for each taken variant was always identical. This indicates that the employees which are involved in the respective processes, actively or unconscious, take alternatives but always to reach the identical process purpose. For example in the purchase to pay process we investigated cases where the process starts directly with the order and afterwards the purchase request was placed in and approved in the system. This indicates that the employee was under time pressure to quickly receive the goods and there was no time to wait for the approval of the request.

Performance increase due to process deviation

Further, we investigated, deviations from standard processes resulting in a shorter throughput time for example due to different starting activities as predefined in the standard process or due to different process activities within the process or due to a different sequence of process steps. These were undesired process steps, but contributed to a better corporate performance.

Therefore, this is already a first indication for a necessary Business process reengineering. This implies that the really taken process path leads to a better performance result than the defined standard process. Are there undesired process alternatives which lead also to a performance decrease management should choose action alternatives to abolish this situation. In case there is a performance increase and also the process steps are desired management should proceed and maintain the current situation. Whereas a performance decrease in combination with desired process steps also indicates a necessary business process reengineering. This implies also that the predefined standard processes lead to a lower performance than the really taken process paths.

Conclusion

This paper investigated the characteristics and emergence of desired and undesired process complexity.

The presented heuristic framework illustrates the cause-and-effect-relationships between impact factors and performance effects of desired and undesired process complexity. It has been shown that an increase of process complexity and the deviation from standard process can increase performance.

First approaches have been developed to explain reasons and influencing factors of process deviations.

From a practical perspective the used data analytics methodology of the process mining tool shows how current data analytics tool can be used in practice and help to analyze big volumes of process data and identify really taken process paths within a

company's business. Further we gave advice for management to choose the correct action alternative based on the level of desired complexity and the performance impact.

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Stakeholders' involvement in additive manufacturing innovations

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Abstract
Additive manufacturing (AM, 3Dprinting) is gaining increasing attention in the manufacturing industry as a collection of novel advanced technologies, supply chains and processes. Firms implementing AM are active in innovation, but successful innovation requires support from other firms in the supply chain and secondary stakeholders. This exploratory study seeks new knowledge on secondary stakeholders' involvement in AM innovation activities. The findings reveal who the secondary stakeholders are and their scope of involvement in the AM firms' innovation process. The study contributes by characterizing the network complexity in AM innovations and guiding AM firms' actions toward stakeholders.

Keywords: Additive manufacturing, stakeholder involvement, innovation

Introduction
Additive manufacturing (AM) is a relatively novel manufacturing approach that implies changes in manufacturing technologies, the use of digital product designs, and a new process of joining and adding material, usually layer by layer (ASTM, 2012), to produce goods. The diffusion of AM technologies in the manufacturing industry will require innovations in the business models, supply chains for the firms involved, and products and services (Weller et al., 2015; Martinsuo and Luomaranta, 2018), driving AM firms to be very active in their innovation activities. Innovation, in its classical sense, means the introduction of a new product, process, or business model for a commercial purpose (Schumpeter, 1934). We concentrate on innovations in AM-related products, including both the manufacturing technologies and the new goods being manufactured.

Creating and introducing new offerings in the competitive industry requires a systematic innovation process (Drucker, 1985). This innovation process can then be divided into three sequential phases that are idea generation, idea development, and the diffusion of the developed concepts (Hansen and Birkinshaw, 2007). In idea generation stage, an idea for the innovation is generated inside a firm or through external sources. In the idea development stage, the best ideas are chosen and the development work starts internally or with external sources. In the diffusion stage, firms try to commercialize the outcome of the innovation.

In the innovation process, the innovating organization can use the support of external resources. Besides firms operating in the direct supply chain of AM, various stakeholders with different interests and demands have an influence on AM product innovations. There are multiple definitions of stakeholders (Miles, 2017) and these different definitions serve their dedicated purposes by focusing on the relevant stakeholder attributes in their context

(Freeman et al. 2010). This study concentrates on secondary stakeholders - those external organizations with an interest in or contribution to AM product innovations, but who are not the key firms, institutions or customers in the direct AM supply chain.

Previous AM-related research has identified that research and training organizations have an important role in giving training regarding AM and transferring knowledge to firms (Rylands et al., 2016). Standardization organizations are important stakeholders when standards are created in the emerging technology (Monzón et al., 2015). Before the specific work of standardization organizations, other stakeholders such as trade organizations and engineering associations specify the need for standards and influence through the standardization process (Koch, 2017). Previous research has identified and mentioned such AM stakeholders only briefly and their input in AM innovations is poorly understood.

The purpose in this study is to explore the involvement of secondary stakeholders in the innovation process of AM products. The goal is to create knowledge on how different secondary stakeholders take part in AM innovation activities with firms in the AM supply chain and, consequently, help firms benefit from their involvement. The primary research question is: *How do different secondary stakeholders participate in AM innovation processes with the firms in the AM supply chain?* The question is approached from the perspective of the innovating firm in the AM supply chain and at the product level in an emerging industry of AM.

Literature review

Defining stakeholders

The term ‘stakeholders’ has many alternative definitions (Miles, 2017). In stakeholder theory, stakeholders are assumed to be a part business and are defined as “groups or individuals that have a stake in the success or failure of a business” (Freeman et al., 2010, p. xv). Often the definitions of stakeholders use the context and stakeholders’ attributes to serve the purpose of the study (Freeman et al., 2010), meaning that in a case of a large multinational firm, stakeholders could be the customers, suppliers and employees. In the strategic management literature, the focus is usually on the attempt to define which stakeholders are important from a firm’s perspective and to which stakeholders should the managers pay attention (Mitchell et al., 1997). Usually stakeholders in strategic management are categorized into shareholders, firm employees, customers, suppliers and sometimes competitors, which can be referred to as primary stakeholders, and then to the secondary stakeholders who are external organizations with regards to the supply chain, not directly involved in for example manufacturing and delivery, but may indirectly influence the innovation process (Freeman et al., 2010). These secondary stakeholders can be for example national governmental organizations and labor associations.

Some management frameworks handle business environment changes for the firms as external forces (see for example PESTLE analysis), and for example legislation is part of such forces. These external forces are difficult to influence, but they have an influence on the firm, and the organizations in question could well be categorized as secondary stakeholders. Stakeholder theory suggests that the relationship with secondary stakeholders is more complex and despite secondary stakeholders’ influence, firms can also use these relationships as two-directional (Freeman et al., 2010).

It has been noticed that firms give relatively little attention to systematically identifying and analyzing important stakeholders (Bryson, 2004), but such relationships can cause uncertainties in the innovation process. Therefore, exploring stakeholders and their relationship with innovating firms in the innovation process is relevant for managers and practitioners. Defining the stakeholders in a too narrow manner would most likely lead to ignore some important stakeholders from the perspective of innovation in an emerging technological area. This study purposely looks *beyond* the manufacturers’ customer-oriented core supply chain and concentrates on those external organizations – secondary stakeholders - with an interest in or contribution to AM.

Involvement of secondary stakeholders in the innovation processes

A focal firm's relationships with the secondary stakeholders have increasingly been considered as an important way of developing innovations (Haeckel, 2004). The secondary stakeholders can participate in the innovation process, for instance, by offering knowledge through a network that they represent (possibly including customers). In some cases these secondary stakeholders are non-profit organizations whose interest is not to make profit by conducting business, but to serve a social cause (e.g. environmental protection, or a university offering education). Developing relationships with these secondary stakeholders can foster innovation by creating suitable conditions for discovering relevant ideas. Gaining access to these dense networks that differ from the focal firm's direct supply chain can offer a different view of the marketplace and offer early warning signs about shifts in public tastes and values (Yaziji, 2004). An empirical finding from biomedical innovations shows that a firm's experience of collaborative relationships with partners in a hub provided by secondary stakeholders was a key determinant of innovation (Powell et al., 1996).

In addition to this passive involvement, secondary stakeholders can have a more active role in the innovation process. Findings from strategic management show that organizations are more inclined to protect their existing processes than develop new ones until they are sure that the development is almost risk free. Therefore, a stakeholder (primary or secondary) outside of the firm can try to force the innovation if a firm does not do it voluntarily (Van de Ven 1986). Developing relationships with non-governmental organizations (NGOs) is good for the firm's social legitimacy. Firms may need these relationships with NGOs to be perceived as socially and environmentally responsible (Berger et al., 2004). Firm-NGO partnerships can address both broad and complex societal issues and they can become a source of competitive advantage (Bonfiglioli et al., 2006).

The earlier studies in the context of AM have mentioned secondary stakeholder involvement in innovation processes briefly. For example, research and training organizations have an important role in giving AM-related training and transferring knowledge to firms (Rylands et al., 2016) so that they can start the AM innovations in the first place. They can be of help also later in the innovation process for example in the testing and development phases. In the case of an emerging technology, standardization organizations are important stakeholders when standards are created (Monzón et al., 2015). Before the specific work of standardization organizations, other secondary stakeholders such as trade organizations and engineering associations specify the need for standards and influence through the standardization process (Koch, 2017). By developing relationships directly with the standardization organizations or more likely through associations, firms can influence in standardization for example so that it enhances their chances to diffuse their innovations.

Research design and method

The research design is qualitative and exploratory in nature because of the limited previous knowledge on stakeholder involvement in AM innovation activities. The study was targeted at two major industries where AM has shown great potential: car manufacturing and medical implants. The focus is on secondary stakeholders.

Figure 1 illustrates the research context. The AM supply chain is presented in the middle. Any firm within the supply chain can be considered as a focal firm, and the other firms are its primary stakeholders. Outside of the supply chain are the secondary stakeholders, whose participation in the innovation process of the focal firm is covered in this study.

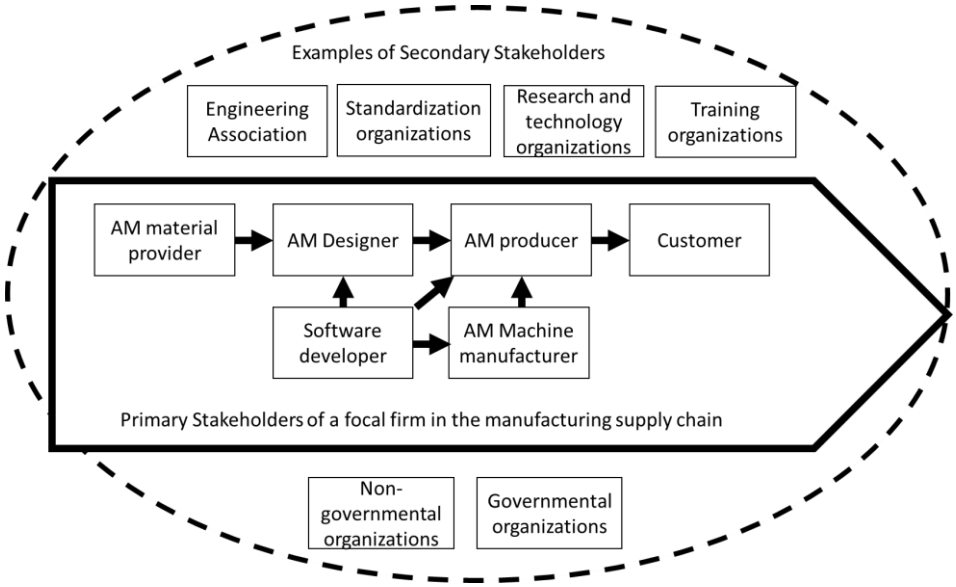

Figure 1 – Illustration of the AM supply chain (primary stakeholders) and secondary stakeholders

Data collection

Data were collected through two workshops and a survey with thirteen AM firm and stakeholder representatives (labeled as organizations A...M). Background information on firms that participated in the workshops and survey is presented in table 1. Organizations A and F are involved solely in the medical implants industry. Organization B represents car manufacturing industry, whereas the rest of the organizations are involved in AM industry more generally, including both – car and medical implants industries.

Table 1 – Background information on firms participated on the workshops and survey

Organization	**AM firm role**	**Secondary stakeholder role**
Organization A	AM designer, AM producer	
Organization B	AM designer, customer	
Organization C	Software developer	
Organization D	AM designer, AM producer	Research organization
Organization E	AM designer, AM producer	Research organization
Organization F		Engineering association, Training organization
Organization G	AM machine manufacturer, AM feedstock provider	
Organization H		Engineering association, Training organization, Research organization
Organization I	AM feedstock provider	Research organization
Organization J		Non-governmental organization, Research organization, Training organization
Organization K		Research organization, Training organization
Organization L		Education organization, Training organization, Research organization
Organization M		Training organization, Research organization

During the first workshop, the participants were instructed to map their dedicated supply chain and actors in it, including all the organizations and institutions inside and outside the supply chain with whom they are developing innovations.

After the listing of stakeholders, a survey was sent to the firm representatives concerning the activities that the stakeholders engage in with the AM firms. The question in the survey was: "Based on your experience, what inputs or requirements do the external stakeholders bring to the network of firms in additive manufacturing supply chain?" External stakeholders were divided into: funding and insurance firms; training organizations; regulators and patent authorities; trade associations and customer representing organizations; research organizations; and other. Respondents had a chance to offer an open-ended response systematically to each identified stakeholder, and also add stakeholders they considered as relevant.

Another workshop was organized with the same firms and a group of researchers to recognize the interactions, activity inputs and outputs of stakeholders with the firms in the AM network. In this second workshop, the participants discussed in industry-specific teams (car manufacturing, medical implants) to fill in and organize a process map that included the previously identified stakeholders and their inputs and requirements. The data created during the workshop covered: the stakeholders' relationships with the firms in the AM supply chain, requirements of the secondary stakeholders, benefits to AM firms from the relationships, and phase in the innovation process of the secondary stakeholders' involvement. Discussion during the workshop was documented into memos and flipcharts.

Analysis

The analysis concentrates first on identifying and defining the secondary stakeholders (results in table 2) and then mapping the secondary stakeholders' involvement for three AM innovation process phases (table 3). Based on the answers about secondary stakeholders in workshop 1, table 2 was formed by listing all the relevant stakeholders, removing those expressions that concerned primary stakeholders, and combining the repeating attributes of secondary stakeholders into logical descriptions.

Based on these data, the power/interest matrix analysis was done, according to the three phases of innovation process, i.e., idea generation, idea development and the diffusion of developed concepts (Hansen and Birkinshaw, 2007). One of the most common stakeholder mapping methods is to use a two-by-two matrix with key attributes on both axes. These attributes can be for example power and interest, importance and influence, or support and opposition (Bryson, 2004). For this study, the power and interest matrix was chosen since it offers the most insight for studying the stakeholders' involvement in innovation. The data from the survey and the second workshop were used, to analyze each phase at the time using the power and interest matrix.

Interest attribute reveals if the secondary stakeholder is very pro-active in its involvement or if is more passive. It is also important to understand the power that each stakeholder possesses, because it creates understanding on whether the secondary stakeholder is empowering or controlling the innovation process. Also the power may lie in the ability to affect innovation in the short term or affect its success and acceptance in the long-term (Mathur et al., 2007) Figure 2 illustrates the power/interest matrix used in this study. During the analysis, the interest of the secondary stakeholder was considered as high if an AM firm respondent described a secondary stakeholder's participation for example as follows: "they brought the idea" or "they started the discussion" or "they were very active". Concerning responses by secondary stakeholders themselves, the interest was considered as high if they claimed an active role such as "we had the idea and then we tried to find a firm to collaborate with us". In the analysis of power, strong power was coded if the respondents expressed that: "we have to comply" or "it is very important to collaborate with them". Weak power was coded if the expressions were for example the following: "it was not necessary but beneficial to us" or "we collaborated voluntarily".

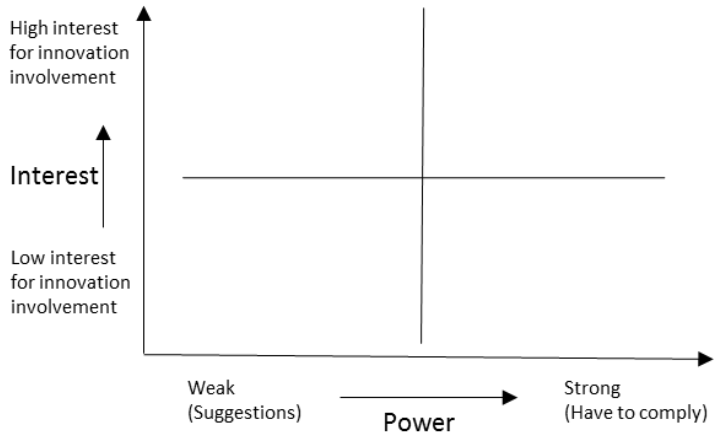

Figure 2 – Analysis framework for the secondary stakeholders

Findings

Identifying and describing secondary stakeholders

This study identified the key secondary stakeholders for AM innovation processes. They are: Regulators, NGOs, funding organizations, training organizations, research institutes, standardization organizations, patent organizations, trade associations, organizations representing customers and end-users and insurance firms. Table 1 shows the identified secondary stakeholders and their description from the perspective of the firms involved in the study, based on their answers to the survey.

Table 2 – Identified secondary stakeholders and their descriptions

Secondary Stakeholder	Description
Regulators	Regulators regulate laws such as tax laws. They also try to secure reliable and sound products, by giving regulations for compliance and granting certificates. For these certificates and laws there needs to be collaboration with research institutes, AM machine manufacturers and AM producers. Regulators also set regulations or encourage firms to develop clean, material- and, energy saving technologies, they set safety regulations and try to create new job opportunities.
NGOs	NGOs in the context of AM most often are protective of the environment and/or the society. Damage to the environment may seem like a small issue at present but as time goes on, repairing such damage becomes increasingly costly. The information that NGOs can provide about the effects of new technology on environment and society can be used to enhance the responsibility of the industry and to protect end-users and the wider society from the social consequences of AM applications.
Funding organizations	Funding organizations can be national or for example European level organizations. Their input - funding - enables new product development in a quicker pace. They require from firms comprehensive resource allocation and reporting to support the AM innovations in the most efficient way.
Training organizations	Training organizations provide standardized training, give knowledge as quickly as possible to the organization in AM and offer different formats in training (including degree programs and lifelong learning). The training can deal with general AM knowledge as well as best practices. Training organizations need to accumulate the state of art knowledge, gather funding, and analyze firms' current situation and the market. Trainings with multiple attendees can enhance the connections within the AM network.

Secondary Stakeholder	Description
Research organizations	Research organizations are sometimes the main contributor and starting point for developing innovations in the early phase (idea generation, development), but they need firms to commercialize the innovations (development, diffusion). Research organizations rely on funding organizations and firm partners to fund their research and development activities to develop innovations. Research organizations contribute to new regulation creating processes, and new standard making processes. They also transfer knowledge to training organizations.
Standardization organizations	Standardization organizations set the standards for characterization of AM produced parts. This includes data formats, reliability, quality requirements and restrictions on software use. Through the standard compliance, this can foster some technologies more than others. To create standards, standardization organizations need to collaborate with industry experts, research organizations and firms in AM value chain. Standards ensure common understanding among stakeholders, which is important for communication and innovation purposes. Standardization organizations also coordinate the expert groups to develop standards.
Patent organizations	Without patents the innovations would be freely adoptable by any competing firm. Since there is a cost associated with innovation, the patents serve as a securing mechanism to protect the ownership of the innovation and enable the owner to make profits to cover the costs of the innovation. Patent organizations provide help and instructions to the firms seeking to file a patent application. Patents can serve also as source of knowledge after they expire and become public. Especially if the patented technology becomes industry standard, firms have all the knowledge about the technology, after the patent expires or it is licensed by the patent owner.
Trade associations	Trade associations provide new knowledge to their members, strengthen current networks, create, and explore new networks. Trade organizations seek to gather information about the markets to provide marketing possibilities to different countries. Trade associations need to collaborate with research organizations, regulators both within their country on outside as well as with its members. Professional associations such as engineering associations are included in this category.
Organizations representing customers and end-users	Organizations representing customers and end users identify possible applications and thematic areas for AM. They collect requirements of the customers and end-user needs to analyze possibilities for further applications of AM. They have the possibility to influence the market (and in this way, the whole value chain) through the feedback of customers and end users. For this, they need to collaborate with communities of interest, informal networks, educators and technology users. Firms in the AM value chain can use the knowledge from organizations representing customers and end users to help to understand the potential needs and concerns from customers and end user.
Insurance firms	Especially in the medical sector, insurance firms can foster some technologies more than the others through the insurance decisions. This is an economic aspect for the medical sector in terms of risk management (granting insurance for AM implants vs. traditional implants), and has to follow regulations as well. Insurance firms also offer background information about risks that inform AM firms about the possible volumes and needs of certain medical implants.

Analyzing the involvement of the secondary stakeholders in the innovation process

The power/interest matrix analysis was done for each of the innovation process phases respectively and the results are presented in the table 3. For example research organizations had a high involvement in the innovation process phases of idea generation and development, as workshop participants discussed this actively. In the car manufacturing sector, research organizations were mentioned as stakeholders who most often generate and introduce new

AM component ideas or AM methods to car manufacturers' products or production. Especially in the medical implant innovation process, workshop participants mentioned that the research organizations have high interest of being involved in the innovation process in the development phase when the implants go through clinical testing. Ultimately they do not have enough power to go through the whole innovation process by themselves, but they need the AM firms. On the other hand the focal firm does not necessarily need the research organizations, but they can benefit from the faster development through the involvement of research organizations.

An example of low interest and weak power in the first phase of innovations comes from training organizations. According to the workshop participants, innovating firm needs training organizations to supply the education, and they have weak power to involve in the innovation process. Of course training organizations try to market their services, but their interest was seen as lower than research organizations among the respondents. This was considered to be applicable in both the medical implant and car manufacturing sector.

Table 3 – Stakeholder involvement in additive manufacturing innovations

	Idea generation		**Development**		**Diffusion**	
Secondary Stakeholder	**Interest**	**Power**	**Interest**	**Power**	**Interest**	**Power**
Governmental organization (Regulations)	Low	Strong	Low	Strong	Low	Strong
Governmental organization (Certificates)			High	Weak	Low	Strong
NGOs	Low	Weak	Low	Weak	High	Strong
Funding organizations			High	Strong	High	Strong
Training organizations	Low	Weak	Low	Weak	High	Weak
Research organizations	High	Weak	High	Weak		
Standardization organizations			Low	Weak		
Patent organizations	Low	Weak	Low	Weak	Low	Strong
Trade associations	Low	Weak			High	Strong
Organizations representing customers and end-users	Low	Weak			High	Strong
Insurance firms					Low	Strong

In the diffusion phase of the innovation process, organizations representing customers and end-users have a powerful position and they have a high interest in involving in the innovation process. These organizations are advocacy groups that can represent for example customers in a certain medical field, or conduct testing and inform the customers about the new innovations and their reliability in the car sector. According to the workshop participants, such organizations try to provide the best new innovations to the customers they represent. Therefore, their role is important for AM firms trying to diffuse their innovations,

and AM firms try to convince and involve organizations representing customers so that their innovations would be successfully diffused.

Insurance firms are an example of the other extreme of the scale compared to the research organizations. Based on the answers from the survey and data from the workshops, insurance firms do not seek the involvement to the innovation process actively at all and their involvement was only seen in the last phase of the innovation process – innovation diffusion. Especially in the case of medical implants manufactured additively, the innovating firms have to convince the insurance firms that their product, which might be more expensive than traditional implants, is in the long scope better for the patient. Therefore, insurance firms were considered to have a low interest in seeking to involve in the innovation process, but they have a great power whether the innovation – medical implant – can successfully be diffused to the market. This can of course be the case because of the rather emerging sector of AM and AM implants, and in the future their role can be more active. The insurance firms were not considered to be very important for car manufacturing sector.

Discussion and conclusion

This research started with the premise that AM innovations require the involvement of stakeholders both within and outside the direct supply chains of AM firms. The research question was: *"How do different secondary stakeholders participate in AM innovation processes with the firms in the AM supply chain?"* With this study, we draw attention to the complex networks where also the secondary stakeholders have an important role with regards to creating and implementing AM innovations. The focus was on stakeholders' participation in terms of interest and power throughout the innovation process.

This study reveals that secondary stakeholders have different types of involvement over the innovation process, and this involvement varies during the innovation process very differently, depending on the specific stakeholder type. Different secondary stakeholders are involved in the AM innovation process with the firms in AM supply chains in four different ways. 1) Their participation may be reactive only when AM firms seek external support and their power is weak meaning that their advice or involvement is voluntarily from the perspective of the AM firm. 2) Their involvement can be very active but weak in power, potentially reflecting the stakeholders' unique capabilities that are useful in the innovation process. 3) Some stakeholders' involvement can be very active and powerful meaning that AM firms need to comply with everything that the secondary stakeholder advises (usually these kinds of stakeholders would greatly endanger the success of the innovations if AM firms do not comply). 4) Some stakeholders' interest is low but powerful (it would be for example against the laws and regulations for AM firms not to comply).

The findings offer contributions by adding to the limited previous research about secondary stakeholders' involvement and, particularly, by offering a holistic view to the stakeholder landscape of AM. This study adds the perspective and involvement of secondary stakeholders to the AM innovation process, while previous attention has tended to be on company dyads or direct AM supply chains only. The findings provide AM firms a way to identify the central stakeholders, promote market access, and achieve other benefits during the innovation process. The study creates new knowledge from the perspective of the firms directly involved in the supply chain of AM, acknowledging the complex business network around them.

The study also lends support to some studies that have covered certain stakeholder groups separately. For example, the findings are in line with Rylands et al. (2016) concerning training organizations and research organizations as important stakeholders in the AM innovation process, Monzón et al. (2015) regarding standardization organizations influencing and being influenced during the AM innovation process, and Koch (2017) about engineering associations as important hubs of knowledge and ideas. The findings of this study also support the views of stakeholder theory (Freeman et al., 2010) in proposing that AM innovations do not happen in isolation within one firm alone, but there are other stakeholders - especially secondary stakeholders - that have an influence on the innovation process.

This study used an exploratory research design with workshops and a qualitative survey to collect data. This research design allowed to have a wide understanding about the phenomenon of secondary stakeholder involvement in the innovation processes. As a limitation, however, the design does not allow to analyze single secondary stakeholders or single innovations very deeply. The findings are limited to medical and car manufacturing sectors of the AM industry. Each of the respondents also gave their firm's point of view to the research task, possibly causing a single-respondent bias. In the future, more respondents from each firm could be involved for a more in-depth study on secondary stakeholders' involvement.

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How do firms develop supply chain capabilities for innovation? A longitudinal case study

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Abstract

Existing studies on the antecedents of innovation performance have focused on firms' internal capabilities. However, the importance of supply chain capabilities in improving innovation has not been fully investigated. In supply chain management practice, managers commonly face conflicting decisions between internal and external capability areas. This causes firms to fall in dilemmas around supply chain decisions for innovation. Drawing upon the extant literature, this paper proposes a conceptual framework to investigate how firms develop supply chain capabilities to improve innovation performance. The framework is exemplified by a longitudinal case study highlighting decision-making dilemmas around supply chain resources, coordination and learning.

Keywords: Supply chain capability, Innovation, Longitudinal case study

Introduction

Innovation is essential for firms to achieve superior business performance. Scholars have conducted numerous studies to investigate the antecedents of firms' innovation performance. In the extant literature, one of the commonly adopted theoretical perspectives is the resource-based perspective, including the resource-based view (RBV), dynamic capability and other branch theories. These studies highlight a focus on firms' internal capabilities. However, firms' innovation decisions are embedded in their supply chain (SC) network, where their connections and interactions with supply chain partners place impact on their innovation performance. This calls for an extension of the resource-based perspective in order to link the innovative firm with its supply chain network.

Recently, the importance of supply chain capability in improving innovation performance has attracted increasing attention (Gao et al., 2017). Supply chain capability is a collective ability or learning of supply chain members to achieve strategic objectives through accessing and deploying dispersed resources (Zhang et al., 2016). It involves the firm's upstream, downstream and spanning processes (Tracey et al., 2005) and is regarded as a kind of network capability. A higher supply chain capability allows more innovative product development and hence more competitive advantages in the market (Morita et al.,

2018). Therefore, supply chain capability serves as a link between the firm and its supply chain network.

In firms' supply chain management practices, it is common that managers face conflicting decisions between internal and external capability areas. This causes firms to fall in dilemmas around various decisions. In the extant operations management (OM) literature, there is a dearth of studies on how firms make decisions when there are conflicts in resource allocation, supply chain coordination, and supply chain learning, which are key dimensions of supply chain capabilities (Zhang et al., 2016). Drawing upon the extant literature, our paper proposes a conceptual framework to investigate how firms effectively develop and utilize supply chain capabilities to improve their innovation performance. The framework has three dimensions, i.e., supply chain resources, supply chain coordination, and supply chain learning. We aim to scrutinize the potential decision-making dilemmas in each dimension. In doing so, this paper is expected to contribute to the supply chain innovation literature by providing a systematic theoretical model to possibly resolve conflicting arguments for internal and external capabilities.

Conceptual Development

This paper proposes a conceptual framework of supply chain capabilities for innovation. It is argued that the supply chain capability development is realized through accessing and deploying supply chain resources (Esper and Crook, 2014), coordinating and integrating activities along the supply chain (Cao and Zhang, 2011; Shou et al., 2018), and adopting effective learning mechanisms with supply chain members (Yang et al., 2018).

The importance of supply chain resources has been widely reported in the OM literature. There are diverse views on their contribution to innovation. In one side of the debate, scholars with the traditional RBV believe that external resources can supplement internal resources and as the result will expand the scope of and speed up the process of innovation. In the other side, scholars with the resource dependent view warn managers about the risk of relying on external resources and subsequently failing to maintain a consistent priority to build up critical resources for innovation. Supply chain managers in practice often find themselves falling in a hopeless situation to avoid the possibilities of being unwillingly constrained by internal resources (path-dependent) and being overly dependent on external resources (hollowed-out) in their innovation initiatives.

Supply chain coordination has two options in general based on collaborative or transactional terms. Collaborative relations can lead to obvious benefits, but the focal firm must possess necessary bargaining power and be prepared to invest in effective coordination mechanisms (including formal and informal processes). Otherwise, the focal firm has to work with suppliers on a transactional basis. In a rapidly changing operations context, managers may consciously maintain a transactional relationship with suppliers in order to explore flexible choices and avoid the risk of being locked in. Dynamic switches between collaboration and transaction are required by the uncertain nature of supply chain innovation, which lead to another set of dilemma decisions.

Supply chain learning, based on shared cognition and practice, has been increasingly recognized as a key strategy for innovation. Such learning practice can focus on the reuse of existing knowledge and the creation of new knowledge. Such explorative and exploitative orientations, albeit being popularly promoted in an ambidextrous strategic setting, require very different toolsets and processes to overcome learning boundaries among individuals, organisations and disciplines. These boundary spanning decisions lead to the third area of innovation dilemma in supply chain management.

Figure1 brings together the above conceptual development in a structured framework. The framework has been used to guide our case study to exemplify how these dilemmas exist in a consistent research setting and to suggest directions to identify possible means to deal with them for supply chain innovation.

		SC Innovation Dilemmas		
		Internal-focused		**External-focused**
SC Capabilities	**SC Resource**	*Path dependent?*	*…*	*Hollowed out?*
	SC Coordination	*Collaboration?*	*…*	*Transaction?*
	SC Learning	*Exploration?*	*…*	*Exploitation?*

Figure 1 – The conceptual framework

Methodology

This paper adopts a case study approach (Yin, 2018). It analyses multiple decision-making frames within a consistent setting of the sampled firm. Our analyses are based on qualitative evidence, as the observations and summaries on firm innovation and supply chain decisions involve qualitatively different types of firm behaviours that are hard to quantify and show variation in kind instead of in degree (King, Keohane, & Verba, 1994). Primary data was collected in three years from 2015 and covered the firm's development in the past over forty years. Hence this case study has a longitudinal nature to possibly identify evolving decision frames around the three dilemmas. Secondary data were used to triangulate the data sources and increase the validity of the study (Voss et al., 2002).

In order to understand the firm's decisions in the process of innovation, relevant context (e.g. key actors, the internal processes of the firm and the network interaction in its supply chain) cannot be separated from the research subject. The research method of case study has the advantage of involving relevant contexts of the research subject (Yin, 2018), and serves as a reasonable strategy for describing a phenomenon as well as exploring theories (Eisenhardt, 1989). This method therefore allows us to develop an in-depth examination of firm decision-making.

This study adopts theoretical sampling in firm selection. The sampled firm – Wensli Group – is a textile and clothing manufacturer in China. In the past four decades, Wensli has achieved lasting superior innovation performance through supply chain management and become a leading firm in the industry. It has established its own brands, partnered with world-class companies, and demonstrated constant strategic capability development for innovation, which has been maintained and supported by various internal and external decisions along time. This firm is therefore of great value for this study.

Data Collection and Analysis

The analyses in this study are mainly based on data collected through semi-structured interviews. A group of managers were interviewed and each interview lasted 3.5-5 hours. Besides primary data, we also collected secondary data from a variety of sources, with the objective of strengthening the validity of observations and analyses. Our first visit to the case firm was in June 2015. This visit established a bilateral agreement between the company and the researchers on the research project and interview plans. Based on the outcomes of the first visit, interview questions were designed with a clear definition of

the research theme and focused subjects related to the research objective. This aimed at achieving a systematic collection of information (Eisenhardt, 1989).

In-depth interviews were then conducted with a group of senior executives of the company in July 2015. Two interviewers in the research team each occupied a unique role. A senior scholar focused on raising questions and chasing detailed answers, and a junior scholar took both audio and written records of the questions and answers. The audio record was taken for the full length of the interview without interruption or manual editing. It therefore provided complete first-hand data of the case study. A third researcher jointly analysed the audio and written records of the interview together with the two interviewers. Information was captured as both integrated notes and original narratives. These two versions of records were cross-checked among all researchers in order to enhance confidence in accuracy and avoid omission of important information. The separation of the two interviewers and the third researcher offered an opportunity for objective analysis. Considering the fact that the research method of case study has the weakness of involving an overwhelming amount of information, the process of partly separating observation and analysis allowed the third researcher to avoid being distracted by a large amount of details during the interview arrangement (Eisenhardt, 1989). The interviews were transcribed in text format, amounting to 37 pages.

In the process of data analysis, evidence was kept chained with research questions (Yin, 2018), and observations were matched with theoretical concepts (Rasmussen, Mosey, & Wright, 2011). Primary data were triangulated with secondary data from multiple sources. These include existing case studies published by local scholars in Chinese, the official company website, archived news and business magazines, and the official firm account on social media. They were used for triangulation (Eisenhardt, 1989) and to enrich the details included in the discussion. This provides information on multiple aspects of the firm's strategies, and therefore increases the comprehensiveness of observations and understandings (Baxter & Jack, 2008). In the presentation of case findings, relevant interview quotes were included as examples of evidence (Yin, 2018).

Case findings were established through analyses of interview data. The initial results of data analysis were presented to the company executives in a third visit in January 2016. This visit aimed at verifying the findings of data analysis with feedback from the interviewees, as well as collecting supplementary information for case analysis. The three visits formed a process of systematic data collection with consistent checks and feedbacks on observations and analyses. This helps to reduce bias and enhance the accuracy of the researchers' understanding and summary on interview data. It therefore improves the reliability of the case finding.

NVivo software was used to facilitate data analysis because it allowed us to identify and develop emerging decision frames with a large amount of qualitative data. Supply chain decision-making dilemmas were identified by coding and comparative analysis across different development stages.

Finding

Wensli Group was founded in 1975 in the city of Hangzhou, where the local manufacturing cluster enjoys traditional craftsmanship in silk making. Wensli focused on the production of silk textiles and women's wear during its early development. The firm was initially founded as a township factory, collectively owned by the local government and community. Between 2000 and 2003, it went through a privatization process and became a limited liability company. The management has remained in the family of the founder general manager, and the positions of chairperson and CEO were handed over to the general manager's daughter and son-in-law in early 2000s. According to the official

company website, the company had over 2,000 employees and annual sales of RMB 16 billion in 2016. The rest of this section summarises Wensli's main innovation performance in the three stages of its historical development since its privatization. Each stage features distinctive strategic challenges and focuses.

Stage 1 (2003-2007): Organisational Innovation and Process Innovation

Silk products used to enjoy strong advantages in the competition with chemical fabric products, as the texture of the latter was relatively hard and rough. However, technological innovations on porous fibre in 2003 improved the softness of chemical fabrics, making them a cheap but qualified substitute for silk. This caused serious shocks to the market of silk products. As a result, silk-textile producers encountered difficulty in maintaining profitability after 2003, including Wensli. Around the same period, recruitment of factory workers became difficult and wage level rapidly increased. The double challenges in product and labour markets pushed Wensli to adjust its strategic focus. Wensli's initial strategic adjustment was reducing production capacity of traditional textile and clothing products and switching business focus to sales of silk-material gifts. To achieve this, the firm subcontracted most production activities to small manufacturing firms in nearby areas and started to focus on design of gift packages and promotion of gift sales.

A new firm was set up for the new business. Wensli took orders from customers and purchased finished products from suppliers. These purchased products were mainly silk scarves and pyjamas. Wensli then designed packages and sold them as gifts.

> *"I decided to close our stores, sell out our production plants and set up a new company without production equipment. I call this an asset-light business model, which focused on the sales of silk gifts." (CEO, 14 Jan 2016)*

For the purpose of cost reduction, Wensli adopted a new organisational structure – asset-light model – and diversified into silk-gift sector. This was realized through the removal of production activity and development of a targeted sales team. The new asset-light model enabled Wensli to remain profitable in a declining market.

Wensli was not able to stand out in the domestic market by selling homogeneous products purchased from subcontractors. After the first diversification into the gift sector, the CEO, Li Jianhua, noticed the potential of cultural concepts in promoting sales – gifts became more meaningful and valuable to consumers when there were cultural stories behind them. Consequently, Wensli began to pay attention to cultural elements that can be linked to silk products.

> *"It was not easy to sell silk gifts, unless you can tell a story which adds value to the products… Our experience in selling silk gifts led us to the idea of promoting cultural elements related to silk materials." (CEO, 21 Jul 2015)*

Wensli then added training process of the sales team to encourage employees to research on Chinese historic stories related to silk materials. For example, speech contests were organized as a training process for employees to present products with a cultural background. Gradually, cultural elements became the potential basis of Wensli's product innovation.

> *"We paid special attention to the training of our salesmen, encouraging them to research on the Chinese cultural elements related to silk…" (CEO, 21 Jul 2015)*

This led to the second step of Wensli's strategic transition – further diversification into cultural and creative industry.

Stage 2(2008-2014): Product Innovation and Marketing Innovation

The first strategic transition made Wensli realize the opportunity of differentiating itself

through focusing on cultural elements related to silk. This led to the firm's focus on innovative concepts and designs with silk-material products. Wensli then set its strategic focus as creating silk-material products to represent the traditional Chinese culture. Its product portfolio initially included mainly scarves, and later expanded to silk books, silk painting decorations and other silk artworks. The CEO described this as a unique and innovative move in the textile industry:

"I don't think any other firm had the same vision [of the value of cultural elements in silk products] as we did… This distinguished us from the competitors." (CEO, 21 Jul 2015)

The adoption of the "cultural and creative product" concept was a major turning point of the company's strategic transition, and it was achieved through a vital event in 2008 – the Beijing Olympic Games. In order to put the new strategic direction on track, managers of Wensli worked on the establishment of a strong brand image closely associated with Chinese silk culture. However, this required substantial investment in advertisement and the company could not afford it. The 2008 Beijing Olympics Games then provided an extraordinary marketing opportunity:

"Sponsoring international events is brilliant marketing opportunities. Through these events, we sell products, promote our brand and build networks with media. Photos on our website with government officials wearing our products drew massive attention to our brand… I believe that this is the most cost-effective marketing approach one could hope to achieve." (CEO, 21 Jul 2015)

The experience of sponsoring the Beijing Olympic Games gained Wensli opportunities to participate in other events (e.g. 2010 Guangzhou Asian Games, 2010 Shanghai Expo, 2016 G20 Hangzhou Summit etc.). Wensli then quickly built up its new position in the silk market. It became a symbol of the Chinese culture and thus a popular choice for cultural and creative gifts. The brand image of Wensli was then differentiated from those of other silk producers, through a cultural and creative brand image.

Stage 3 (Post-2015): Business Model Innovation

Through sponsoring major international events, the Wensli brand became well-known in the domestic market. This led to the firm's ambition of gaining a competitive position in the global market. Although Wensli ranked among top Chinese textile firms, compared to global leader firms in the industry, it has significant gaps in terms of product quality and brand awareness. In order to further differentiate itself from other Chinese textile firms, Wensli attempted to create a China-based luxury brand in 2015:

"We've done well in building our brand name in China. The new objective is to further improve our products and promote our brand globally. We aim at pushing Wensli to the very top of the sector, and so we decided to develop a China-based luxury brand." (CEO, 14 Jan 2016)

This new objective led to a higher level of complexity of Wensli's business portfolio. After a decade of relying on suppliers for production, Wensli acquired a French factory for high-quality scarf production and recruited the former CEO of a French luxury brand for the purpose of learning. The acquisition enabled Wensli to gain some advanced techniques in silk production and learn experiences in luxury brand operation. The new production facility enabled Wensli to provide high-end products labelled "Made-in-France". This also turned Wensli into a China-based subcontractor of some world-famous luxury brands.

The three development stages of Wensli and its innovation performance in each stage are summarized in Table 1.

Table 1 – Summary of firm development and innovation performance

Stage	Strategic Focus	Critical SC Decisions	Innovation Performance
Stage 1 **2003 - 2007**	**Cost reduction** • Technological innovation of porous fibre • Increasing costs of factory workers	• Liaise with local government to be involved in city-restructure project; • Remove production facilities and lay off factory workers; • Completely rely on external suppliers for production; • Recruit college graduates to build sales team; • Develop targeted training process on cultural concepts in sales of gift products	**Organisational innovation** • Asset-light model **Process innovation** • Focusing on sales with cultural concepts
Stage 2 **2008 - 2014**	**Differentiation** • Limited market size and homogenous products of silk gifts	• Liaise with local government to build contact with the Beijing Olympics Organisation Committee; • Sponsor major international events with specially-designed products (with external designer); • Gradually build own design team (and win patents for new product design); • Firmly establish brand image as a representative of traditional Chinese culture; • Build a new factory for high-end products and R&D (take back part of production from external suppliers)	**Marketing innovation** • Promotion of brand image through sponsoring international events **Product innovation** • Cultural and creative design of products
Stage 3 **Post 2015**	**Further differentiation** • Gap with global leader in production techniques, product design, managerial skills and brand awareness	• Build contact with a French factory through CEO's alumni network; • Acquire the French factory to produce for some luxury brands; • Hire the former CEO of a French luxury brand for learning purpose	**Business model innovation** • Building a China-based luxury brand

Discussion

The 2003 transition enabled Wensli to change its focus from production activity to sales of silk gifts. The objective was to remove the historical burden of the old organisational structure and establish a new one. However, in 2003 Wensli had a large amount of real estate assets and a number of plants, but limited cash to support the development on sales activity. The management hence wanted to dispose of the lands and buildings for cash.

In order to realize the new organisational structure – the asset-light model, Wensli negotiated with the local government to join the ongoing urban renewal project. As a result, the firm's lands and buildings were involved and the municipal government acquired them with financial compensation.

"With the government's support, we adjusted our asset structure and invested in the new business… We recruited college graduates to be salesmen and were able to develop the new firm for gift sales." (CEO, 14 Jan 2016)

The local government helped liquidate Wensli's physical assets, which provided the firm with financial resources for the implementation of the new structure. The CEO stated that without Wensli's connection with the local government, it would have been very hard to realise the change.

"I took over the management of Wensli in 2003. Before that, the founder general manager had built close connections with the local government. These relationships played a critical role in facilitating our changes." (CEO, 21 Jul 2015)

"The local government helped Wensli… we were not part of the urban renewal project in the beginning." (HR Dean, 21 Jul 2015)

In this development stage, Wensli made use of its network connection with the local government to adjust its internal pool of resources and realised a change of non-strategic, physical resources into strategic, financial resources. In terms of supply chain activity, the realisation of Wensli's new organisational structure depended on its partnership with suppliers. After removing production activity, Wensli relied on external suppliers for product manufacturing.

Since 2003, Wensli had switched its business focus from textile production to gift sales. During the process of concentrating on sales activity, Wensli discovered the benefits of cultural elements on gift sales, and the firm developed a specialized focus on the training of its sales team. This self-learning led to its latter positioning of the brand image as a representative of the traditional Chinese culture.

The 2008 Beijing Olympic Games enabled Wensli to firmly establish its brand image. The firm's connection with the local government again provided important aid in the realisation of this marking approach. There was a fierce competition among firms for the sponsorship license of the Beijing Olympic Games. Wensli became one of the candidates in 2006, and proposed product design catalogues with silk materials. Instead of waiting to be selected, Wensli made use of its network connection to pursue a winning chance. When the founder attended a government conference, she showed Wensli's catalogue to state government officials, and explained Wensli's idea of promoting the Chinese culture through silk products. The state government officials then recommended Wensli's design to the organizing committee of the Olympic Games in Beijing. Soon after, Beijing sent out a consulting team to Wensli for discussion on potential silk products for the games. As a result, Wensli won the opportunity to provide uniforms, medal ribbons and souvenir products with silk materials for the games.

"The Beijing Olympic Games were a major turning point in our development… Our success in winning this chance significantly benefited from the support of the government… The medal ribbons we provided for the event were patented after the games, and this was the start of our product-design activities. The experience of sponsoring this event also won us opportunities to participate in other events… The organizing committee of the 2010 Guangzhou Asian Games offered the sponsorship license to Wensli, because of the reputation of our brand name." (CEO, 21 Jul 2015)

Wensli's products significantly featured the Chinese culture with creative design of silk materials. They therefore attracted great attention through wide media exposure, and the company's concept of cultural silk product was firmly established among consumers.

For the marketing approach of promoting the brand through participating in international events, Wensli's network connection brought the opportunity for the company to demonstrate its expertise in silk materials and win the sponsorship. It was also during such cooperation with external designers in this international event that Wensli gradually built its own design team and developed the capability in creating cultural and creative products with silk materials.

Since its first transition in 2003, Wensli had been relying on external suppliers for production activities. The firm was once highly dependent on the manufacturing resources and capabilities of its suppliers. But during its development, continuous upgrading of the production process was necessary for Wensli's new product lines. As a result, Wensli slightly adjusted its asset-light model at a later stage, from completely relying on external suppliers to building a self-owned factory. This is for the purpose of

quality assurance on high-end orders, product R&D, as well as the protection of intellectual property in its unique design and technology. The self-owned production extended further when Wensli acquired the French factory and undertook production for some international luxury brands:

"Our cooperation with the French enterprise improved our knowledge in running a luxury brand. It also enabled Wensli to join the global network of luxury brands, through being the subcontractor of many of them." (CEO, 14 Jan 2016)

Therefore, Wensli's organisation of production activity, although featuring a stable cooperation with its supply chain partners, showed a high level of flexibility and demonstrated considerations on various factors. The firm constantly receive and produce knowledge during its interactions with various partners in the supply chain network. But the external learning showed a focus on knowledge-reuse, whereas knowledge creation appears to have happened mostly inside the firm itself, e.g. its discovery on cultural value of gift sales and its design on cultural and creative silk products.

"We have over 3,000 self-designed styles of scarf in our database, and we upgrade our software for continuous innovation in design. In contrast with firms struggling in the industry, we enjoy a 28% growth of sales revenue and a 40% growth of profit this year." (CEO, 14 Jan 2016)

Figure 2 summarises the case findings in the proposed theoretical framework.

		SC Innovation Dilemmas
		Mixed actions & Internal focus
SC Capabilities	**SC Resource** *- accessing, mobilising, deploying resources*	**The deployment of SC resources has two functions:** - facilitating strategic use of internal resources - re-configuring the focal firm's internal resource pool Stage 1: network with local government enabled the firm to change its non-strategic physical resources to strategic financial resources Stage 2: network with local government enabled the firm to reach out for business opportunity, and then the firm's expertise (craftsmanship in silk materials) won the competition for the Olympics sponsorship Stage 3: network with local university enabled the firm to enrich its production resources through acquisition
	SC Coordination *- organising, coordinating, integrating activities*	**Multiple factors affect SC coordination** (e.g. cost of activity, the focal firm's strategic focus, development stage of core competence, protection of intellectual property) Stage 1: the factor of cost of activity caused the firm to eliminate production activities and rely on external suppliers Stage 2: the firm's strategic focus on design and product quality caused it to take back part of the production activity Stage 3: the firm undertook production activity for other firms (French luxury brands) for the purpose of learning
	SC Learning *- being taught, finding out, managing knowledge*	**SC learning leads to knowledge re-use while internal learning significantly contributes to knowledge creation** Stage 1: through the practice of sales activity, the firm developed its own understanding on the value of cultural concepts on gift products Stage 2: cooperation with external designers enabled the firm to develop design capacity, yet the unique design of patent products was created by the firm's own team Stage 3: the firm is learning from other brands to manage its new business in luxury market, but at the same time it is developing its own business portfolio.

Figure 2 – Theoretical Framework with Initial Results

Conclusion

Drawing from the existing literature, our paper proposes a theoretical framework of supply chain capabilities for innovation. Based on this framework, the case study illustrates the complex interactions among critical supply chain decisions for innovation in internal and external areas. It is evidenced that there are three typical dilemmas in supply chain capability development decisions. For resource access and deployment, a key question is to rely on internal resources or external resources for innovation performance. The results showed that external resources facilitate the strategic use of internal resources as well as the re-configuration of the firm's internal resource base. For the coordination and integration of supply chain activities, there are multiple factors to consider in order to serve different types of innovation performance. For supply chain learning, while external learning leads to knowledge re-use, the firm's creation of new knowledge appears to rely heavily on its internal processes. High quality decision-making in these three dimensions helps enhance the firm's innovation. This study contributes to the supply chain and innovation literature by providing implications of building supply chain capabilities, as well as guidance for firms' dealing with decision making dilemmas in enhancing innovation performance.

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An Overview of Supply Chain Integration and Performance

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Abstract

Although many scholars have investigated the impact of supply chain integration (SCI) on performance, there is no consensus about their relationship. This paper conducts a first tertiary review to synthesize the main methodological approaches adopted in literature reviews (LRs) on the field, as well as to identify mediation and moderating factors that influence the link of SCI and performance. Findings indicate that the field has matured and reveal the main types of variables discussed (moderators and mediators) in the LRs. The present study also reinforces the high variety of dispersed results in the literature.

Keywords: Supply Chain Integration, Tertiary Literature Review.

Introduction

The advent of global markets, technological breakthroughs, and higher customer expectations are some of the factors driving companies to integrate efforts with supply chain members to face increasing competition as well as to better fulfill customer demands (Simatupang *et al.*, 2002; Tarifa-Fernandez and Burgos-Jiménez, 2017). Therefore, firms are integrating intra- and inter-company processes and information, downstream or upstream the supply chain (Flynn *et al.*, 2010), with the ultimate goal of achieving mutual benefits (Prajogo and Olhager, 2012; Huang *et al.*, 2014). On the same vein, recent studies have revealed that such inter-organizational integration efforts, in the literature refered to supply chain integration (SCI), are an essential source to obtain companies' competitive advantages (Zhao *et al.*, 2013; Vanpoucke *et al.*, 2017).

Although inter-organizational integration along supply chains is of significant theoretical and practical relevance, it is far away from being linear and straightforward. One of the most researched issues in the literature is the complex relationship of SCI and performance. This research topic has been intensively investigated in the last years by

empirical studies; however, their results show divergent conclusions. (Chang *et al.*, 2016; Ataseven and Nair, 2017). While some researchers claim that integration directly impacts companies' performance (Rosenzweig *et al.*, 2003; Li *et al.*, 2009), others advocate that this relationship is not always direct, or, in specific cases, might not even be positive (Hertz, 2001; Wiengarten *et al.*, 2014). Since empirical studies have not reached a consensus on the integration and performance relation, literature reviews (LRs) have played a significant role in this discussion to comparatively understand their main findings, as well as to structure the main variables (mediators and moderators) that are constituting and influencing the integration and performance interdependency. Despite the high importance of these findings for both academics and practitioners, no study has comparatively analyzed and synthesized the LRs, and their evolution on "SCI and performance". For this reason, this present paper conducts a first tertiary review with the focus on (i) synthesizing the main methodological approaches of the different LRs and (ii) identifying mediation and moderating factors, which influence the relationship of SCI and performance. Thus, the following research questions (RQ) are investigated:

- RQ1: How have the LRs on "SCI and performance" been conducted?
- RQ2: What are the main variables influencing the relationship of SCI and performance?

By integrating the findings from previous LRs on SCI and performance, this paper, firstly, provides a better understanding of the methodological steps applied in these studies, addressing RQ1. This analysis reveals valuable finding on how SCI research on performance has evolved in recent years. Secondly, concerning the RQ2, this work provides a first comprehensive overview of the variables (mediators and moderators) that can explain how and under what conditions integration can positively affect performance. This is particularly relevant for practitioners to understand and improve integration practices within real-life settings. By identifying trends and possible future research directions on the moderators and mediation variables and their role in the relationship between SCI and performance, the paper paves the way for future research in this area.

The remainder of this paper is organized as follows. First, the methods applied to the tertiary research synthesis are described. Second, the study descriptors and the LRs´ methodology evaluation are presented. Third, the main variables involved in the relationship between SCI and performance are structured and analyzed. The paper ends with the presentation of conclusions and future research directions.

Research Design

This paper adopts a tertiary review approach, which is a systematic literature review (SLR) from existing LRs in a specific domain (Kitchenham *et al.*, 2009). The three steps for SLRs from Tranfield et al. (2003), which offers a methodology for management research, guided the present study: (i) *planning the review*; (ii) *conducting a systematic review*; (iii) *reporting and disseminating*.

In the first stage, *planning the review*, the authors identified the need for an analysis of the increasing number of LRs on SCI and performance, in order to assess how these works have been methodologically conducted, what variables have been addressed and what still needs more attention in future research. Based on that, the authors specified the research problem/questions and developed a research protocol, which structures the activities and the content for the following steps.

In the second stage, *conducting a systematic review*, the keywords were defined according to the literature, as well as providing tests in search platforms. The selected keywords were adopted from studies in the literature and can be divided into two main groups: (i) *supply chain integration* (Alfalla-Luque *et al.*, 2012); (ii) *research synthesis*,

systematic review, evidence synthesis, research review, literature review, meta-analysis, meta-synthesis, mixed-method synthesis, narrative reviews, realist synthesis, meta-ethnography, state-of-the-art, rapid review, critical review, expert review, conceptual review (Thomé *et al.*, 2016). Scopus and Google Scholar were chosen as the search platforms

Regarding the articles' selection process, title, abstract and keywords were first analyzed for identifying LRs on the topic SCI and performance. For that, the authors applied the following exclusion criteria: (i) the article is not a LR approaching the research topic SCI and performance; (ii) the main focus of the study is not the development of a LR; (iii) the article is not a journal publication; (iv) the study is not in English. Moreover, the search process was not limited to a specific timeframe.

As a result, an initial sample of 141 articles was obtained, from which 23 were duplicated. After screening title, abstracts and keywords from 118 unduplicated articles, 32 LRs were selected for a more detailed evaluation of their full texts. Finally, 22 LRs were selected and form the final sample of the present study. To address RQ1 and RQ2, a content analysis of selected articles was conducted (Seuring and Gold, 2012).

First, concerning RQ1, the LR's evolution and methodological contributions were reviewed based on the number of LRs published per year as well as on the analytical categories from the research process model of Thomé *et al*. (2016). The analyses were developed based on the three most recurrent LRs' types in operations management (OM): *narrative*, *meta-synthesis*, and *meta-analysis* (Thomé *et al.*, 2016). *Narrative* reviews have been linked in literature to studies, in which "scholars read various literature sources, relate them to each other, and try to make sense of them." (Seuring and Gold, 2012, p. 545). Although these reviews can bring significant findings, they lack explicit, transparent and rigorous processes, what is overcome by *meta-synthesis* and *analysis*. *Meta-synthesis* focus on qualitative SLRs, which, in some cases, can be used together with quantitative methods, for instance, in quantitative content analysis (Krippendorff, 2004; Thomé *et al.*, 2016). *Meta-analyses* are statistical analyses for SLR, which is normally applied to integrate various quantitative results of individual researches (Glass, 1976).

The review of the content for addressing RQ2 was conducted by taking into consideration the qualitative analyses, research models, statistic evaluations and the variables selected by the studies, including dimensions, moderators and/or mediators. Mediators are variables, which can explain the ways by which integration dimensions affect performance (Magon *et al.*, 2018). Moderators are variables, which explain when integration dimensions show variations in relation to performance outcomes (Magon *et al.*, 2018). For identifying them, coding schemes were developed by the authors to comparatively synthesize this content (Tranfield *et al.*, 2003; Seuring and Gold, 2012).

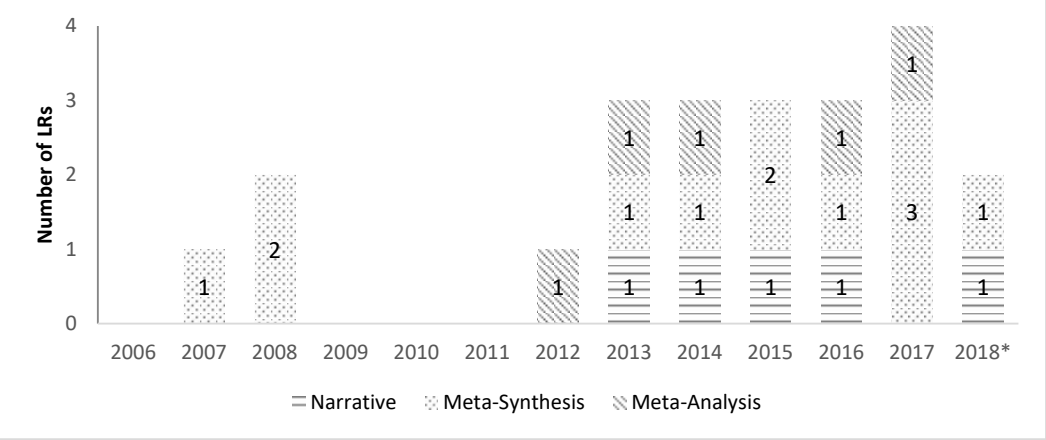
Regarding the final phase, *reporting and dissemination*, the findings regarding RQ1 and RQ2 are presented in the following sections.

Evolution and Methodological Evaluation of SCI-Performance LRs

This section reveals how LRs have been conducted in the SCI and performance research field over the years with the target of answering RQ1. Many LRs have investigated the relationship of SCI and performance with the main target of synthesizing and analyzing previous empirical research. The selected LRs were published in journals from different disciplines, like OM, information management, economics, and business. This fact shows the multidisciplinary nature of the topic. However, the majority of publications, around 85% of the selected LRs, were published in operations and technology management related journals (according to the British Association of Business Schools (ABS) 2015 classification). This indicates the importance of the OM field for the topic. Almost 50%

of the total number of studies selected were published in four journals: *The International Journal of Logistics Management* (4 studies); *Supply Chain Management: An International Journal* (2 studies); *International Journal of Physical Distribution & Logistics Management* (2 studies); *International Journal of Production Economics* (2 studies).

Figure 1 presents the LRs evolution by year and review type. The number of LRs has significantly increased over the last decade, especially after 2013. Narrative reviews represent the lowest number of LRs on SCI and performance, reaching an amount of 5 studies until 2018. The first meta-synthesis was identified in 2007, while its importance increased along the years and turns into the dominant research approach until 2018 with 12 publications. Meta-analyses are more recent contributions than meta-syntheses with 5 articles in total. The limited number of meta-analyses might be related to the heterogeneity of dimensions, data and measures in management research, what hinders its application for synthesizing empirical studies (Tranfield *et al.*, 2003; Denyer and Tranfield, 2009). The lower number of publications in 2018 can be explained due to delays in updating the selected databases, and by the fact that the literature search covers publications until October 2018 (Tarifa-Fernandez and Burgos-Jiménez, 2017).



* January to October

Figure 1 - LRs evolution by type and year (n = 22)

Figure 1 also shows that the growing number of LRs comes along with more transparent, reproducible and thorough research approaches such as meta-synthesis and meta-analyses (Tranfield *et al.*, 2003; Seuring and Gold, 2012). This can be seen as an indicator that SCI and performance research is maturing and consequently evolving to become a more consolidated research topic. The same development can be observed in more evolved research areas, such as medical science or OM (Tranfield *et al.*, 2003; Seuring and Gold, 2012; Thomé *et al.*, 2016). To explore the way LRs have been conducted, Table 1 presents a synthesis of formal review steps and types.

Table 1 shows that a majority of meta-syntheses and meta-analyses transparently presents the research descriptors, whereas this is often not the case for narratives. Especially meta-analyses showed to be rigorous and transparent regarding the descriptors. “Research questions (RQs)/hypothesis” were reported by 60% of the narrative reviews, 83% of the meta-syntheses, and 100% of the meta-analyses. “Analytical categories” were defined by the majority of the studies. Regarding the descriptors: “period covered,” “criteria of study selection,” and “description of keywords,” meta-analyses have the most transparent results, while almost no narrative study has applied these steps.

Table 1 – Percentage of research steps by LRs' type (n = 22)

Review Steps	Types of LRs			Total (%)
	Narrative (%)	Meta-Synthesis (%)	Meta-Analysis (%)	
RQ/Hypotesis described	60	83	100	81
Analytical categories defined	60	100	100	87
Period covered	20	83	100	68
Criteria study selection	0	83	100	61
Description of search keywords	20	92	100	71
More than one database selected	0	67	60	42
Backward/foward search	0	8	60	23
More than one reviewer/coder	20	58	100	59
Statement about literature type included	20	92	100	71
Quality appraisal of primary research	0	58	80	46
Likelihood of publication bias reported	40	75	100	72

In relation to the "number of databases," it was difficult to accurately code this information from some meta-syntheses and meta-analyses since many of them limit their research to specific journals, thus, not making clear the utilized search platforms. Even so, the value obtained for meta-synthesis and meta-analysis is around 60%. "Backward/Forward search" is the descriptor presenting the lowest percentage of all categories, 0% for narrative, 8% for meta-synthesis and 60% for meta-analysis. For future studies, more attention should be given towards snowball search, as this is a powerful step against selection bias. The "participation of more than one reviewer/coder" and "the statement about literature type (e.g., peer-reviewed, grey, etc.)" is almost not reported in narratives, inhibiting the reproducibility of these studies. "Quality appraisal of primary research" is more likely seen in meta-analyses (80%) than in meta-syntheses (58%). Finally, the "likelihood of publication bias", in which authors state possible bias or limitations of their research, was reported in 40% of narratives, 75% of meta-syntheses and 100% of meta-analysis.

SCI Mediators and Moderators

The present section addresses RQ2 and summarizes the main variables (moderators and mediators) which, according to the literature, can influence and explain the relationship between SCI and performance. In a nutshell, more recent SCI publications strengthened the evidence that SCI positively affects a majority of the measured performance relations (e.g., internal and external integration to strategical, relational and operational performance) (Kim, 2013; Mackelprang *et al.*, 2014; Chang *et al.*, 2016; Ataseven and Nair, 2017). However, the same studies also claim that this relationship is not always direct and can vary depending on the environment and/or on specific organizational factors (Kim, 2013; Mackelprang *et al.*, 2014; Chang *et al.*, 2016; Ataseven and Nair, 2017). Chang et al. (2016), for instance, investigate how three types of firm performance (i.e., strategic, relational and operational) mediate the integration-performance link, as well as how time, relationship quality and national culture influence the strength of the measured relations. To structure the dispersed findings in that regard, Table 2 depicts the main categories of mediators and moderators discussed in the selected LRs. Moreover, the identified trends and possible future research directions are also discussed in the following.

Regarding Table 2, it is important to highlight that one variable can be seen both as a mediator and as a moderator, which relates to the author's interpretation, or also on the theoretical lenses applied in the selected LRs (Magon *et al.*, 2018). The present

investigation identified a high amount of different variables with distinct names and conceptualizations that have been structured into the main categories presented below. A text coding process was developed by the authors to synthetize this content. According to Magon et al. (2018), the variety of variables and approaches is a common phenomenon in maturing research fields with an increasing number of publications, which fits with the literature's evolution depicted by Figure 1. Table 2 also shows that moderators have the highest rate of occurrence (60) followed by mediators (13). The low number of occurrences regarding mediators was unexpected and indicates the need for more LRs critically reviewing empirical publications with the focus on better understanding the mechanisms through which integration dimensions impact upon performance.

Table 2 – Main Moderators and Mediators in Integration-Performance LRs (n = 22)

Type of Variable	Number of Occurrences*	Studies
I - Moderators	**60**	
Uncertainty	25	van der Vaart and van Donk, (2008); Sofyalioglu and Üniversitesi, (2012); Kim, (2013); Ataseven and Nair, (2017); Hong and Marvel Jon H., (2015); Sagawa and Nagano, (2015); Tarifa-Fernandez and Burgos-Jiménez, (2017); Zhu et al., (2017)
Supply Chain, Industry or Firm Characteristics	19	Fabbe-Costes and Jahre, (2007), (2008); Kim, (2013); Leuschner et al., (2013); Mackelprang et al., (2014); Martinez Neri, (2016); Ataseven and Nair, (2017); Tarifa-Fernandez and Burgos-Jiménez, (2017)
Organizational Relationship	8	Chang et al., (2016); Fabbe-Costes and Jahre, (2008); Mackelprang et al., (2014); Tarifa-Fernandez and Burgos-Jiménez, (2017)
SCI Dimensions	6	Kim, (2013); Ataseven and Nair, (2017); Tarifa-Fernandez and Burgos-Jiménez, (2017)
Information System Capability	2	Ataseven and Nair, (2017); Tarifa-Fernandez and Burgos-Jiménez, (2017)
II - Mediators	**13**	
Performance Measures	7	Kim, (2013); Mackelprang et al., (2014); Chang et al., (2016)
Organizational Relationship	6	Tsanos et al., (2014); Wang et al., (2016)

* One study can have more than one occurrence

The most discussed variables (25 occurrences) were related to *uncertainty*. In the last decade, there have been many calls, based on the contingency theory, for investigations of the question *"under what conditions integration can be beneficial to performance"* (van der Vaart and van Donk, 2008; Fabbe-Costes and Jahre, 2008; Leuschner *et al.*, 2013; Mackelprang *et al.*, 2014; Ataseven and Nair, 2017). Since *uncertainty* is one of the main categories often related to the contingency theory (Sagawa and Nagano, 2015), many works might have recognized the importance of these calls, and incorporated them into their analysis. The *uncertainty* category consists of variables related to two main groups: environment and organizational processes (e.g. production, transportation) (Sagawa and Nagano, 2015). Most of the papers discuss the moderation effect of environmental uncertainty focusing on a broader external context, such as "demand uncertainty/seasonality," "market characteristics," "competitive intensity," "technological uncertainty," "supply complexity." In relation to the organizational process uncertainty, "lead-time," "product quality," "failures and machine breakdowns" were mentioned as possible moderators. The amount of papers, which approach environmental uncertainty were more frequently discussed than those that reviewed process uncertainty, indicating a necessity for further research related to process uncertainty. In general, the moderation effects of *uncertainty* present negative or positive variations, depending on the SCI dimensions and performance measures (Tarifa-Fernandez and Burgos-Jiménez, 2017). The most frequently quoted variables were "technological" and "demand uncertainty." For "technological uncertainty," most of the

reviewed works present a positive moderation effect when considering customer integration and sharing information to performance. Regarding "demand uncertainty," which depicts the difficulty to predict customer demand, authors have not reached a consensus about its moderation effect yet.

Another important category with a higher number of occurrences (19) is *supply chain, industry or firm characteristics*. In this group, variables such as "company size", "company location", "organizational structure", "supply chain (network) configuration", "supply chain position", "type of industry", "production complexity", "firm age", "product and processes types" are mentioned as factors, which can increase or decrease the integration-performance relationship results. These are traditional variables in OM for contingency investigations (Magon *et al.*, 2018). From the variables mentioned above, however, only the impact of "company size" on integration-performance was reviewed by the selected LRs; the other variables were suggested for future investigations by the authors of the selected LRs. Concerning "company's size", Tarifa-Fernandez et al. (2017) and Kim (2013) state that it is expected that larger companies, which have greater capacity and access to resources, are in a better position to design and implement integrative efforts, and in doing so, have also more chances to increase their performance outcomes. However, the reviewed LR's findings present mixed results about the "company size" moderation, and, therefore do not permit generalizations. Further studies are still necessary in that regard.

Still concerning the results depicted in Table 2, *organizational relationship* factors might act as moderators of integration performance outcomes. This means that companies working in a friendlier environment, in which there are commitment and mutual trust among the supply chain partners, are more likely to achieve higher levels of integration and performance (Tsanos *et al.*, 2014). The most discussed variables under *organizational relationship* were, "relationship quality," "cultural aspects," and "trust." In a meta-analysis, Chang et al. (2016) combined the results from different publications to homogenize the moderation effects of "relationship quality" and "cultural aspects" into one study. Firstly, the authors found that supplier integration can achieve better performance results when focal firms and suppliers have a high relationship quality. Secondly, the research also reveals that internal and supplier integration can be translated into higher levels of performance in Asian than in Western cultures. The authors state that the research's nonsignificant results, especially in relation to the moderators and customer integration-performance, may be associated to smaller numbers of estimates available in literature (Chang *et al.*, 2016). The moderation from "trust" was not measured by meta-analyses, nor sufficiently reviewed by any of the selected others LRs, which also indicates a gap to be fulfilled in the literature (Ataseven and Nair, 2017).

SCI Dimensions (6 occurrences), more specifically, internal, supplier and customer integration, comprises the most frequently quoted SCI variables in the literature. These variables have been operationalized in two different ways to measure the link between integration and performance: first, as part of a direct relationship (e.g. Mackelprang *et al.*, 2014), and, second, also as moderators with the aim of identifying if one dimension can influence the outcomes of the others (Kim, 2013; Tarifa-Fernandez and Burgos-Jiménez, 2017). In this sense, a consensus in the selected LRs is that internal integration positively affects external integration by the effect of moderation (when customer and supplier integration are jointly considered). Internal integration helps companies to build the necessary foundations to absorb, interpret and apply external integration (Kim, 2013). Furthermore, supplier integration has also been mentioned to have a positive moderation effect on customer integration (Tarifa-Fernandez and Burgos-Jiménez, 2017).

The category with the lowest number of occurrences (2) is concerned with the positive moderating effects of *information systems capabilities* on integration and performance. Since information systems are a critical resource in the integration of information and processes among supply chain partners (Ataseven and Nair, 2017), it seems that there is a need to increase research on how this variable influences the relationship under investigation.

Moreover, Table 2 also depicts that "performance measures" (7 occurrences) and "organizational relationship" (6 occurrences) act as mediators in the integration-performance relationship. This means that "performance measures" (i.e., operational performance, relational performance, strategic performance) and "organizational relationship factors" (i.e., trust, commitment, mutuality, and power) are drivers of integration practices to foster higher performance levels. As stated before, the low rate of mediators occurrences in the literature was unexpected. Mediation variables were very disparately mentioned (concentrated in only 5 LRs). Besides that, only one meta-analysis measured the mediation effects on integration and performance (Chang *et al.*, 2016). Chang et al.'s (2016) findings indicate that operational, relational and strategic performance significantly mediate the relationship of SCI dimensions and performance. However, the mediation of other frequently investigated variables in the OM field, such as "SCI dimensions", "supply chain practices" (e.g. information sharing) "relationship factors", among others (Hsu *et al.*, 2009; Wu *et al.*, 2014), are still an open research avenue for LRs in integration and performance.

Discussion and Conclusions

The present work offers a tertiary review of peer-reviewed LRs on the topic of "integration and performance". In a nutshell, the integration and performance research field has matured and presents an increasing number of LRs as a response to synthesize a growing amount of empirical studies. In relation to RQ1, the third section offers a discussion of the importance of LRs design and respective guidelines for more transparent, reproducible and thorough research approaches. Narrative reviews represent 5 of the selected articles. The first SCI meta-synthesis was conducted first in 2007, turning to the dominant research approach until 2018 with 12 publications. Meta-analyses counts with only 5 publications and have demonstrated higher methodological rigor than narratives and meta-syntheses. These findings support the evidence that the LRs in this research field have evolved, offering increasingly more systematic and transparent approaches.

Although the field has matured, and more recent SCI publications strengthened the evidence that SCI is positively related to the majority of performance measures, the literature presents a high variety of dispersed results, which hinder generalizations about the conditions and ways by which integration influences performance. The analysis of RQ2 shows that the reviewed studies present a high variety of different variables, making comparisons of the results difficult. On top of that, the results, which can be compared, are, in many cases, not free from contradictions. Most of the LRs focused on the direct relationship of integration and performance, and are, with little exceptions, superficially discussing the influence of moderation and mediation variables in their analyses. The low number of occurrences regarding mediators was unexpected and indicates the need for more LRs, which are critically reviewing empirical publications in that regard. Despite these issues, some consensus could be identified in LRs. "Technological uncertainty," according to the most reviewed publications, present a positive moderation effect when considering customer integration and sharing information to performance. Supplier integration can achieve better performance results when focal firms and suppliers have a

high “relationship quality.” The same meta-analysis also reveals that internal and supplier integration can be translated into higher levels of performance in “different cultures.” “Internal integration” helps companies to achieve better results with external integration (Kim, 2013). Finally, Chang et al.’s (2016) findings indicate that “operational, relational and strategic performance” significantly mediate the relationship between SCI dimensions and performance.

Considering these findings, the literature results still are too dispersed. Therefore, research needs to be conducted for unequivocally understanding under what conditions, as well as in which ways integration dimensions impact performance measures. This opens opportunities for future research directions. A comprehensive investigation of the main SCI and performance variables, as well as their conceptualizations could contribute to the development of a common understanding about SCI in a consistent and comparable way. Since the empirical publications in the SCI field are growing and only 5 meta-analyses were identified, there is room for the development of more studies applying this approach to align the dispersed findings in the integration-performance literature. The analysis and discussion of mediators should be more explored in future research. Moreover, as internal integration represents an important enabler for external integration, it appears promising to conduct an investigation regarding the moderating and mediation effects within internal integration practices, such as Sales and Operations Planning.

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Forgetting Stakeholders – Sentiment Analysis of Tweets on Rana Plaza Incident

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Abstract

Stakeholders strongly oppose negative and unethical incidents immediately after their occurrence. However, as the stakeholders temporally move away from the occurrence of the incident, they have been observed to forget the incident and the negative impact it had on the associated individuals. The objective of our research is to empirically investigate this observation by longitudinally examining the perception of stakeholders on Rana plaza incident. Rana plaza incident in Bangladesh was one of the biggest tragedy witnessed due to lack of health and safety mechanisms. The incident had a detrimental impact on the reputation of various renowned western clothing brands and their associated supply chains. The quick backlash after the incident from different stakeholders such as consumers, non-governmental organizations, social activists and government bodies was immense, and it significantly affected the perception of the brands and their supply chains. To achieve the objective of this research, we mined the tweets of different brands which were associated with Rana Plaza incidents from 2013 until 2018. Sentiment analysis were conducted on the collected tweets to understand how Rana plaza incident affected the stakeholder perception of different brands and how their perceptions changed year after year. The results show that average yearly sentiment score of majority of the brands consistently increased from 2013 to 2018. We further explain this observation by drawing from willfully ignorant memory effect where consumers/individuals exhibit a systemic bias while trying to remember the ethicality of the brands or products. Our results raise questions for further research such as what should be the immediate and long-term response of ethical supply chain to negative events after their occurrence to differentiate themselves from unethical brands, and how can they transform forgetting stakeholders to forgiving stakeholders for rebuilding a long-term relationship. This research will provide insights on good practices that ethical supply chain can follow in the aftermath of negative incidents to retain or recover the trust of stakeholders.

Keywords: Stakeholder memory, Ethical supply chain, Social Media, Sentiment analysis, Rana plaza incident.

Introduction

Supply chain (SC) management literature has studied different types of negative incidents that have disrupted the supply either via catastrophic disasters or by minor business disruptions. Natural disasters are one of the crucial source of SC disruption. The flooding of Daimler Chrysler suspension parts manufacturing factory by Hurricane Floyd eventually closed their seven other plants across North America (Norrman and Jansson, 2004). Similarly, the outbreak of diseases have a widespread impact on agri and manufacturing SC. For instance, the impact of foot and mouth disease in UK in 2001 has a much wider impact than its occurrence twenty-five years ago (Juttner et al., 2002). In addition, car manufacturers, Jaguar and Volvo, were forced to halt deliveries pertaining to shortage of quality leather supply. Fire in the manufacturing factories is also widely discussed in literature for their potency for SC disruption (Ellis et al, 2011). One of the crucial example is fire in Aisin Seiki in 1997 leading to closure of eighteen plants owned by Toyota accounting for financial loss of $125 million (Norrman and Jansson, 2004). Inaccurate supply planning could also significantly hamper the product/financial flow within SC (Hendricks and Singhal, 2005) as it lead to inventory shortage of sportswear giant, Nike and consequently sales for third quarter in 2001 were lagging $100 million behind the target (Norrman and Jansson, 2004). Similarly, briskly declining demand in conjunction with supply agreements led Cisco to get rid of inventory worth $2.5 billion in second quarter of 2001 (Norrman and Jansson, 2004).

All stakeholders including consumers, non-governmental organizations (NGOs), environmental watchdogs, government agencies, social activists, media and human right entities react punitively to negative incidents that arise due to SC inefficiency or ineffectiveness, especially to those with catastrophic environmental and social consequences. The most severe and immediate reaction usually comes from consumer stakeholders who decide to boycott the product (Hartmann and Moeller, 2014). For instance, the western consumers boycotted some of the clothing brands that were found to be the reason behind Rana Plaza incident. The stock prices of firms and demand of products that are involved in the SC glitches have a significant decline (Hendricks and Singhal, 2005; Jacobs and Singhal, 2017; Endrikat, 2016). For example, the sales of meat products in UK and Ireland started falling after the outbreak of horsemeat scandal (Barnett et al., 2016). Labour union along with NGOs have raised their concern over manufacturing firms for overlooking safety violations in factories. They urge them to improve working conditions for labourers and failure to do so can be proclaimed as criminal negligence (Jacobs and Singhal, 2017). The leading press and social media also echoed similar arguments and held culprit firms accountable for unsafe working conditions deeming it to be their moral obligation (Bhagwati and Narlikar, 2013). The government bodies in developing countries might be paralysed pertaining to lethargic and corrupt legislation framework. However, the government entities in developed nations where buying firms are based have taken stringent action in the event of SC related negative incidents. For instance, US government revoked certain trade privileges for Bangladesh in aftermath of Rana Plaza incident and similarly the European Union signed a sustainability pact with Bangladesh government to enhance factory safety and worker rights (Jacobs and Singhal, 2017).

However, all the aforementioned stakeholder reaction were immediate reaction post SC disasters. The intensity of these reactions usually become milder or totally insignificant over time. For instance, stock market reaction to western retailers was extremely negative at the very day of occurrence of Rana Plaza, however, for the next eleven days, there was no evidence of stock market catastrophe attributable to Rana Plaza

and for slightly longer time duration, sixty days, the impact of Rana Plaza incident was completely nullified (Jacobs and Singhal, 2017).

To answer the above stated research questions, we use the lens of willfull ignorant memory effect. Willfull ignorant memory effect suggests that consumers allow their want self to dominate over should self to overlook negative information pertinent to a firm involved in a conflict. The want self typically attempts to forget non-pleasant information whilst the should self emphasizes what the consumer considered is righteous. Usually, the solution of this conflict is more aligned in favour of want self by overlooking negative information associated with a firm. Reczek et al. (2017) demonstrated that consumers perceive overlooking negative information associated with a firm as more morally acceptable than remembering it but avoiding it, thereby illustrating that willfull ignorant memory is a more morally conventional way out of addressing conflict amongst want self and should self.

For gathering the data to answer the research question, we first mined the tweets using Twitter streaming application programming interface (API) by employing relevant keywords pertaining to various stakeholders and Rana plaza incident since its outbreak from 2012 up until 2018. After pre-processing the collected tweets, support vector machine was used to perform sentiment analysis of tweets (positive, negative) and thereby gain intelligence into the variation in stakeholder's reaction over time using the lens of wilfully ignorant memory effect.

The results of sentiment analysis reveal that the stakeholder reaction is strongly negative immediately after the occurrence of Rana plaza incident. However, the intensity of their negative reaction became milder over time in line with wilfully ignorant memory effect. To further validate the result of this study, sentiment analysis prior (2007-2012) to Rana plaza incident was also performed where it was evident that sentiment score was mostly inclined towards neutral or positive. However, the outbreak of Rana Plaza incident had a devastating impact on the sentiment score of the firm just like the prices of their shares in stock markets.

The structure of the paper is as follows. In the next section, we review the literature on stakeholder's reaction to negative supply chain incidents. In methodology section, support vector machine is introduced to analyse collected tweets and gain contextual intelligence from it. The methodology section is followed by results and discussion, where the rising sentiment score is explained using the wilfully ignorant memory effect underpinning the stakeholder's reaction. Finally, the paper concludes by providing valuable insights into good practices that firms could mimic to prevent reputational damage through their involvement in negative supply chain incidents.

Literature Review

Impact of negative incident on organizations

The extant literature have demonstrated how firms entangled in social, ethical and product harm scandals (i.e. negative incidents) have witnessed reputational damage (Balmer et al., 2011; Firestein, 2006; Beder, 2002) amalgamated with financial consequences. The scale of reputational damage imposed by a particular scandal varies depending on the nature and magnitude of scandal (Laufer and Coombs, 2006) along with the extent of accountability of a scandal attributed to the firm (Coombs, 2007). Also, the past of a firm with respect to its association with former scandals and the image of firm prior to scandal plays significant role in the reputational damage (Coombs, 2006). Hartmann and Moeller, (2014) proposed that the impact of SC liability is severe if environmental deteriorating incident is generated by either behaviour of supplier instead of force majeure or decision

of a firm instead of an employee. Chain liability effect pose a significant risk for the focal company as higher responsibility attributions adds up to consumer's anger and eventually their tendency to boycott. Media is also very potent in this context as the firms with high media visibility are prone to experience higher reputational damage given the familiarity of their brand name amongst the masses (Fombrun and Shanley, 1990).

Collective reputation suggests that reputation of a focal firm is not influenced by merely its own activities, however, it is also affected by the actions of its industrial peers. This phenomenon is widely discerned in oil and gas, and chemical industries (Bertels and Peloza, 2008, Barnett and Hoffman, 2008). These negative incidents could lead to reputational spillover thereby jeopardising the image of firms within similar domains irrespective of their association with negative incident (Yu and Lester, 2008). An example of collective scandal is from year 2013 when beef products across Europe were exposed to be adulterated with horsemeat thereby tarnishing the reputations of multiple beef suppliers, retailers and restaurants (Comyns and Franklin-Johnson, 2018). Barnett et al., (2016) further highlighted the major issues in having an impact on consumer' trust on meat processing industry post-horsemeat scandal. They employed an online tool VIZZATATM for collecting responses of 61 consumers in UK and Republic of Ireland. It was revealed that consumers trust on processing food consisting of meat has diminished along with their consumption of these products.

Sometimes, firms ignore harsh working conditions under their premises and are therefore more accountable for the consequences. For instance, Foxconn (Apple's major supplier) labourers committed suicide (Parmigiani et al., 2011) pertaining to miserable living conditions, frequent overtime and appalling behaviour such as restriction on toilet breaks and conversations. Apple being aware of these conditions sent their monitoring unit, however, still they couldn't breakthrough on how to improve social sustainability across their supply chain. Social issues of this magnitude if overlooked could induce product boycotts, spoil brand equity and thereby lower economic performance (Parmigiani et al., 2011). Keeping in mind the hostile publicity generated from social disputes in sourcing as faced by Levi-Strauss and Nike in 1990, numerous retailers revamped their sourcing policies to address environmental and social inconsistencies (Doorey, 2011). Social and environmental oriented undertakings uplift the reputation of a firm along with raising the goodwill trust of stakeholders (Siltaoja, 2006). The extant literature on social financial performance also validates this notion as environmental and social ventures enhance reputation eventually raising revenue and profit (Surroca et al., 2010).

SCM literature has paucity of work investigating the risk generated from consumer's perception of non-sustainable activities of supplier. Sen and Bhattacharya, (2001) suggests that negative events have wider influence than positive events. Consumer's reaction to negative events are emotional and behavioural reflecting their anger towards culprit firms (Struthers et al, 2005). Emotions pave the way for coping behaviours such as boycotting (Rowley and Moldoveanu, 2003). Hence, social and environmental inconsistencies could impact purchase related decision making of consumers (Klein et al., 2004).

Research Gap

None of them have investigated the variation in the intensity of stakeholder's reaction over time. In this study, we bridge this gap by longitudinally analysing the stakeholder reaction over social media (Twitter) to Rana Plaza incident by using wilful ignorant memory effect as the theoretical lens.

Theoretical Background

Willfull ignorant memory effect suggests that consumers allow their want self to dominate over should self to overlook negative information pertinent to a firm involved in a conflict. The want self typically attempts to forget non-pleasant information whilst the should self emphasizes what the consumer consider is righteous. Usually, the solution of this conflict is more aligned in favour of want self by overlooking negative information associated with a firm. Reczek et al., (2017) demonstrated that consumers perceive overlooking negative information associated with a firm as more morally acceptable than remembering it but avoiding it, thereby illustrating that willfull ignorant memory is a more morally conventional way out of addressing conflict amongst want self and should self.

Data & Methods

The number of tweets mined for this paper were 10,068. They belong to the time range of year 2013 to 2018. The tweets mined were confined to those in English language only with no geographical barrier. Thereafter, keywords were chosen to mine the tweets pertinent to this study. In order to select the keywords, around 55 academic journal and newspaper articles published on Supply chain incident on Rana plaza incident were thoroughly investigated. This led to the selection of optimum keywords given the scope of this study. The aggregate tweets were then pre-processed via this keywords list resulting in the focused set of 3340 tweets. It was observed that amongst those, 52% of tweets were made in Europe and 32% originated from North America. Some of the mined tweets are depicted amongst the flowing word clouds:

Figure 1 – Visualisation of mined tweets via word cloud

Results & Discussion

Sentiment analysis was performed on the collected data (3340) sets by using Support vector machine on R platform. They were classified based on year in which they were made and the brands (Primark, Walmart, Mango, Benetton, H&M, Zara, Matalan, Calvin Klein, Kohl's) they are associated with. Then, variation in yearly sentiment score of individual brand was investigated. For instance, the annual variation in sentiment score of Gap is depicted in following figure:

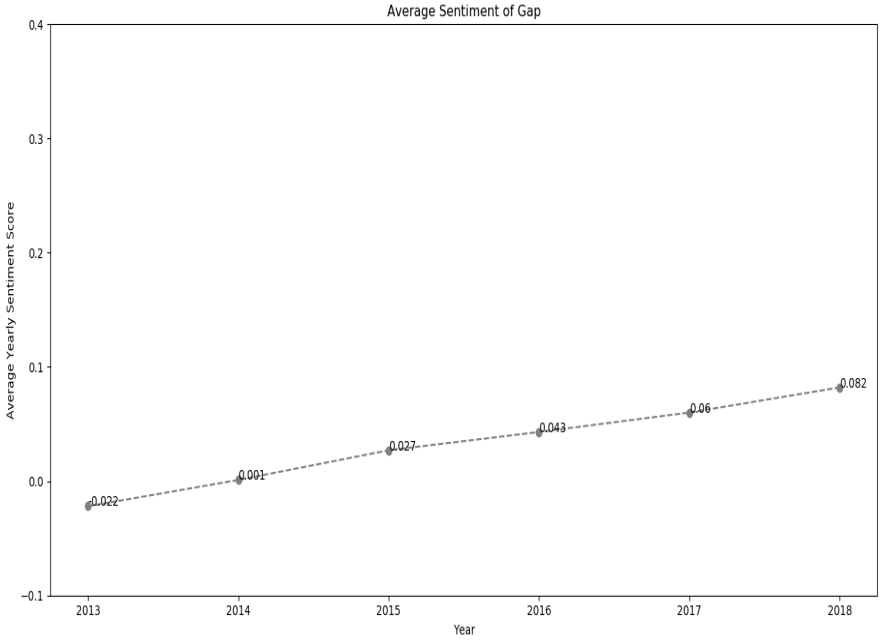

Figure 2 – Average Sentiment scores of Gap (2013-2018)

It could be observed that in year 2013 when the Rana plaza incident happened the sentiment score of Gap was really low -0.022. However, it has increased from there on up until 2018. It reflects that the intensity of Rana plaza incident amongst stakeholders primarily consumers have became milder over the time.

Similarly, the yearly sentiment variation of Zara is shown in Figure 3. Unlike Gap, Zara's sentiment score in 2013 when Rana Plaza collapse happened was relatively positive (0.083). This could be due to the sustainable brand reputation Zara has accumulated over the years and also significant amount of their manufacturing operations are done in Europe (Spain). From year 2013 onwards, the sentiment score of Zara has also risen. Although the slope of increment is not as high as Gap, yet, the sentiment score of Zara in 2018 was 0.132, which is much higher than that of Gap (0.082).

To further investigate the variation in yearly sentiment scores of different brands, a cumulative sentiment score of all the fashion brands accused in Rana Plaza incident was calculated. This annual variation is depicted in Figure 4.

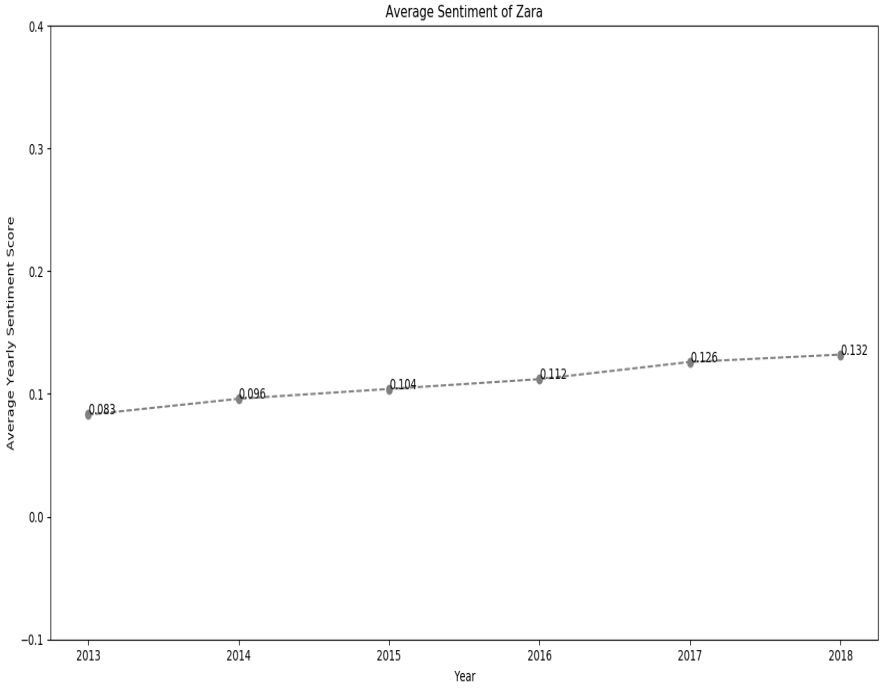

Figure 3 – Average Sentiment scores of Zara (2013-2018)

The cumulative score of fashion brands in year 2013 when Rana Plaza incident happened was 0.014, which not as low as that of Gap (-0.022), which reflects the reputational damage Rana Plaza incident has caused to Gap in year 2013. From time period of 2013-2015, the aggregate sentiment score has risen but at a very low pace. This was the time when various Western Brands got united to address this issue and two frameworks were set up: Accord on Fire & Building Safety in Bangladesh led by European fashion retailers and Alliance for Bangladesh worker safety, which was led by American counterparts. From year 2015-2016 which is 2 years after Rana Plaza, the average sentiment score has risen rapidly reflecting that stakeholders had forgotten the accused firms completely during this time period. In the time period 2016-2018, the sentiment score kept on increasing although the slope was not as high as its predecessor time period, yet it was much higher as compared to 2013-2015 where the memories of Rana Plaza incident was fresh amongst the consumers. This observation was in line with the wilful ignorant memory effect discussed earlier. The stakeholders primarily consumers tend to avoid or boycott the accused firms at the occurrence of negative events like Rana Plaza where their should-self dominates over want self. However, with the passage of time, they tend to willfuly forget these negative ethical past of accused firms in the influence of want-self dominating over their should-self.

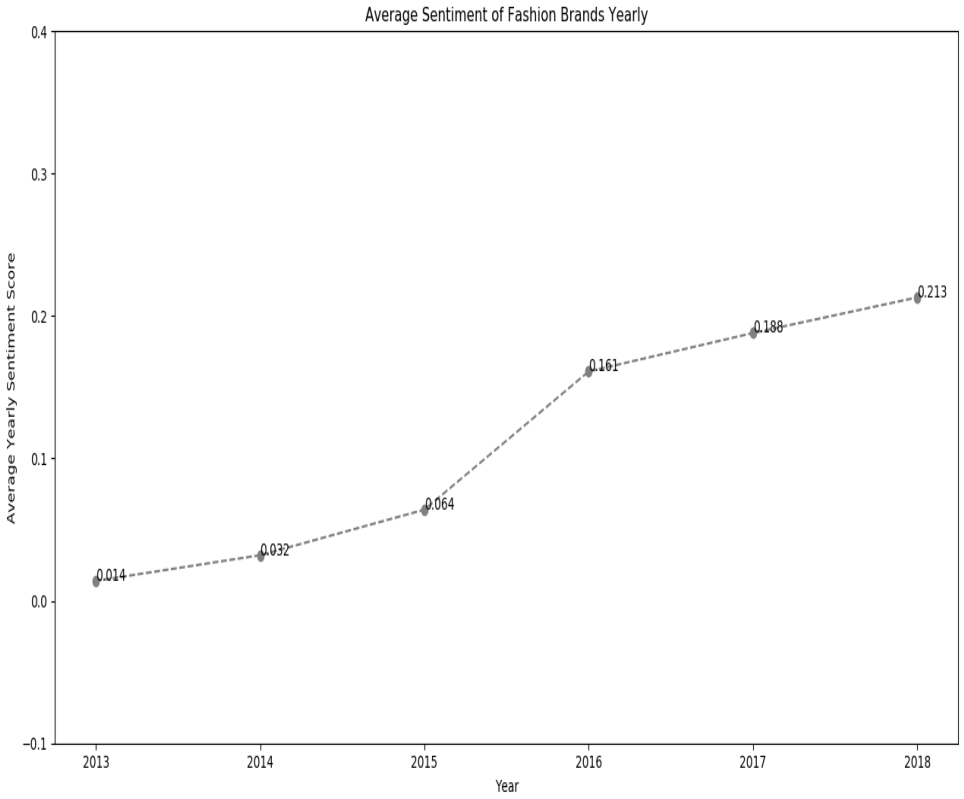

Figure 4 – Average Sentiment scores of fashion brands (2013-2018)

Conclusion

In this article, Twitter data was employed to study consumer sentiments associated with numerous fashion brands accused in Rana Plaza incident. More than 10,000 tweets were mined using multiple thoughtfully chosen keywords. Sentiment mining grounded on the Support vector machine was utilised for investigating sentiments of various stakeholders: consumers, non-governmental organizations (NGOs), environmental watchdogs, government agencies, social activists, media and human right entities towards the accused fashion brand during the five year time duration (2013-2018).

The results obtained via sentiment analysis revealed that the aggregate sentiment score of all the fashion brands combined has increased over the years since the time of Rana Plaza in 2013 until 2018. The rise of sentiment score was slow in 2013-2015 where the atrocities caused by this disasters was fresh amongst stakeholders. However, in the following time period (2016-2018), appreciable rise in sentiment scores has been recorded thereby reflecting the stakeholder's primarily consumers tendency to wilfully ignore the negative past of accused firms in line with the wilful ignorant memory effect. After elapse of certain years, stakeholders mostly consumers let their want self to dominate their decision making over their should self by knowingly ignoring the negative ethical attributes associated with a corporate firm.

This study would be insightful for corporate firms in designing their mitigation strategy in the occurrence of disasters like Rana Plaza to prevent their reputational damage thereby preventing their revenue from declining. Also, simultaneously emphasizing the significance of having sound sustainable image amongst passive stakeholders as that of Zara in this article, whose sentiment scores in year 2013 was much better as compared to that of Gap's sentiment score in 2018.

The limitation of this study is the results are generated based on information gathered from Twitter, which may not be the reflection of true opinion of the stakeholders. Future research could be conducted to address this by utilising conventional primary data collection channels: survey, interviews amalgamated with reliable secondary data sources such as company databases, sales figures, etc.

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The information exchange pyramid in construction supply chains

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Abstract
The purpose of this paper is to identify the information need in order to facilitate efficiency of the construction industry. Over 20 interviews were conducted with different actors in the construction supply chain. It was found that different actors have similar needs of information type, namely information concerning t delivery, plans and projects. Thus, the need of information can be described as hierarchical with delivery information in the bottom, delivery plans, in the middle and project information on the top. The result contributes to the current debate on information exchange in construction.

Keywords: Construction supply chain, Information need, Information exchange,

Introduction
The Swedish national board of housing, building and planning has determined that the need for new housing in Sweden 71000 per to 2025 (Boverket, 2018). Despite this, only about 50 000 homes per year were constructed between 2012 and 2019, i.e. far from the need (Boverket, 2018). The production of houses follows the economic cycles. With an upcoming recession in economics, the need for increasing productivity and lowering construction costs become even more important for reaching. There are many reasons why the construction industry do not reach the productivity needed, of which the most frequent issues are: insufficient information exchange and complex communication channels (Titus and Bröchner, 2005), low degree of digitalization (Bossen and Ingemansson, 2016), and low understanding of the need for logistics planning (Thunberg and Fredriksson, 2018). Information exchange in supply chains can decrease costs and improve productivity as a prerequisite for improved planning and control (Prajogo and Olhager, 2012). One of the consequences of lacking information exchange is decreased efficiency, illustrated in the infamous Bullwhip effect (van Ackere *et al.*, 1993).

However, to reach the efficiency boost of sharing information, the exchanged information need to be relevant and meaningful to the receiver (Kaipia and Hartiala, 2006). Understanding what information to exchange with whom in the supply chain is part of information quality (Gustavsson and Wänström, 2009). Though, what information is relevant is context dependent and the construction industry differs context-wise from other industries

by being project oriented, fragmented, opportunistic, and with temporary supply chains. Information exchanged in other industries like point-of-sales data and inventory levels, might not necessary be of the same importance in the construction supply chains. It is therefore relevant to explore what information that needs to be exchanges among which actors in construction supply chains. Briscoe and Dainty (2005) showed that attempts to integrate construction supply chains and exchange information has been hampered by the reluctance of clients and contractors to exchange information with all parties in the supply chain.

Cheng *et al.* (2010); Pala *et al.* (2016); and Samuelson and Björk (2014) all study how information could be exchanged in construction supply chains through use of IT systems and tools. Samuelson and Björk (2014) argue that a lot of information exchange is done through the use of Electronic Document Management (EDM) systems and portals; thus, rather digitizing information than digitalizing it. This still makes it difficult to exchange information as manual work on uploading, downloading, reading and extracting relevant information has to be done. Cheng *et al.* (2010); and Pala *et al.* (2016) suggest the use of IT tools like Enterprise Resource Planning (ERP) systems. However, they also stress that ERP systems many times are not developed for project driven industries and that it is difficulties in "aligning" systems between actors in a construction supply chain. They recognize the importance of understanding what information to digitalize and the importance of using IT systems for future information exchange.

As elaborated on, we need to increase understanding of what information is needed by whom in construction supply chains. Thus, the purpose of this paper is to identify the information need of different actors in order to improve efficiency in the construction industry. Construction, as a fragmented engineer to order industry, requires vast amount of information to be gathered and exchanged with several actors. The focus in this paper is on the information exchange between the actors in the construction process and the actors in the supply chain process. This interface has been identified by many as a critical area for information exchange (Thunberg and Fredriksson, 2018), illustrated in Figure 1 below.

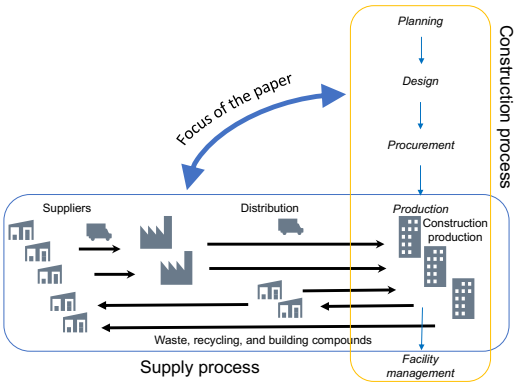

Figure 1: The area of focus in this paper.

Based on the focus of this paper, as illustrated in Figure 1, an overall classification of information needs can be that the information in question is either concerning the construction process or the supply chain process. Information concerning the construction process is based on how project management is defined by the PMBOK issued by PMI. This means that information regarding the construction process concerns the scope, time, and budget of the project; the quality of the product; procurements, human resources, and

communications necessary for the success of the project; but also information concerning risk and stakeholder management.

Regarding information of the supply chain process, focus here is on the interface between the construction process and the supply process. This means that information is exchanged through customer orders from the contractor/installation company to the supplier. A general customer order consists of agreed price, delivery quantities, delivery due-dates, delivery locations, and other relevant delivery information (Jonsson and Mattsson, 2009). The customer order can therefore be seen as consisting of one-part delivery plan (or delivery schedule) and one-part delivery information/call-off information. The former one consists of a mid-term long plan of quantities of a good to be delivered and when (type of product, amount, delivery due-date and time, delivery place, necessary documents) while the latter one consists of other relevant information of the good such as quality aspects, any hazardous aspects, contact information, help with unloading, specific roads to use etc.

To summit up, three main groups of information relevant to analyze here are project related information, customer order information, and delivery call-off information

The paper is outlined as follows. The next chapter describes the research design and methods used for collecting and analyzing data. Thereafter the empirical data collected is presented followed by a data analysis chapter. Last, the paper is wrapped up with discussion of conclusions, research implications, managerial contributions, and future studies.

Research Design and Method

Semi-structured interviews allows for an understanding of a subject from the perspective of different responders (Flick, 2009), and is therefore a suitable methods to fulfil the purpose of this paper.

The first step in the research process was to identify which actors to interview. The goal was to get a width by covering three perspectives in logistics; the goods owner, the carrier and the transport infrastructure. Therefore, responders representing seven different actors (covering the three perspectives on logistics in the construction supply chain) were interviewed: clients, contractor firms, installation companies, machine rental companies, material suppliers, recycling companies, transport actors and municipal offices. Relevant respondents were identified by an initial workshop consisting of project members of the Vinnova financed research project, DigiPlan, coming from different parts of the construction and the IT industry. A total of 23 respondents were interviewed, presented in Table 1.

Table 1: Information about the respondents.

Client	Two project managers, one construction manager, one traffic strategist
Contractor	CEO, Lean manager, IT manager, two operational logistics coordinators
Installation Company	One IT manager, one energy manager, two project manager, one central purchaser
Machine Rental Company	One project manager, one head of regional planning
Material Supplier	One head of logistics, two customer relationship managers
Recycling Company	One seller
Transport Actors	One head of logistics, three transport planner, one sustainability manager

Semi-structured interviews focusing on the following topics were held; the information needs, the consequences of inadequate information exchange, and how the information exchange is currently done.

The analysis was done by first analyzing the data derived from each actor to find common areas of information needs. This was implemented through a coding principle called thematic coding (Flick, 2009). After analyzing data from each group of actors, a cross-analysis of data from the different groups was made to see the communities and differences between actors.

Data Description

In this section the information needs, current information exchange and consequences of not exchanging relevant information is presented for each actor. The information needs for each actor in summarized in Figure 2 whereas the current information exchange and consequences of not exchanging relevant information is described in text.

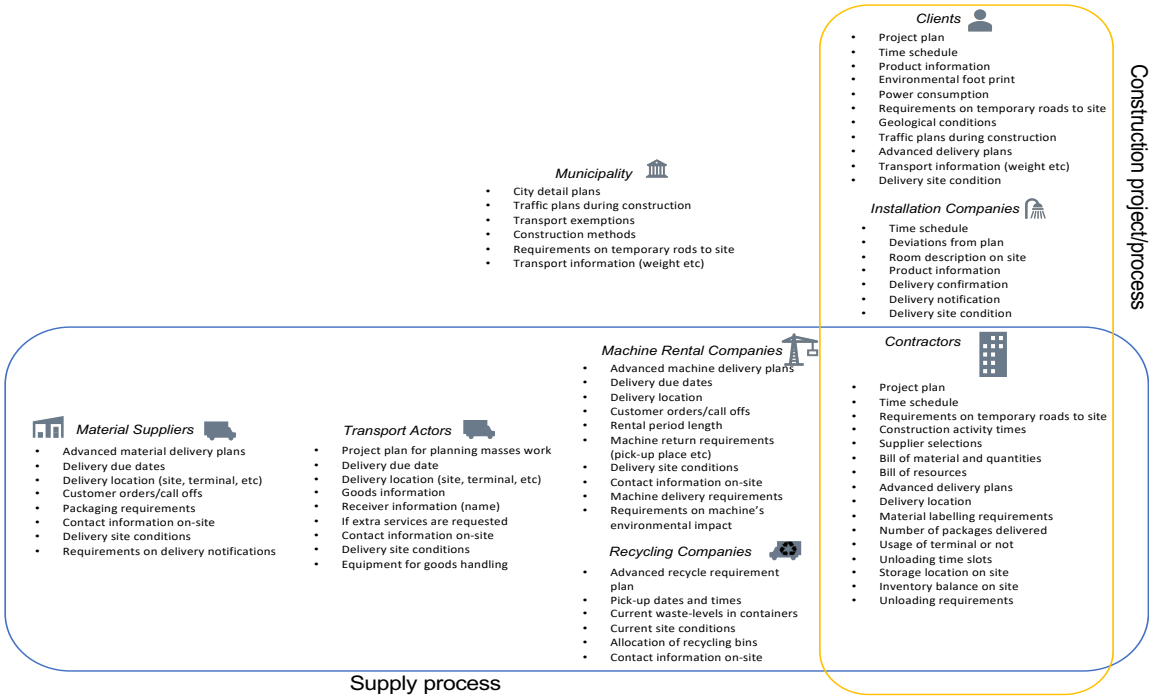

Figure 2: The different information needs.

Client/Municipality

- **Current information exchange:** Much of the information is sent via email in the form of PDF files, exchanged orally or through project portals. E.g. through tender documents, drawings, structural documents, timetables, and weekly meetings with the contractors; via meetings with the municipality or via catalogues regarding product information. Information is also sourced from detailed development plans and traffic request plans submitted to the municipality.
- **Consequences:** Impaired overall coordination of project and its impact on surrounding society and the environment. Cannot provide the authorities and the general public with the right information. Cannot ensure right type of temporary roads to be built, planning routes and dimensioning unloading sites. If the information is not updated, it is likely that decisions are made on incorrect basis.

Contractor

- **Current information exchange:** The information exchange today takes place mainly through weekly meetings with all actors on-site. Some information is exchanged internally at the contractor when work disposition plans are developed. The information is distributed to subcontractors and suppliers orally or through PDFs via e-mail. Some contractors use digital delivery calendars, updated manually.
- **Consequences:** Do not know what delivery to site is to what recipient among the sub-contractors, which increases the risk of time waste. Difficult to plan the time for a delivery, where to put the material, what resources are needed to unload the material. Use of too heavy trucks and that subcontractors store materials in the wrong place. This makes the delivery process taking longer time than necessary and the material must be moved around often. Knowing what material to go via terminal enables planning of the terminal and facilitates deliveries from there. If all activities are not included in the time plan, with associated material needs, there is a risk of missing relationships between activity and material. This can lead to delays or that the subcontractors arrive when there is no possibility for them to perform their job.

Installation Companies

- **Current information exchange:** Building meetings, team meetings, inspection protocols, drawings.
- **Consequences:** Have to move and look for material, start new activities, rush activities (several activities might be done at the same time, cannot work efficiently, wastes, a lot of ad hoc work, and bad mood in the team), chaos, and delays.

Machine Rental Company

- **Current information exchange:** Start-up meetings with contractors where checklists are used to ensure that they get the right information. Much information exchange takes place the day before shipping, by phone. It is desirable to get information via ERP systems/web-systems.
- **Consequences:** deliveries go to wrong address, machines that cannot be used on the project are delivered, and that the transporter cannot reach the construction site with large bulk deliveries. The rental company cannot provide machines and tools as they are not available nearby, leading to unnecessarily long delivery and waiting times. Nor is it possible to efficiently plan their own resources, which increases transport costs. More than necessary time is spent on managing rental lists.

Material Suppliers

- **Current information exchange:** takes place through start-up meetings with project managers and site manager at the contractor. The material suppliers' sellers have a checklist to capture what the contractor want. Call offs are made by email, telephone, personal meetings or via a web portal. Efforts are made to get more and more contractors to use suppliers' project portals.
- **Consequences:** wrong type of transport cannot be unloaded as planned or that the wrong goods are delivered, resulting in more transports than necessary. Not reaching the person who will receive the delivery may result in waste and additional work. A problem associated with the short planning of orders from contractors (i.e. that orders

the sent the same day as the need arise and that they change their orders the same day) is unnecessary transport.

Recycling Companies

- **Current information exchange:** Orders are received via an ERP system, current container locations, contact person, delivery information, and time plans are usually exchanged through start-up meeting, where recycling companies and contractors and sometimes transporters participate.
- **Consequences:** difficult for recycling companies to plan and perform their business effectively. This is reflected in deliveries that are not possible to carry through and must return to the recycling company, delays, and ad hoc deliveries.

Transport Actors

- **Current information exchange:** EDI, e-mail, and phone calls. Additional services needed are often order by phone in panic by the contractor. The rough plan for mass handling that the carrier receives in the beginning is perceived to be insufficient and rarely updated. Current delivery information given includes street address and a phone number to a goods receiver on-site.
- **Consequences:** the carrier must return material, the contractor gets the wrong material, that the contractor does not receive material, equipment deliveries and waste collections at the wrong time. In general, transport actors in most cases cannot contact construction sites directly and they have to hunt information many times.

Analysis

Figure 3 below illustrates each type of information need from the different actors categorized as either project, customer/purchase order, or call-off information. It can be seen that project information seems to be of more importance for those actors managing the project such as clients and contractors. But it also tells us that most actors are of interest of customer order and call-off information. The text below describes what each category of information consists from the point of each actor.

The information for the clients concerns necessary information for successfully realize the project in accordance to different authority claims such as impact on environment, applicable detailed development plans and traffic requirement plans, and surrounding society, but also to different customer requirements. Information such as quality of the building materials as well as its environmental impact of vehicles to site becomes important to facilitate maintenance in the future and fulfill requirements from authorities. The clients also need to know building and installation material/systems being built-in (product information) so that those who manage and maintain the installation systems later have access to the right information. Relevant project information for contractors are information regarding the actual construction process such as time plans, materials to use, suppliers to buy from, etc. However, it is also important that requirements from the customers and the authorities put on the client is handed over to the contractor. Therefore, is also information such as temporary roads to use and its bearing important for the contractor. The information need for the installation companies are similar as for the contractors with the addition of knowing when deviations in the time plan exist.

Figure 3: Categorization of information needs (project, customer order, call-off information).

The second category of information is customer order related. Those who are in most need for this kind of information are actors associated with the supply process such as suppliers and transporters. However, the contractors and installation companies act as the customer here and the coupling point between the construction process and the supply process. The contractor acting as the coordination party in the projects is in need of material delivery plans for all subcontractors and installation companies. This also includes number of packages delivered for ensuring space on-site. The contractors also raised the question of how packages should be labeled and if deliveries should go through a construction logistics terminal or not. Installation companies also report on that information about when delivery notifications will be done in order to prepare for unloading their incoming deliveries on-site. From a supplier's perspective they need to know what to deliver, when, and where. However, supplier-internal IT systems have problems with consolidating deliveries to the same construction site, e.g. if there are several contractors or addresses for the same site. This is a problem as larger construction sites almost always work under these conditions. The machines tie up large amounts of capital for the machine rental company and if information is provided in good time, they can reallocate their machines between their rental centers and thus have the right machines available on time, minimizing tied up capital. The same goes for information about when rental machines will be returned. There are many similarities among the transport actors' information needs. It concerns knowing delivery-related information such as: what kind of material should be delivered and when.

The final category of information, call-off information, is of importance mainly for those actors working with transporting goods to the site, but also for those receiving it on-site. Even the clients need some information regarding call-off information such as the weight of the transport and delivery site condition. This is important for planning future access roads in upcoming projects. For contractors and installation companies it is important with notification of incoming deliveries for making resources available for unloading deliveries.

The contractor also needs unloading time slots for all their subcontractors, where they will store materials, how much will be stored. They also need to know if the equipment for unloading goods is necessary, turning radius of the trucks, weight etc. For the transporter actors is it necessary with unloading time slots, contact information on-site and site condition for knowing how to enter and exit the construction site. It is also necessary for them to know if extra services such as unloading help, help with transferring goods to mounting location, etc is ordered or not.

Discussion

Based on what is presented in previous chapters, it can be seen that different actors have different information needs in the interface between the supply chain process and the construction process, as summarized in Figure 4 below. The figure should be read as each layer in the pyramid adds to the lower layers.

As Kaipia (2009) notes, it is of utmost importance to exchange for the receiver relevant information. Exchanging too much information can counteract the positive effects of exchanging information, leaving the receiver to sort out relevant information in a vast amount of information (called *information overload*). This counteracts information quality, i.e. not meeting the receiver's demands of information (Gustavsson and Wänström, 2009). The kind of information needed depends largely on the actor's role in the supply chain. What we can see is that transport actors foremost need delivery call-off information, such as address, contact persons, slot times, site conditions including access roads and parking spaces, unloading spaces, storage locations, and the need for unloading facilities. Having this information enables them to easily plan and control their deliveries, which avoids consequences such as searching for recipient staff and unloading spaces when arriving at site and increasing efficiency in their deliveries. This in turn reduces the risk of transporters just dropping goods outside the construction or to anyone nearby (a real problem). Enabling all project partners, including all subcontractor and in turn their subcontractors, to have access to the above-mentioned delivery information will increase the delivery reliability.

The next level of information need concerns all those actors responsible for delivering materials, machines, or waste management services. They as the transport actors also need delivery information as they hand them over to the transport actors, but they also need information about delivery plans in order to plan their deliveries and their operations. Delivery plans include time and date for deliveries and what to deliver and in what amount, if packages should be marked, and whether it will be stored on a distribution terminal or not. Providing suppliers with an updated picture of when their materials/machines/services are needed at the construction site is important for them to better plan their work and this information can reduce impacts in the form of extra transport and unnecessary storage, both on site and at the material supplier. Furthermore, this also improve the availability of these goods to the contractors.

The final level of the information need applies to all those actors who are required to perform work on site or are responsible for the product after it is completed, i.e. contractors, installation companies, and clients. They need information about the products and building material and how the project's actors plan to perform their work, for coordination purposes. Project information includes e.g. time plans, involved actors to be coordinated, product information, and detailed development plans from the municipality. In addition, different site conditions are included such as load-bearing on roads and information about surrounding buildings and roads.

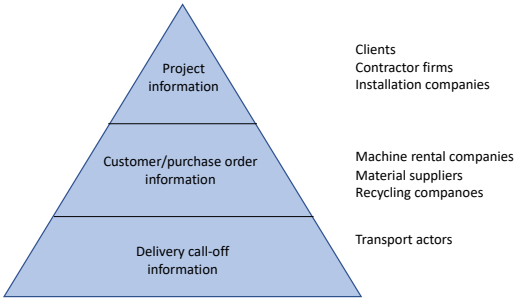

Figure 4: The hierarchy of information needs.

The information needs hierarchy in Figure 4 helps in understanding that the closer an actor is to the customer (i.e. developer), the greater the information needs is. However, it is not self-evident that all actors on the top layer (project information) need the underlying information. Those with a transport infrastructure perspective on logistics constitutes an exception, like the municipality. They only have a certain need of project information, the one that relates to how other infrastructure and social functions will be affected by the construction project. They are not primarily dependent on delivery information and delivery plans as suppliers and carriers are and are thus located outside the pyramid of information.

Conclusions

This study has focused on information needs and provided a suggestion on how to look at information needs in the interface between the supply chain and the construction process. This has been achieved by interviewing actors from different parts of a construction project that has different perspectives on the construction process and supply chain process interface: clients, contractors, installation companies, machine rental companies, material suppliers, recycling companies, and transport actors. Similar information needs were identified among most actors, but some of the information needs identified differed. The information need among the actors in a construction project can be divided into three hierarchical layers, see Figure 4, where the bottom layer regards delivery call-off information, found to be relevant for everyone in one way or another. The middle layer regards customer/purchase orders, information relevant to everyone except the transport actors but especially relevant to machine rental companies, material suppliers, and recycling companies. The top layer is project information and is only relevant to clients, contractors, and installation companies.

Some of the challenges associated with increased information exchange in the construction industry are: (1) there are many actors who need information and need to exchange information; (2) not known what information is needed by whom and when; (3) information is stored in many IT systems without the possibility of exchange between systems (4) who should take the coordination responsibility. Questions like who generates what information, where should it be stored, who should have access to it, what are the value for the companies in exchange this information, who should be responsible for collecting, storing and providing access to the information needs to be answered. The effects of information exchange also need to be quantified.

The result of this research contributes to the academy but also provides practical benefits to different organizations associated with the construction industry. From an academic point of view, research continues on both Pala *et al.* (2016) and Samuelson and Björk (2014) on information management and digitization. An interesting insight was that all information may

not need to be digitized in the way Pala *et al.* (2016) suggests (such as ground conditions) but may be better suited according to a well-structured and accessible EDM system that Samuelson and Björk (2014) highlight. It also contributes by showing that information needs are context dependent as suggested by Kaipia (2009) and that improved information quality can improve efficiency as suggested by Kaipia and Hartiala (2006).

There are practical benefits for several industry actors. From a municipality perspective, the results of this study can be a part of an investigation, which deals with how collaboration in the construction industry can be improved. The study shows what information needs to be exchanged between municipalities, contractors and clients during a construction project to minimize the impact on third party. For contractors, this research contributes with the knowledge that what seems to be irrelevant information to some is actually information that almost everyone needs, such as delivery plans and delivery information. This can provide better resource utilization for all involved. One last positive impact that the work contributes to is an increased understanding among IT system vendors about what kind of information needs to be included in different systems. Industry standard Beast e.g. provides a clear understanding of what kind of delivery information needs to be exchanged between contractors and suppliers. However, Beast lacks information needs from municipalities and clients, and does not include any information other than the delivery information.

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Making sense of cost-driven outsourcing

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Abstract
This study contributes to operations management and supply chain management literature and in particular that on cost-driven outsourcing. It explores events, actions and altered management situations that followed cost-driven outsourcing and, how senior management enacts and makes sense about organizations' cost-driven outsourcing. The study widens the understanding of cost-driven outsourcing and complements contemporary research, which increasingly challenges outsourcing decisions based on pure cost efficiency considerations and calls for further understanding of cost-driven outsourcing. It advocates that cost-driven outsourcing based on narrowly confined decision-making schemes can hamper organizations' strategic development and stresses managements' concerns regarding competences, revenue and strategic opportunities.

Keywords: Outsourcing; Supply chain management; Case study.

Introduction
Cost reduction is a prominent argument for organizations' to outsource and relocate production, and during the last four decades jobs have migrated from high-cost to low-cost areas (e.g. Kakabadse and Kakabadse, 2002; Kinkel and Malloca, 2009; Kinkel, 2012; Drauz, 2013). However, research on offshore outsourcing increasingly reports a lack of achieved benefits from cost-driven outsourcing (e.g. Kinkel, 2012, Larsen et al, 2012), and a relative increase in backshoring and insourcing (Tate, 2014).

Following these tendencies, authors now call for a broadening of our understanding of the outsourcing and insourcing decision-making processes (Kinkel, 2012). They urge a depart from a pure cost focus to an enquiry into how managers take into account the broader value chain perspective in their sensemaking and their decisions related to opportunities in outsourcing and insourcing (Young and Macinati, 2012). Specifically there is currently scarce empirical knowledge on, how senior managers make sense of the managerial consequences following cost-driven outsourcing. Therefore, the purpose of this research is to deepen our understanding of the managerial sensemaking process in relation to cost-driven outsourcing. A multiple case study approach is applied to explore the effects, actions and altered management situations, which followed cost-driven outsourcing in six different companies. The following research question is addressed: *How does senior management enact and give meaning to the managerial implications that follows cost-driven outsourcing?*

Cost-driven outsourcing decisions
During the last two decades, literature on production relocation has been growing. This includes literature on outsourcing, insourcing, offshoring and backshoring. Also, and

more recently the number of studies that explore and problematize decisions to outsource value chain activities has been growing.

Defining outsourcing

Outsourcing and offshoring are sometimes used as synonyms. However, the concepts differ significantly in nature and purpose (Kinkel and Maloca, 2009). Offshoring is a '*spatial*' concept within literature and denotes relocation of production outside the home country. Outsourcing, on the other hand, does *not* indicate a geographical relocation (Olsen, 2006), but is defined in terms of '*ownership*' and the organization's degree of vertical integration. Thus, outsourcing reduces the share of the company's in-house production related to the total value creation of the final product (Drauz, 2013) and implies an alteration in the scope of the organization's operation. In this research, outsourcing denotes such a change in ownership, where a company transfers production to a third party outside the formal boundaries of the organization.

Antecedents to outsourcing

Many factors have been reported as antecedents to outsourcing. Most predominantly however is 'costs', or rather 'cost reduction' as a motive for outsourcing (e.g. Kakabadse and Kakabadse, 2002; Arlbjørn et al, 2013). The cost-argument often relates to expected reductions in direct operating costs due to regional differences in wage levels. However, literature also irradiates other, though still explicitly cost-related reasons for companies' outsourcing decisions: Reduction in transaction costs (Kakabadse and Kakabadse, 2002); assumed differences in productivity (Arlbjørn et al, 2013); increased capacity utilization (Kinkel and Maloca, 2009); and reduction in capital layout and capital costs (e.g. McFarlan and Nolan, 1995).

In relation to other antecedents to outsourcing the following have been reported in literature: Access to other competences and skills (Arlbjørn et al, 2013; Drauz, 2013); altered organizational focus on core competences that has made certain activities less strategic important (McFarlan and Nolan, 1995; Kakabadse and Kakabadse, 2002) and vicinity to customers (Kinkel, 2012; Drauz, 2013). Accordingly, these motives for outsourcing fall in a somewhat broader strategic category that embraces the organizations' core competences and position in the value chain.

Failed cost-driven outsourcing

Research reports increasing concerns regarding, cost-driven outsourcing decisions based on narrowly confined cost efficiency considerations (Kinkel, 2012). These more contemporary ideas stem not only from studies on the effectiveness of outsourcing but also from studies exploring the antecedents to insourcing of previously outsourced production. Some contributions even suggests that a reverse shift in production location is understood better in a sequential empirical setting (Kinkel and Maloca, 2009).

In addition, several studies direct their attention to the discrepancies between expected and realized costs (e.g. Veltri et al, 2008; Kinkel and Maloca; 2009; Arlbjørn et al, 2013; Drauz, 2013). These discrepancies manifest themselves in a variety of ways. That is for instance in: Increased cost of coordination and monitoring (Kinkel, 2012); differences between expected and realized productivity (Arlbjørn et al, 2013); quality breaches (Arlbjørn et al, 2013); and reduced capacity utilization (Kinkel and Maloca, 2009).

Outsourcing decision-making

Most literature on outsourcing decision-making is dominated by contributions applying a transaction cost perspective (Larsen et al, 2012) or a resource-based perspective (Liao et al, 2009) in order to understand and normatively guide outsourcing decisions.

Although these contributions are highly valuable in broadening our understanding of the complexity necessary in making outsourcing decision not only taking into account the labor cost dimension, they also fail to see outsourcing decisions as embedded in a more complex and dynamic practice. Kinkel (2012), for instance, argues that decision-making schemes should embed qualitative environmental factors and advocates that organizations in their practices integrate dynamic concerns and use scenario planning. Along such more complex perspectives, academia also directs attention to loss of knowledge (Drauz, 2013), thus adds a knowledge-based perspective (Liao et al, 2009).

Another problem is that the many reported cases of failed cost-driven outsourcing, challenges the suitability and robustness of the outsourcing decision-making practices actually performed in firms. However, literature is rather sparse on attempts to understand these practices and do only rarely follow outsourcing and insourcing decision-making processes and its embedded managerial reasoning in empirical settings.

Design, methodology and approach

The presented research takes a philosophical stance in pragmatism (Bernstein, 2010) and adopts a sensemaking perspective (Weick, 1995 and 2001). Sensemaking is in this research understood as the process of '*reciprocal exchanges between actors (Enactment) and their environments (Ecological Change) that are made meaningful (Selection) and preserved (Retention)*' (Weick et al, 2005, p. 414) as shown in Figure 1.

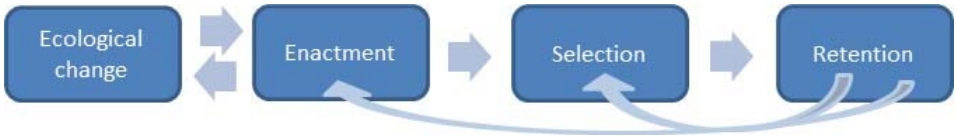

Figure 1 – The connectivity between Ecological change, Enactment, Selection and Retention. Based on a simplification of the model presented in Weick et al, 2005, p. 414

This paper has an onset in senior management's enactment. Enactment '*is first and foremost about action*' (Weick, 1995, p. 36), which creates new understandings. If these are selected and retained, they provide a new perspective, which is subject to the ongoing, reciprocal exchange with changes in the environment. Observed discrepancies between expectations and experience become instances for new actions, enactment and the making of sense. Therefore, the events, actions and altered management situations that followed the cost-driven outsourcing come into the forefront, when we study, senior management's enactment and, in turn, their formation of meaning about the organization's outsourcing.

In order to track and portray the effects, actions and altered management situations cost driver theory and taxonomy were applied (Shank and Govindarajan, 1993; Anderson and Dekker, 2009). Specifically the structural properties of the organization understood as its scope, scale, competences and complexity, i.e. the breadth and depth of the product portfolio including its supporting service offerings, were used in the analysis. Thus, based on this perspective we assume that structural decisions defines the cost *structure* and confine the *executional* maneuverability of the organization. In relation to executional cost drivers, quality, capacity utilization, flexibility and management of relationships were included in the analysis.

The research utilizes a qualitative research methodology and mobilizes a multiple case study approach. With support from the national industrial confederation, six companies were approached and selected as cases. They are non-deviant and non-extreme cases, share fundamental strategic and operational similarities and are larger manufacturing companies with own international affiliates. They produce different tangible products, which are augmented by supportive technologies and services. The organizations operate as suppliers in international business-to-business environments. All have undertaken cost-driven outsourcing, which structurally altered the scope of their in-house upstream operation; i.e. altered their backwards integration. In addition, all case organizations have to some extend insourced previous outsourced activities. For all involved firms their overall corporate strategies had remained unchanged since their outsourcing.

Data was collected based on interviews with senior management and archival material (e.g. accounts, investment appraisals). In total, 31 interviews were conducted in the six different organizations.

During the first analysis of transcribed interviews and archival material, data was coded and presented as emplotted narratives. Emplotted narratives introduce a '*structure that allows making sense of the events reported*' (Czarniawska, 2004, p. 122), which includes '*the chaining of cause and effects or stimulus and response into a pattern, structure or network*' (Boje, 2001, p. 108). This enabled the linking and explication of structural decisions and executional implications into a more coherent whole. We applied both a '*feedforward*' and a '*feedback*' strategy (Czarniawska, 2004, p. 119). The former emphasizes the chronological account of the events, actions and altered management situations retrospectively in a historical process perspective to represent the organizing process, the organizational transformation and ecological changes. The purpose of the latter is to achieve an understanding of among others the cues (e.g. Weick, 1995 and 2001) that interweaved in the organizing process; e.g. cost calculations, cost representations and similar insights into cost structures and drivers. In addition, the research applied a '*zooming in*' approach that enriches the accounts and a '*zooming out*' approach, which entrenches details to a larger picture of the organization (Czarniawska, 2004, p. 120).

Thus, the narrative approach exhibits plausible explanations for the events, actions and altered management situations and in turn the formation of management's perspectives and meaning about the cost-driven outsourcing that had taken place. The development of the narratives was an iterative process moving between the field and the literature. Narratives-in-the-making were shared with respondents during the research process and often prior to interviews and the gathering of additional data. Thus, they formed part of the basis for further probing and documentation. The final case narratives were all subject to approval by senior management.

Case study findings

The research found that all case organizations experienced numerous effects following the cost-driven outsourcings, which surprised the organizations beyond that of simple calculative errors. Some of these effects were completely new to the organizations in the sense that they have not formed part of the decision-making schemes. Other unexpected effects had been stipulated beforehand, but wrongly as to their operational impact. The unexpected effects required actions that incurred costs. This section unfolds these unexpected effects and the subsequent managerial actions. These actions, in turn, enacted new environments in the form of new understandings and altered managements' situations as well as new, unanticipated, selected and retained managerial perspectives.

Immediate and unexpected executional effects and subsequent actions

The involved case organizations' outsourcing ventures were all cost-driven, and all organizations outsourced primary activities, which altered their vertical scopes. Our analysis found that all case organizations experienced more or less immediately, unanticipated executional effects that required managerial intervention.

The analysis found many examples of breaches in quality of the intermediate products, which were now produced by suppliers. In addition, many issues in terms of lack of flexibility in the operations were identified after the cost-driven outsourcing decision was implemented. Another set of issues related to the fact that all case organizations had to implement extra initiatives related to the management of their inter-organizational relationships and this more than expected. These initiatives were for instance remediates for monitoring and enforcing the relationship, and this incurred costs. Table 1 lists examples of identified unexpected effects. Our analyses also demonstrated, how the executional effects were highly interrelated. One example was an instance of a quality breach, which required management actions and remedies such as a stop/decrease in in-house production. This in turn, affected in-house capacity utilization in organization 6.

Table 1 – Examples of unexpected immediate and interrelated executional effects

Company	1	2	3	4	5	6
Main structural outsourcing effect	Altered Scope	Altered Scope	Altered Scope	Altered Scope	Altered Scope	Altered Scope
Examples of immediate (and major) executional effects	Quality/ Relationship	Flexibility/ Relationship	Capacity utilization/ Flexibility/ Relationship	Quality/ Flexibility/ Relationship	Relationship /Flexibility	Quality/ Relationship
Examples of interrelated executional effects	Quality – Capacity utilization	Quality – Capacity utilization	Capacity utilization – Relationship	Quality – Capacity utilization	Capacity utilization – Relationship	Quality – Capacity utilization

The connection between flexibility and that of the management of relationship is another example of interrelations between the executional factors that the involved organizations experienced. Here, organization 5 experienced a larger need for relationship management resources than expected prior to the outsourcing decision; and that was both upstream with the supplier and downstream towards the organizations' customers. The findings in Table 1 by large confirm existing contributions on effects of outsourcing and various reasons for insourcing, although the immediate effects are more prominent within literature compared to reflections upon the nature and extent of the interrelated effects.

Senior management acted upon all the immediate and interrelated effects. As an example, organization 6 who experienced breaches in quality and subsequent effects that materialized in reduced in-house capacity utilization took obvious management actions in respect to their operational problems. Management put additional quality control in place and increased stocks of the intermediate product now provided by the supplier. In addition, senior management strengthened the enforcement of the relationship and contract. The other organizations also took actions that are manifest and thoroughly explicated in operations management and supply chain management literature.

The structural concerns and enacted understandings

It is likely of no surprise that the executional effects and related actions just reported, both seen in isolation and intertwined, evoked senior managements' structural considerations. This is demonstrated in this section, where we again use organization 6 as an example.

The cost-driven outsourcing altered all organizations' scope in their production (i.e. their vertical integration), and some companies experienced immediate quality breaches. Figure 2 illustrates, how senior management in organization 6 acted upon the encountered effects and evoked an altered understanding.

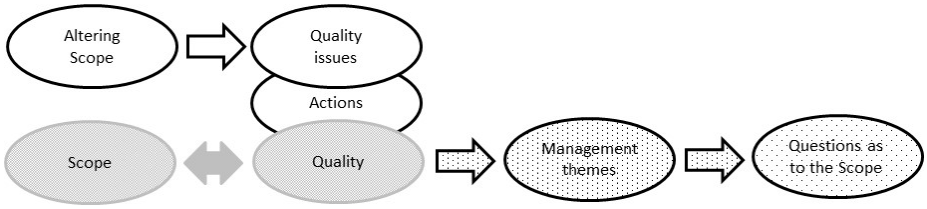

Figure 2 – A single structural and executional effect in Organization 6

This enacted an understanding that enabled sensing the discrepancies and anomalies compared to the company's expectations prior to the cost-driven outsourcing. It followed, that senior management increasingly questioned both the comprehensiveness of the outsourcing decision-making scheme and, perhaps more important, the scope of the organization. Simply stated, the alteration of the scope lead to quality breaches that required action, which in turn ignited managerial interest and queries related to the new scope. Thus, senior management enacted a new understanding of the relationship between scope and quality (see the grey-toned ellipses in Figure 2) and raised management issues that questioned the scope (see the 'spotted' ellipses in Figure 2).

Senior management also enacted new understandings about other structural properties because of the interrelated executional effects. The aforementioned interconnectivity between breaches in quality and in-house capacity utilization in organization 6 brought forward the relationship between capacity utilization and scale. This is well known within production economics and operations management. Thus, senior management not only commences questioning the scope due to breaches in quality as illustrated in Figure 2. Senior management also took actions in relation to the in-house capacity issues (e.g. increased stocks), which spawned from the quality issues. Thereby senior management also enacted structural queries regarding the scale of the in-house operation. The relationship is portrayed by the 'spotted' ellipses in Figure 3.

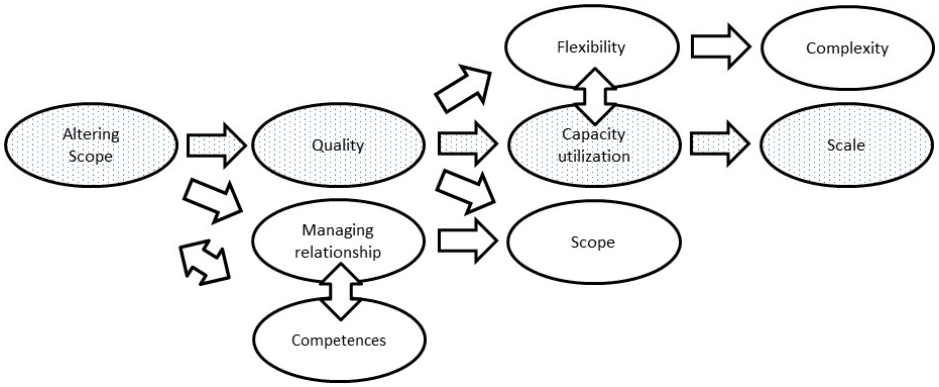

Figure 3 – Structural and executional properties and their interconnectivity in organization 6

Thus, senior management enacted new understandings of the relationships between the fundamentally different structural themes of scale and scope. This did not form part of the decision-making scheme prior to the outsourcing.

The issues of quality and in-house capacity utilization were interrelated with the issue of flexibility in upstream production and downstream delivery. Flexibility was part of the concerns prior to the outsourcing decision. However, upstream and downstream flexibility were affected more than assumed, and therefore called for unanticipated management interventions. In addition, our study also found that the issue of flexibility and associated management remedies (e.g. stock and inter-organizational relationship management) induced structural themes in relation to complexity and internal competences in organization 6. The latter structural theme of competences, however, mainly related to an emerging, ongoing exchange with management of linkages and scope. This is illustrated by the white ellipses in Figure 3 above.

New enacted organizational perspectives

This could have been portrayed much more complicated, if Figure 3 had included all the effects and actions in our study. However, this is not necessary to convey the idea that new meanings steamed from senior management's continuous enactment; an ongoing creation triggered by continuously enacted understandings and ecological changes. In addition, competences were not only about capabilities in relation to altered operational tasks associated with the management of new inter-organizational (and intra-organizational) linkages. The concerns about structural property of competences also emerged from within due to among other evolving ideas about the organizations' abilities to develop new products. The study also found conditions outside the organizations that primed these management queries. Altered external conditions (e.g. change in customers' requirements and new emerging markets), for instance, fostered the calls for competences in product development. This accounted for all the organizations though differing in nature and magnitude.

All organizations to some extent insourced previous outsourced production, although the insourcing was not fully comparable to the previous outsourcing. One organization for instance only partly insourced previous outsourced production, and the organization later sold off the production to another company. However, the organizations' insourcing of production addressed, at least partly, the same activities in the value chains, and the overall corporate strategies remained unchanged.

Table 2 – Some enacted structural themes and main insourcing reasons

Company	1	2	3	4	5	6
Examples of (main) enacted and interrelated structural concerns in the management perspectives	Scope, Scale and Competences	Scale, Competences and Complexity	Scale, Scope and Complexity	Scope, Scale, Competences, and Complexity	Scope, Scale, Competences, and Complexity	Scope, Scale, Competences, and Complexity
Main reasons for subsequent insourcing	Scope/ Scale/ Executional issues	Scope/ Competences/ Complexity	Scope/ Executional issues	Scope/ Scale/ Competences/ Complexity	Scope/ Scale/ Competences/ Complexity	Scope/ Scale/ Complexity

Table 2 summarizes some of the more significant structural themes that senior management enacted after the outsourcing decisions. In addition, the table provides an overview of the major reasons for the subsequent insourcing.

Discussion of perspectives in cost-driven outsourcing

The analysis shows, exemplified primarily by organization 6, how the case organizations did prepare the outsourcing ventures with the intention of adopting the most appropriate

structure and approaches. In more detail, all the analysed organizations were well prepared in taking into account the structural change embedded in their cost-driven outsourcing, the organizations' aim to align with the corporate strategies as well as for a smooth implementation and subsequent operation. However, all organizations experienced numerous unanticipated effects, which affected each other and created new enacted understandings and perspectives.

The ongoing creation and management perspectives

The emplotted narratives introduce a relationship between the events, actions and altered management situations by connecting 'cause and effect' and 'stimulus and response' into a structure (i.e. Boje, 2001; Charniawska, 2004). They evidently exhibit that senior management enacted new understanding of the relationship between executional issues such as quality and capacity utilization and the structural properties of scope and scale of the operation. These are well known to academia and practitioners, and by large the study confirms contemporary research's contribution as to numerous and unanticipated effects from the cost-driven outsourcing (e.g. Veltri et al, 2008; Kinkel and Maloca; 2009; Arlbjørn et al, 2013; Drauz, 2013). In addition, our case analysis demonstrates the limited usefulness of narrowly confined decision-making schemes that rest upon pure cost efficiency considerations. Thus, the study confirms contributions that call for a broader and more dynamic perspective on the outsourcing; thus in the management of the companies' value chain (e.g. Kinkel, 2012; Young and Macinati, 2012).

The research also highlight that the normative and prescriptive decisions-making models may be contested for not attributing sufficient emphasis to the notion of the ongoing creation. Our exploration demonstrates that there is an ongoing creation at the senior management level, which involves alteration of the perceptions about the relationship between executional and structural themes as well as the formation of new, unanticipated relationships between various structural properties in the organization. This includes relationships between the organizations' structural properties such as the scope in terms of vertical integration and the scale mainly related to the horizontal integration as well as the organizational competences and complexity. In addition, the analysis shows how cost-driven outsourcing and the possible effects, actions and altered management situations are contextual. Although the organizations shared several similarities, the effects of the cost-based outsourcing endeavor evoked a process of very different actions, understandings and management perspectives.

The study suggests that the relationships between scope and quality as well as that of scale and capacity utilization is subject to somewhat generic management issues, even when they interrelate. However, the elevation of the management perspectives regarding the structural properties of competences and complexity seem more unpredictable and subject to an even more complex process in the organization. It is plausible that the enacted environments and the subsequent understanding of complexity is a multi-facetted construct with both an internal and an external customer-oriented dimension. Thus, it is plausible that it is not only a question of breadth and depth in the product portfolio including its service attributes such a flexibility in delivery. This also becomes a question, which relates explicitly to the process of managing the linkages across the organization and inter-organizationally and, in turn, how that connects to the offerings downstream. In terms of the organizational competences, this also has both an internally as well as an externally driven aspect. The latter, of course, associates to the competences needed in product development to meet market and customer requirements, thus it ties to

complexity in the product portfolio, not least in terms of process-related service offerings such as flexibility in delivery, while the former interconnects with the executional issue of managing the inter-organizational relationships.

A structural property perspective on cost-driven outsourcing decisions

This indicates that a transaction cost economics approach; a knowledge-based perspective; and a resourced-based view on cost-driven outsourcing appraisals is not sufficient. Thus, it is plausible that organizations would benefit from extending decision-making schemes in cost-driven outsourcing with appraisals that problematized the relationship between key structural properties of the organization in various scenarios.

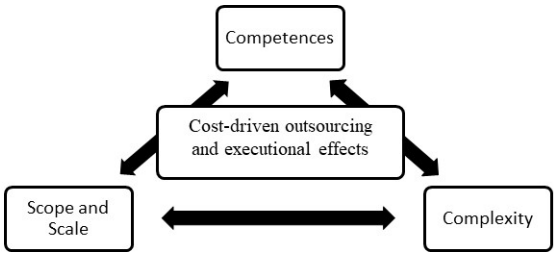

Figure 4 – Structural properties in cost-driven outsourcing

Building on this, Figure 4 relates the structural properties and the various, possible executional effects and indicates that cost-driven outsourcing, despite its straightforward conception within literature, is a highly complex and contextual decision. This, in turn, fundamentally questions outsourcing based on a perspective, which solely rely on narrowly confined cost considerations related explicit, and solely, to scope-related issues.

Conclusion

The presented research complements contemporary research, which calls for a further understanding of the managerial perspectives and implications of cost-driven outsourcing (Kinkel, 2012). The findings suggest that senior management enacts organizational perspectives that embed new understanding of the relationship between the various executional themes and structural properties of the organization. Hence, cost-driven outsourcing should be understood as an ongoing creation with highly complex interconnectivity between events, actions and new management situations.

The study challenges normative and prescriptive decision-making models and approaches. It suggests that while such might be rooted in views based on transactions cost economics, knowledge and resources, or a combination hereof, which indeed offers highly valuable insights, it is plausible that organizations would benefit from adding a structural property perspective, which recognizes the contextualized interconnectivity between the structural properties and the ongoing creation and organizational learning.

The research presented in this paper further supports contributions, which advocate that cost-driven outsourcing based on narrowly confined decision-making schemes can hamper the organizations' strategic development. Such endeavors are partial per se. They are literally 'experiments' due to among other an absence of management concerns regarding competences and the ongoing formation of sense. In that respect, the need for certain competences is also related to product development and meeting markets' and customers' needs. Revenue and strategic opportunities becomes apparent foci even in simple cost-driven outsourcing decision-making schemes.

Thus, this research supports contemporary research and adds a structural property perspective that also infers revenue and strategic opportunities. It gives a contemporary view that counterbalance ideas of alignment and adaptation. However, we need more case studies to develop our insights into the complex implications of cost-driven outsourcing and the forces that govern management practices. We suggest in particular that future research further explores the interconnectedness between structural concerns such as scope, scale, complexity and competences in outsourcing. This is important as structural changes embed substantial risk and define executional maneuverability; thus, in turn connects to corporate and competitive strategies. Although, this study does adopt an empirical setting based on known sequential events prior to the commencement of the study, and contributions suggest possible benefits from such an approach (e.g. Kinkel and Maloca, 2009), it would be of value to opt for longitudinal studies, which are commenced at the very beginning of the cost-driven outsourcing.

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Social Supply Chain Risk Management: A Case Study in a Brazilian Company

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Abstract

This paper discusses the social risk supply chain management through a case study in a Brazilian company. We map the social risks and the main consequences of these risks tracked by the organization. By comparing the findings of the case study with the literature, the paper contributes to the academic studies with 2 new social risks, the main consequences of these risks, and the description of the company's strategy to manage its risks.

Keywords: Social Risk, Risk Management, Case Study.

Introduction

Academic researches in supply chain risk management (SCRM), in general, address the risks that occur due to interruption at some point in the chain, which later blocks the flow of materials, funds or information among the entities of the supply chain (Bode et al., 2011). Therefore, they approach the traditional view of SCRM, with the focus on avoiding interruptions along the chain to reduce financial losses that this disturbance can cause (Bode et al., 2011; Hofmann et al., 2014).

The risk management literature is diverse, but researches on financial risks have been studied for a longer time and have greater repercussion due to significant economic changes for organizations. However, this classical approach focused on financial performance does not consider the social view to be purely economic (Busse, 2016).

The social risks started to gain academic attention with the introduction of the concept of Triple Bottom Line (Elkington, 1994). Nevertheless, research on the social risks in which the supply chain of a company may be involved is still needed (Tang, 2018). Basta et al. (2018) also argue that when addressed, social risks are mostly

limited to labor rights and working conditions.

Therefore, the present paper aims to study the social risks in supply chains through a case study answering two research questions:

(i) The social risks and consequences found in academic literature are found / relevant also in a business enterprise?

(ii) What strategies does the company use to manage its social risks?

The case study considers a Brazilian company of Cosmetics, involved in the manufacture, industrialization, distribution and sale of cosmetics, fragrances and personal hygiene products. We compare and validate the results of the case with the list of 24 social risks and 13 consequences proposed by Cunha et al. (2019).

The remainder of the paper is organized as follows: Section 2 addresses the case study methodology. Section 3 presents the results and discussion of the case study, followed by a section presenting the concluding remarks and suggestions for future research.

Research Methodology

The present research adopted the case study methodology proposed by Yin (2013), composed of six steps: plan, project, preparation, collection, analysis, and sharing.

The plan aims to identify the relevant situation for the accomplishment of the case study in detriment to other research methods. Thus, the event to be studied within the context of real life is the management of social risks in supply chains.

We present a unique case as an exploratory study of a theme little covered by the literature. The present research considers common case study to capture the circumstances of a daily situation to provide processes related to some theoretical interest.

The project was carried out with a Brazilian company of Cosmetics recognized for its vision of sustainability, the principle of generating positive impacts on society and for being an organization that combines economic growth with the promotion of social and environmental well-being. The research question compares the social risks and the consequences that these risks can generate for a company covered by the academic literature with what is observed in a supply chains of a real company. The criteria for data interpretation to actual data that can reinforce, complement or contrast with the results derived from the academic literature to bring new insights to the strategies to mitigate these risks.

In the preparation stage, we developed the case study protocol, defining candidates, selecting the final case to be studied and synthesizing the initial definitions of the study.

Data was collected through documents made available by the company, interviews, and secondary documents from the internet. First, the professionals of the studied company answered an online questionnaire. This questionnaire was based on Cunha et al. (2019) and made available to respondents through the SurveyMonkey platform. Then, we conduced face-to-face interviews with open questions based on answers previously reported by company professionals. Finally, we compiled documents made available by the interviewees and secondary materials available on the website of the company studied.

The professionals considered in these interviews effectively deal with the risks of the company, and are: (i) the Supply Manager, responsible for Performance

Management and Relationship with Suppliers; (ii) the Audit Coordinator of Supply Management, and (iii) the Compliance Coordinator.

The data analysis considers the pattern matching technique, in which the theoretical reference is used as prognosis and compared with the results of the case study.

Finally, the sharing stage consists of the publication of the present paper.

Results and Discussion

The company's mission is to promote well-being through the mobilization of a network of people capable of integrating scientific knowledge and the sustainable use of the rich Brazilian botanical biodiversity, in order to deliver the cosmetics manufactured from natural elements of the Brazilian flora, processed, distributed and sold.

Through the online questionnaire, it was possible to understand that the company has three areas responsible for its risks, namely: (i) the Supply area, which deals with risks related to suppliers; (ii) the legal and Compliance area, an area concerned with issues related to labor laws, including the risks of corruption and bribery; (iii) the area of Corporate risks, encompassing other risks.

Through the interviews, it was possible to understand that the Brazilian cosmetic company has means of identifying social issues present in its supply chain through an audit carried out periodically by the company, through a complaint from one supplier over another (which has already occurred with a textile supplier), and through the media.

The interviewees stated that the company has a list of risks predefined by a multidisciplinary group (encompassing area of supplies, risk management, legal area and relationship with suppliers), which is reviewed every two years and serves as the basis for the supplier's audit checklist.

Among the 24 social risks found in Cunha et al. (2019) and listed for the interviewees, 11 of them are not on the list of pre-defined risks to be audited for the studied company, these being: unfair or low wages, although the same worries about workers' compensation however, it still cannot reach the level of detail of the amount paid by its suppliers to employees; access to drinking water; access to basic sanitation; unfair compensation; reallocation or rupture of indigenous peoples; exposure of communities near the end of activity; unavailability to public facilities; expropriation; exposure to unemployment; reallocations without explicit grounds and equality before the law.

Some of the social risks present in Cunha et al. (2019) do not fit directly with the area of cosmetics addressed. However, some risks such as low or unfair wages, exposure of communities close to the end activity and unavailability to public facilities are suggested as possible risks to be added to the list of social risks to be audited as they can cause significant damages to the company.

The respondents added two social risks to the list of Cunha et al. (2019): Corruption and Bribery and Compliance with Local Labor Legislation. Corruption and bribery should be added to the list presented in Cunha et al. (2019), as they may create critical social risks. For example, if the money destined to the aid of an Amazon community is diverted, the community will not receive the necessary assistance and may trigger various social risks. However, concerning local labor legislation, this risk applies to the cosmetics company studied because its suppliers

are within the Brazilian territory. If the company has suppliers located outside Brazil, the law to be followed should be the one proposed by the International Labor Organization (ILO, 2017).

Besides the company's identification of the social risks found in the academic literature, the developed questionnaire also addressed the consequences that these risks could bring to the company.

Regarding the consequences presented in Cunha et al. (2019), those that appear most frequently in the questionnaire are the damage of the company's reputation, the risk of operational stops, individual claims or collective action and payment of mandatory compensation by the court. The profit reduction consequence was mentioned only twice which demonstrates that the company has a social concern that goes beyond the financial consequence that these risks can cause.

In addition to the two respondent areas of the online questionnaire, the Audit Coordinator explained the process in more detail during the interviews. As strategy to manage the social risks that may be present in its supply chain, the company performs two types of audits, one related to the new suppliers and another related to the contracted suppliers of the company.

The main objectives of the Audit process for the company are to mitigate risk of shortages of products, to protect the company's image and the integrity of employees, contributing to the maintenance/ obtaining of certifications and awards which guarantee brand value, and to integrate company beliefs and values into the supplier relationship network, ensuring the development of the value chain.

The audit process takes place through a checklist questionnaire answered by direct suppliers. According to the criticality of the supplier, audits take place at one-year intervals (most critical suppliers) to five years (less critical suppliers). The company studied has a partnership with eight different companies that perform around 300 audits per year with their suppliers. The companies to be audited are defined by the company studied, and the process of auditing the suppliers happens with a marked date, that is, without surprise for the suppliers.

The checklist is based on six pillars: Quality, Environment, Health and Safety at Work, Legal Requirements, Code of Conduct, and Social Responsibility. In this way, the supplier can be classified into three groups: (i) approved; (ii) approved with restrictions, where the supplier is still able to sell, but must adapt within 3 months with the requirements demand in a corrective action plan; (iii) Disapproved, where the supplier will not be able to supply. The corrective action plans are individual and depend on the responses of each supplier. Some items make suppliers automatically disapproved, such as: forced or compulsory labor, child labor, environmental requirements, legal noncompliance, non-compliance with benefit payment rules, non-compliance with health and safety standards, and corruption.

Conclusion

The case study answered two research questions. The first one was answered as several social risks found in the literature coincide with the social risk monitored by the studied company. However, it became clear that social risks vary according to the area in which the company operates. Therefore, risks related to areas of construction, mining or oil and gas may or may not refer to the risks present in the area of cosmetics.

The second research question encompassed the strategy used by the company

to deal with its social risks. Cunha et al. (2019) presented the strategies in a general manner, whereas in the case study the process of supplier auditing was discussed as the strategy used by the company to manage social risk in its supply chain.

In this way, the main contribution of the paper to bring new insights to the academic literature through comparison between a real case and the results from Cunha et al. (2019). The social risks found by the academy may be included in the social supply chain management of the company. On the other hand, we demonstrate that the business environment brings updates back to the academy.

As future research, more case studies should investigate other supply chains, highlight disparities in relation to the private and public sector, and explore different types of organizations as well as different organizational areas, such as oil and gas, mining, construction, cosmetics, and textiles. Additional studies may also focus on the importance of stakeholders and their social risk management actions and other social risk management strategies.

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When do 3PLs initiate low carbon supply chain integration?

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Abstract

As a response to global climate change, decarbonizing supply chains has gained increasing attention from academia and industry. Motivated by the evolving role of third-party logistics providers (3PLs) from a service provider to a resource integrator in supply chains, this paper investigates when 3PLs initiate supply chain integration in order to decarbonize their supply chains. Drawing upon three theoretical lenses, i.e. social network theory, institutional theory and resource-based view of the firm (RBV), this paper develops a theoretical framework and tests it using survey data from 348 Chinese 3PLs. The findings have implications for both researchers and managers.

Keywords: 3PLs, Supply chain integration, Low carbon supply chain

Introduction

With growing pressure on reducing carbon emissions from supply chain management (SCM), decarbonizing supply chains has gained increasing attention from academia and industry. Given the critical role of third-party logistics providers (3PLs) in supply chains, previous research has examined the operational importance of 3PLs in decarbonizing supply chains (Das, 2018). However, the strategic role of 3PLs in decarbonizing supply chains has not received enough attention, although many researchers show that 3PLs have now taken on a more proactive manner for customers by organizing networks, sharing information, managing assets, and reducing inventory (Zacharia *et al.*, 2011).

Further, despite the substantial amount of research on supply chain integration (Flynn *et al.*, 2010; Huo *et al.*, 2017), the majority of these research focuses on manufacturer-initiated SCI, and there is a dearth of research on the antecedents and effectiveness of SCI from the perspective of 3PLs, let alone in LCSC research. To fill the gap of low carbon supply chain integration (LCSCI) from the perspective of 3PLs, this paper focuses on 3PL-initiated LCSCI, namely a customer integration initiated by 3PLs to achieve LCSCs, and investigates the drivers and outcomes of 3PL-initiated LCSCI.

Based on the social network theory (Choi and Kim, 2008), institutional theory

(DiMaggio and Powell, 1983), and the resource-based view of the firm (Barney, 1991), we propose a theoretical framework of the antecedents and consequences of 3PL-initiated LCSCI, including customers' outsourcing scope, government (environmental) regulation, 3PLs' decarbonisation capabilities and 3PLs' financial performance.

The remainder of this article is structured as follows. The subsequent two sections review the literature and develop research propositions. This is followed by a description of research method, in which the sampling method and measures are illustrated. Next, analysis and results are presented and discussed. The conclusion is then put forward.

Literature review

Low carbon supply chain management (LCSCM)

Low-carbon supply chain management (LCSCM) is considered as the combination of low-carbon operations management and supply chain management in response to climate change, focusing on activities that reduce carbon footprint in supply chains (Damert *et al.*, 2018). Although some researchers argue that the drivers, barriers and performance outcomes of LCSCM should be similar to those of green supply chain management (GSCM), the empirical findings on the determinants and effectiveness of LCSCM have been inconclusive (Rivera, 2004; Zhang and Wang, 2014).

Low carbon supply chain integration

Supply chain integration (SCI) refers to "the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes" (Flynn *et al.*, 2010, p. 59), where the inter-organization (or external) SCI includes collaboration that takes place between a focal firm and its suppliers and customers. With the evolving importance of LSPs in supply chains, there is a rapidly growing research on the effectiveness of SCI between a focal firm and its LSPs on firm performance (Huo *et al.*, 2017). The common feature of these research is that they all take the perspective of the focal manufacturing firm; the amount of research on SCI from the perspective of LSPs is limited.

Vachon and Klassen (2006) are among the first who link supply chain integration and the green supply chain practices. Mao *et al.* (2017) show that manufacturing firms' low-carbon supply chain integration (LCSCI) have positive effects on their environmental and financial performances. Nevertheless, there has been no research on LCSCI from the perspective of 3PLs, and it remains unclear about the drivers and outcomes of 3PL-initiated LCSCI. To fill the research gap, this research takes the perspective of 3PLs and focuses on their LCSCI. In particular, we define 3PL-initiated LCSCI as a customer integration initiated by the 3PLs to achieve LCSCs.

Theoretical foundations and hypothesis development

Relationship between outsourcing scope and 3PL-initiated LCSCI

The social network theory (SNT) has conceptualized the supply chain as a functional social network between companies consisting of nodes and links (Carter *et al.*, 2015). Embeddedness is one of the core ideas at the heart of organizational social network theory and is defined as "the extent to which a firm relies on a supply network and perceives the influence of the network" in the context of SCM (Kim, 2014, p.220). Usually, the structural and relational embeddedness are adopted to measure the social capital within supply networks (Choi and Kim, 2008).

The impact of outsourcing scope on the supply network as well as 3PL-initiated

LCSCI can be understood from the perspectives of the relational embeddedness, which refers to the quality or the strength of a relationship (Moran, 2005). Since a wide outsourcing scope is usually associated with increased mutual dependence, commitment and interactions, it gives rise to the strong tie. As the relationship between firms becomes stronger, environmental collaboration in supply chains is more likely to occur (Tate *et al.*, 2013).

Therefore, an increase in the outsourcing scope can lead to an increased level of relational embeddedness of 3PLs, which is positively associated with 3PL-initiated supply chain integration and environmental collaboration. Hence, we propose that the outsourcing scope of 3PL services may have a positive relationship with 3PL-initiated LCSCI.

H1: Outsourcing scope has a positive relationship with 3PL-initiated LCSCI.

Relationship between environmental regulations and LCSCI

Institutional theory identifies three dimensions of isomorphic drivers as institutional pressures that influence firms to adopt organizational competitive environmental alignment, namely coercive, normative, and mimetic drivers (DiMaggio and Powell, 1983), where coercive pressure refers to pressure exerted by those in power, such as the government environmental regulations (Sarkis *et al.*, 2011). To conform to the environmental regulations by the government, 3PLs are motivated to form environmental collaborations in the supply chain (Vachon and Klassen, 2006), and build the strategic supply chain relationship and dependence with their customers (Huo *et al.*, 2017), and thereby leading to 3PL-initiated LCSCI. Thus, we propose the following hypothesis:

H2: Government regulation has a positive relationship with 3PL-initiated LCSCI.

The role of 3PLs' decabonisation capabilities

Decarbonisation capabilities refers to firm-specific capabilities to decarbonize the supply chain. Previous research has indicated that the lack of firm-specific capabilities is one of the most common obstacles to GSCM practices (Wu *et al.*, 2012). According to the resource-based view (RBV), firm-specific decarbonisation capabilities are rare, valuable, non-substitutable, and difficult-to-imitate resources in LCSCM.

We argue that these organization-specific capabilities and resources contribute to the collaborative relationship between the 3PLs and their customers, since the decarbonisation capabilities enable 3PLs to circulate their professional knowledge and resources efficiently to their customers, which is helpful for building strong ties with dependency and trust, thereby increasing the 3PLs' relational embeddedness (Choi and Kim, 2008). Therefore, we propose that the effect of outsourcing scope on 3PL-initiated LCSCI can be stronger if the 3PLs have higher decarbonisation capabilities.

H3: Decarbonisation capabilities play a positive moderating role in the relationship between outsourcing scope and 3PL-initiated LCSCI.

Although 3PLs with higher decarbonisation capabilities can be more able and willing to initiate LCSCI proactively rather than responsively, they may become more self-motivated and less motivated by coercive pressures, such that the effectiveness of government environmental regulations on motivating 3PL-initiated LCSCI could be stronger for the 3PLs with lower decarbonisation capabilities than on their higher capabilities counterparts. Therefore, we propose that 3PLs' decarbonisation capabilities may weaken the effect of government environmental regulation on 3PL-initiated LCSCI.

H4: Decarbonisation capabilities play a negative moderating role in the relationship

between government environmental regulation and 3PL-initiated LCSCI.

Relationship between 3PL-initiated LCSCI and 3PL's financial performance

3PL-initiated LCSCI is related to interaction and collaboration in the social networks. As 3PLs build tense and strong ties in their networks through frequent interaction and intense collaboration with their customers, operational efficiency and economic performance will follow, as long as they are not embedded too much (Uzzi, 1997). Also, the relational capabilities gained from increased level of embeddedness will ultimately enable them to combine cross-organizational complementary resources in unique ways and realize sustainable advantage over their competitors (Paulray, 2011). Therefore, we propose a positive relationship between 3PL-initiated LCSCI and 3PL's financial performance.

H5: 3PL-initiated LCSCI has a positive relationship with 3PLs' financial performance

The theoretical framework in this study as well as the proposed hypotheses are shown in Figure 1.

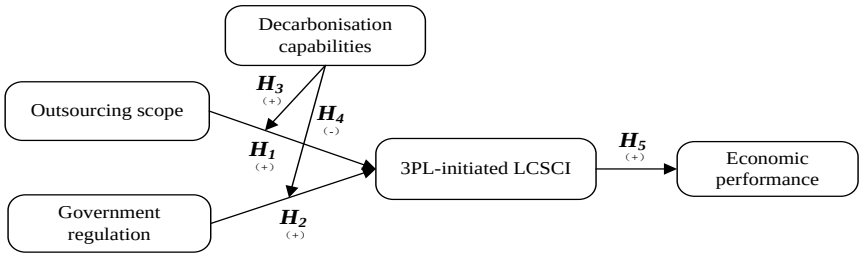

Figure 1 - Theoretical framework

Research method

Data collection and sample profile

The sample was derived from 3PLs located in Guangdong province, China. As one of the earliest regions to open up in China, Guangdong province enjoys advanced economic development; its logistics industry grows rapidly. To collect the data, we collaborated with logistics and SCM organizations in Guangdong province, inviting them to participate in an online questionnaire survey. A total of 1300 3PLs took part in the survey, which was distributed in two rounds. After screening out invalid responses such as blank and incomplete questionnaires, we identified 191 and 157 valid responses for the first and second rounds, respectively, resulting in 348 in total. Thus, the response rate was 26.7%. Table 1 outlines the profile of the sample in line with four characteristics: business origin, ownership, the number of employees, and firm size.

Construct measurement

The constructs measured in this study were derived from the existing literature. Since the empirical investigation was carried out in China, we employed back-translation in order to ensure conceptual equivalence (Cai *et al.*, 2010). The measurement scales were first translated into Chinese and further amended by two research assistants. The initial questionnaire was developed and then examined by using a random selection of 60 samples to conduct validity analysis, exploratory factor analysis (EFA), and correlation analysis using SPSS software. After this, three SCM professors were invited to verify the questionnaire, and the final version of the survey used for delivery was confirmed.

The items in the questionnaire were measured using a five-point Likert scale, with a score of 1 indicating 'strongly disagree', 2 indicating 'disagree', 3 indicating 'uncertain', 4 indicating 'agree', and 5 indicating 'strongly agree'.

Table 1- Survey sample profile

Variables	Total Responses	First-wave frequency	Second-wave frequency	Chi-square test
Business origin				
Transportation-based 3PLs	116	60	56	$\chi2$=2.162 df=2 p=0.339
Warehouse-based 3PLs	100	61	39	
Integrated 3PLs	132	70	62	
Ownership				
Private company	86	55	31	$\chi2$=4.707 df=3 p=0.195
State-owned	165	89	76	
Foreign-funded	81	40	41	
Joint-venture	16	7	9	
Number of employees				
<100	97	51	46	$\chi2$=0.851 df=3 p=0.837
100-200	111	63	48	
200-500	71	37	34	
>500	69	40	29	
Firm size				
<5	55	25	30	$\chi2$=9.149 df=5 p=0.103
5-10	98	61	37	
10-20	77	37	40	
20-50	51	27	24	
50-100	26	18	7	
>100	41	22	19	

Non-response bias and common method bias

We used the method recommended by Armstrong and Overton (1977) to compare the two samples. As shown in Table 1, a Chi-Square test for the firm characteristics variables indicated that there was no statistical difference between the two rounds, thus confirming that both rounds of samples were unbiased.

Since the data investigated was derived from a single source, common method bias was likely (Podsakoff *et al.*, 2003). Therefore, we implemented Harman's single factor test, whereby we conducted an unrotated principal component analysis, yielding 5 eigenvalues greater than 1 after extraction. The first factor explained 38.203% (lower than 40%). In addition, we conducted a confirmatory factor analysis (CFA) for Harman's single factor model (Sanchez and Brock, 1996). Compared to the measured model, the indicators of the tested model were poor ($\chi2$/df=3.297, GFI=0.635, AGFI=0.539, IFI=0.595, TLI=0.551, RMR=0.077, and RMSEA=0.081. This showed that overall, common method bias was not a problem in the data.

Reliability and validity analysis

The results of the reliability and validity tests are shown in Table 2. Internal consistency was measured using Cronbach's coefficient. The Cronbach coefficients of all the constructs ranged from 0.808 to 0.898 (above 0.7). This confirmed that the constructs had psychometric properties. An examination of the CFA of all the constructs showed that all the indicators of the measurement model, such as $\chi2$/df, GFI, AGFI, IFI, TLI,

RMR, RMSEA, were ideal, and therefore that the constructs were unidimensional (Bentler and Bonett, 1980). In addition, as suggested by Fornell and Larcker (1981), we measured convergent validity. The results showed that all the standard factor loadings were above 0.7, and the t-values were above 10 for all but two items (0.67 and 0.692). Thus, convergent validity was confirmed. Composite reliability and AVE can be used to measure the reliability of constructs (Hair *et al.*, 2006). When CR and AVE are above 0.7 and 0.5 respectively, it indicates a high degree of internal consistency, and that the consistency between the constructs/traits is higher than that of the errors (Hair *et al.*, 2006). As shown in Table 2, the composite validity values of the constructs ranged from 0.807 to 0.873 (above the threshold value of 0.7), and the AVE values ranged from 0.527 to 0.635 (above the threshold value of 0.5). Table 3 presents the arithmetic square roots and correlation coefficients of the constructs. The results showed that the arithmetic square roots were larger than the correlation coefficients of the construct and the correlated construct, thus confirming that the measurement scale of the constructs had sufficient discriminant validity, as suggested by Fornell and Larcker (1981).

Table 2 - Construct measurement

Scale	Factor loading	S.E.	t-value
Outsourcing scope			
1. The function of low-carbon logistics service expands	0.717	--	--
2. The content of low-carbon logistics service increases	0.728	0.081	12.286
3. The number of users of low-carbon logistics service increases	0.732	0.083	12.52
4. The low-carbon logistics service industry increases	0.722	0.08	12.692
5. The geographic coverage of low-carbon logistics service increases	0.742	0.088	11.875
Government regulation			
1. Policy law promulgated by the government for low-carbon business environments	0.736	--	--
2. Policies and regulation issued by local governments for local business environments	0.675	0.094	10.678
3.Policies issued by the government for low-carbon logistics services	0.701	0.095	11.287
4. Carbon auditing assigned by the government	0.75	0.098	11.669
Decarbonization capabilities			
1. Possess the ability to design low-carbon logistics services	0.796	--	--
2. Possess carbon-reduction technique	0.743	0.074	14.018
3. Possess low-carbon facilities	0.716	0.07	13.765
4. Possess low-carbon coordination capability	0.73	0.068	14.33
5. Possess carbon-reduction capability	0.781	0.069	15.28
6. Possess the capability for improving low-carbon logistics services	0.73	0.072	13.229
3PL-initated LCSCI			
1. help customers and their supply chains to make plans for low-carbon logistics integration	0.726	--	--
2. help customers and their supply chains to achieve low-carbon logistics coordination	0.778	0.085	13.097
3. help customers and their supply chains to achieve technical support for low-carbon integration	0.704	0.088	11.685
4. help customers and their supply chains to achieve environmental goals regarding low-carbon logistics service integration	0.738	0.088	12.272
5. build up strategic alliance with customers for low-carbon logistics integration	0.692	0.091	11.475
Economic performance			
1. market competitive position increase	0.778	--	--
2. logistics cost reduction	0.670	0.072	12.553
3. ROI increase	0.905	0.069	17.037
4. customer satisfaction increase	0.816	0.061	16.205

*Standardized factor loading

Table 3 - Discriminant validity

	Mean value	S.D.	Outsourcing scope	Government regulation	*Decarbonization* capabilities	3PL-initiated LCSCI	Economic performance
Outsourcing scope	3.92	0.69	0.728				
Government regulation	3.97	0.65	0.365**	0.716			
Decarbonization capability	3.87	0.89	0.724**	0.330**	0.751		
3PL-initated LCSCI	3.96	0.65	0.657**	0.433**	0.658**	0.726	
Economic performance	3.79	0.76	0.415**	0.516**	0.401**	0.326**	0.797

Note：** P<0.01；the values on the left-hand side of the diagonal line are correlation coefficients; and the values at the diagonal line are arithmetic square roots.

Results

Using SPSS 20.0 software, we set two explanatory variables (‘government regulation’ and ‘outsourcing scope’) and moderating variables, and multiplied them to obtain interaction items. Next, we set ‘3PL-initiated LCSCI’ and ‘economic performance’ as dependent variables and used stepwise regression to perform a hypothesis test. As shown in Table 4, Models 1-3 set ‘3PL-initiated LCSCI’ as the dependent variable, and Models 4-5 set ‘economic performance’ as the dependent variable. The tolerance of all the models was above 0.15, indicating that multicollinearity was not a problem. In Model 2, the regression coefficients of ‘outsourcing range’ and ‘government regulation’ were 0.579 (t=13.503, p<0.001) and 0.233 (t=5.550, p<0.001). This result indicated that these two factors had a positive impact on ‘3PL-intiated LCSCI’, and therefore that H1 and H2 were verified. In Model 5, the regression coefficient of ‘3PL-initiated LCSCI’ was 0.323 (t=0.323, p<0.001), indicating that ‘3PL-initiated LCSCI’ had a positive impact; hence, H5 was verified. Model 3 tested the moderating role of ‘decarbonization capabilities’. With this model, the regression coefficient of ‘outsourcing scope’ was 0.236 (t=3.778, p<0.001), indicating that ‘decarbonization capabilities’ positively moderated the relationship between ‘outsourcing scope’ and ‘3PL-initiated LCSCI’, and therefore that H3 was confirmed. The regression coefficient of ‘government regulation’ and ‘decarbonization capabilities’ was 0.362, indicating that ‘decarbonization capabilities’ negatively impacted the relationship between ‘government regulation’ and ‘3PL-initiated LCSCI’; hence, H4 was verified.

Table 4 - Stepwise regression results

Variables	Dependent variable：3PL-initiated LCSCI			Dependent variable：Economic performance	
	Model 1	Model 2	Model 3	Model 4	Model 5
Number of employees	0.064	-0.03	-0.061	0.144†	0.124†
Firm size	0.065	0.083	0.105*	-.066	-0.087
Transportation-based 3PLs	-0.027	0.035	0.024	-.018	-0.009
Warehouse-based 3PLs	-0.064	0.029	0.009	.007	0.027
SOEs	-0.227†	-0.068	-0.025	-.108	-0.034
Private owners	-0.161	0.053	0.076	-.155	-0.104
Joint ventures	-0.126	-0.014	-0.13	-.050	-0.010
Outsourcing scope		0.579***	0.295***		
Government regulation		0.233***	0.139***		

Decarbonization capabilities			0.397***		
Outsourcing scope *Decarbonization capabilities			0.236***		
Government regulation *Decarbonization capabilities			-0.362***		
3PL-initiated LCSCI					0.323***
Tolerance	⩾0.16	⩾0.2	⩾0.15	⩾0.16	⩾0.16
R^2	0.035	0.492	0.595	0.025	0.126
Adjusted R^2	0.015	0.479	0.581	0.005	0.105
R Square Change		0.458	0.096		0.101
F Change		152.266	28.38		38.978
Sig. F Change		0.000	0.000		0.000

Notes: 1. Coefficients are standardized; 2. *** *P<0.001; ** P<0.01; * P<0.1*.

In order to reveal the moderating role of the variables, we set the average of 'decarbonization capabilities' as standard, dividing the sample into two groups: high level of decarbonization capabilities (high level) and low level of decarbonization capabilities (low level) in order to conduct a regression analysis of '3PL-initiated LCSCI'. Figure 2 shows that in the low-level group, the regression coefficients of 'outsourcing scope' and 'government regulation' were 0.409 (t=6.619, p<0.001) and 0.378 (t=5.7890, p<0.001), revealing a significant positive impact on '3PL-initiated LCSCI'. In the high-level group, the regression coefficient of 'outsourcing scope' was 0.526 (t=7.946, p<0.001), indicating that this variable also had a significant positive impact on '3PL-initiated LCSCI', but the degree of impact was larger than in the low-level group. In addition, the regression coefficient of 'government regulation' was 0.058 (t=0.89, p>10%), showing that the impact of this variable on '3PL-initiated LCSCI' was smaller than in the low-level group, and was not statistically significant. This analysis further verified H3 and H4.

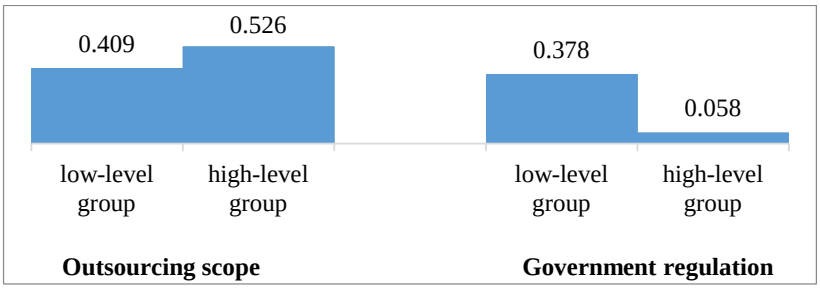

Figure 2- The moderating role of decarbonisation capabilities

Conclusion and future research

Drawing upon three theoretical lenses - social network theory, institutional theory and RBV - this study develops a research framework for 3PL-initiated LCSCI, the constructs of which were verified by the empirical investigation conducted in China. The research results highlights the positive impact of 3PL-initiated LCSCI on corporate performance. It appears that, with the advent of decarbonized economies and societies, logistics service provision has been given greater environmental focus, distinct from traditional logistics functions. The emergence of 3PL-initiated LCSCI, to a large extent,

echoes Bowersox's (1998) prediction that "the logistical mission of yesterday is being replaced by a broader concept driven by social responsibility" (p.2). This study shows that, as a strategic action, 3PL-initiated LCSCI is developed in response to a low-carbon economy. The findings of the current study provided evidence of 3PLs as supply chain orchestrators in decarbonized economies and their strategic benefits. Differing from many previous studies that focused on green SCI and 3PLs, this study provides a new perspective on 3PL-initiated LCSCI in consideration of the role of 3PLs as low-carbon supply chain orchestrators. Thus, the research results can contribute to knowledge development not only for SCI but also 3PLs. The present study also identified practical benefits for 3PLs in becoming supply chain orchestrators in a decarbonized economy and society. It suggests that, although the increasing pressure to outsource low-carbon services from both customers and government regulation, 3PLs be aware of their ability to initiate LCSCI, particularly their decarbonization capabilities. In order to gain the most from this initiative, 3PLs should optimize all their related processes, such as developing low-carbon logistics service design, techniques, and coordination capacity.

The empirical investigation can also provide scope for further exploration. Firstly, in relation to the factors that influence 3PLs to initiate LCSCI. This study assumed the degree of 3PL development to be at the same level. Given the negative role of decarbonization capabilities identified regarding the impact of government regulation on 3PL-initiated LCSCI, future research could examine the impact of these two factors on 3PL-initiated LCSCI in 3PLs at different stages. For example, when 3PL possess mature decarbonizing offerings, what is the impact of government regulation? Secondly, the empirical study was conducted in China; therefore, future research could investigate the differences between LCSCI initiated by 3PLs in cross-culture settings. Finally, the sample used in this study was relatively narrow, as data was only collected from one region. Future studies could expand the geographic coverage of the data.

Acknowledgments

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Opportunities and limitations of blockchain based supply chain traceability

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Abstract

Blockchain is provoking significant disruptions, impacting supply chain management. We strive to progress the research regarding blockchain based supply chain traceability by identifying opportunities and limitations of the technology adoption. We a) reviewed concepts of supply chain traceability, b) conceptualised key elements of blockchain technology and c) highlight opportunities and limitations when implementing traceability using blockchain technology. Many of the blockchain's characteristics represent incremental enhancement to current systems, when the technology features are adopted selectively, rather than the blockchains' privacy model is embraced fully. Opportunities for disruptive change from disintermediation need to become focus of research.

Keywords: Supply Chain Traceability, Blockchain, Distributed Ledger

Introduction

Producers and customers alike demand verifiable evidence of traceability as an important criterion of sustainable products. Tracking data can aid demonstrating regulatory, social and environmental compliance. Stringent legal provisions and regulations, as well as high cost of product recalls provide strong reasons for traceability.

Furthermore, capturing the history of a product through the supply chain enables the optimisation of processes and the prediction of downstream time and quality issues, resulting in advantages in terms of costs, time and customer satisfaction (Abramovici et al., 2008). Traceability can accelerate innovation and sustainability within the organisation, leading to competitive advantage through differentiation. (Bosona and Gebresenbet, 2013).

Technological advances promise to ease challenges presented by traceability systems. Supply chains can benefit from the adoption of new technologies like the blockchain. Starting from the financial industry, blockchain incrementally is recognised in different industry applications, including supply chain management. Korpela et al. (2017) found that blockchain technology accelerates digital supply chain integration.

With the ability to perform peer-to-peer transactions in privacy, without third party intervention, blockchain can mitigate risks associated to the data manipulation, compromised privacy, or compliance with government rules and regulation. (Min, 2019)

However, alternative designs to a pure peer-to-peer model like public or private, permissioned or permissionless blockchains are discussed (Narayanan et al., 2016)

Several authors raise the concern that the pick and choose attitude towards blockchain technologies might result in blockchain being little more than the "new database tool" rather than the "next internet" (Jack Tatar, 2019). Consequently, private blockchain would just be confusing name for a shared database. (Narayanan, 2015)

Theoretical Background

Supply chain Ttraceability

Seuring and Müller (2008) recognise the sustainability aspect of supply chain management and extend earlier definitions to "sustainable supply chain management as the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements." Companies, Government and customers are building the core interest groups for supply chain traceability information.

Supply chain traceability is the capturing and analysis of custody, transformational and environmental information of material flows through the supply chain aiming to satisfy stakeholder needs regarding environmental, social and economic performance, compliance and quality. Traceability con be a source of competitive advantage through ensuring a transparent and sustainable supply chain. Traceability serves as an important component of business information system. With an efficient and effective system transmitting accurate, timely, complete, and consistent information, supply chain can significantly reduce the operation costs and increase productivity (Bailey, Bush, Miller, & Kochen, 2016).

Furthermore, companies need to cooperate to determine the requirements for tracking and tracing, so that all necessary information of the supply chain can be managed efficiently and effectively (van Dorp, 2002). Certifications and related documents are major means of validating product origins and sustainability fulfilments, which can be subject to falsification (Bailey et al., 2016) Customers are demanding more transparency from brands, manufactures and producers throughout the supply chain. Consumers focus strongly on the origin of products and show a preference towards sustainability. Therefore, customers and non-governmental organisations demand information regarding product origin, quality and sustainability.

"Traceability is required to recall what has already occurred in time; and that "It must be possible to trace from one entity to another" (Kim et al., 1995, p.109). Tracking is the determination of the current information that indicate the status, like the location, of an object being tracked downstream through the supply chain (Fritz and Schiefer, 2009). Tracking also referred to as forward traceability, being "the ability to follow the downstream path of a product along the supply chain, possibly according to some specific criteria" (Bechini et al., 2008)

Therefore, a clear identification of the products as well as the links between the components, combined in the internal processing, are required (Jansen-Vullers et al., 2003). To enable traceability, products, including materials, components, and assemblies, require to be uniquely identifiable. At each stage of the supply chain, the physical location of a specific object can be determined which facilitates logistical activities, recalls, and the provision of information to consumers and other stakeholders. (Moe, 1998; Opara and Mazaud, 2001)

Traceability system refer to all methods, procedures and routines used to manage traceability in its supply chains. Traceability systems are used by individual partners to increase visibility across their own organisation and contribute to end-to-end supply chain traceability (Global Standards One, 2017). Moe (1998) is separating chain and internal

traceability. Chain traceability focusses only on a subset of information, following the movement of the product through the supply chain from the source to the end customer. Internal traceability, within partners in the supply chain, allowing for more granular traceability information of the transformation process data. The different aspects of supply chain traceability are shown in *Figure 1*.

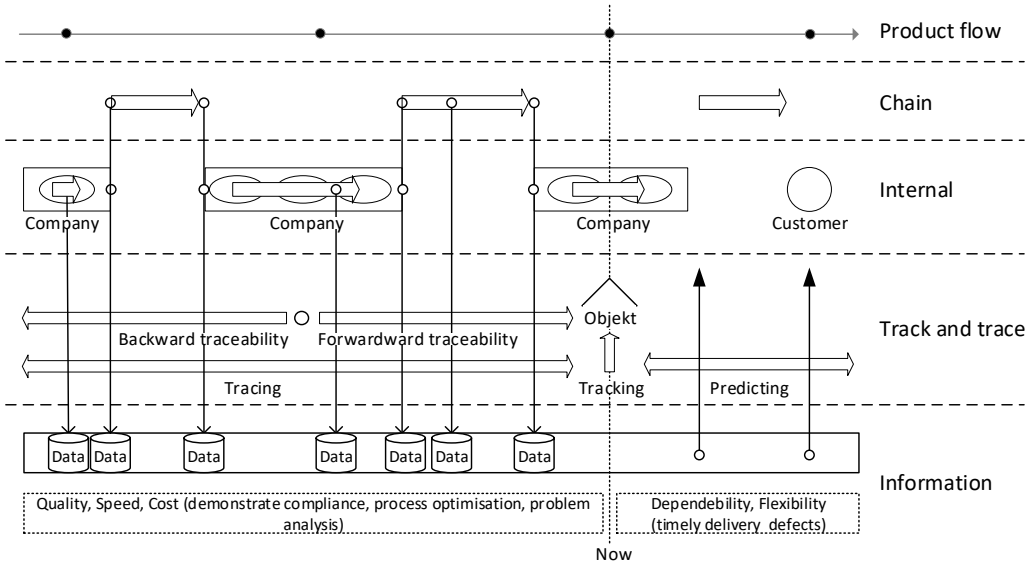

Figure 1- Supply chain traceability

Capturing the history of a product through the supply chain enables the optimisation of processes as well as to demonstrate regulatory compliance (Abramovici et al., 2008).

While Kim et al. (1995) saw traceability as being "backwards in time" other authors recognise the importance of tracking data for predicting downstream events on the supply chain. Tracking data enables prediction of defects and adverse events (Skilton and Robinson, 2009), quality (Bollen, 2005) or arrival time (Biagioni et al., 2011).

Traceable information include supply chain trading volumes, address information like the origin and source of product, as well as dimension or chemical composition (Bosona et al., 2018). Additionally, continuous monitoring of conditions such as temperature, humidity, and vibration can be applied to assess quality". The analysed information can be used to minimize quality loss or improve transportation services (Chaudhuri et al., 2018).

The data, generated continuously by multi-entities, has to be resilient against tampering or falsification. Integrity and reliability of the information has to be ensured. Handling the large amount of data generated along the supply chain in an efficient, secure, and economic way is a key challenge of traceability. (Qiao et al., 2018)

However, smaller scale companies often use manual, paper-based tracking, even though it limits the ability to accurately record, store, and query data to identify and track products. Pencil and paper systems present these companies a low-cost alternative to sophisticated information technology-based solutions (Karippacheril et al., 2017). Wilson and Clarke (1998) recognise product tracking information as incomplete, inaccurate, untimely, not useful and inaccessible.

Inaccurate storage and timely retrieval of, the high volumes of traceability data is problematic. Additionally, trust, privacy, security, and reliability of tracking data limits

the effectiveness of supply chain traceability systems. As systems are required to operate in complex supply chains, with large, dynamic groups of participants, cost can be high. (Thomas et al., 2015)

The use of information technology to ensure comprehensive product traceability throughout the supply chain enables companies to control cost and meet legal requirements. (Abramovici et al., 2008; Aung and Chang, 2014)

Petersen et al. (2016) state that decentralized, rather than centralized storage of the data generated in the decentralized process steps throughout the supply chain, is necessary to realize traceability in the context of the digitization of supply chain activities.

Figure 2 shows the different scenarios for the organisation of traceability data. In the centralised model all parties share their information to a central repository. The central database holds the complete set of is systematically enhanced traceability data. However, access rights might be set individually for all parties. In the networked scenario, the participating parties keep their individual data in local systems, providing supply chain partners query access to relevant information. In the cumulative model, the traceability data is enhanced as it moves together with the material downstream along the supply chain from one partner to the next. Here data is only shared with the downstream partners. For the decentralised scenario, as used in the blockchain technology, all data is systematically enhanced and shared with all supply chain partners. Each partner is managing a local copy of the complete set traceability data. While centralised and decentralised models provide a single traceability data set for a complete view, the cumulative scenario provides only local and upstream information out of the individual data set. For traceability in the networked scenario multiple, distributed datasets of the partners need to be queried. (Global Standards One, 2017) .

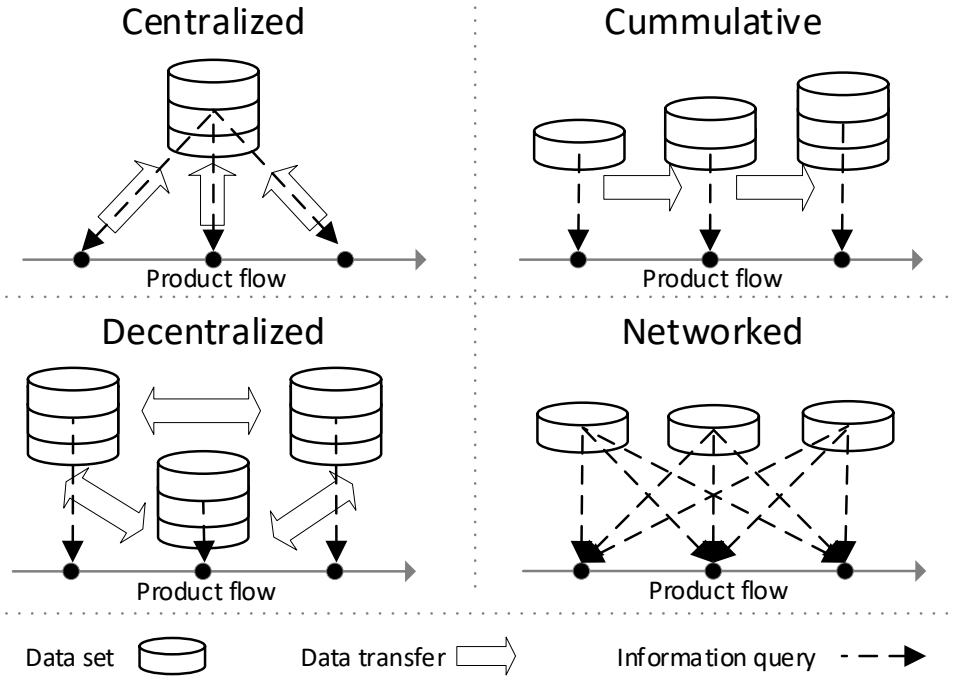

Figure 2- Distribution of traceability data

Blockchain Technology

Blockchain, the base of Bitcoin, is an decentralised, distributed ledger "for electronic transactions without relying on trust" (Nakamoto, 2008). The application functions as an immutable ledger which allows transactions directly between anonymous parties to be performed in a decentralised fashion (Zheng et al., 2017). The information is stored transparently, chronologically and unchangeably (Schlatt et al., 2016). While blockchain ensures persistent storage and the consistency of the public data, the technology does not provide interfaces for retrieval, update, evaluation or management the users, data structure or the data itself.

However, database functionality like the management of large amounts of shared data, a coherent database state, protection against misuse, data recovery, security control for accessing and/or changing information, data set distribution and transparent access have been adopted since decades. (Abiteboul et al., 1996). Furthermore, smart contracts (Nick Szabo, 1994) , hash trees (Merkle, 1979), digital timestamping (Haber and Stornetta, 1991) and cryptography (Diffie and Hellman, 1976) has been discussed since the second half of the last century.

Blockchain's disruptive decentralisation and disintermediation characteristics can impact to supply chain management (Queiroz et al., 2019). By replacing the reliance on centralised architectures and trusted third parties, with blockchain's decentralised privacy model, the technology introduces serious disruptive potential for traditional business processes (Casino et al., 2019). Furthermore, does blockchain enable "fundamental organisational changes in governance" and therefore "may be characterised as a disruptive innovation that breaks up established business models" (Fridgen et al., 2017).

In summary, blockchain has following four key characteristics:

Privacy Model

Blockchain's disintermediation is reflected in the new privacy model. Nakamoto (2008) revises the privacy model, whereby the transactions are public, while the identities of the transacting parties are protected (Figure 3). Through the new design the element of trust between the identities or the entities and a third party could be eliminated. In the revised privacy model, all participants are equal, and all transactions are visible to the public. Privacy is achieved through protection of the transacting parties through the anonymity induced by public-key cryptography. However, to validate the public transactions of anonymous nodes, a new validation process needs to be revised (Nakamoto, 2008).

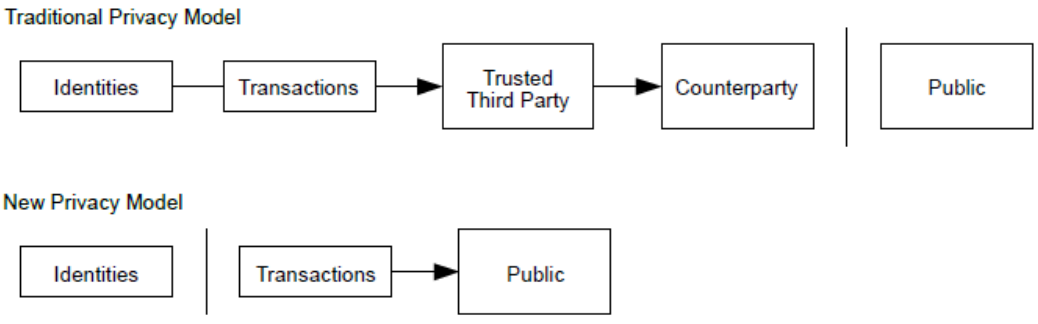

Figure 3 – Blockchain - Privacy Model

In fact, "When we talk about replacing traditional systems fully or partly with technological alternatives, we are really talking about redistributing power from well-established legal, social and financial institutions." (Narayanan et al., 2016, p.303)

Anonymity

Blockchain realises anonymity using changing pseudonyms and unlikability of participants and objects. Public-key cryptography (Diffie and Hellman, 1976) is applied, whereby private and public keys are used to preserve the privacy of nodes. Nodes are identified only by their public key address. Due to their anonymity there can be no trust relationship established between the nodes. Changing the public key address for each transaction prevents transactions to be linked to a participant. Additionally, the blockchain does not provide linkage to off-system assets.

Decentralisation

All participants are equal nodes in a pure peer-to-peer decentralized and distributed network, whereby "any single, arbitrary chosen terminal entity can be removed from the network without having the network suffering any loss of network service" (Schollmeier, 2002, p.102). The decentralized architecture leads to an increases resilience of the system, as it removes any single point of failure. However, the decentralisation requires participants to utilise resources for transmitting, storing and validating the data sets.

Due to the lack of a central governing party, a permissionless consensus mechanism allows nodes to coordinate the system status by mass collaboration. (Bogart and Rice, 2015). Consistency between the different nodes is ensured through this protocol.

Additionally to block formation and block validation, the propagation of new blocks through the decentralised network introduces delays in the processing of transactions (Sompolinsky and Zohar, 2013).

Immutability

Blocks of transactions are created when the blocks are timestamped, linked through a hash (Merkle, 1979) to the previously created block and signed (Haber and Stornetta, 1991). The network participants can verify the integrity of a transaction by recalculating and comparing the hash chain. Therefore, "to modify a past block, an attacker would have to redo the proof-of-work of the block and all blocks after it and then catch up with and surpass the work of the honest nodes. " (Nakamoto, 2008). Consequently, the chain becomes tamper resistant as manipulations can be detected and rejected by the network.

Findings Opportunities and limitations

The blockchain does not per se resolve cost, integration or information management challenges of supply chain traceability.

While the data transparency of the privacy model supports needs of supply chain traceability, the overall concept of anonymous identities performing in a pure peer-to-peer environment collides with traceability requirements. Firstly, producers, researchers, governments and consumers are key stakeholders in supply chain traceability. However, the blockchain privacy model aims at eliminating third party control. Secondly, most traceability systems are envisaged as a private or permissioned block chain. Nevertheless, this implies discarding anonymity in the peer-to-peer network, while introducing a permissioning authority. Thirdly, the publicity of the data calls for the anonymity of the transacting identities.

The identities in the blockchain are anonymous. The missing link between information and organisations allows companies to share internal data. Though, provenance and

custody information are key interests of supply chain traceability. Furthermore, the unlikability of the transactions and pseudonyms an important factor in ensuring the overall anonymity. Furthermore, traceability aims at creating visibility of the flow of uniquely identifiable objects downstream the supply chain. In contrast, blockchain's privacy model demands anonymity through pseudonymity and unlinkability to enforce participants anonymity.

Blockchain's decentralisation mirrors in many aspects the organisation of supply chains. The fully decentralised approach, necessitated by the absence of a central third party, is at the core of the blockchain. However, supply chains, with heterogeneous capabilities and interests of supply chain partners, present challenges for the decentralised organisation of the system data. Specifically, companies financial and technical resources to distribute, store, validate, analyse or otherwise exploit large amounts of traceability data might differ greatly. Additionally, while supply chain traceability requires constant participation of all partners in the supply chain, Contrary, the blockchain's pure peer-to-peer approach allows participants to join or withdraw from the network without impacting the blockchain. Latency in the block chain is introduced through block building, validation and network distribution. This latency hinders blockchain adoption when supply chain traceability requires real-time information.

Blockchains approach to tamper-proof the information supports the demand of supply chain management for trustworthy, immutable information. The error-prone manual recording and analysis of required information will introduce system complexity to maintain the data immutability characteristic within the blockchain. Requirements for archiving expired data out of fast-growing traceability pools are limited by the need to keep transaction chains for validation in the blockchain.

Conclusions

Not much of the revolution is left, once the blockchain is wrapped into an access controlled, distributed system. Decentralisation and disintermediation, as key drivers of the disruptive force in the blockchain, are relying on the anonymity of identities.

The absence of central control, mediator and system owner in the blockchain model, makes it hard to create business cases and therefore restricts companies' exploration of the blockchain technology. However, public blockchains, with business models utilising blockchain information, could be path to utilize the technology in a commercial context.

In the tension between disintermediation and business model lies an opportunity for researchers. Advancement of the privacy model, rather than focusing on technical aspects, could proof to be highly beneficial for traceability as well as overall supply chain performance. Supply chain spheres where institutional interest is lacking, supply chain partner struggle to coordinate their activities, individual infrastructure investment cannot be justified, or data privacy is a hard requirement, could be viable areas of research. Additionally, supply chain performance could be improved in areas where costly intermediaries are be replaced by approaches embracing blockchain's new privacy model.

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Supply Chains and Short Food Supply Chains: Coexistence Conceptual Framework

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Abstract

This article aims to establish and describe the coexistence conceptual framework of the Short Food Supply Chains (SFSCs) and Supply Chains (SCs), at odds with the current polarisation of the literature on chain approaches. Based on a review of the literature, the paper draws on biology and market performativity notions to establish and describe a coexistence conceptual framework of SFSCs and SCs. This framework was arranged around two main criteria: i) convergence of interests; and ii) need to add value. Four types of coexistence were established and described with empirical evidence: i) competitive; ii) co-ordinative; iii) co-operative; and iv) unco-operative.

Keywords: Short food supply chains, Supply chains, Coexistence.

Introduction

A paradigm shift is observed in management theory, in which firms no longer compete as independent individuals, but start to act as Supply Chains (SCs) (Lambert and Cooper, 2000). On the other hand, new concerns have emerged from agricultural and agro-industrial practices in the areas of the environment, food safety and health, such as animal welfare and ecology (Renting, Marsden and Banks, 2003). Therefore, the development of Short Food Supply Chains (SFSCs) has gained prominence in recent years.

While these two approaches study similar phenomena, SCs and SFSCs are intertwined with different elements that regard both chain models as competing with each other. Clearly, in studies of SFSC one finds an attempt to characterize this model as an alternative to the conventional model of the SCs (Watts, Ilbery and Maye, 2005; Chiffoleau, 2009; Aubry and Kebir, 2013).

However, the focus - though shy - does not concern the replacement of long chains by short chains. Scholars (Oglethorpe and Heron, 2013; Schoenherr, Narasimhan and Bandyopadhyay, 2015) argued that the strategies should progressively strengthen the economic sectors and activities that allow the integration of increasing numbers of actors involved in both agrifood chains. It is possible to sustain that the propelling factors of SCs and SFSCs are present in the same space and period of time, showing that the two models coexist (Marsden, Banks and Bristow, 2000; Renting, Marsden and Banks, 2003).

Thus, this article shows how SCs and SFSCs are characterized and at which points they diverge and converge. Drawing on biology and market performativity, it establishes and describes the coexistence of the conceptual frameworks of SCs and SFSCs, instead of the current polarisation of the literature on chain approaches.

Given the analogy made by Nenonen et al. (2014) in market plasticity, it is possible to note that the application of the coexistence term is, in most cases, used in biological and ecological matters. The research objects in the coexistence aspects are based on a focus to analyse the competition or mutual existence between two agents (called species) in a certain time and place (environment), as stated by Schoener (1974). Thus, Chesson (2000, p. 343) affirms that "the most common meaning of diversity maintenance is coexistence in the same spatial region of species having similar ecology".

According to Hanski (1981), the coexistence between two or more agents can happen through aggregation, and it can affect the environment and the relation among other agents in the same place and time. So, this perspective provides a positive outlook as a mutualistic relation by coexistence. However, "two like species may or may not coexist regionally, depending […] on the intensity of competition" (Hanski, 1983, p. 493).

Based on Rothschild (2004), the business ecosystem is a conjugation of species (firms, stakeholders, chains and other actors) doing business in the same space in a given period of time. In this case, the chains can coexist by integration, co-operation and competition, the latter being a predatory coexistence for survival.

Considering from a performativity perspective, Kjellberg and Helgesson (2006) argue that market practice is characterised by multiplicity. Hence, market actors do not necessarily act from the perspective of a single market, and may instead engage in divergent market practices (Kjellberg and Helgesson, 2006). Analogically to the chains, it can be understood that the actors do not necessarily focus on only a single chain, as empirically revealed by Benson-Rea, Brodie and Sim (2013). Thus, actors are able to operate in both chains (SCs and SFSCs), and, in case of such occurrence, this fact may characterise a new different type of coexistence.

Therefore, Kjellberg and Helgesson (2006, p. 849) state that "[…] different exchange, normalizing and representational practices may simultaneously perform different versions of the same market. Further, these versions need not be at odds with each other, but may more or less peacefully co-exist". Given the multiple realities, it is recognised that actors can not only enact multiple (even conflicting) ideas, but that they can also participate in the formation of multiple market versions (Kjellberg and Helgesson, 2006). This notion can be transposed into the reality of the chains, given that each of the chains can establish itself (or may have already established itself) as a market (Flint, Lusch and Vargo, 2014).

Broadly speaking, "[…] the co-existence of multiple and potentially conflicting versions of the same entity does not imply conflict or indeed the necessity of any kind of coordination unless two or more of these versions encounter each other in a specific situation" (Kjellberg and Helgesson, 2006, p. 850).

Based on this perspective of coexistence, in the literature a competitive coexistence is highlighted, in which the SFSCs are established as an alternative to SCs. On the other hand, it is possible to recognise coexistence as pointed out by Hanski (1981), and even as co-ordinative, as presented in Kjellberg and Helgesson (2006).

In this aspect, the existence of chains is shown in a space-time dynamic in a contemporaneous scenario. Regardless of their particularities, both chains present established relations through the various actors in an arranged process that composes the chains for use of territories and value creation for the chains, actors and consumers. Thus,

SC and SFSC coexistence is characterised below, in order to understand how they converge and diverge.

Convergences and Divergences Between SCs and SFSCs

Sonnino and Marsden (2006) show that, while abstract, distinctions can be made between alternative and conventional food systems. There are, however, no clear boundaries between them. Therefore, the concepts, perspectives and dimensions suggest a possible intersection and coexistence between the theoretical frameworks at certain moments, but also highlight the difference between the models.

The convergent and divergent characteristics between SFCSs and SCs are synthesised in Table I. In particular, a comparison of focal components is presented, namely: objective, configuration, relations among the chain actors, interest, spatial relations and needs of the productive system and consumption.

Table I Comparison of SFSCs and SCs by focal components

Components	SFSCs	SCs
Objective	Co-operation, integration and greater autonomy of actors; *generating value for the farmers and the consumers*, as well as alternatives and opportunities for rural and local development	Strategic co-operation for the *creation of value and efficiency* of the entire chain through the integration processes that are essential to the business of the chain actors
Configuration	*Interactional network among actors*, mainly focused on bringing together producers and consumers	Gravitation actors around the focal firm, forming a *network of various businesses and relations*
Relations among the chain actors	*Proximity, formal and informal*, among the actors, mainly between farmers and consumers; relations based on trust building in the origin and quality of food products Need for greater integration among farmers (local) to strengthen the region	*Formality among actors*, moderate relations with trust features and institutional aspect among actors Need for greater integration between actors to strengthen the chain
Spatial relations	*Relocation* Consumer knowledge about the location, production, product and spatial conditions of production; local and regionally-based	*Delocation* Absence of spatial reference of the product; no incentive to understand the food origin; products without space/ land/territory/place
Interest	Community, regionality, territorial development, *enable the farmer to capture greater value and generate added value to the consumer*	Diffuse along the chain; in general, *generate added value for the various chain actors and the consumer*
Needs of the productive system and consumption	Provide value to the chain actors; convergence of interests	Provide value to the chain actors; convergence of interests

It is sustained by Sonnino and Marsden (2006) that the current dichotomy between standardised and localised foods does not fully represent the reality of the food sector. In other words, there are no clear boundaries between these two approaches, despite the abstract distinctions between them.

Specifically, there is emphasis on the evolution in the conceptualisation of SCs, which has developed approaches partially similar to the structure of SFSCs; the relations among

SC actors require higher levels of interaction, characteristics that are similar to those of SFSCs in the Renting et al. (2003) model, such as in Schoenherr et al. (2015), which developed a framework for the assurance of food safety via relational networking.

With SC evolution, there is a redesign and repositioning of the supply chain and its actors (Folkerts and Koehorst, 1997). In this sense, new concepts emerge, such as sustainability (Carter and Rogers, 2008; Seuring and Müller, 2008; Pagell and Wu, 2009) and a green supply chain (Srivastava, 2007; Lee, 2015), without disrupting the main characteristics of SCs.

Such evolution has also happened in the SFSCs, and can be read in the concept model of extended SFSCs proposed by Renting et al. (2003) and applied in empirical cases by Oglethorpe and Heron (2013), which identifies supply chain barriers and constraints that occur in local food supply chains based on smaller producers when they seek to increase market penetration across a wider geographical area.

Thus, it is possible to notice a certain conceptual convergence of the SFSCs and SCs from a territorial and geographical perspective. In a certain period of time, they tend to take on co-ordinative functions, become co-operative and overlap, depending on the interests involved, opportunities and threats of markets and the needs for value that the chains may have in common. Therefore, the combination of adding value and convergence of interests by interacting factors is present in both SFSCs and SCs.

To deepen this discussion, the following topic emphasises coexistence, introducing the coexistence conceptual framework based on the combination of adding value and convergence of interests. In addition to the framework, empirical evidence is presented that characterises different types of coexistence between SCs and SFSCs.

Coexistence and Empirical Evidence

Schoenherr et al. (2015) highlight the current phase of the SC, due to awareness of food safety, product traceability, environmental impacts, among others. Therefore, some of the concerns that have led to the development of SFSCs are also reshaping the conventional SC. There is a collective reflection leading to a sustainability approach in order to reduce the negative impacts along the chain (Validi, Bhattacharya and Byrne, 2014).

As an outcome, the concept of sustainability is introduced in the SCs' approach. Despite the focus on environmental/green issues (Srivastava, 2007; Seuring and Müller, 2008; Lee, 2015), there are also efforts to incorporate the social aspects of sustainability, demonstrating the relations among environmental, social, and economic performance (Carter and Rogers, 2008; Seuring and Müller, 2008; Pagell and Wu, 2009).

Thus, it is observed that conventional SCs are attentive to the new demands of consumers with regard to food safety, ecology and origin (traceability), highlighted by Ilbery and Maye (2005) and Renting et al. (2003) as drivers of SFSC creation, and may therefore constitute convergence points of interests and value.

The convergence of interests can be justified by Blasi et al. (2015) emphasising the need for an integrated perspective of the interests in the chain approach, namely the quality and value mechanism for the actors along the chain. On the other hand, the coexistence of the SFSCs and the SCs concerning the need to provide value is justified by the conceptual convergence presented by both Lambert and Cooper (2000) and Renting et al. (2003), who claim that the main focus of their approaches is the value to be created within the chains and provided to the consumers.

This paradigm shift points to a perspective of simultaneity among the chains, raising a model of coexistence that considers the combination of adding value and convergence of interests, as shown in Figure 1.

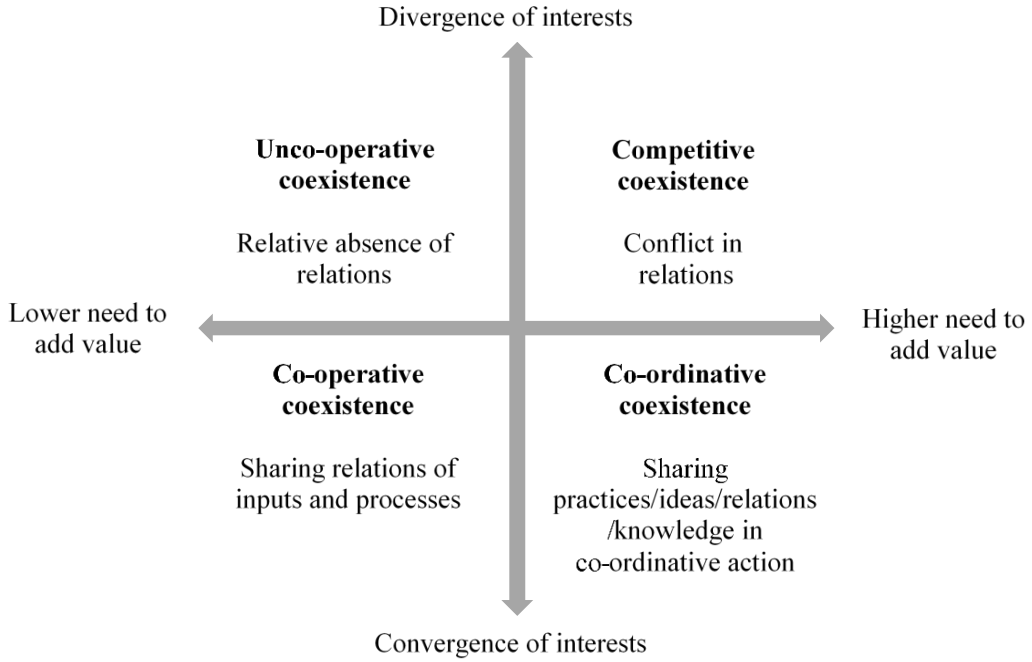

Figure 1 - Quadrant of coexistence between SCs and SFSCs

Taken together, these two dimensions create a conceptual space that allows mapping of a broad coexistence between SCs and SFSCs. In Figure 1, the need to add value is represented by the x-axis (horizontal), and the convergence or divergence of interests is represented by the y-axis (vertical). As it approaches the vertex between the two axes it means a reduction in the intensity of the coexistence factor, whereas distancing from the vertex indicates increased intensity of the coexistence factor.

The conceptual framework identifies four types of coexistence: unco-operative, co-operative, co-ordinative and competitive.

Unco-operative Coexistence

Initially, the ***unco-operative coexistence*** shows a reduction in both factors (convergence of interests and added value), having features, such as the absence or small convergence of goals by chains, which reflects a divergence of interests among the chain actors. Therefore, SCs and SFSCs offer their products and services without relations between them.

Based on the market performativity perspective, this coexistence can be understood as different versions of the same market, and, although potentially conflicting, does not imply conflict or even the need for any kind of co-ordination (Kjellberg and Helgesson, 2006). In this case, having a small need to add value to their products and services, the chains coexist in an independent manner from each other, with a relative absence of relations.

This type of coexistence is justified by the SFSCs' initial emphasis based on alternative means in lieu of conventional ones, which explains the divergence of interests. Thus, this divergence had as an outcome the arrangement of alternative products in different forms of connection with consumers, and the smaller need to add value and maintain the absence of relations between the CSs and SFSCs. In this way, a focus on alternative products, such as organic ones, can be observed in the literature (Aggestam et al., 2017; Aguiar et al., 2018; Aubry and Kebir, 2013; Enjolras and Aubert, 2018; Galli and Brunori, 2013; Giampietri et al., 2016, 2018), in order to build a new market version that supports the

SFSCs, although the conventional SCs are present at the same time and in the same space supported by another market version.

In this example, it is emphasised that the SFSCs are closely linked to organic and local foods, and to traditional small-scale production (Giampietri, Finco and Del Giudice, 2016), where the concept of food is related to being: fresh, organic, slow, high quality, traditional and others (Galli and Brunori, 2013). Thus, organic production becomes a parameter in SFSC studies (Aubry and Kebir, 2013; Giampietri, Finco and Del Giudice, 2016; Aggestam, et al., 2017; Enjolras and Aubert, 2018; Giampietri *et al.*, 2018) and is considered as a critical factor for the implementation of SFSCs (Sellitto, Vial and Viegas, 2018). On the other hand, conventional products are associated with SCs, and these are supported by the conventional market, the one that is already established, and commonly is not demanding added value, because it usually represents willingness to pay a premium price for the alternative product or the close relation with the farmer (Aschemann-Witzel and Zielke, 2017).

Co-operative Coexistence

In ***co-operative coexistence*** there is highly intense convergence of interests, and chains have a small need to add value. This coexistence features co-operation, association and dissemination of inputs and processes along the chains, as well as their relations due to the convergence of their actors' interests.

However, there is no concern about or a common commitment to joint investment among the components of the chains, based on a greater need to add value. On the other hand, a small need to add value in the co-operative coexistence may be associated to products and services well established in the market, and based on chains with a high market share; in this case organisations and chains co-operate to maintain the status quo, which is also the result of the necessity/scarcity of resources and suppliers.

In this coexistence, the dichotomy among the chains is questioned, evidencing blurring among them. Thus, it is understood that farmers tend to combine different types of chains, rather than specialise in a single one (Aubry and Kebir, 2013). From this perspective, several systems and hybrid food spaces emerge, instead of two unique opposing approaches. (Ilbery and Maye, 2005; Aubry and Kebir, 2013; Aggestam, et al., 2017).

Studying the French SFSCs, Aubry and Kebir (2013) highlight that, in many cases, there is a link with the global market based on SCs. In this case, the complementarities between SCs and SFSCs "[…] enable farmers to complement their supply with additional products (in quantity and variety, according to the season) and to meet consumers' demand" (Aubry and Kebir, 2013, p. 89).

Thus, "the majority of Ile-de-France farmers, including AMAP farmers, regularly use this type of long supply chain which, notwithstanding its drawbacks, does offer effective services with minimal commitment for selling or buying their products" (Aubry and Kebir, 2013, p. 90). This fact is also reported on the Scottish-English border. Ilbery and Maye (2005, p. 331) emphasise that, "[…] driven by a strong economic imperative, they often have to 'dip' into various 'links' associated with more conventional (commodity-based) food supply chains".

In this case, "…'alternative' producers often have to resort to the use of 'conventional' abattoirs, carriers, wholesalers and commercial customers" (Ilbery and Maye, 2005). The authors also sustain that even organic meat producers have their animals slaughtered by the only local abattoir, stressing the need for co-operation. Thus, while actors create a context for closer social ties between farmers and consumers, it is evident that these still remain fundamentally rooted in commodity relations (Hinrichs, 2000).

The opposite is also observed in which SCs adopt sharing relations with SFSCs. Aware of consumers' interest in knowing the origin of food, Aubry and Kebir (2013) evidenced that more and more supermarkets are looking for local suppliers, SFSCs' actors.

In this sense, focusing on the coffee chain (certified), Raynolds (2009) highlights that, despite creating distinct 'worlds', in reality these chains are continually being negotiated within and between economic networks. Thus, it is based on the assumption that "'alternative' normative frameworks, qualification systems, and institutions mediate 'mainstream' commercial/industrial conventions in Fair Trade networks" (Raynolds, 2009, p. 1084).

However, despite these cases of SFSCs mixed with SCs, this fact questions the sustainability of the former. As evidenced by Ilbery and Maye (2005), by sharing inputs and suppliers, conventional food producers are not necessarily more sustainable.

Co-ordinative Coexistence

Co-ordinative coexistence is related to convergence of interest and high intensity of need to add value in chains. This coexistence is characterised by the integration of chains and actors, allowing full coexistence of chains through co-operation, joint action, integration and interaction of processes, structures, people, knowledge, technology and information, and it can act in formal and informal manners.

In this coexistence, the chain commitment to adding value can be the result of convergent interest of new chains in the market to achieve greater space and establish a competitive basis through collaboration and integration among chains (Bowen, 2010; Aggestam et al., 2017).

Through a broader view, it is possible to note that the sharing of practices and ideas that result in shaping the chains happens by means of an appropriation of principles from one chain to another.

In an empirical network, analyses based on different systems of direct sales in the South of France, Chiffoleau (2009, p. 221) highlights that "[…] the link with alternative chains is not evident: terroir products are today distributed just as much through long chains, even if their attendant image is associated more with market niche products intended for direct sale".

In this sense, there are new strategies in contemporary SCs that are related, as highlighted above, to sustainability and location. One example is the geographical indications (GIs) that, although largely attributed to a local actor, are "[…] nested in wider regional, national, and international networks; and the passage from local to extra-local markets introduces new costs and benefits and new relations of power into the supply chain" (Bowen, 2010, p. 209).

In other words, "[…] the territorial embeddedness of GIs can serve as a link between local production systems and global markets, between increased competition and higher quality, and between economic and environmental sustainability" (Bowen, 2010, p. 238). Thus, in co-ordinative coexistence, an attempt to shorten SCs is observed, improving traceability and integration with other supply nodes (food services) and non-food sectors, e.g. heritage tourism (Ilbery *et al.*, 2004).

In the opposite case, one may also observe sharing of SC practices and ideas that are incorporated into SFSCs, as in scaling-up, revealed by Aggestam et al. (2017), where SFSC actors have intentions to scale-up. Being unlikely to restrict the specific market to solely one region, it is suggested "[…] a development that allows a 'hybrid' business model that combines abilities from both large mainstream producers and smaller regional producers to emerge" (Aggestam, et al., 2017, p. 70).

This picture emphasises the complexity of contemporary agrifood production. Murdoch and Miele (1999), not mentioning co-ordinative coexistence, illustrate this complexity through two Italian cases: in the first, the authors evidence a large egg producer company that participates in SCs, and has gone from standardised production to a plurality of new products imbued with quality and practices shared in SFSCs. On the other hand, the second case involves a group of small organic producers, established under the principles of SFSCs, who collectively establish a structure, standardising the 'dedicated' organic produce.

Another important case is the coffee sector, where, for a long time, it has focused on SCs (global chains) and on a standardised product (commodity). With the crisis and concerns related to quality, there is an emergence of voluntary regulatory systems (Muradian and Pelupessy, 2005). Specifically, a larger focus can be given to third party certification schemes, such as Fair Trade and organic certification, practices and ideas initially developed for SFSCs (Muradian and Pelupessy, 2005; Raynolds, 2009) and which were appropriate for the global coffee chains.

Competitive Coexistence

Finally, ***competitive coexistence*** is marked by a great need to add value in chains and a high degree of divergence of interests. In this coexistence it is notable that the chains are competitors, thus featuring a zero-sum game where chains compete for better market positions and more consumers (Oglethorpe and Heron, 2013).

In this coexistence, relations, technology, processes, people and chain structures are used in the competition against other chain components, given the divergence of interests and the intense need to add value and also capture it. This is the most illustrative coexistence in the literature involving the themes, and it is here that the highest stress in the polarisation takes place. It is necessary to say that the greatest emphasis on competition is found in the literature about the SFSCs (Aubry and Kebir, 2013; Hinrichs, 2000, 2003; Ilbery et al., 2004; Ilbery and Maye, 2005; Marsden et al., 2000; Sonnino and Marsden, 2006; Watts et al., 2005), and the competition occurs in positioning the other as a reference point that assists in the comparison to highlight the advantages/qualities/benefits of the chain that oppose the one already in position.

It is considered a coexistence with a difficult relation between SCs and SFSCs, which represents the difficulty in convergence and performance in networks involving these different chains. It is sustained by Aggestam et al. (2017, p. 70) that "[…] SFSC producers require innovative and entrepreneurial skill-sets that enable their brands to distinguish themselves from conventional products found on the mainstream market".

In the same way, analysing the consumers' behaviour towards SFSCs, Giampietri et al. (2016; 2018) emphasise an antagonistic view among the chains, where it considers the preference and the purchase of foods in SFSCs, instead of conventional markets or SCs.

Moreover, Sonnino and Marsden (2006, p. 181) affirms that, rather than viewing them as separate spheres, they see them as highly competitive, emphasising "[…] the need to explore the competitive relationships that alternative food networks have with the conventional sector to expose power imbalances and the effect these may have on wider rural development processes". For this reason, Hinrichs (2000) stresses that, to develop an alternative to the market, a decommodification of food is necessary. Thus, this coexistence features the SCs and SFSCs stressing conflicts in relations.

Conclusions

This article has highlighted the divergent and convergent points between SCs and SFSCs, the concepts, perspectives and dimensions suggest a coexistence between them. In this

sense, it has established and described a coexistence conceptual framework of the SFSCs and SCs, arranged around two main criteria: i) need to add value; and ii) convergence or divergence of interests.

Consequently, the coexistence was arranged between divergence and convergence of interest and a greater and smaller need to provide value, thereby generating a conceptual framework expressing four types of coexistence, namely: i) competitive; ii) co-ordinative; iii) co-operative; and iv) unco-operative.

Thus, this article sheds light on new analysis of SFSCs and SCs from points of coexistence between them, creating opportunities for future researches. It is also emphasised that better understanding of coexistence is expected to have managerial implications regarding the retail food sector involving different forms of simultaneous chains.

Finally, research themes are suggested to advance the coexistence framework and analyse them in an integrated manner, and not only in a competitive mode, for instance: i) how chains develop their strategies for different types of coexistence; ii) performativity in chain coexistence, i.e., how the chain's actions, assumptions and modelling perform in the other coexistence chain, and also how it impacts the previous chain; iii) assuming that this coexistence is not static, it is suggested that understanding be sought and their dynamics analysed.

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Benefits of Deploying Supply Chain Analytics in a Renewable Fuel Company

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Abstract

The proportion of bio and renewable fuels has recently increased, strongly affected by the biofuel legislation of the European Union. Simultaneously companies have been forced to optimize their increasingly complex supply chains in order to gain a competitive edge. This paper studies the benefits of deploying advanced supply chain analytics in this new business area. Decision recommendations provided by advanced analytics are compared to those obtained from the previously utilized heuristic tools and unstructured interviews of supply chain planners and managers are conducted. The findings suggest that the deployment of advanced analytics has brought substantial business benefits.

Keywords: Supply Chain Analytics, Model-Assisted Decision Making, Renewable Fuel Production Planning

Introduction

Neste Corporation is one of the world's leading renewable fuel companies. It operates both in traditional oil products and base oils, and also in the rapidly growing business area of renewable products. The supply chain of Neste Renewable Products consists of feedstock supplies, storage facilities, refineries, blending facilities, retail outlets, and transportation. Most of the feed, including waste and residues, and vegetable oils, comes from farms and industry all around the world. These feedstock materials are transported to terminals and finally to refineries, where the raw materials are converted into the products of transportation fuels for automobiles, trucks, railcars, airplanes, and chemicals, such as plastic. Some of these products are transported to terminals before they are sold to customers.

Management of renewable fuel supply chain involves the planning and management of raw materials supply, manufacture of product, and logistics. The challenge to maximize the enterprise value involves supply chain related decisions, such as the selection of

feedstocks, products, and refinery operations. These decisions are constrained by the current price data and refining options. In addition, customer demands strongly steer the choice of feedstocks and product qualities. For example, requirements for supply chain traceability and for the mixture of processed feedstocks are typically defined by customers. Moreover, value maximization related decision making is strongly dynamic as the availability of feedstocks, demands with requirements, market prices, and refining capabilities change all the time (e.g., Kim et al., 2011; Awudu and Zhang, 2012). While most demands are fixed and steered by the EU biofuel legislation, some demands are uncommitted, thus increasing the volatility of the business. Currently, these kinds of supply chain related challenges are expanding as the growth of the renewable fuel business increases the number of potential feedstocks, markets, terminals, and different transportation options. Thus, the complexity of supply chain network continuously increases.

These complexities in the renewable fuel supply chains have motivated the development of different analytical tools to support management decisions. Especially uncertainties have highly been recommended to take into account while optimizing supply chains of renewable fuels (e.g., Awuzu and Zhang 2012; Dal-Mas et al., 2010; Kim et al. 2011; Labadidi et al., 2004; Sodhi and Tang, 2009). In addition, Che and Chiang (2010) have recommended to utilize multi-objective optimization models to include both financial and sustainability related objectives in decision making. Even the parallel processing of different optimization methods have also been considered applicable to renewable fuel supply chain optimization, as argued by Banos et al. (2011).

Despite there exists plenty of methodological research on supply chain analytics, only little research has focused on analysing the benefits which advanced analytics yields in practice. This research analyzes the benefits obtained from deploying advanced supply chain analytics to supply chain optimization in the business area of Renewable Products in Neste Corporation. The research hypothesis is that the deployment of analytics tools produce value by supporting to find the best match with the feedstock, demand, and refining capabilities. Therefore, supply chain analytics has been deployed for raw material planning and product portfolio selection in Neste Corporation. The analytics tools have been integrated with the corresponding ERP systems and business processes. This has led to significant value-add due to increased profits, and cost savings in supplies, logistics, and refinery processes.

Study Methodology

Supply Chain Planning Process at Neste Corporation

In the beginning of the Renewable Products business at Neste Corporation, heuristics supported by spreadsheet based tools were used to support the supply chain management related decision making. However, because of a large amount of potential supplies, sales, as well as production and logistics possibilities, the supply chain network of Renewable Products has developed a complex entity. Currently, 200 interesting supply-production-sales combinations are available based on business specific overviews and prospects. Therefore, the analytics tool Spiral Network has been utilized to support the effective supply chain management of Renewable Products with sophisticated map validation. The use of the optimization tool enables to consider multiple locations and complex logistic constraints by simplifying the complex supply chain network to find the optimal configurations between all possibilities.

The current supply chain management for Renewable Products is based on long-term planning for the following 15 months. The responsible supply chain planner updates the

plan every month by the Spiral Network optimization model to get financial forecast, planning guidelines, term deal strategies, and logistics network design. The model is configured so that all possible refining options in the varying business environment are evaluated in optimization to achieve an integrated solution instead of sub-optimal business solutions. Spiral Network tool is supported by Excel files and the reporting tool Tableau as shown in Figure 1.

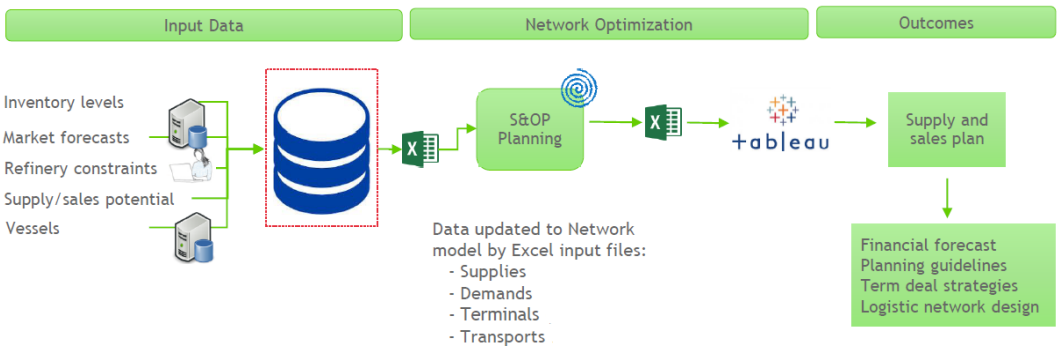

Figure 1 – Network model update process

Comparative study

To analyze the benefits obtained from advanced analytics, the optimal plans generated by old spreadsheet based tools were compared to those obtained from Spiral Suite software. As the input to these models utilized real data set from the time period October 2017 – December 2018. This data set includes records of supplies, demands, including both forecast based plans and actual sales, and operations during the following 15 months starting from October 2017. Key figures of this data set are presented in Table 1.

Table 1 – Data Content of Business Case Study from October 2017 to December 2018

Data Structure	Amount
Supplies	600
Demands	20 000
Plants	3
Inventories	200
Transport Links	3 000

Interviews

In addition to the quantitative comparative study, unstructured interviews with supply chain planners and managers in the business unit of renewable fuels are also used to gain insights on the qualitative benefits obtained from deploying Spiral Suite for supply chain planning. The main themes covered in these interviews related to the benefits of using analytical methods in managing the renewable fuel supply chain and the advantages of supply chain analytics over the previously utilized tools. In addition, the profit increase enabled by the new tools were discussed, as well as the possible future challenges with the tools.

Optimization Model

Spiral Suite covers feedstock data management, trading, plant, and network optimization, as well as scheduling and process unit monitoring by the following three modules: Plan,

Schedule, and Network (Aveva, 2019). The Plan module provides the graphical flowsheet representation for fluent modeling with scenario analyses and reporting capabilities for the need of economics and engineering. The Schedule module focuses on short-term operations planning, whereas middle- and long-term strategic planning is performed by the Network module to manage a complex logistic network.

The Spiral Network model is based on nodes and transportation links between the nodes. Nodes can be divided into supplies, plants, terminals, and demands. A simplified network model representation is shown in Figure 2. Due to the business growth of renewable fuels, the amount of model nodes and transportation options has increased time after time. The management of this supply chain model by utilizing Spiral Network is demonstrated in Figure 3.

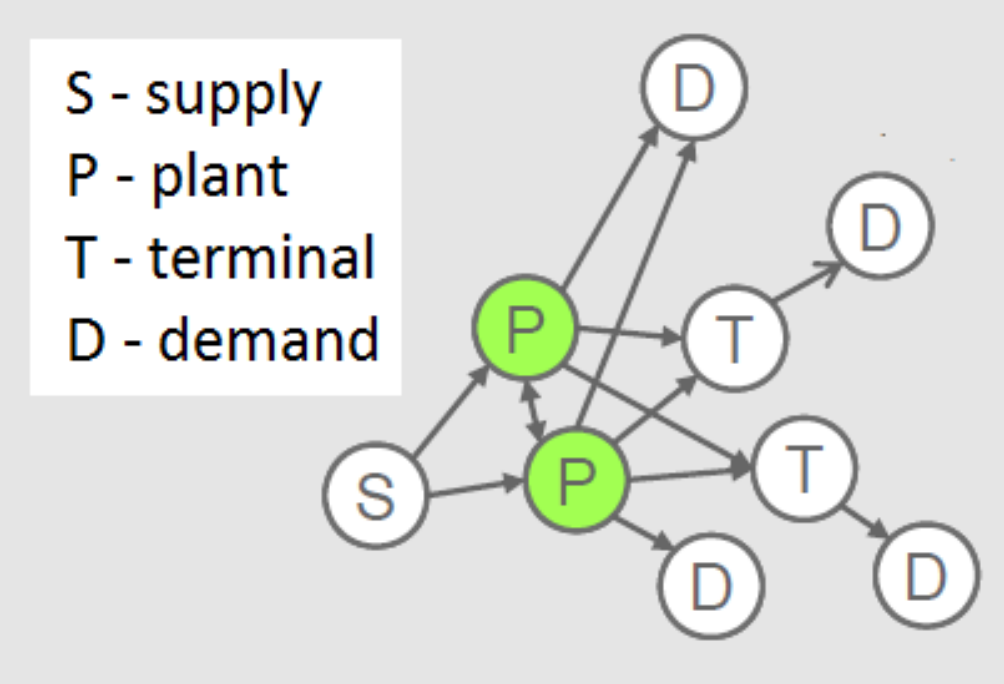

Figure 2 – Simplified Network model structure

Figure 3 – Spiral Network Tool

Findings

We compared the profits made using the new and old tool and found out that both profit increase and cost savings are achievable with the more advanced supply chain optimization tool. The total profits identified based on the results of the new tools is 590 MEUR, which is 350 MEUR (+146%) more than with the old tools. The new analytical tools have contributed to bring significant cumulative value from October 2017 to December 2018 to Neste Corporation due to higher sales profits and savings in raw material, logistics, and manufacturing costs.

Most significant strategic changes leading to the profit gains have been noticed in the following areas:

- Market shares
- Supply quality and suppliers
- Logistics network and transportation

Better use of big data largely explains the profit increase. As the new tools have managed to deal with the big variety of business options, new opportunities have been identified for market shares, supply and demand contacts, as well as logistics. This has led to significant profit gains and increase in the variety of sales. Today the company can identify a higher number of profit increase and cost saving opportunities as part of supply chain planning. For example, from the viewpoint of sales, earlier the deals may have been done based on the previous experience, and thus many potential deals and volatility of markets may have been ignored while lacking of advanced tools to include

all potential customers in decision making. However, with the support of advanced supply chain analytics, even a complex supply chain network with multiple demand possibilities can be managed.

The findings of interviews support and extend the results of the quantitative study. It has been concluded in interviews as well that real practical value has been achieved from deploying supply chain analytics. Even the management of big planning data and business prospects were experienced challenging without the advanced tools. By advanced supply chain analytics, planning transparency has also increased due to the more integrated ERP systems. By a single source of knowledge, as demonstrated in Figure 4, decisions between diverse teams across global locations are shared and communicated regularly, simultaneously enabling to explore faster new business opportunities in a complex supply chain network and reduce operational risks. In addition, common systems ease the update of planning data and encourages learning across the organization instead of an individual level. However, despite all the benefits acknowledged from deploying supply chain analytics, future challenges were still seen with the full utilization of the new tools in daily work across the whole organization.

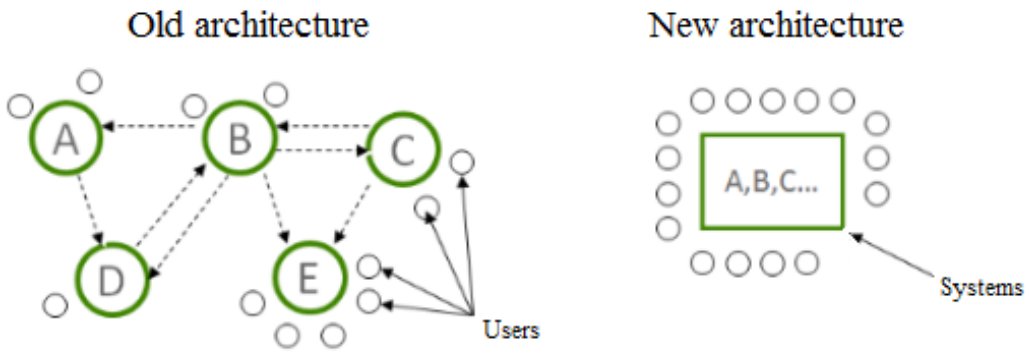

Figure 4 – Differences of old and new enterprise architectures from the viewpoint of planning transparency

Contribution

A promising research avenue stems from this research to support the practical use of advanced supply chain analytics in the novel applications of the bio and renewable fuels industry. This study suggests that advanced supply chain analytics can yield substantial benefits both in terms of profits and fluency of supply chain planning by reporting supply chain analytics related experiences in a real business context. The results contribute to existing literature by strengthening the link between researchers and practitioners in the field of operations management. Despite theoretical model development has been studied a long time, the value of deploying advanced analytics in the practical use in complex supply chain planning may have been underestimated (Little, 1970; Liberatore et al., 2000). However, the findings recommend to put more efforts on utilizing advanced analytical tools in decision making to achieve real increase in profits. This argument is also supported by Chevron (Kutz et al., 2014), which has promoted similar kind enhancements to its optimization models and obtained significant economic benefits from deploying advanced supply chain analytics.

The selected case study naturally affects the quantitative results while investigating the planning decisions and their effects on the profits made in the past. Thus, similar studies for multiple case studies in different time spans could be useful in the future

research. In addition, despite the benefits of supply chain analytics may have been acknowledged, real challenges may have caused when implementing advanced analytical tools. Such benefits and limitations of model-based decision making have also been reported by Sodhi and Tang (2008).

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A study on Supply Chain Risk Management at an automaker and a first-tier supplier in Brazil and Spain

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Abstract
Supply Chain Risk Management (SCRM) has emerged recently, especially in globalised industries, such as the automotive one. Therefore, this article presents some results of research conducted in a large global automaker and one of its main global first tier suppliers. The purpose was to identify, systematise and analyse how these companies conducted the SCRM in their supply chains considering both operating environments in Brazil and Spain. The results show an essentially reactive posture from the companies regarding the SCRM and a great concern with the present momentum of the auto industry and the risks to its current business model.

Keywords: Supply Chain Risk Management, Automotive Industry, Brazil, Spain

Introduction

Over the past few decades implementing Supply Chain Management (SCM) and Just-in-Time practices has significantly reduced inventory volumes in many industrial segments. Outsourcing processes have also made industrial companies much more dependent on their suppliers. The logic of buying anywhere in the world, where it is most convenient, derived from the so-called "globalisation of the economy" has made companies much more dependent on suppliers located physically distant, thus increasing the risks of their logistics supply processes. Therefore, the effects of events such as natural disasters, political crises, factory and customs service strikes, company bankruptcies, etc., have had an unprecedented negative "domino effect" on supply chains.

Considering this, Supply Chain Risk Management (SCRM) has emerged and gained relevance in recent years, especially in highly globalised industrial sectors, such as the automotive one. Thus, avoiding any stops on final assembly lines has become a basic concern of the operations in the sector, especially by the automakers, where usually one-minute halts mean one less vehicle being produced. In this context, this article presents the main results of research conducted during 2018 in a large global automaker and one of its main global first tier suppliers aiming to identify, systematise and analyse how these companies identify, evaluate, mitigate and monitor the risks in their supply chains. Moreover, the study also considered two distinct operating environments of these two companies: in Brazil and Spain.

Supply Chain Risk Management

In one of the pioneering articles on the subject, Christopher and Lee (2004) defined Supply Chain Risk Management (SCRM) as the risk management through a coordinated approach among supply chain members to reduce the vulnerability of the supply chain as a whole. In addition, Tang (2006) defined it as the risk management in the supply chain through coordination or collaboration among partners in the supply chain to ensure its profitability and continuity.

With respect to the SCRM itself, Fan and Stevenson (2018) state that this process generally involves four steps: risk identification, risk assessment, risk treatment/mitigation and monitoring. These steps are the same as those used by Pires et al. (2013) and are shown in Figure 1.

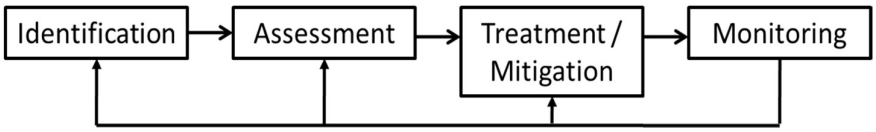

Figure 1: Main four steps of an SCRM process

Risk Identification

Risk identification seeks to uncover all relevant risks and recognise future uncertainties to proactively manage them. This stage is critical to the success of SCRM because only after a risk is identified can any risk management activity be triggered. This implies that an early judgment is necessary in this identification to decide whether a risk is relevant, and therefore should be better evaluated, mitigated and monitored (Kern et al., 2012).

Risk Assessment

Authors, such as Fan and Stevenson (2018) consider that an effective SCRM requires a comprehensive, rapid, technical, and economically feasible evaluation. Assessing a risk is not usually a trivial task and usually covers both qualitative and quantitative aspects. They often also involve complex interrelationships, since removing a risk can help mitigate certain risks and at the same time create others. Roehrich et al., (2014) consider that although over the last years some studies have discussed risk assessment strategies, this is a topic where more research is needed. They affirm that risk assessments should take greater account of the intangible consequences and losses inherent in the occurrence of the risk being assessed, such as credibility, reputation, status, authority and trust. They also affirm that these immaterial consequences are often neglected by researchers.

Fan and Stevenson (2018) also argue that managers generally assess risks based on their own experience and business performance, but it is important to consider how other indicators or signs of change in the business environment can be incorporated (Hora and Klassen, 2013). Likewise, it is important to have a broader understanding of risk in the context of the supply chain. For example, not only direct risks need to be assessed, but the possible causes or sources of these risks also need to be examined at all significant links along the chain (Wever et al., 2012).

Risk Treatment (Mitigation)

The literature has adopted various terms for the types of risk treatment actions available, usually influenced by the business context of the study. However, the five most commonly reported types (strategies) of risk treatment are: *acceptance, avoidance, transfer, sharing, and*

mitigation. Overall, most research on the subject focuses on risk mitigation. Besides this, in the context of SCRM, the terms "risk treatment" and "risk mitigation" are often used interchangeably, although mitigation is in fact one of the options for treating with a risk (Fan and Stevenson, 2018).

Risk Acceptance: there are no standard guidelines for determining how much risk an organisation should accept. The acceptable level is dependent on the context and may be linked, for example, to risk propensity, i.e. the willingness of a person or organisation to engage in risk behaviours and to accept uncertain outcomes in decision making. However, the willingness to accept the risk does not mean that the risk should be ignored. It must continue to be considered and tracked to ensure that the consequences do not increase. Moreover, if the potential consequences of risk exceed a certain threshold, companies need to consider how to avoid, transfer, share, or mitigate risk (Park et al., 2016).

Risk Avoidance: organisations may choose to eliminate the types of events that may carry the risk. For example, a company may discontinue specific products, suppliers, or geographic markets if operations in the supply chain are unreliable. Thus, it will remove the cause of the risk (Fan and Stevenson (2018).

Risk Transfer: it seeks to transfer responsibility for risk to another party. For example, business interruption risks can be transferred through business interruption insurance. Risk transfer, however, seems to be more appropriate for interruption risks with a low likelihood and high impact (such as natural disasters and terrorist attacks) than for high probability and low impact operational risks (Aqlan and Lam, 2015).

Risk Sharing: it involves another party sharing some or all the risks. From the buyer's point of view, risk can be shared generally through contracts with clauses that account for possible changes in the associated risks and the development of collaborative relationships. Suppliers, for example, would pre-order inventory risk in the presence of financial constraints or increase capacity when orders were secured by customers. Similar to risk transfer, risk sharing seems appropriate to deal with risks that are low probability and high impact in order to reduce associated costs and increase levels of customer service (Fan and Stevenson (2018).

Risk Mitigation: it seeks to actively reduce risk to an acceptable level and applies both to reducing the likelihood of a risk event and its consequences. Mitigation strategies are typically adequate for operational risks with high probability and low impact. The selection of a risk mitigation strategy also depends on the type of risk and the organisation's budget. As risks are usually interconnected, relieving one type of risk can aggravate and/or mitigate another (positive and negative dependence). Therefore, mitigation strategies should be used carefully because at the same time mitigating one risk may increase another risk. (Tummala and Schoenherr, 2011).

Risk Monitoring

It is a fact that risk is not a static phenomenon and needs to be continuously monitored to assess how sources of risk are developing and whether any changes in treatment strategies need to be applied. It is important that risk monitoring is based not only on trial assessments, but also on formal processes. Moreover, although risk monitoring is an important part of SCRM, it has received little attention under the aspect of academic research (Hoffmann et al., 2013).

Researchers have mainly suggested the establishment of specific data management systems for risk monitoring. Managers, on the other hand, tend to incorporate monitoring tasks into existing management routines, such as performing them by monitoring company performance indicators (Fan and Stevenson (2018).

Concluding this topic, one can consider that different sets of risks may require different risk management strategies. As companies have limited resources, it is important to understand how they can best be used in the SCRM. Hence, investing in risk prevention seems to be necessary when there is a high probability that it will occur. Risk acceptance may be allowed for low probability and low impact risks. Risk mitigation appears to be more appropriate for high probability and low impact risks, while risk transfer and risk sharing seems more appropriate for low probability and high impact disruption risks, such as natural disasters and terrorist attacks. And above all, the situation needs to be continuously monitored and aligned with the strategy chosen to address the risk (Fan and Stevenson (2018).

Methodology

The research was conducted using an in-depth case study addressing a large global automaker and one of its main global first tier suppliers (dual approach) and their SCRM in two countries with distinct operating environments where they both have a strong presence and market share: Brazil and Spain. It is also worth noting that the supplier company is a major supplier of the automaker and, on the other hand, the automaker is a major customer of the supplier company.

In order to conduct the field research, a framework and a semi-structured questionnaire were devised, covering the stages of identifying, evaluating, treating/mitigating and monitoring risks. In terms of supply chain scope, operations were considered in the (1) internal limits of the company, (2) outside the company and internal to the supply chain and (3) outside the supply chain.

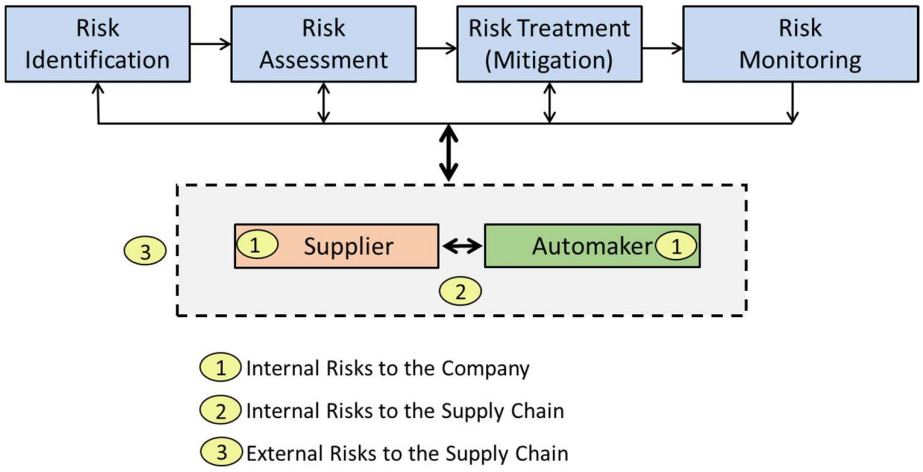

Figure 2: The scope of the empirical research

For the interviews, the main highest-level managers involved with the subject matter within the companies were interviewed. More details on the interviews and the qualification of the interviewees will be reported here later.

The empirical data collected from the interviews were complemented with visits to the company's facilities and all the company's documentation relevant to the research that was available was retrieved and analysed.

Empirical Research

The investigated **auto parts** company was a large European firm with a global presence. It has about 150 factories around the world, some of them in Brazil and Spain. The company defines it as "*an automotive supplier and partner to automakers around the world, providing innovative mobility solutions with a particular focus on the intuitive direction and reduction of CO_2 emissions*". The company also provides and distributes spare parts to the dealers' distributors of automakers and independent aftermarket companies.

The interviews were conducted with a company's global corporate purchasing director, a purchasing director for Latin America and a Europe-Latin America sales director. They were conducted mostly in person at the company headquarters in Europe in April and May 2018 and a total of approximately eight hours of interviews was recorded. In this case, factors such as the position occupied within the company (global and regional directors), the experience and knowledge accumulated in the sector and the interest in the subject researched raised the level of interviews. Thus, in addition to discussing the issue in the context of Spain and Brazil, one can extrapolate the discussion to the practice of the SCRM within the company in all parts of the world where it acts as a major supplier of large automakers.

The auto parts company divides its operations into four business units: (1) thermo systems (radiators, air conditioning), (2) power train systems (alternators, starters, clutches), (3) visibility (headlights, windshield wipers) and (4) comfort assistance (arrow switch, stop control, sensors). In global terms, each of these business units practically contributes with 25% of the company's revenues, which is a balance considered internally as very positive.

In relation to the SCRM concerning the automakers, the biggest problem considered is the fluctuations in demand and the difficulty that this imposes on the management process as a whole. The drop-in production volume in the Brazilian market after 2013 is cited as an example, i.e., the whole industrial segment prepared for a production of around 5 million vehicles a year and demand remained well below this value, generating a large idle capacity in the segment. Another difficulty is managing more multipurpose (not dedicated) factories (such as those located in Brazil, Argentina and developing countries), which produce a greater mix of products and a smaller volume of each one. In turn, in Europe there are usually more dedicated factories, which meet a more stable demand from the automakers and with a reduced mix of products and high volumes of each product. Already in terms of risks, causing a stop at the final assembly line of the customer automaker is always a threat, something to be avoided due to the financial losses and credibility that this entails.

In the company, the supplies (materials) represent from 60% to 70% of the costs of the products and it buys a wide range of materials. Concerning this, and in terms of value in the global scope, approximately 20% are resins and plastics, 20% are steel and derivatives (forged steel, cast steel, stamping), 20% aluminium (parts and coils) and 20% electromechanical (motors, motor components, starting motors, copper wires) and 20% are electronics (embedded technology). In Brazil, computing all the factories of the company, electronics still represent about 3%, which illustrates well how much the local industry still has to go in terms of electronics used in their vehicles.

Moreover, supply management and inbound logistics are based on a categorisation of all materials purchased in about 40 categories, which have a global and local structure dedicated to their management, with strategies and procedures that consider the particularities inherent in

each one of them. For example, steel purchase management is quite distinct from electronics purchasing, and so on. The company maintains purchasing teams in its plants around the world, but the procedures for development, homologation, contracting and evaluation of suppliers are centralised at corporate headquarters. This allows for a greater standardisation of procedures and savings in the processes of purchases made in a consolidated (global) way. It also allows greater uniformity and consistency in the approval procedures of suppliers, in an industrial segment with several standards (such as VDA, IATF 16949, QS 9000, etc.) to be met.

In turn, risk management in supply chains is conducted within (jointly with) the management procedures of the approximately 40 categories of materials purchased, i.e., considering the particularities of each one of them. The basic (and simple) goal is to reduce material costs (and inventories) and minimise the risks of material shortages and non-fulfilment of customers' requirements. However, the greatest difficulty lies in fulfilling this objective, especially with materials that are bought from single suppliers and centralised production in single factories, as is the case of a growing number of electronic components. Therefore, the proper definition of the supplier (or suppliers) of a given material still in the product development stage has become a key decision for risk management in the supply chain being created.

With respect to SCRM procedures per se in the company, they are still mostly reactive, that is, more focused on providing a quick solution to a risk situation that arises or is identified. Some proactive procedures, in the sense of anticipated identification of potential risks, are still considered timid and incipient by the directors interviewed. Moreover, the biggest justification for this procedure is the difficulty the company has to economically justify creating a dedicated team for a proactive risk management in its supply chains. However, despite this difficulty in allocating a dedicated internal team to perform such a task, the company has resorted to some services from external companies that provide analyses of economic scenarios and information about the economic performance of some of its suppliers. The main purpose here is to try "to view" a little beyond what the conventional supplier performance indicators usually show, and thus anticipate unpleasant surprises such as, for example, the unexpected bankruptcy of a supplier. In this example, it should be remembered that many of these suppliers belong to industrial groups and their financial results are generally disclosed in a grouped form, which makes it more difficult to identify any problems at the level of their productive units.

In turn, the **automaker** investigated belongs to a large European group that has more than one hundred factories around the world and operates in the market with some different product brands. In Brazil, the researched plant presents a relatively diversified range of products and assembly processes, ranging from complete (conventional) assembly of vehicles to assemblies in Completely Knock-Down (CKD) and Semi Knocked-Down (SKD) procedures. The main interview was held in January 2018 with the supply chain and logistics director of the factory and lasted about 5 hours. In Spain, a plant was investigated of the industrial group that produces vehicles with a brand different from that one researched in Brazil. This plant produces a relatively large range of vehicles geared specifically to the domestic and European marketplace. The interviews were conducted with an engineer and a manager from the logistics process development of the plant. They were carried out in November 2018 and in total had a duration of about 6 hours.

Following a corporate procedure, the two companies also manage their purchases of materials based on approximately 10 different groups of materials. For each of these groups, the company maintains a strategy and procedures for purchases and stock levels, which follow the guidelines of the automotive group to which it belongs. Thereby, there is a range of approaches ranging from materials where maintaining larger inventories can at certain times be considered "strategic" (steel, for example) to situations where stocks should be minimised to the extent

possible, with sequenced deliveries from suppliers (just in sequence) right into its final assembly line. In addition, as in the supplier investigated, the development, the homologation, the hiring and evaluation procedures of suppliers and the SCRM seek to contemplate the specificities of each of these groups of materials. In general, there are some normative procedures that are common to all categories and should be strictly followed as they are essential qualifying (homologating) elements for suppliers. Moreover, it is also necessary to consider the specific elements of each of the categories of materials. It should be emphasised that, because it involves the issue of human mobility and safety, the automotive industry (as well as the aeronautical, for example) is quite standardised and restrictive in relation to the homologation of suppliers. Thus, this creates a difficulty in replacing suppliers (at a time of failure of the original supplier, for example), since, for a basic cost issue, the preference of the companies is always to work with as few suppliers as possible for each item of product. Therefore, as single sourcing has become very common over the last two decades in the auto industry, a major negative effect of this dependence is clearly the increased risk of shortages of its product assembly lines.

A case in this sense occurred in 2016, when the supplier of a structural component classified as a security item, interrupted the supply to all the units of the investigated automaker in Brazil for a period of a relatively long time. Other automakers operating in the country also had the same problem. Because it involves an item that requires expensive homologation tests, the natural choice of the automaker was to decide on a single supplier. Moreover, this exclusivity turned out to be very harmful when the supplier suddenly ceased to supply, requiring a relatively long time for the development and homologation of a new supplier.

In terms of general SCRM procedures in the automaker company investigated, they remain predominantly reactive, with the formation of multi-departmental task forces to solve problems whenever necessary. In this case there is a kind of roadmap to guide the administrative procedures to be followed and with the basic purpose of normalising the situation as quickly as possible, even if the situation involves using a more costly mode of transportation, such as a dedicated air freight case. In more academic language, we can say that in this situation of abnormality, the company tries to be the most agile and resilient possible, even performing its operations at a higher cost. Furthermore, the rationale for a much more reactive rather than proactive approach in SCRM is the same as that of the supplier investigated, that is, the difficulty in economically justifying the creation and maintenance of an internal team to deal exclusively with SCRM. The company also understands that improving the visibility of operations and working with more stable production levels are essential to minimise the risks in their supply chains. Thus, the company in Spain is starting to work on a project that seeks to build a large computational tool and interface in the form of a large control panel (such as a cockpit) and with the purpose of increasing the general visibility of operations in all their supply chains. This project, still in its initial phase, should provide a more proactive character to SCRM within the company.

The auto parts and automaker's data analysis also show that factors such as (1) using factories with a more diversified mix of products and lower production volumes, (2) the geographical location in the world, (3) the lower availability and higher cost of logistics infrastructure and (4) the customs bureaucracy, tend to make SCRM more complex in Brazil.

Therefore, these four factors have a more significant effect in identifying, evaluating, treating and monitoring risks under operational reality in Brazil. On the other hand, the main causes of line interruptions are generally the same across the geographic scope investigated (Brazil and Spain), i.e., facts such as the occurrence of a natural disaster, a failing supplier, a machine breakdown, etc. Moreover, the data from the field research (with the supplier and automaker)

shows a predominantly reactive posture of the companies with respect to the SCRM, since they consider that the allocation of a team working in a dedicated way still has a great difficulty to be justified under the economic aspect traditionally prevailing in companies. However, some initial movements were also identified in order to treat SCRM more proactively, such as contracting external risk monitoring services (in the case of the supplier company) and the construction of a system of cockpit visibility and monitoring of operations throughout the supply chain (in the case of the automaker).

Table 1 identifies some points regarding the SCRM in both companies and countries.

Table 1: Some identified points regarding the SCRM in both companies and countries

Country	Supplier	Automaker
Brazil and Spain	- SCRM procedures carried out jointly with the purchasing and inbound logistics management and segmented into about 40 groups of materials. - SCRM conducted based on global corporate guidelines, with some materials with local management and with corporate and global management. - Difficulty to economically justify to the company the allocation of a dedicated full-time team to conduct the SCRM. - Reactive posture, with "task-force" formation in case of imminence or occurrence of risk.	- SCRM procedures carried out jointly with the purchasing and inbound logistics management and segmented into about 10 groups of materials. - SCRM conducted based on global corporate guidelines, with some materials with local management and with corporate and global management. - Difficulty to economically justify to the company the allocation of a dedicated full-time team to conduct the SCRM. - Reactive posture, with "task-force" formation in case of imminence or occurrence of risk.
Brazil	- Proactive actions and procedures still very incipient. - Less dedicated factories with a greater product mix, lower production volume for each of their products, and less stable master production schedules, which makes SCRM relatively more difficult.	- Proactive actions and procedures still very incipient. - Relatively less stable master production schedules, which makes the SCRM more difficult.
Spain	- It has some initial proactive actions, such as hiring an outside company to monitor the financial performance of suppliers. - More dedicated plants with large production volumes and more stable master production schedules, which makes SCRM relatively less difficult.	- Initiating proactive actions with the development of a monitoring system for operations in its supply chains, in the form of a large control panel. - Relatively more stable master production schedules, which makes the SCRM less difficult.

Final Remarks

The investigation results also show that the framework constructed to guide its conduction, although laborious, led to the results and knowledge of several real SCRM practices and cases that, when published in the near future in some articles, will certainly contribute to the knowledge on the subject. An example of these findings concerns the conduct of the SCRM in

companies according to the classification of groups of materials. To the best of our knowledge, we have found nothing reported in this regard in the academic literature available.

Furthermore, the research also highlights the turbulent historical moment that the automotive industry is currently experiencing, a fact that is more evident on the European continent. Therefore, although this was not the main purpose of the investigation, it was clear at the outset that the automotive industry is going through a period of great unease due to several elements that currently threaten the stability and *status quo* of its players. Among these elements are mainly the so-called autonomous driving, connectivity, electrification and travel sharing, which has led to new forms of mobility. Thus, topics such as cyber security, user interface technologies, telematics, gesture/voice recognition, parking and mobility optimisation, sensors and semiconductors, stand-alone solutions, electrification and energy storage, vehicle rental and fleet management, among others, are now on the daily agenda of the industry, especially of automakers and first tier suppliers.

Therefore, a research that began to focus only on the risks that could cause a stoppage in the final assembly line of both companies (supplier and automaker) ended up having to also consider the current moment. This means having to also consider the growth of risk for the automotive business as a whole, mainly due to possible breakdowns and/or disruptions in its technology and in its current business model in the near future.

This risk can be well illustrated by a statement from one of the interviewees of the automaker investigated when questioning whether "*the car of the future will be a car from our automaker with a software from Google or will be a Google car with the hardware of our automaker*"?

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Uncertainty of natural materials and various aspects of the supply chain - Case study of two automobile parts manufacturing companies in Japan –

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Abstract

This paper clarifies the reality of supply chains involving automobile parts suppliers using natural materials. It identifies problems unique to natural materials and examines possible solutions through interviews with two Japanese tertiary suppliers of products using bamboo and leather. The research found the issues of unstable quantity and quality in material procurement, which inevitably prolongs the procurement lead time, resulting in larger inventory. The solution to this is inventory control through coordination of procurement and production, and process innovation by parts suppliers. This improvement could curb costs and contribute to making carmakers' supply chains more efficient as a whole.

Keywords: supply chain

Introduction

The automobile market is changing rapidly due to the diversification of products, with parts suppliers, along with carmakers, being pressed to respond quickly to market conditions with flexible production systems. However, parts suppliers using natural materials have different problems from those using industrial materials in two aspects. The first is fluctuating demand from carmakers. In many cases, natural materials are used for luxury models as part of the companies' product differentiation strategies. This causes fluctuation in demand. The second is unstable procurement, which is different from the cases where industrial materials are used. Considering these aspects, it can be expected

that parts suppliers using natural materials will design supply chains differently from suppliers using industrial materials.

This paper examines aspects of supply chains established by parts suppliers using natural materials through case studies of two tertiary suppliers of steering wheels for Toyota Motor Corporation. Until now, there have been few studies of supply chains focusing on material procurement by parts suppliers or procurement of natural materials by them. This study aims to offer a new perspective on supply chain diversity and enrich such knowledge by revealing the realities of supply chains developed by parts suppliers using natural materials.

Literature Review

Supply chains of natural materials present different challenges from those of industrial ones. Adding variations to supply chain models and viewpoints will contribute to the study of supply chain diversity. Therefore, this review focuses on different approaches to supply chain studies.

Studies on product characteristics

The first step in designing an efficient supply chain is to understand the essence of product demand. Products can be divided into two types: those with easy and those with difficult demand prediction. Each type is further categorized as to whether products are functional or innovative. Supply chains are designed according to the characteristics of each type. However, the same product can be considered to be both functional and innovative, and that is where difficulty in choosing the right supply chain lies (Fisher, 1997).

Problems arise from various types of demand according to product characteristics in an unpredictable market. However, they can be effectively solved by appropriately matching three managerial elements: strategy, structure, and process, with such characteristics. This enables intra- and inter-company supply chains to be integrated, thereby solving the problems and developing improved supply chains (Nakano, 2016). Studies on supply chains focusing on product characteristics have developed various measures to respond to unstable demand. However, there have not been enough supply chain studies concerned with material procurement to provide effective solutions to fluctuating demand.

Studies on the coordination of demand and production

Supply chains are designed to be lean or agile, depending on which type of demand pattern they face, effective or responsive. In either a lean or agile supply chain, responses to demand fluctuations can be controlled by where the decoupling point is set (Naylor et al., 1999). In many cases, whether a manufacturer can match demand and supply depends on the ability to flexibly control the amount of supply at the time demand information is obtained (Simchi-Levi et al., 2002). Studies of this nature concern themselves about where to put the decoupling point. There are only a few studies which discuss measures to coordinate production and procurement in response to demand fluctuations.

Mass-market cars and luxury models offer different values. In the case of steering wheels, for instance, the difference between classes of automobiles is often expressed through the use of different materials, which generates product characteristics with different demand. As a result, a differentiated product with fluctuating demand may exert influence on material procurement at the far end of the supply chain. Despite the close relationship between demand and procurement, the influence of demand fluctuation stemming from product characteristics has not yet been clarified.

Parts suppliers using natural materials issue procurement orders long before they obtain actual demand information. There is always a disparity between their annual plans and

firm orders they have received. To respond flexibly to demand fluctuation, suppliers are required to adjust not only their own production system but also their procurement system. Therefore, unless we investigate production-procurement coordination, and not just demand-production, the issues to be solved cannot be identified. Until now, there have been no such studies adopting this approach.

This paper aims to clarify aspects of supply chains in relation to differences in the materials used, not product differences. It also probes how production and procurement are coordinated in response to demand fluctuation. This study focuses on aspects of supply chains constructed to overcome problems peculiar to natural materials through an examination of automobile parts suppliers.

Research Design

Qualitative data was obtained through interviews at two Japanese automobile parts suppliers which use natural materials. Company X and Company Y manufacture steering wheels made from bamboo and leather, respectively. A total of five interviews were conducted with their purchasing managers.

Parts suppliers using natural materials need to address issues involving the instability of quality and quantity peculiar to the materials. This research suggests that the solutions to these problems could become a key to improving supply chains.

The question of differences in materials has hitherto been overlooked in supply chain studies. This new approach of focusing on such differences will help solve supply chain problems.

Case of Company X, bamboo steering wheel supplier

Company X in Kochi Prefecture is a tertiary supplier that was established in 1999 through a joint investment from a private hunting gun maker in Kochi, a major Toyota-affiliated automobile parts supplier and an associated company in Aichi Prefecture. Company X's unique skill of producing laminated bamboo parts by gluing and bending simultaneously enabled bamboo to be used as automobile parts for the first time. The company's bamboo steering wheels have been adopted for seven luxury models, including those in the Lexus and Crown line. Company X produces about 600 steering wheels a day in different shapes and colors.

Gaps between Advance Demand Information (ADI) and the supplier's annual plan

Company X's procurement lead time is four months and, in most cases, the ADI from the automaker, which is customarily issued three months in advance in the auto industry, is different from their plan for a given month based on their annual plan. With such a long procurement lead time, the company needs to place advance orders and maintain a certain amount of stock to respond to changes in demand. The disparity between the ADI and the annual plan for bamboo demand is 18.3% per annum on average. However, the fluctuation can grow more extreme, putting Company X at the risk of material stockouts throughout the year. In 2017, the disparity between the ADI and their plan ranged from 6.9% to as high as 72.4%.

These fluctuations are too large for small-scale enterprises to deal with. To reduce the burden on Company B, the upstream bamboo processor, Company X places a fixed order every month. Taking the material yield into consideration, Company X adjusts orders for the following month at the end of each month to minimize the effect of order changes on Company B as well as the bamboo provider, Company C. Without this adjustment, it would be difficult to maintain constant procurement from small-sized suppliers.

As seen here, the procurement lead time for natural materials is long, and therefore planning needs to be based on an annual plan, which often results in fluctuating disparities between the annual plan and the actual monthly plan. Unstable downstream demand has a greater effect on companies upstream. Company X compensates for such disparities by adjusting its orders to smaller enterprises so as not to pass on the burden. In addition to this instability in demand, natural materials have inherent problems of quality instability. Company X needs to deal with problems concerning both quantity and quality (Figure 1).

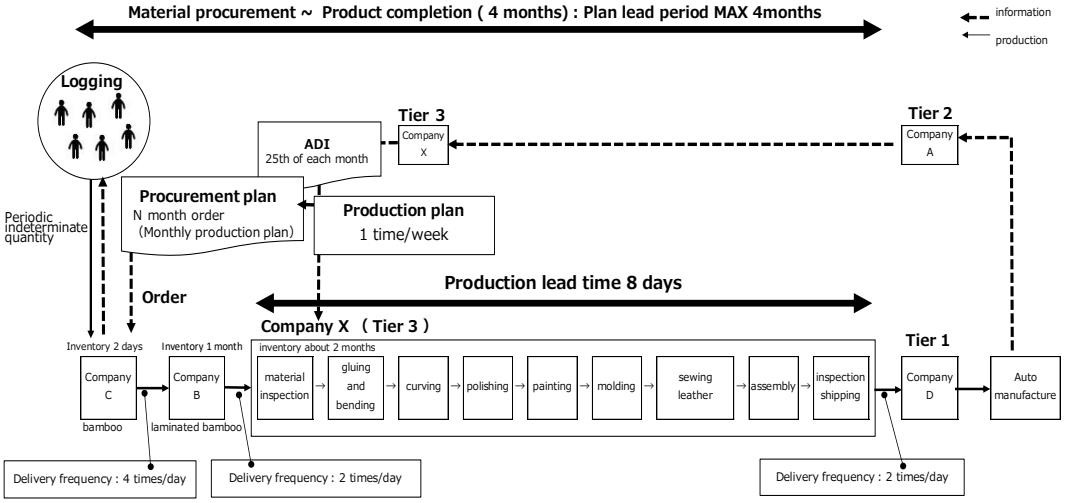

Figure 1: Company X's flow of production and information

Measures to prevent instability in material quantity

Bamboo contains more moisture than wood and its level of moisture differs depending on the season and the soil of the growing area. The best season for cutting is said to be during autumn and winter, and it is customary that bamboo used for processed goods is cut and dried naturally between November and February for a year's use. However, bamboo procurement for automobile parts needs to meet the daily order requirement in the automaker's just-in-time system. Therefore, Company X found two suppliers near Kochi City, Company C for material procurement and primary processing and Company B for secondary process of drying. The firm constructed a supply chain for bamboo steering wheels from scratch, realizing stable procurement of bamboo throughout the year.

When the company started manufacturing bamboo steering wheels in 2012, they were for only one model, the Lexus GS450h, and the total number shipped was small, at 1,300. However, a year later, this jumped to 23,000 as four Lexus models (ES, LS, HS, and RX) installed bamboo steering wheels, which made it impossible for Company X to procure enough bamboo material to catch up with demand.

Once parts suppliers have entered into a contract with an automaker, they have to meet the fluctuating amount of orders. However, procurement of natural materials with limited procurement routes cannot be flexibly adjusted at short notice when the amount vastly exceeds estimates. In addition, the long production lead time of the component material, laminated bamboo, is another factor making the adjustment difficult. On top of that, the amount required was significantly higher than that of the previous year, resulting in extremely large procurement shortages.

To secure stable procurement and avoid the risk of shortages, Company X asked Company C, a bamboo provider, to increase the number of professional bamboo cutters it employed and expand procurement routes by adding a local forestry association as a bamboo provider. Stable procurement of natural materials for industrial parts is an important issue in supply chain management.

Measures to prevent instability of material quality

Material defects are most often found at Company B, the secondary processor. When bamboo is peeled, some spots or uneven colored parts unexpectedly appear under the apparently perfect surface. In some cases, some inner parts are unusable due to insufficient specific gravity. These defects cannot be found before processing. Moreover, the bamboo harvested in spring contains more moisture because bamboo absorbs more water from the soil during its growing period. The quality of bamboo with higher moisture content is unstable even after artificial drying, resulting in yields of under 40% in some cases.

To solve this problem, Company X re-examined the moisture content of bamboo and reviewed the method of processing, and found that by adding a pre-processing drying stage, moisture content can be controlled to make the material consistent in quality. Pre-drying processing boosted the average yield to 65% from 45%. The company has continued to improve the processing method, eventually achieving a yield ratio of around 85%. It is crucial for a manufacturer using natural materials to keep improving material quality through industrial innovation after the start of mass production.

Effect of unstable material quality and quantity on production systems

The instability of bamboo procurement both in quality and quantity affects Company X's production system. In terms of quality, even after the yield of bamboo lamina was improved to around 85% at Company B, unstable elements of bamboo still remained and appeared as in-process defects in Company X's production. Bamboo has more water vessels than wood, which tends to cause variations in quality, and the rate of in-process defects was about 10% per month.

Concerning quantity, the amount of laminated bamboo which Company B delivered twice a day is not always the same as that required due to the unstable yield. To solve this problem, Company X maintains up to two months' inventory volume after the acceptance inspection stage, in order not to stop their production line. Controlling the upstream supply chain in terms of quality and quantity is the most important task for parts suppliers which use natural materials.

Summary regarding Company X

Due to the fluctuating demand situation, a tertiary supplier such as Company X must perform an adjusting function to stabilize demand for the primary and secondary suppliers. The company devised a new supply chain management system and closely linked the supply chain to procure enough bamboo material in response to the huge surge in demand. Through process innovation, the firm also resolved the quality control issue regarding bamboo, which is susceptible to the weather and the season.

Following the situation at Company X, we will now explore the research data at Company Y, which faces the same quality and quantity problems involved in dealing with natural materials.

Case of Company Y, leather steering wheel supplier

Company Y, established in Aichi Prefecture in 1957, is a parts supplier which applies a leather sewing process to making interior automotive parts. The process is dependent on the dexterity of craftsmen to flexibly meet various requirements and their proficiency in stitching accurately. The company's leather steering wheels come in 205 types and are installed in 14 models, mainly luxury cars. They produce about 3,000 leather-wrapped steering wheels a day in different colors, employing different sewing methods in accordance with specifications.

Gaps between Advance Demand Information (ADI) and the supplier's annual plan

Company Y imports the leather it uses, and it takes about six months from material procurement to product completion. Therefore, the three-month prior ADI does not provide it with enough notice about demand. Company Y orders materials six months in advance, with seven months being the longest procurement lead time.

The procurement procedure and time durations are as follows. First, it takes two or three months for materials to reach a processing factory in Thailand by sea from Brazil. It then takes another month for primary processing there, which is followed by a three-week journey to Company Y's factory in Japan. The total period of time necessary is at least five months, therefore it is quite difficult to shorten their procurement lead time.

The company orders materials for a given month at least three months before receiving the ADI. To fill the gaps between the ADI and their own monthly plan, based on their annual plan, Company Y adjusts their orders every time they receive the ADI and keeps its material inventory volume within a range of 1.5 to two months throughout the year to absorb any discrepancies. However, demand fluctuation is moderate compared to that of Company X, as leather steering wheels are built-to-order products with stable yearly demand (Figure 2).

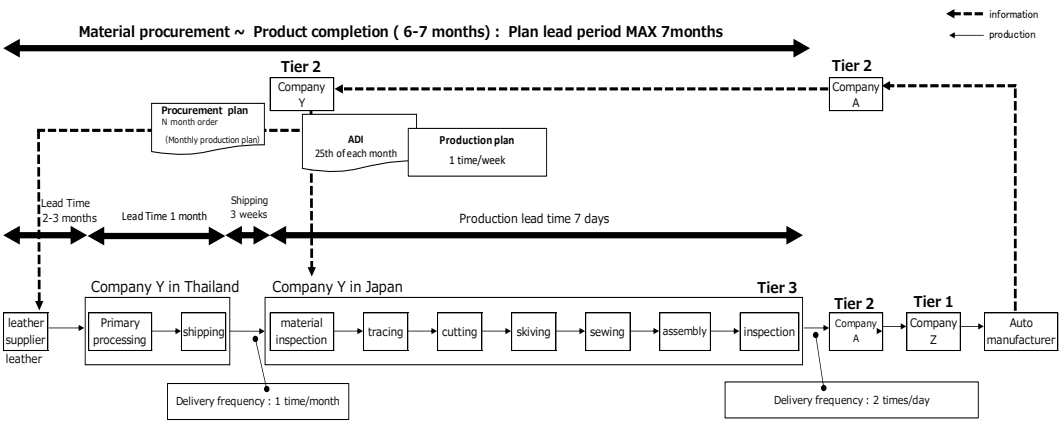

Figure 2: Company Y's flow of production and information

Measures to prevent instability of material quality

The yield of leather Company Y procures is about 50% on average, with a large fluctuation rate of 25%. At the time of sewing, some defects, such as slight blemishes, stains and pinholes, can be detected on irregular surfaces of the leather. Such defects are difficult to find at the procurement stage before sewing.

Therefore, they set the estimated yield at 50%, and workers maximize the yield by visually checking the material piece by piece and carefully patterning it in a way to avoid defective areas. Taking advantage of importing whole hides, they have been improving the yield through patterning innovation.

Although the yield of leather changes depending on the quality of the lot they receive, Company Y is able to absorb the changes with their inventory volume of at least 1.5 months. Maintaining the inventory volume also helps avert the risk of stockouts related to the long procurement lead time. Appropriate inventory control is a crucial measure for suppliers of natural material products to maintain product quality and avoid stockouts.

Summary regarding Company Y

The procurement lead time of Company Y is longer than that of Company X, which results in greater gaps between the ADI and their estimates. Even though the demand fluctuation is smaller than that of Company X, the yield of the leather material is low and it fluctuates widely. To solve the problem of unstable quality, Company Y absorbs the discrepancy by keeping a minimum of 1.5 months of inventory volume as a buffer. Technical innovation to improve the yield was also observed at Company Y as well as Company X. Process innovation after mass production has started is an important measure to curb costs for suppliers using natural materials.

Results

Upstream parts suppliers have common problems to address with long lead times from material procurement to product completion and implement wide-ranging planning accordingly. To avert the fluctuation risk caused by the gap between their annual plan and the ADI, they need to be willing to maintain a certain amount of inventory. Inventory control is especially essential for natural materials since their yields are low and changeable because of their quality instability. As a solution to fluctuating demand from downstream and the instability of material procurement from upstream, both Company X and Company Y devised a unique function for themselves as a buffer, adjusting inventory in the middle of the supply chain.

Appropriate inventory control is necessary to link a supply chain in a stable way. Parts suppliers located in the middle of the supply chain can play a role in coordinating procurement, production and industrial technology to link the supply chain more effectively. The examples seen here show that reducing inventory is not always the best plan. The significance of case-by-case inventory control is crucial, especially when dealing with natural materials.

Findings

This study has made three important findings.

First, we identified the influence that product characteristics have on material procurement. Bamboo steering wheels are differentiated products, installed in Lexus models for the first time, and have a greater range of demand compared to leather steering wheels. This fluctuating demand affects upstream primary and secondary suppliers more greatly than Company X. Thus, Company X adjusts the demand to minimize its influence upstream. We therefore, consider that product characteristics exert significant influence on material procurement as well as demand fluctuation.

Secondly, we recognized the importance of coordinating procurement and production to solve the problems related to the unstable quality and quantity of natural materials. The

instability hinders flexible adjustment in procurement, resulting in larger inventory. Unlike with industrial materials, there are limits to the amount of inventory reduction that can be achieved with natural materials. As a result, maintaining a certain amount of inventory is unavoidable.

Thirdly, we observed parts suppliers have continued technical innovation to improve yields after mass production has started. Similar to cases involving industrial materials, process innovation relating to natural materials curbs costs, leading to greater efficiency of an auto manufacturer's supply chain as a whole. However, technical innovation bears more importance in dealing with natural materials, which require greater inventory costs.

Theoretical contribution

This paper identifies problems unique to the procurement of natural materials, bamboo and leather, through case studies of suppliers which manufacture steering wheels, and considers solutions in constructing supply chains based on differences in materials.

This research points out the positive aspect of maintaining a considerable amount of inventory, which has been negatively evaluated as an obstacle to cutting costs in supply chains of industrial materials. Natural materials are not procured as flexibly as industrial materials because of their instability of quantity and quality. This difference generates differences in supply chains

The supply chain of a carmaker is constructed from smaller-scale supply chains. In the process of producing finished cars starting from material procurement and parts production, the chain is supported by the linkage of a multilayered structure of minor supply chains. Among them, the realities of small-scale supply chains at the uppermost part are revealed here. This study reveals the role of upstream parts suppliers from a viewpoint of natural material characteristics. This paper takes the first step in studying supply chains from this perspective.

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Cross-functional integration in demand management processes: impacts on customer value

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Abstract

The objective of this paper is to analyse the mechanisms that integrate the functions related to the demand processes and their respective impacts on customer value delivery in payment method companies. A case study was carried out in a Brazilian payment method company. Fourteen in-depth interviews were conducted with managers from different areas. The most mentioned integration factors are informal in nature, however, some formal integration factors were able to stimulate the occurrence of other informal factors. According to the interviewees, integration can improve commitment with common goals, related to the achievement of agility and service delivery.

Keywords: Cross-functional integration. Demand Management. Customer Value. Payment methods

1. Introduction

Several studies about cross-functional integration have been developed since the 1960s (Lawrence & Lorsch, 1967; Ellinger, 2000; Enz & Lambert, 2015; Jugend et al., 2018). Cross-functional integration plays an important role in the generation, dissemination and delivery of customer value. One approach that studies this connection between integration and customer value is the Demand and Supply Integration (DSI). DSI seeks to improve the customer value proposition by addressing several concepts related to the integration of internal functions involved in demand management and supply management processes (Esper et al., 2010).

Customer value is the result of the set of costs and benefits desired with the purchase of goods and / or services during the delivery process by the suppliers (Grönroos, 2011). The integration of internal functions plays an important role in the existing connection between the organization and its clients. This is because, in addition to integrating process flows, it is also a way to internally disseminate market information (Grönroos, 2009). In order to put this into practice, integration mechanisms are necessary to join demand processes and supply processes. This initiative can

alleviate conflicts and improve the efficiency of the supply chain (Piercy & Ellinger, 2015).

It is important to analyze cross-functional integration and to understand how its practice can help in the planning and monitoring of demand (Santos & D'Antone, 2014). In addition, cross-functional integration has been poorly studied in the sense of uniting academic debates with practice, particularly in the context of demand management (Piercy & Ellinger, 2015). Hilletofth (2011) points out that organizations need to be aware of the process of creating customer value. For this author, the integration between marketing, operations and supply chain may facilitate customer value generation.

Therefore, the studied literature about demand management presents indications about the necessity of cross-functional integration to increase customer value. However, it is necessary to explore the operationalization of the integration mechanisms and their respective impacts in this context, in order to join the research and academic discussions with practice (Piercy & Ellinger, 2015). A sector that can provide examples of this issue is the payment method market. The creation of value in these companies depends on the agility and flexibility of the internal functions in order to meet the service processes (Chan et al., 1999). Based on this discussion, the following question is proposed as a research problem: How can cross-functional integration be operationalized in demand processes in order to create customer value in the payment method sector? The objective of this paper is to analyze the mechanisms that integrate the functions related to the demand processes and their respective impacts on customer value delivery in payment method companies.

2. Theoretical review

Value is a result of the set of costs and benefits intended by the customer with the purchase of goods and / or services and the process of delivery of that good and / or service by the suppliers. The final decision of a customer for a product is related to the perception of added value (Grönroos, 2011).

For Grönroos & Ravald (2011), customers are always value-makers and suppliers have the opportunity to influence value creation through interaction processes in which customer engagement and resource integration occur.

Still about value, Grönroos (2011) states that it should not be treated as an attribute embedded in the product, but from the perspective of the Dominant Logic of the Service, as a quality or offer created in and by the interactions of customers and suppliers. It is important to emphasize that this interrelationship is not exclusive to a single department within the organizations, but must involve all employees, putting into practice organizational strategies (Grönroos, 2009). It is understood, then, that internal and external relationships are decisive for the creation of business value.

The employees of an organization need to be aligned with the creation and delivery of value to customers, executing all business strategies (Grönroos, 2009). Creating value for consumers should be the reason for the company's existence and certainly for its success (Slater, 1997), and in this context, cross-functional integration is a fundamental tool in order to reach market alignment (Kohli & Jaworski, 1990, Jaworski & Kohli, 1993). For this, it is important to analyze the practice of integration, i.e.: how organizations interact internally and externally to carry out the planning and the monitoring of demand (Santos & D'Antone, 2014).

In this context, the Demand and Supply Integration (DSI) represents a strategic approach that seeks to improve the value proposition to the customer in order to create value in the market. This perspective interconnects several related concepts in the areas

of Marketing and Supply Chain, including: cross-functional integration and value generation (Esper et al., 2010). Mentzer, Stank and Esper (2008) report the importance of integration between Marketing, Logistics and Production for the efficiency of organizations in their external integration with the other links in the supply chain. This proposition is grounded in the following definition from the Council of Supply Chain Management Professionals (CSCMP): "in essence, Supply Chain Management integrates supply and demand management within and across companies".

Demand management must be done through the connection between the areas of operations and marketing. This enables the understanding of the market, the development of actions aligned with the company's strategy and productive capacity, and also meet the needs of the customer (Jüttner et al., 2007).

Demand and Supply Integration (DSI) symbolizes a strategic approach, which seeks a customer value proposition, a process of value creation in the market (ESPER et al., 2010). According to these authors DSI is:

> […] the balancing of demand and supply market information and business intelligence through integrated knowledge management processes to strategically manage demand and supply activities for the creation of superior customer value. (Esper et al., 2010, p. 7).

The integration between the demand and supply processes helps the companies to fulfill their objectives and the customers' needs in real time, besides identifying with more precision the limitations of the capacity of supply (Esper et al., 2010). The demand management must incorporate all the processes related to the creation and fulfillment of demand. Hilletofth et al., (2009) give some examples of demand processes, such as: strategic marketing planning, marketing research, market segmentation, product development, product marketing and sales, product life cycle management. Esper et al. (2010) also mention some examples of demand side processes: demand forecasting, branding, positioning, new product launches, advertising, selling.

From the definitions above, we can cite three common points between these demand management perspectives and customer value definitions, from Grönroos (2009) and Vargo and Lusch (2004): (1) coordination and collaboration between suppliers and customers; (2) International integration of demand and supply processes (3) a process flow perspective. Therefore, the nature of demand management perspectives, particularly DSI, is focused on integration of functions that are necessary to fulfill the demand and supply processes. In this sense, the next paragraphs are dedicated to explain concepts about cross-functional integration.

Integration can be defined as "the quality or state of collaboration that exists among departments that are required to achieve unity of effort by the demands of the environment" (Lawrence & Lorsch, 1967 p.11). Cross-functional integration can take place formally through the sharing of information, in order to empower the areas involved in decision-making (Gimenez & Ventura, 2005; Jütnner et al., 2007). However, integration may also occur informally on the basis of interpersonal processes (Kahn, 1996; Ellinger et al., 2006).

A difficulty when integrating functions is the fact that each internal function is concerned firstly with its own activities and objectives. Therefore, without integration, the behavior of the department tends to be individualistic, because the areas seek their particular interests, disconnected from the interests of the organization as a whole (Lawrence & Lorsch, 1967; Ellinger et al., 2006). To overcome these challenges, integration factors are necessary, as mechanisms that motivate the different departments

to cooperate with each other (Kahn, 1996). Some authors have studied integration factors as antecedents of cooperation between internal functions and, their respective impacts on the management of demand and supply processes (Turkulainen et al., 2017; Pellathy et al., 2019).

Pimenta et al. (2016) present a multidimensional framework composed by the following five tenets, systematically involved in the integration processes:

- **Boundary-spanning activities**: activities and processes that demand involvement of different functions to be performed;
- **Integration factors**: mechanisms that generate integration among functions;
- **Formality/ informality**: forms of operationalization of the integration factors (implemented by managers or spontaneously developed);
- **Level of integration**: intensity of the cross-functional relationship;
- **Integration impacts**: benefits and outcomes obtained as the consequences of integration.

This research focuses on the study of the application of integration factors as drivers of customer value in demand management processes. Thus, Table 1 shows the main integration factors shown in the literature, which supported the field data collection in this research.

Table 1 - Integration factors investigated in the research

Integration factor	Authors
Willingness to work together to resolve conflicts	Murphy & Poist (1994)
Group spirit	Ellinger et al. (2006)
Joint planning	Pellathy et al. (2019)
Adequate communication	Pimenta et al. (2016)
Cross-functional meetings	Lambert & Cook (1990)
Functional interdependence recognition	Pellathy et al. (2019)
Senior management support	Pagell (2004)
Longevity in relationships	Ellinger et al. (2006)
Mutual understanding about each other's activities	Ellinger et al. (2006)
Consideration of the informal working groups	Pimenta et al. (2016)
Information Sharing	Turkulainen et al. (2017)
Trust	Ellinger et al. (2006)
Physical proximity of workplaces	Pagell (2004)
Job rotation	Kahn (1996)
Hierarchical dependence between functions	Pimenta et al. (2016)
Non-conflicting objectives between functions	Turkulainen et al. (2017)
Cross-functional teams	Lambert & Cook (1990)
Mutual evaluation and rewards systems	Lambert & Cook (1990)
Cross-functional education and training	Ellinger et al. (2006)
Congruence of functional objectives and organizational strategy	Feger (2014)

3. Methodology

A case study was carried out in a Brazilian payment method company. The case study method was chosen because it makes it possible to investigate a phenomenon that is not yet clearly defined, and when the research problem contains questions related to why? and how? (Yin, 2001). From a theoretical point of view, it is justified because the integration within the processes of demand are still presented superficially in the literature and need further exploratory studies (Piercy & Ellinger, 2015). The company was chosen according to the following criteria: 1) It is a large company (more than 3 million issued cards and 115.000 accredited stores), 2) it has a complex supply chain, 3) it is dependent on several efforts of cross-functional integration for creating and delivering customer value.

Fourteen in-depth interviews were conducted with managers from different hierarchical levels of Marketing, Sales, Operations, Logistics and Planning areas. The interviews lasted 1 hour in average, with the support of a research protocol with the following script: 1) The interviewees were asked to describe the demand management processes in which they are most involved (Esper et al., (2010). 2) They were asked to define which internal functions are essential to fulfil the chosen processes. 3) They were asked to evaluate the integration factors from Table 1 in a 5-point Likert scale according to their perception of occurrence within the chosen processes, i.e: from "occurs very often" to "rarely occurs". 4) They were asked to detail the operation of the integration factors evaluated as "occurs often" or "occurs very often" (4 or 5 in the scale). 5) Finally, the interviewees explained if these integration factors are able to generate customer value at some stage of the chosen process, and how it occurs.

Two additional data sources were collected in order to provide data triangulation. The questionnaire described in item 3 (integration factors) was responded by 33 people who are subordinate to the interviewees, as a trial of validating the existence of these factors. In addition, a qualitative questionnaire was applied to 21 current clients to identify the meaning of customer value. These responses were compared to the interviewees' perceptions about item 5. The interviews were audio-recorded, transcribed and subjected to content analysis. The coded analysis obtained though the interviews was compared with the meaning of customer value according the perception of current clients.

4. Findings

The interviewees described the processes of demand management that they are most involved with. The most mentioned processes were: market strategy planning, market segmentation, product development, sales & marketing and product life cycle. Two other processes emerged from the data: marketing research and demand forecast, but according to the interviewees they do not have a cross-functional characteristic within the company. Marketing research is mostly performed by third parties and is not focused on the numbers of demand forecast. The process of demand forecast does not involve multiple internal functions, and is basically focused on the amount of sales from previous years.

The interviewees pointed out the internal functions that are essential to perform the activities related to the demand processes mentioned above: Marketing, Sales, Customer Relationship, Credit Analysis, and Operations (that comprises: Network Management, Logistics, Customer Care and Operations Management). The analysis of

the integration factors that provide cooperation among these functions is presented in the following topic.

4.1 Integration factors in the demand processes studied

In order to achieve the integration of the internal functions that comprise the demand management processes analyzed, the studied company presents several integration factors, according to Table 2. It presents all the factors identified in content analysis, as well as their frequency mentioned by the interviewees.

Table 2 – Integration factors identified in the company

Integration factors	Frequency
Group spirit	8
Consideration of the informal working groups	7
Longevity in relationships	7
Senior management support	6
Willingness to work together to resolve conflicts	5
Trust	4
Cross-functional meetings	4
Adequate communication	3
Non-conflicting objectives between functions	3
Physical proximity of workplaces	3
Functional interdependence recognition	3
Mutual understanding about each other's activities	2
Information Sharing	2
Congruence of functional objectives and organizational strategy	2
Cross-functional teams	2
Mutual evaluation and rewards systems	2

The most mentioned factors in Table 2 are informal in nature, which depends on people's willingness to integrate rather than on formal management intervention. Group spirit is related to a cooperative climate in the business environment, when work teams reach a behavioral pattern in pursuit of common goals.

> When a large customer enters the company, for example. People are dedicated to meeting its demands. While some people do the development, other teams are giving support (Product Manager). Many areas engage in this group spirit, but not all of them (Sales Manager).

The longevity of relationships exists because of a low turnover, which makes it easier for people to interact and understand individual values.

> If we have known each other for a long time, we have a certain agility to solve what we need, it gets easier to communicate (Product Manager).

The willingness and joint work to resolve conflicts represents the ability to work together to solve possible conflicts, establishing agreements between functions and the willingness of managers to adopt integrative behaviors. It is observed that this factor is related to group spirit.

> In the past, when a product was going to be created, we would create the product, present it to the director and proceed with the project. Today we are restructuring this, involving other areas. We make a process, which involves legal, commercial, compliance, marketing, financial, controller, many areas of the company (Innovation Manager).

Consideration of informal working groups refers to the managerial attitude that supports the union of informal teams within the functions and stimulates joint work. Management should identify and adopt the collective behavior of the aggregate groups in order to obtain benefits for both the company and the employees.

> There is support between areas and managers. It makes us see that everybody depends on each other to deliver the solution to the client. When the areas are integrated and we can make a delivery to the customer, he will see value in that (Relationship Manager).

In addition to these results, employees reporting to key interviewees were consulted on the existence of these integration factors. These respondents indicate that the most present factors are: Consideration of the informal working groups, Trust, Longevity in relationships, Non-conflicting objectives between functions, Willingness to work together to resolve conflicts, Mutual understanding about each other's activities and Group spirit. These complementary results indicate a good alignment of perception among the managers and subordinates, who realize that the integration occurs at several hierarchical levels, not only at the managerial and strategic levels.

4.2 Cross-functional integration as a driver of customer value

Before reporting which integration factors are able to generate customer value, a careful analysis was conducted in order to understand the meaning of customer value through the perception of three agents: managers interviewed, employees reporting to them and direct clients. It is important to clarify that the studied company offers different products in terms of benefits cards: meal cards, fuel cards, salary anticipation cards, pharmacy and dental benefits cards.

Both the managers and their subordinate people elected Agility and Service delivery as the most important elements of customer value within the demand processes. Service delivery is also related to the solving of operational issues from the demand processes. In their view, Agility and Service delivery mean a fast solution of problems related to the use of the benefits cards. There is an emphasis on solving operational problems, rather than understanding how the agility of this solution could bring benefits to the customers' life.

On the other hand, the clients' responses were more focused on the direct benefits of the service on their lives, in order to define what customer value represents to them. They affirm that a benefits card allows the company to value the employee.

> The cards offer more credibility, tranquility and agility. It is a significant benefit, that in addition to an appreciation of the team, generates loyalty of the employees to the Company (Meal Card Client).

Another element related to customer value, according to the clients, is the ease of using the card instead of receiving the benefit through other forms. According to them, it is easier and safer for both paying (for the company that gives the benefit) and spending (for the employee who receive it).

One important element of customer value was mentioned by the clients of fuel cards and fleet control. According to them, the service is very good, mainly because the online information system, provided by the local company, allows them to perform a rigid control regarding how the vehicles are being used and fueled.

> We need to have control of the fuel supply process of the vehicles and to avoid fraud (Fuel Card Client)

Finally, there are some points in common between the company and the clients with regard to customer value. Most of the customer value elements mentioned by the clients were not emphasized by the company's respondents. The latter agent, is focused on Agility and Delivery. These two elements were also mentioned by the clients, but less emphatically, because they are more concerned with the issues directly related to the convenience that the card brings them when carrying out daily activities. Thus, it is assumed that the interviewees did not demonstrate a very in-depth view of the concept of customer value, so as to transpose their concern with the execution of the demand processes in benefits related to the consumer behavior of their services.

In this case, a higher level of cross-functional integration could improve the awareness about customer demands. As mentioned by Grönroos (2009), cross-functional integration is a way to internally disseminate market information. Figure 1 presents the main characteristics of the studied case, with regard to the capacity of cross-functional integration to generate customer value on demand processes.

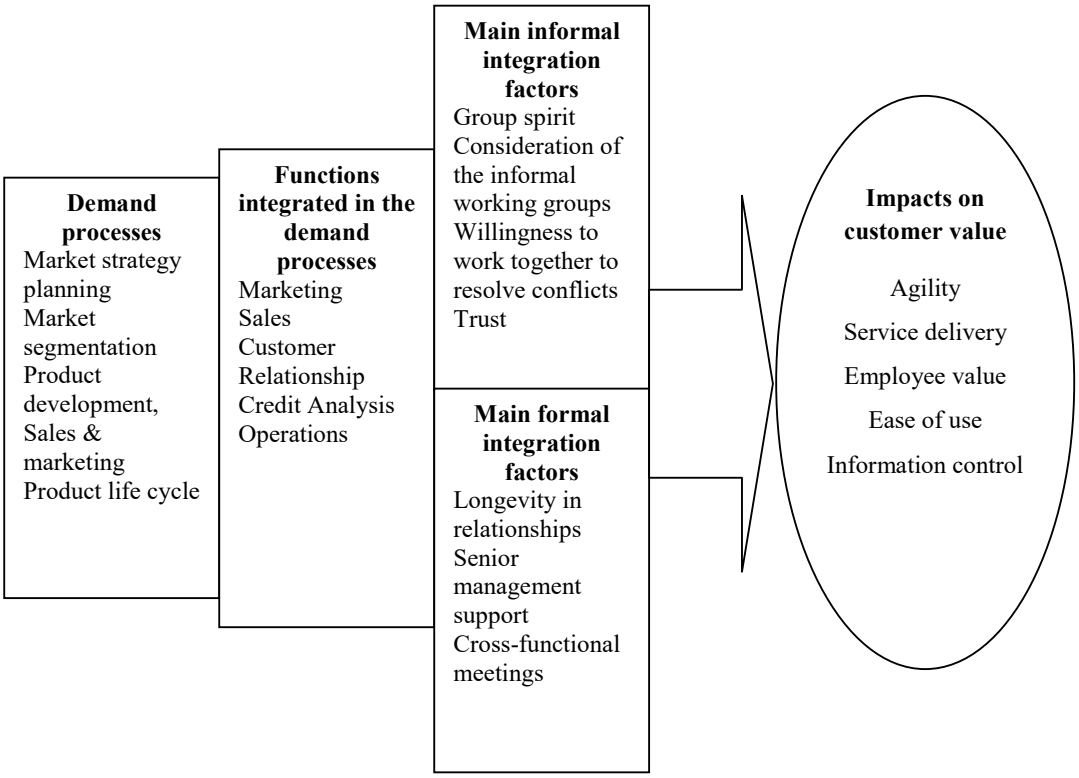

Figure 1 – Main integration factors and impacts on customer value in the studied demand processes

An important feature identified during the analyses is that the application of some formal integration factors, such as cross-functional meetings and Senior management support, stimulate the occurrence of other informal factors. For example, when there is joint planning between related areas with top management support, cross-functional meetings occur and, if they are regular, they can strengthen group spirit. In turn, these consequences increase the level of trust between people, which encourages

greater information sharing. Therefore, according to the interviewees, Agility and Service Delivery can be improved. This occurs due to the greater responsiveness to the market achieved by internal integration.

> Without integration, each one would think only of their problem or area, we would work individually, without thinking about the whole firm. The integration of the areas contributes to a broader understanding of the difficulties and functioning of the areas, strengthening team spirit and consequently, speeding up problem solving, minimizing negative impacts on customer value delivery (Regional Sales Manager).

According to OP3, when there is integration between the areas, there is affinity of thought and clarity. The members feel like part of a team, sharing the objectives and committing themselves to the goals delineated in value delivery.

> When different functions are speaking the same language, with aligned goals towards the delivery to the customer, the perception about the client's needs is much better, showing the synergy between the processes and deliveries of the company as a whole (Innovation Manager).

5. Conclusions

The field study presented the characteristics of some integration mechanisms, such as: Group spirit, Considerations of informal working groups and Longevity of relationships. The interviewees perceive a climate of cooperation between the internal areas. When people have known each other for a long time there is agility in resolving conflicts. There are problems of integration in demand processes management, which are mainly associated to the lack of the following integration mechanisms: information exchange, cross-functional training, adequate communication, proximity among departments and joint planning.

Regarding the impact of integration, the interviewed managers state that the integration among areas is responsible for agility in the resolution, delivery of customer service, solution of problems, resolution of conflicts and delivery of demands within the term. The managers agreed that agility is the most important capability towards value creation in the studied company. Finally, the analysis of the results shows that cross-functional integration affects the creation and delivery of customer value, helping to increase satisfaction with the service, to create a sense of solving and to avoid setbacks.

This research is grounded on demand management and cross-functional integration literature. Specifically, this research aims to contribute to the advance of studies on value creation in demand processes, presenting concepts poorly discussed about cross-functional integration in this context, based on a case study in a company of payment methods. The results showed that it is possible to deliver more value to customers by practicing cross-functional integration, which means that the relations between internal areas are important and should be encouraged. Different areas of the company should be organized in order to generate harmony with each other. It helps to improve the flow of the demand processes, and, consequently, to facilitate delivery of customer value.

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Environmental Risk Management in Supply Chains: A Multiple Case Study

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Abstract

The present paper explores the environmental risk supply chain management through multiple case studies conducted in three Brazilian companies. We compare the literature findings with the business reality, bringing insights on how environmental risks are managed by industries and their supply chains, what the potential losses perceived by companies are and the strategies adopted to hedge against them. The case studies' findings show that most of the risks found in the literature were considered by the companies and that two environmental risks highlighted by one of the companies can be added to the academic list.

Keywords: Environmental Risk Management, Supply Chain Management, Multiple Case Study

Introduction

Risk management is one of the most significant challenges faced by supply chains (Torres-Ruiz and Ravindran, 2018). Risks occur due to an interruption at some point in the chain, which successively clogs the flow of materials, funds or information among the entities of the supply chain (Bode et al., 2011). Global competition and outsourcing render supply chains more exposed to disruptions caused by several factors, such as uncertain economic cycles, consumer demands, natural and man-made disasters (Torres-Ruiz and Ravindran, 2018) and adverse environmental impacts (Levner and Ptuskin, 2018). Furthermore, supply chains are more vulnerable to stakeholder scrutiny, which might generate vulnerability to reputation damage (Christopher et al., 2011; Hofmann et al., 2014; Valinejad and Rahmani, 2018), access to capital and to regulatory compliance (Torres-Ruiz and Ravindran, 2018).

This paper focuses on environmental risks and presents a multiple case study on the topic, since the increase of diversity and the grow of the supply chains sizes, highlighted the importance of the environmental concerns in supply chain risk management research (Levner and Puskin, 2018), and the literature on supply chain risk management has largely overlooked ecological and social issues in their operations (Hofmann et al., 2014).

As suggested by Oliveira et al. (2019), case studies should be conducted across different companies in order to strengthen the practical field of environmental supply chain risk management and form a basis for comparability between academia and practice. Thus, in order to compare, validate and add new evidence to the findings of Oliveira et al. (2019), the present research aims to explore the environmental risks, the stakeholder effects and the consequences to the companies, as well as the environmental strategies adopted, by conducting multiple case studies across three large companies located in Brazil. The companies, here designated as companies A, B and C, are respectively a petrochemical company, an air compressor manufacturer and an agrochemical biotechnology company. More specifically, this paper aims to address the following Research Question (RQ): *Are the environmental risks, consequences and environmental strategies found in the academic literature also found/relevant in a business reality?*

The following section outlines the case study methodology adopted for this study. The results achieved through the conducted case studies are presented and discussed in Section 3. Section 4 presents the concluding remarks and suggestions for future research directions.

Research Methodology

The present research adopts the case study methodology proposed by Yin (2001), composed of six steps: planning, project, preparation, data collection, data analysis and sharing.

The planning intends to evaluate the relevant situation for the development of the case study in contrast to other research methods, justifying the choice of the case study method. Yin (2001) clarifies that the case study intends to investigate a contemporary phenomenon within its real-life context, particularly when the boundaries between phenomenon and context are not clearly defined. Thus, the case study method meets the need of this research which is to analyse environmental risk management in supply chains, since it uses several sources of evidence, and does not have a clear definition of the boundaries between the phenomenon to be studied and the context of the real life in which it is inserted.

Hence, the phenomenon to be investigated within a real-life context is the management of environmental risks in supply chains, addressing the consequences that these risks may generate for the organisations and the strategies adopted to hedge against these risks.

The project aims to elaborate on the research question, define the case study project (single or multiple) and define the criteria for interpreting the findings (Yin, 2001). Therefore, the main question of this study is centered around comparing and validating the environmental risks, consequences, and strategies proposed by Oliveira et al. (2019), with the real-life situations, observed and applied in the supply chains of three large companies located in Brazil.

Cauchick and Souza (2012) elucidate that, in the single case study, it is

expected that there will be greater depth in the investigation and less capacity of generalisation. On the other hand, in multiple case studies, there is a possibility of greater generalisation, with perhaps less deepening in the evaluation of each case. According to Herriott and Firestone (1983), the evidence resulting from multiple cases is considered more convincing, and consequently, the study is considered more robust. In order to provide greater robustness to the research, through the analysis of several organisational realities and the cross-referencing of these various cases, the present work undertakes a multiple case study.

The case studies were conducted in three large companies located in Brazil: a petrochemical company, an air compressor manufacturer, and an agrochemical and agricultural biotechnology company, chosen for being ones recognised for their sustainability visions and principles of generating positive impacts on communities and environment.

For the preparation, Yin (2001) proposes the development of a research protocol, which is extremely important to increase the reliability of the work, guiding the researcher in conducting data collection for cases. Thus, for this study, the research protocols were developed in order to guide the researchers in performing the collection of data from the multiple case studies.

Data collection considers multiple sources of evidence, such as: semi-structured interviews, documents, file queries, physical artifacts and direct observation (Yin, 2001). Yin (2001) recommends the use of several sources of evidence, since these multiple sources allow for greater detail in the collection of data. Considering the cases studies performed here, the data collection was conducted in the same way with the three companies under analysis. This collection took place in three different stages and used the following sources of data: documents provided by the company, semi-structured interviews and secondary documents sourced from corporate websites.

For data collection, a questionnaire was initially created based on a systematic literature review (SLR) performed by Oliveira et al. (2019) and was sent to the companies through the *SurveyMonkey* platform, in order to collect background information about their management of environmental supply chain risks. Then, three semi-structured interviews with different managers from the companies were performed in October and November 2018. Open questions based on feedback from the questionnaire were used in the interviews. Finally, the documents provided by the interviewees and secondary materials available on the companies' websites were compiled and analysed.

The professionals considered in these interviews are specialised in dealing with management of environmental risks, and are: (i) Environmental, Health and Safety Engineer of Company A; (ii) Environmental Analyst of Company B; and (iii) Environmental, Health and Safety Engineer of Company C.

The data analysis, according to Yin (2001), is concerned with the examination, categorisation, tabulation, testing or recombining of evidence, in order to produce discoveries based on empiricism. This step can be driven by four different techniques: to construct validity, internal validity, external validity and reliability (Yin, 2001). In this study, the technique adopted is the internal validity by means of the adaptation to the standard, where the theoretical references of systematic literature review are used as prognosis and compared with the results of this empirical study, in order to reinforce the validity of the study (Yin, 2001).

The final step of the methodology, sharing, aims to transmit the relevant information of the study through the presentation of the results (Yin, 2001). This

step is further presented in the following section.

Results and Discussion

This section presents the results and discussion of the case studies conducted in the three Brazilian companies. The online questionnaire and the interviews allowed for the evaluation of the environmental risks along the companies and their supply chains.

Firstly, through the online questionnaire and the interviews, it was possible to understand how the environmental risks and consequences were perceived and managed by the companies. Among the environmental risks listed for the interviewees, the ones considered for Company A were: greenhouse gas emissions (GHG) and ozone-depleting substances (ODS); industrial ash and soot emissions; chemicals and toxic effluents released into water or groundwater and oil; inefficient use of water; inefficient use of energy; and explosions, fires, chemical accidents. The most cited consequences that the risks may generate for the company were reputational consequences. Thus, the company realises that the losses go beyond the financial consequences that these risks can cause.

Company B considered the following environmental risks: greenhouse gas emissions (GHG) and ozone-depleting substances (ODS); chemicals and toxic effluents released into water or groundwater and oil; inefficient of raw materials; inefficient use of water; inefficient use of energy; non-compliance with sustainable laws and regulations; and explosions, fires, chemical accidents. For Company B, the most frequent consequence was the reputational consequence. The Company understands that damage to the companies' reputation can cause it irreversible losses.

Company C considered the environmental risks already mentioned, except the environmental risk related to industrial ash and soot emissions, especially as it is not closely related to its activities. With regards to consequences, those that were most frequent were financial and reputational consequences.

Respondents from Company C added two risks that were not previously included in the list of environmental risks related to the systematic literature review, with these being: inadequate disposal of hazardous solid waste and a risk of loss of biodiversity. These new risks should be added to the SLR list presented in Oliveira et al. (2019), as they may create critical environmental issues. However, the risk of loss of biodiversity is a specific risk related to the activity of Company C, which perhaps will not fit into the list of risks of all company.

Finally, regarding the strategies to deal with the risks, among the strategies identified in the literature, the most frequent strategies cited by the three companies were: wastewater and solid waste management; carbon and water footprint monitoring; efficient consumption of natural resources; substitution, precaution, and reduction in the consumption of chemicals and toxic waste; introduction of carbon emission reduction initiatives and practices (e.g., use of renewable energy, filters, freight consolidation, driver efficiency, etc.; auditing, monitoring suppliers and the use of sustainable criteria for supplier selection, encouraging suppliers and partners to promote a sound environmental policy.

It was observed that the companies have a robust environmental policy to deal with their environmental risks, once they consider most of the strategies identified in the SLR of Oliveira et al. (2019).

Regarding the consequences, the respondents of the companies reported that,

nowadays, organisations are becoming more aware of ecological issues, especially due to stakeholder pressures, legal requirements and environmental regulations. Thus, the companies perceived reputational losses in the same light as financial consequences. Furthermore, it was also concluded from the interviews that all the consequences are closely related since damage to a company's image directly affects the company's profits. The legal consequences are also associated with financial losses since fines and legal penalties minimise the company's profits.

Environmental risks caused by supplier irresponsibility and their failure to abide by environmental standards are still poorly addressed by the Companies. Only recently have the risks arising from the suppliers become a perceptible topic in the field of supply chain management, as mentioned by Torres-Ruiz and Ravindran (2018). For example, recently Company A has developed voluntary engagement actions of suppliers with a focus on sustainability, requesting them to report their greenhouse gas emissions and water consumption, as well as the risks, opportunities and strategies related to these specific issues.

Company C also pointed out that it seeks to engage with its suppliers, promoting workshops in order to influence and engage them into sustainable management practices. The workshops are also intended to encourage them to participate in the Reforestation Program which seeks to balance the emissions of greenhouse gases generated in their transport processes. Company B also emphasised that it is engaging with its suppliers regarding environmental issues, but did not mention specific actions or programmes adopted.

However, despite the engagement policies mentioned by the Companies, they did not have a well-structured matrix of the environmental risks from the suppliers. Companies A, B and C only audit the contracted service providers for the destination, treatment and transportation of their chemicals effluents and waste. Thus, it is found that the companies do not have well-structured management of environmental risks that exceed the borders of companies (environmental risks of the suppliers). Thus, due diligence, i.e. the co-responsibility and diligence of the counterparties, is a topic that needs to be addressed and further explored.

Conclusion

This paper explored the environmental risks in supply chains. This was accomplished through a multiple case study conducted in three Brazilian companies. From these cases studies, it was possible to identify the environmental risks, consequences, and strategies presented in the companies and its supply chains. The results achieved allow to provide an answer to the research question of this paper. The findings indicate that several environmental risks presented in the literature coincide with the environmental risk considered by the studied companies. However, it is relevant to highlight that although the types of adverse environmental impacts are universal, the risk types should be specified for every individual industrial enterprise (Levner and Ptuskin, 2018). For example, the risk of loss of biodiversity mentioned by Company C may not apply to another company.

The contribution of the present study for researchers was to perform a comparison and validation between the business reality and the academic findings from Oliveira et al. (2019), showing that the environmental risks found in the academic literature are in line with the environmental risks presented in a business environment. From the case studies, we realised that the environmental risks from

the suppliers are still poorly addressed by the companies, as opposed to the environmental internal risks of the companies.

Furthermore, our findings contribute to the supply chain risk management field as this paper introduces the environmental perspective and addresses the consequences that can be felt by the companies and environmental strategies from a practical business environment.

For future research, case studies should also consider different country perspectives to yield interesting insights from other cultures. Moreover, case studies conducted in different economic and climatic regions may result in different perceptions and effects of environmental risks. The region in which the company is located, the exposure to the risk, the intensity of stakeholder pressure and the legal requirements of the region will certainly influence the management of the environmental risks in the supply chain.

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Blockchain-sustainability affair in the Fashion Industry

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Abstract
Sustainability is becoming a key aspect to compete in nowadays fashion market since customers, NGOs and governments are pressuring companies to become more sustainable. Having full knowledge of all actors and activities carried out along the supply chain is therefore becoming an essential factor for the fashion industry to ensure adequate levels of sustainability. In this context this study aims at investigating the issue of supply chain traceability. Secondary sources were analyzed to deepen the adoption of traceability, in particular by analysis the blockchain technologies, along fashion supply chain in order to support sustainability purposes.

Keywords: Sustainability, Traceability, Blockchain, Fashion

Introduction

Sustainability has become more and more a fundamental driver to the competitive success of fashion firms. In recent times, due to environmental and social scandals, as mistreating of animals, application of unequal working and payment conditions to employees, and the creation of eco-unfriendly collections based on polluting industry, we have witnessed the creation of a profound furrow in customers minds, dividing clearly companies which behave in a sustainable way and which are worth to be taken into account, form those which do not.
Literature maintains Supply Chains (SC) in Fashion Industry are tightly chained with the question of contributing to business sustainability (Caniato et al., 2012, Li et al., 2014). Many activities related to the production of fashion products are affected by critical environmental and social issues indeed, as the use of chemical reagents to obtain precise aesthetic features (e.g. tanning activities, Masilamani et al., 2017), or the lack of regulations for employees. Consequently, achieving a high degree of sustainability performances in SC has become strategically crucial for competing in the fashion markets. A review on the issue has showed how scholars evaluate diverse viewpoints on how to pinpoint the right SC strategy to reinforce the responsibility of company towards the environment and society. One of them is enhancing the visibility level along SC by mean

of a traceability system (Macchion et al. 2018; Moretto et al. 2018), to identify the sources of contamination, or defects or critical nodes, or to assure trust among the peers of the SC network (Marucheck et al., 2011), and to make decisions in a consistent manner with the own values.
In this perspective, the digital era has been providing companies with many opportunities offered by technology advancements to be exploited in operations. One example is blockchain technology (Casey & Wong, 2017; Tapscott & Tapscott, 2017), but how it can be practically useful for trace objects and elements along the fashion SCs is still missing in literature.
Based on these gaps, this paper aims at investigating the adoption of traceability practices along fashion supply chain in order to support sustainability objectives. In particular the blockchain will be investigated based on cases of application of this technology within the fashion supply chains.
This goal is tackled through the analysis of secondary sources, specialized in the fashion context, which describe examples of companies that have adopted, or are adopting, blockchain technologies to track their internal processes and supply chain for sustainability objectives.

Literature review

Sustainability in the fashion industry
The recent environmental and social scandals emerged across the world and the growing pressures by non-governmental organizations (NGOs) have brought under the public spotlight the topic of sustainability as an urgent issue to be addressed (Ageron et al., 2012).
Companies in several industrial contexts, therefore, have become always more sensitive to such challenge and started working on the internal processes and on the products/services they deliver. However, this is not enough, as the public community realized that managing environmental and social issues is not only confined to the boundaries of focal companies, but must be extended to the supply network (Krause et al, 2009) and through the distribution channels as well (Zhu et al., 2005). It follows that companies have now moved to address the emerging issue related to the challenge of sustainable supply chain management, which is defined as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements" (Seuring and Müller, 2008).
The extension of these virtuous behaviours from focal companies through their supply networks might not be easy to accomplish and could rely on different strategies. For instance, some players, in several industrial contexts, have decided to abolish those current suppliers that are not proactive on sustainability, in favor of new ones more sustainable; in some other cases, the focal companies themselves developed sustainable capabilities to be forcedly extended to suppliers. In some other situations, the focal companies developed green and social capabilities, but in partnership with current suppliers; finally, there are also cases in which companies cooperate with competitors in order to develop sustainable standards and grow sufficient levers to exert such behavior to suppliers (Zhu et al., 2010). Notwithstanding such strategies, the extension of sustainability practices to an entire supply chain represents one of the most complex business challenges of the moment, as the globalization has brought to a fragmented scenario, in which suppliers are dislocated in different parts of the world, below different environmental and social regulations (Sarkis, 2012).
These issues are more than relevant for the fashion industry (de Brito et al., 2008), whose entire business model has been mainly built on the use of fragmented suppliers - often located in low-labour cost countries and where environmental and social regulations are not strict - and on

production processes highly polluting and consuming (Lo et al., 2013). The fashion industry, in fact, is now acknowledged as a business in which there is a high level of pressure on costs and prices, leading several fashion producers, in order to meet such requirements, to offset their workers' rights and environmental emissions. This has attracted the attention of several NGOs, which have considerably raised their attention to such industrial context, starting numerous initiatives (such as the known Detox Campaign by Greenpeace) which aim is to inform the public opinion about the unpleasant aspects behind this industry.

Traceability and blockchain in the fashion industry

Notwithstanding the recent interest by academics on the issue of sustainability in the fashion industry, tracing all the actors in the supply chain still remains a discussion point.

In the fashion market, in which the identification of suppliers collaborating in the production is becoming a weapon of success, giving evidence (and therefore tracing) of the origin of supply chains is assuming a key role. However the development of traceability for the network remains an open challenge due to the difficulty of structuring traceability practices cross national boundaries to identify suppliers located internationally (Macchion et al., 2017).

In structuring traceability systems companies must define tools and mechanisms to transmit information, by focusing not only in their internal processes but on the development of a complete inter-organizational traceability that could align different actors of the supply chains and ensure the data exchange in a standardized way.

The development of traceability practices should be supported by proper tags, labels, barcodes, microchips or RFID, applied directly to each product or batch, but nowadays new tracking technologies are developing in the market thanks to the growing possibilities offered by new digital technologies: the blockchain.

The early blockchain concept was proposed by a developer hiding behind the pseudonym Satoshi Nakamoto, which has been fully validated through the bitcoin system implementations since 2009. Even if the blockchain was born for bitcoin contexts, paradoxically, it could also save the fate of fashion market, that increasingly requires the most complete traceability of garments and production, to guarantee both social and green supply chain sustainability. The blockchain, in fact, allows to check the history of the product along the supply chain, as well as the prevention, or at least the reduction, of the phenomenon of counterfeits, by leaving the final consumer the possibility to verify this information.

As stated by Fu et al. (2018) "The blockchain entries could represent transactions, contracts, assets, identities, or practically anything else that can be digitally expressed using smart devices. New versions of blockchain technology implementation offer support for the implementation of smart contracts encoded in ledger's blocks, which implements different business rules that need to be verified and agreed upon by all peer nodes from the network. When a transaction arrives, each node updates its state based on the results obtained after running the smart contract. Such replication process offers a great potential for control decentralization". Based on this structure composed of nodes, it represents a weapon to protect the consumer on one side, and the brand itself on the other side, considering the possibility that some stocks end up in the so-called Gray market (i.e. the parallel sales market outside official circuits of the brand). Moreover, its development could be supported by greater consumer demand for tracked products. According to a recent Pwc report, customers would be willing to pay 5 to 10% more than the list price to buy traced products.

Research aim and research methodology

This paper revolves around the role of technology advancements to achieve higher level of sustainability within supply chains, by understanding to which extent they could be catalysts of a progress in the sustainability performance of SCs. In light of this consideration, the following research question is formulated:

RQ: How advanced Digital Technologies, such as Blockchain, might improve SC sustainability?

In pursuance of our aim, for the exploratory nature of the topic under investigation this paper is based on a secondary data qualitative analysis methodology on five different companies. This methodology provides the opportunity to understand complex phenomena in their whole facets by examining companies' documents and code of conducts, newspaper reports and sustainability and CSR reports available on the company's website and represents an important source for empirical studies (Harris, 2001). In fact, in order to plan how to select and invest on technologies to address the sustainability journey at a SC level, a profound understanding of all the practices undertaken in the field is needed. Thus, to explore our research question we embraced a supply chain perspective, and we selected five important firms consistent with the following eligibility criteria:

1. The selected company is the focal firm of each SC and is large size brand owner. Hence, it has sufficient levers to structure and influence its entire supply chain;
2. The selected company delivers products at the international level; therefore, the whole supply chain has to be compliant with different national and international sustainability regulations.
3. The selected company must have begun the path of digitalization and sustainability to study sustainability implications due to technological changes over the years.
4. The selected company must publish available information related to their commitment to sustainability and digitalization also in their online site as evidence of their sustainable path.

In order to collect data, we focused on gathering two diverse type of information consistently to the researched field. First, the different digitalization practices and projects to assess and measure the digital maturity of companies, and in particular of their SCs (Plomp, 2010; Schumacher, et al., 2016; Bienhaus and Haddud, 2018). Second, the environmental and social strategies and practices adopted by the companies during the considered years. All the collected practices of digital transformation and sustainability have been catalogued in a spreadsheet and they have been analyzed. The whole analysis has been conducted during the years 2018 and 2019 and information were collected starting from the first implementation of digital transformation and sustainability principles and practices within the supply chains. As specified, the research was conducted on a group of 5 international companies belonging to different SC networks and market segments. The selected firms all belong to the fashion industry; they are positioned in different market segments; they are homogeneous in terms of size (i.e. more than 1bn revenue), brand longstanding existence (i.e. 150 to 50 years); they show a high level of world-class operational and organizational practices; they state to pay attention to sustainability (i.e., mentioned as a competitive priority); and they are at diverse stage in the approach to digital transformation, showing to have conducted explorations on the chance offered by technology to digitalize their SCs.
Moreover, the selected companies are heterogeneous per type of products (i.e., clothes, accessories and jewelry) to cover the variety of products of the fashion industry and per country of origin of the headquarter, to understand the impact of country of origin in the approach to digitalization and sustainability.
Table X summarizes the profiles of the chosen companies.

Name of the company	Revenue (€)	Year of foundation	Headquarter's country	Main Products	Main Market Segment	Use of Blockchain

LVMH	42,8 bn (2018)	1987; Louis Vuitton: 1854	France	Clothes, Wine	Luxury	Product Traceability System
De Beers	6,1 bn (2016)	1888	South Africa	Diamonds	Luxury	Product Traceability System
Alrosa	4,09 bn (2018)	1954	Russia	Diamonds	Luxury	Product Traceability System
Levi Strauss	5,5 bn (2018)	1871	US	Clothes	General Purpose Clothing	Workforce condition Traceability System
Hugo Boss	2,7 (2018)	1924	Germany	Clothes	General Purpose Clothing	-

The selected companies

- LVMH is a French luxury company founded in 1987 as result of the merger between Louis Vuitton and Moët Hennessy. Over the years, it has progressed by acquisition, adding to its portfolio more than 60 brands such as Bulgari, Céline, Christian Dior, Givenchy, Loro Piana or Sephora. LVMH group has produced 46.8 bn € revenue in 2018 (+10% on 2017) and it counts 150.000 employees. Besides the fashion industry which amount to 40% of the revenues, its business comprises also selective retailing, wine, cosmetics, and jewelry. (LVMH, 2019).
  LVMH in 2017 has created a blockchain-dedicated team to develop MVP of a blockchain-based traceability system. The platform AURA leverages on Quorum by JP Morgan, an industrial adapted version of Ethereum. Within the network of companies, Louis Vuitton and Parfums Christian Dior have been elected to test the MVP with the purpose to scale-up the solution to the entire company. The strategical idea at the bottom is to co-opt inside this network not just the entire SCs but also the competitors as well. However, the project is still in its infancy and it has not been officially confirmed by LVMH. (Coindesk, 2019)

- De Beers and Alrosa are two leaders of the diamonds industry. Their business owns the entire Supply chain: form the exploration in search mineral deposits, to the mining process, and to the production and B2C selling of jewelry.
  Since its foundation in 1888, De Beers has been based in South Africa. Its business spreads toward 35 different countries with a revenue of 6.1bn € in 2016 and more than 20.000 employees. (De Beers, 2019). The Russian Alrosa, founded in 1954, follows De Beers as the second largest player of the sector, with revenues audited around 4,09 bn € in 2018 (300bn Rub) (Alrosa, 2019).
  De Beer and Alorsa have joined their forces on the development of a traceability system to combat the illegal diamond trafficking and forgery. From their union rose Tracr, a blockchain system with the purpose of tracking the gems status form the mining process to the customer ownership. Ensuring the quality and the history of a diamond is important also to safeguard the overall value of the market. Indeed, incumbent as De Beer or Alorsa are continuously threatened by innovation in chemistry like the synthetic diamonds, or changes in customers priorities. (Trackr, 2019)

- With 5,5 bn€ revenue divided between more than 110 countries, Levis Strauss is a US global general-purpose clothing producer and seller. Its brand is worldwild recognized mainly for its historical leadership in jeanswear. The origins of the company date back in the 1853's California, and to date the company comprises more than 15.000 employees. Recently, the firm has signed a partnership with

Harvard University to investigate how blockchain may be used to reinforce the workforce welfare. The project pilot has gained the sponsorship of the U.S. Department of State, and it aims at monitoring the workers' condition within the entire Supply Chain (Coindesk, 2019).

- Hugo Boss Group is one of the world market leaders in the premium segment of the apparel market that accounts almost 14000 employees and in the fiscal year 2018 it achieved net sales of 2,7 billion euro. The actions of the company are guided by the vision of being the most desirable fashion and lifestyle brand in the premium segment, and by the believes that the desirability of its brands will be the most important factor in the group's long-term success. Hugo Boss's management has claimed in diverse occasion to foresee Blockchain as a disruptive technology, which potential need to be explored. In particular, it is currently studying how to leverage on a blockchain-based system to track products along their Supply Chian (SCF Briefing, 2019).

Results and discussion

Thanks to the analysis of secondary data from companies listed above, the potential contribution of visibility and traceability through blockchain for sustainability was hinted.

The term Digital Supply Chain (DSC) refers to the data exchanges between actors involved within a supply chain. As stated by Büyüközkan and Göçer (2018), DSC is about "how supply chain processes are managed with a wide variety of innovative technologies", as IoT, Big Data Analytics, cloud computing and blockchain itself.

This great volume data shared between actors in a supply chain is increasingly growing and offers a wide range of opportunities for enhancing the chain efficiency and effectiveness, yet creating complexities, unclearness and issues in data management. Moreover, many supply chains still suffer from lack of integration between parties, many documents are still paper-based, and a lack of visibility on processes is still evident. Businesses are therefore trying to focus on integrating processes and transactions, which generates a huge challenge. According to Santos and Eisenhardt (2005), supply chain integration constitutes a key driver for minimization of network's governance costs, in particular the costs associated to information exchanges with other actors in the ecosystem. Scholars agrees in recognising that integration between participants in a supply chain builds supply chain efficiency.

The key area in which supply chain digitalization can provide benefits is integration between actors, in complex supply chains.

Blockchain technology can create a support towards supply chain integration. According to Korpela, et al. (2017), blockchain can address DSC limitations thanks to the following features:

- A distributed ledger of transactions replicated to every node of the blockchain network. As already discussed, the distributed ledger is open to all nodes (which may have restrictions depending on the permission level). Transactions create new blocks that are chained to the previous, and everyone who has read permissions can verify the validity of transactions (for instance, the seller can notify the buyer about a transaction, and verify the existence directly from the ledger).
- The possibility to develop smart contracts, for automating business transactions and document exchanges between parties within the supply chain. Smart contracts are

developed on blockchains and can be used to "automate DSC transactions at a very detailed level" (Korpela, et al., 2017). As an instance, smart contracts could enable automated transactions in dependence of pre-determined agreements between parties.
- The use of public key cryptography (PKC), to encrypt and decrypt a transaction. This feature ensures a high security level, as well as sustaining the whole architecture.

As a result, blockchain could enable a quick, reliable and efficient execution of transactions and document exchanges, in a secure way and at low cost (Korpela, et al., 2017).

According to evidences provided by secondary case studies, blockchain adoption in business transactions is not supposed to replace enterprise systems, but to be integrated with them in order to receive and store data in ERP's relational databases, while leveraging distributed ledgers properties to provide trust and accountability to business processes.

An insight on some benefits that can be achieved by integrating enterprise applications with blockchain is provided by Banerjee (2017).

- ERP store information about purchase, storage, production or shipment of a product. Integrating with blockchain can provide a copy of this information into the network, which is indelible, immutable and trackable at any time.
- ERP generate financial transactions. Integrating with blockchain can make transaction transparent and reliable.
- ERP holds procurement information, like purchase order and purchase agreements. These can be registered in digital formats in a blockchain and made available only to the intended parties through their private key. This would harshly reduce the need for emails or other means of communication.
- Integrating ERP with blockchain can reduce disputes over invoices. From the results of an IBM survey (Guarini, 2016), over 100 million of dollars of invoices worldwide are subject of disputes. According to IBM estimations, blockchain could avoid this kind of disputes in 90-95% of cases.
- Integrating ERP with blockchain can replace Electronic Data Interchange protocols (EDI). Messages can be transferred across members via blockchain nodes, with confidential data stored and accessible with a private key.

Pandey (2019) proposes a framework for implementing blockchain in company's ERP databases, with the purpose of solving the issue of inconsistencies in data flows. The solution is proposed in the case of two actors (a buyer and a seller), within a generic interaction based on contract, order, payment and delivery. If records are correctly uploaded on a blockchain platform, this becomes a single source of truth, and both actors can access to relevant information in real time. This approach can be followed also at a full supply chain perspective, with more actors involved. In the same way, blockchain provides a ledger where to keep record of all transaction and information exchanges.

Cases have also allowed to identify where blockchain could play a stronger role to increase transparency within companies' processes and along the supply chain. The main potential benefits are the following:

- ***Transparency and auditability***: The distributed ledger is replicated to every active node, capable of communicating with ERPs. The ledger is immutable, and each

member of a transaction channel can have access, read or write according to their permissions. Moreover, auditability is made easy thanks to data integrity: for instance, financial audits are immediate and certain.

- ***Transaction processes***: The most important information transactions occurring between actors are automated thanks to smart contracts, making the process smoother, more efficient and less subject to errors.
- ***Visibility:*** Data about the status of purchase orders are constantly updated, and information is available almost in real time.
- ***Trust:*** The adoption of smart contracts and of a shared ledger provides the highest possible level of trust between parties. Data are shared and immutable, and each involved party has access to the same version of truth. For this reason, it is expected to reduce disputes on orders or invoices.
- ***Multi-party collaboration***: Actors can easily exchange digital information and access to shared data uploaded on blockchain.
- ***Document exchange***: Paper flows are replaced with digital data exchanges, which can easily synchronize data that were previously spread across systems. Moreover, documents can be digitally stored in dedicated databases and are fully auditable.
- ***Failures identification***: Thanks to the increase in visibility on flows, and the reduction of information asymmetry, detection of issues is easier and faster.
- ***Lead time***: Increase in visibility and data sharing efficiency could reduce downtimes due to slow exchanges of information. However, no evidences that time savings are expected to be significant, if compared to the overall process lead time, can be obtained.
- ***Cost***: Increase in process efficiency is expected to reduce time required by operators in repetitive tasks, which can be dedicated to more value-adding activities. However, due to the high costs implied by the blockchain service provision, these cost savings are not relevant.

Thanks to the preliminary analysis of secondary case studies, we were also able to link benefits of blockchain listed above with sustainability practices, to understand for which practices blockchain could also become an enabler of sustainability practices.

Sustainability practice	**Details**	**Role of blockchain technology**
Adoption of recognized sustainability standards	• Life Cycle Assessment (LCA) • EU Eco-Management and Audit Scheme EMAS • UNGC • ILO • Guidelines for Multinational Enterprises • ISO 26000	Transparency and auditability Transaction processes Trust Document exchange
Certifications	• LEED • ISO 14000 • ISO 50000 • SA 8000 • EPD • GOTS (Global Organic Textile Standard) • Other (such as certified cottons and fibres)	Transparency and auditability Transaction processes Visibility Trust Document exchange
Purchase of sustainable material	• Eco-friendly / certified materials • Recycle raw materials • Eco-friendly packaging and shopping bag	Transaction processes Visibility Trust

Suppliers selection	• Selection according to
	  o environmental and social indexes
	  o certifications obtained by suppliers
	  o geographical location
	• Request of adoption of
	  o Restricted Substances List – RSL
	  o Manufacturing Restricted Substance List - MRSL
		Transaction processes
		Visibility
		Trust
		Document exchange

Suppliers monitoring	• Supplier audit • Self-certification • Sanctions • Extension of code of conduct to suppliers	Transparency and auditability Transaction processes Trust Document exchange Failures identification Lead time
Supplier collaboration	• Supplier training • Knowledge sharing with suppliers and actors of the SC • New processes and technologies development with suppliers and actors of the SC • Joint development of projects oriented to improvement of sustainability practices • Financial support to suppliers	Trust Multi-party collaboration Lead time Cost
Evaluation and consumption mapping	• Mechanical and/or chemical analysis on final product • Internal energy, water consuming, air pollution audit	Transaction processes Document exchange Lead time Cost
Eco-friendly production processes and machines	• New clean technology for water saving and air pollution minimization • Energy efficiency programs • Manufacturing machinery renewal	Lead time Cost

Conclusions and future developments

This paper investigates the topic of traceability for supply chain sustainability, with a main focus on the contribution that blockchain technology could play to foster these benefits. Whether the relevance of sustainability for the fashion industry is well recognized by both practitioners and scholars, companies are still struggling in identifying methods to enable and foster sustainability at the supply chain level. Literature presents visibility and transparency as key drivers to push sustainability, and blockchain technology appears as one of the most promising tools to enhance transparency. Through the analysis of secondary data from leading fashion companies, this paper identifies the main potential benefits of blockchain technology and makes a possible link between these benefits and the main supply chain sustainability practices.

This paper is just a preliminary step of a broader research project, oriented to investigate how blockchain technology could enable the achievement of sustainability in the supply chain. Further steps have the purpose to make direct interviews with selected companies, to triangulate data collected through secondary resources. Moreover, future research aims at assessing the potential contribution of blockchain, selecting cases that already implemented the technology to compare the ex ante and the ex post performance in terms of sustainability and the consequent level of implementation of practices.

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An empirical analysis of the relationship between supply chain strategies, product characteristics, environmental uncertainty and performance

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Abstract

This paper investigates supply chain strategies empirically, analyzing the adoption of lean, agile, leagile and traditional SC concerning product characteristics, environmental uncertainty and business/innovation performance. The exploratory analysis was carried out based on a sample of 329 companies from Portugal and Brazil. Hierarchical cluster analysis and ANOVA were conducted and many differences between the clusters were identified, highlighting that companies with leagile SC present the highest performance, while those with a traditional SC present the lowest; companies with agile SC compete in the most complex environments, while those companies with lean SC present a clear predominance of functional products.

Keywords: Supply chain strategies, Business conditions, Performance

Introduction

Supply chain (SC) strategy has attracted attention from academics in the last years due to its potential to help companies to improve performance and obtain competitive advantage (Naylor, Naim, & Berry, 1999; Perez-Franco & Phadnis, 2018; Qi, Boyer, & Zhao, 2009). The choice of the most appropriate SC strategy is a challenge to managers, as such a choice needs to consider the various features of companies and their environments (Fisher, 1997; Lee, 2002).

Previous studies have theoretically and empirically discussed and tested different patterns of the adoption of SC strategies and the importance of their alignment with a variety of aspects (Fisher, 1997; Prajogo, Mena, & Nair, 2018; Qrunfleh & Tarafdar, 2014; S.M. Wagner et al., 2012). Product and environmental characteristics are often viewed as antecedents to SC strategies, as they help to understand the choice of a particular strategy, while performance can be understood as a consequence of the chosen

strategy (Arora, Arora, & Sivakumar, 2016; Prajogo et al., 2018; Qi et al., 2009). However, the relationship between SC strategies, the nature of the products and performance is not consensual, as some authors have studied different aspects and have found different results (Lo & Power, 2010).

In this sense, the aim of this study is to add to the knowledge about the role of SC strategies within companies by means of an exploratory analysis of their relationship with product characteristics, environmental uncertainty, business performance and innovation performance. Part of the paper is developed as a complement to previous studies, contributing to the generalizability of the previous findings, while assessing the same subjects under different conditions (Goldsby & Autry, 2011). As stated by Goldsby and Autry (2011) and by van Weele and van Raaij (2014), replication of previous studies should be more frequent in SCM research, as it helps to increase the validity, credibility and relevance of theory developed in the field.

Moreover, this study will try to go further by contributing to extending the knowledge regarding the role of SC strategies by including an assessment of the adoption of the different strategies with respect to environmental uncertainty and innovation performance. Thus, the objectives of this study are: (1) to assess/confirm the taxonomy of SC strategies adopted by companies; (2) to assess/confirm the link between product characteristics and SC strategies; (3) to assess the link between environmental uncertainty and SC strategies; (4) to assess/confirm the impact of SC strategies on business performance; and (5) to assess the impact of SC strategies on innovation performance. The following question will be addressed: what differentiates the companies that adopt each type of SC strategy in terms of product characteristics, environmental uncertainty and performance?

This paper contributes to theory, as it analyzes a set of characteristics related to the adoption of the different SC strategies that have not been tested together before; and to practice, as the results may help managers in the challenging task of choosing the most appropriate SC strategy. Resource-based view (RBV) constitutes the theoretical foundation for this paper as it has been applied to supply chain management in recent years (Sjoerdsma & van Weele, 2015) and, according to the RBV, the resources and capabilities of companies are the key sources of sustained competitive advantage (Menguc, Auh, & Yannopoulos, 2014).

Theoretical background and literature review

The competitiveness that characterizes today's business environments leads companies to incorporate strategic SCM in their competitive strategies (Arora et al., 2016; Narasimhan & Narayanan, 2013; Zimmermann, Ferreira, & Moreira, 2016). The choice of an SC strategy is a complex and dynamic process, as the main elements that constitute the nature of the SC, such as product life-cycle, product demand and product variety, can be dynamic as well (Christopher, 2000). Companies have to adapt their strategies and practices constantly to maintain the fit with changing contextual aspects and to obtain higher performance (Perez-Franco & Phadnis, 2018; Prajogo et al., 2018). Thus, the SC strategy adopted must help to overcome the (more or less) volatile environment and influence the competitiveness of companies positively.

To respond to the different requirements of the environments where companies compete, two main approaches are presented and discussed in the literature: increasing efficiency (usually described as a lean or efficient SC) and/or responding quickly to market demands (usually described as an agile or responsive SC). Although each SC strategy demands different and specific requirements, the complexity of the business environment makes the existence of conditions that require purely lean or agile SCs

unusual. Companies adopt different levels of leanness and agility to meet the specific needs of their business conditions (Mason-Jones et al., 2000; Naylor et al., 1999). The combination of the two paradigms is often called leagile (or lean/agile) (Qi et al., 2009). On the other hand, when companies do not emphasize either lean or agile principles, they adopt what is known as a traditional SC strategy (Qi et al., 2009).

Among the most relevant aspects that guide companies to choose the right SC strategies, it is possible to point out a set of characteristics that influence a company's conditions to compete and perform its business, such as product characteristics (Christopher & Towill, 2002; Fisher, 1997; Qi et al., 2009), supply and demand uncertainty (Lee, 2002), the dynamism and competitiveness of the business environment (Prajogo et al., 2018), technological and marketing turbulence (Arora et al., 2016), supplier management practices (Prajogo et al., 2018), among others. In this study, besides product characteristics, the relationship of environmental uncertainty with SC strategies is analyzed.

Product characteristics is a concept traditionally linked to SC strategies (Fisher, 1997; Qi et al., 2009) as it is one of the main features that has to be considered when defining a strategy. To choose the most suitable SC strategy, companies have to consider characteristics such as product life-cycle length, predictability of demand, product variety and market standards for lead times and services (Fisher, 1997; Qi et al., 2009). Two types of products are considered in this study: functional and innovative, replicating the measures used by Qi et al. (2009).

The second aspect assessed as an antecedent of SC strategies is environmental uncertainty. The definition of environmental uncertainty encompasses the inability, at different levels, to establish the probability of future events and to predict the consequences of the decisions accurately (Sia, Teo, Tan, & Wei, 2004). Environmental uncertainty is adopted in this study according to the model proposed by Aldrich (1979) and Dess and Beard (1984), who classify the concept in three dimensions: environmental munificence, environmental dynamism, and environmental complexity. Environmental munificence refers to the extent to which the environment where companies compete can support sustained growth (Aldrich, 1979). Environmental dynamism is related to the extent that the environment is characterized by changes that are hard to predict and that heighten uncertainty for key organizational members (Aldrich, 1979; Dess & Beard, 1984). Environmental complexity refers to the complexity of the environment, measured by the extent that the environment is characterized by great uncertainty and a great information-processing requirement (Dess & Beard, 1984).

Considering the characteristics of each one of the three dimensions, it is expected that companies which compete in environments with high degrees of dynamism and complexity tend to adopt agile SC characteristics, while companies in an environment with low degrees of dynamism and complexity tend to adopt lean SC characteristics. Environmental munificence, on the other hand, is expected to have a lower level of correlation with the choice of the SC strategy, as munificence can be found in different types of environments, both more or less dynamic and complex (Pan et al., 2018).

The impact of the adoption of SC strategies on business performance and innovation performance is analyzed. Business performance has been used in a great variety of ways (Gonzalez-Benito, 2007; Rauch, Wiklund, Lumpkin, & Frese, 2009). There are several possible dimensions to measure performance, which may differ for business managers and for researchers, and a consensual model does not exist (Franco-Santos et al., 2007). A measure of business performance can be understood as a set of metrics used to quantify both the efficiency and effectiveness of companies' actions (Franco-Santos et al., 2007; Neely, Gregory, & Platts, 1995).

The performance of innovation is included in this study as a way to contribute to theory and practice, evaluating whether or not SC strategy is related to the performance of innovation and complementing the idea behind the relationship between SC strategies with product characteristics (functional or innovative products), previously evaluated by Qi et al. (2009). Innovation performance is a complex and non-consensual issue. In this study, the concepts of product and process innovation effectiveness are used, following Alegre and Chiva (2008), who based their model on the Oslo Manual (OECD & Eurostat, 2005). Nowadays, many innovation studies use this widely validated scale (Alegre & Chiva, 2013). Figure 1 shows the research model adopted in this study.

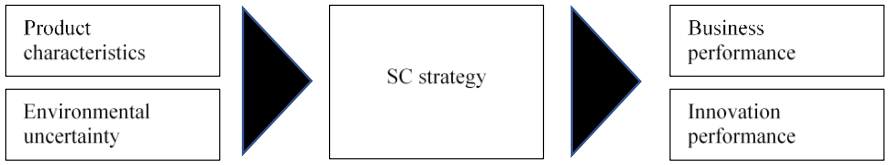

Figure 1 – Research model

Methodology

Data were collected from firms operating in Portugal and Brazil. The questionnaire was developed from a variety of references. The reliability and validity of the instrument was ensured by means of a set of actions, including preliminary interviews with experts, translation and back translation to Portuguese and English and pilot test (Zhao, Flynn and Roth, 2007). The questionnaire was made available in an online platform and an invitation was sent to 1.000 firms and Portugal and 1.000 firms and Brazil, encompassing firms from various sectors. The total number of responses was 329 (179 from Portugal and 150 from Brazil) and the return rate was 16.5% (17.9% in Portugal and 15.0% in Brazil).

Following the guidelines proposed by Craighead, Ketchen Jr. and Dunn (2011), the questionnaire was answered by two respondents in each firm, improving the reliability of the data and minimizing the risk of common-method bias. Nonresponse bias was assessed by contacting a random sample of nonrespondents and examining the differences between early and late respondents – the analyses indicated that nonresponse bias does not appear to be a concern. Secondary data were also used to triangulate survey data, reducing the risk of common-method bias (Montabon, Daugherty, & Chen, 2017).

Hierarchical cluster analysis was used to identify patterns among the firms and define the different groups of SC strategies and one-way analysis of variance (ANOVA) was applied to test the relationship between SC strategies, business conditions and performance.

The main measures used in the exploratory analysis are: SC strategies (Qi et al., 2009), product characteristics (functional and innovative) (Fisher, 1997; Qi et al., 2009), environmental uncertainty (munificence, dynamism and complexity) (Aldrich, 1979); Dess & Beard, 1984), business performance (Gonzalez-Benito, 2007) and innovation performance (Alegre and Chiva, 2013).

Results and discussion

A set of methods was applied to assess the reliability and validity of the constructs. First, exploratory factor analyses were conducted for each construct as proposed by Qi et al. (2009). The first analysis was made according to lean and agile SC characteristics. All the items were maintained as they presented factor loadings greater than 0.5 in the factors they were supposed to measure.

The second factor analysis was made for the items of product characteristics. One item (DC5) was excluded from the final construct, as it presented high cross loadings (higher than 0.4), following the suggestion of Hair, Black, Babin and Anderson, (2010). The next factor analysis assessed the constructs for innovation performance. Three items (DIPS8, DIPS9 and DIPS10) were excluded due to the presence of high cross-loading values (higher than 0.4).

Cronbach's alpha for SC strategy, business performance and innovation performance were also tested as they help to assess the internal consistency of the constructs (Hair et al., 2010; Peng & Lai, 2012). All the Cronbach's alpha results are greater than 0.8, suggesting that the constructs have sufficient reliability (Peng & Lai, 2012). Eigenvalues were also analyzed for the constructs. The analysis of the constructs for SC strategy showed that the scale for agile explains 27.0% of the variance (eigenvalue = 3.78/7 items) and the scale for lean explains 25.8% of the variance (eigenvalue = 3.61/7 items). The factor analysis for business performance also resulted in two factors – commercial performance – which explains 34.65% of the variance (eigenvalue = 2.43/4 items) – and economic and productivity performance – which explains 31.98% of the variance (eigenvalue = 2.24/3 items). Innovation performance also presents two factors, where product innovation performance explains 32.1% of the variance (eigenvalue = 4.17/5 items) and process innovation explains 26.2% (eigenvalue = 3.40/7 items). Regarding product characteristics, the scale for innovative products explains 38.1% (eigenvalue = 1.52/2 items) and the scale for functional products explains 26.9% (eigenvalue = 1.08/2 items).

The fit indices of the structural model were also tested, and the results obtained are satisfactory ($p < 0.001$, IFI = 0.926, TLI = 0.912, CFI = 0.924 and RMSEA = 0.054), providing support for the nomological validity of the structural model hypothesized.

Adoption of different SC strategies

Hierarchical cluster analysis (Ward's method, squared Euclidean distance) was conducted based on the constructs for lean and agile. The analysis of the number of clusters followed the method proposed by Frohlich and Dixon (2001). Lehmann (1979) suggests that the number of observations in each cluster should be between 30 and 60. Considering the size of the sample (N = 329), the number of clusters in this study should be between 5 and 10. However, taking into consideration that the choice of the final number of clusters is subjective, and after analyzing solutions with four and five clusters, the solution with four clusters was chosen as it provided a better understanding of the characteristics of each cluster. Moreover, the solution with four clusters matches with the solutions applied by Qi et al. (2009) and, for that reason, the clusters were named according to this study, where the four clusters are defined as: lean, agile, leagile and traditional.

Next, a one-way analysis of variance was conducted to test for differences in group means. The ANOVA and the Scheffe post hoc tests of mean differences helped to analyze the specificities of each cluster and interpret the results (table 1).

Table 1 – Analysis of variances of the SC strategies using hierarchical cluster analysis

	Cluster 1 – Leagile N = 90		**Cluster 2 – Agile N = 40**		**Cluster 3 – Traditional N = 74**		**Cluster 4 – Lean N = 125**		
	Mean*	SE	Mean*	SE	Mean*	SE	Mean*	SE	F Value
Lean SC	5.55 (2,3)	0.11	2.95 (1,3,4)	0.16	4.14 (1,2,4)	0.18	5.72 (2,3)	0.10	156.02**
Agile SC	5.39 (2,3,4)	0.12	5.83 (1,3,4)	0.12	4.81 (1,2,4)	0.17	3.71 (1,2,3)	0.11	308.66**

SE = standard error; * Based on a seven-point Likert scale; ** p<0,001; Numbers in parentheses indicate the cluster from which this cluster is significantly different at 0.05 level of significance based on the Scheffe pairwise comparison.

The four clusters identified present very well-defined features when analyzing the constructs for SC characteristics, which can be seen by means of the results of Scheffe's multiple comparison test, which indicates significative differences among the clusters.

As showed in table 1, the companies which are part of the leagile cluster present high means for the characteristics of lean and agile SCs, which means that they demonstrate a balance between leanness and agility in upstream and downstream SCs, according to the environment where they compete (Mason-Jones et al., 2000). Companies in cluster 2 present the highest means for agile SC characteristics among all the groups and the lowest value for lean, meaning that this group clearly prioritize characteristics such as: a quick response to the changing market environment, high capacity buffer and personalized products (Qi et al., 2009). On the other hand, companies in cluster 4 present the highest values for lean, and the lowest values for agile. This group has a clear predominance of practices that focus on predictability and reduction of waste, reducing costs through mass production and providing customers standardized products. Finally, cluster 3 group companies do not present a clear focus on leanness or agility, as they show low levels of both strategies. This group is called traditional SC (Qi et al., 2009).

The characteristics of each cluster were analyzed with respect to demographic characteristics of the companies that are part of each cluster. Two aspects were analyzed: company size and industry sector. Tables 2 and 3 show the results of the analyses.

Table 2 – Company size by SC strategy cluster

Variable	**Cluster 1**		**Cluster 2**		**Cluster 3**		**Cluster 4**		**Total**	
	Number	%	Number	%	Number	%	Numbe	%	Number	%
< 50	6	6.7	3	7.5	3	4.1	6	4.8	18	5.5
50 – 100	8	8.9	9	22.5	7	9.5	24	19.2	48	14.6
101–500	46	51.1	14	35.0	35	47.3	42	33.6	137	41.6
501-1000	13	14.4	8	20.0	13	17.6	28	22.4	62	18.8
> 1000	17	18.9	6	15.0	16	21.6	25	20.0	64	19.5
Total	90	100.0	40	100.0	74	100.0	125	100.0	329	100.0

Regarding the size of the companies, no significative difference was found among the clusters, indicating that the choice of the SC strategy does not depend on this feature. This result is similar to previous studies.

Table 3 – Company industry sector by SC strategy cluster

	Cluster 1		**Cluster 2**		**Cluster 3**		**Cluster 4**		**Total**	
	N	%*	N	%*	N	%*	N	%*	N	%
Food/beverages	25	36.8%	7	10.3%	12	17.6%	24	35.3%	68	20.7%
Automotive	12	22.2%	5	9.3%	9	16.7%	28	51.9%	54	16.4%
Construction and materials	8	25.8%	3	9.7%	6	19.4%	14	45.2%	31	9.4%
Machinery	6	26.1%	4	17.4%	9	39.1%	4	17.4%	23	7.0%
Textiles/apparel	4	17.4%	7	30.4%	7	30.4%	5	21.7%	23	7.0%
Ind. metals	4	18.2%	4	18.2%	6	27.3%	8	36.4%	22	6.7%
Household goods/pers. care	6	30.0%	2	10.0%	5	25.0%	7	35.0%	20	6.1%
Others	25	28.4%	8	9.1%	20	22.7%	35	39.8%	88	26.7%
Total	90	27.4%	40	12.2%	74	22.5%	125	38.0%	329	100.0%

* % of companies in the industry sector which adopt the SC strategy

Concerning the industrial sector, some interesting findings can be highlighted. Companies in the food and beverage sector (the most common among the respondents) adopt lean and leagile SC strategies predominantly. Although food and beverage is a highly diverse and heterogeneous sector, the results indicate that part of this group can be

characterized by mass production and relatively low variability. Moreover, more than 50% of the companies in the automotive and parts sector and 45% in the construction and material sector adopt a lean SC strategy, indicating a predominance of this strategy among companies in these sectors, which can be explained by the characteristics of these sectors, especially mass production, when compared with other sectors. Among the companies that adopt an agile SC strategy, it is possible to note the presence of those from the textile and apparel sector, although this sector presents a relative homogeneity regarding the choice of SC strategy.

Antecedents to the adoption of SC strategies

One-way analysis of variance was also conducted to analyze the differences between the clusters regarding product characteristics and environmental uncertainty (table 4).

Table 4 – Analysis of the variance of business conditions by SC strategy clusters

	Cluster 1		**Cluster 2**		**Cluster 3**		**Cluster 4**		
	Mean*	SE	Mean*	SE	Mean*	SE	Mean*	SE	F Value
Functional product	4.03 (2,4)	0,17	3.41 (4)	0,23	3.76 (4)	0,18	5.35 (1,2,3)	0,14	4.89***
Innovative product	4.61	0,18	5.13 (4)	0,25	4.29 (4)	0,19	4.00 (2,3)	0.14	6.29***
E. Munificence	5.70	0,11	5.40	0,18	5.49	0.13	5.62	0,08	1.11
E. Complexity	4.53 (2)	0.16	5.30 (4)	0.23	4.49 (2)	0,17	4.38 (2)	0,13	3.89***
E. Dynamism	4.51	0.17	5.45 (4)	0.21	4.39	0.18	4.16 (2)	0,13	7.36**

SE = standard error; * Based on a five-point Likert scale; ** p<0.001; *** p<0.01; Numbers in parentheses indicate the cluster from which this cluster is significantly different at 0.05 level of significance based on the Scheffe pairwise comparison.

The results show significant differences among the clusters, especially when it comes to product characteristics and environmental complexity. It is possible to highlight the frequent significant differences between agile and lean. Companies in leagile group have relatively high levels of functional and innovative products. Considering that leagile is a combination of lean and agile and that lean is more related to functional products and agile to innovative products (Fisher, 1997; Wagner, Grosse-Ruyken, & Erhun, 2012), the findings confirm the theory developed in previous studies. The environment where companies in this cluster compete is characterized by high levels of munificence and average levels of complexity and dynamism (well below agile but above lean and traditional strategies). To cope with this relative uncertainty, this group needs to be able to respond quickly to changes, which explains the need for a certain degree of agility.

The results show a predominance of innovative products~among the companies in cluster 2. This can be explained by existing theory as an agile strategy is often linked to innovative products (Fisher, 1997; Wagner et al., 2012), and product characteristics can be considered one of the main antecedents to an SC strategy (Qi et al., 2009). Complexity and dynamism characterize the environment of these companies, which helps to explain their choice of this strategy, while munificence is relatively low. Cluster 3 shows a relative balance between functional and innovative products, which may help to explain their apparent lack of focus (Qi et al., 2009). The environment where this group of companies competes is characterized by average munificence and low complexity and dynamism. In cluster 4, there is a clear predominance of functional products, rather than innovative products, confirming the theory that a lean strategy is related to functional products (Fisher, 1997). The environment of this group is characterized by low complexity and dynamism, which helps to understand the cluster's strategic choice, and relatively high munificence.

Impact of the SC strategies on business performance and innovation performance
The impact of the adoption of the different SC strategies on business performance and innovation performance was also assessed by means of one-way analysis of variance, as presented in table 5.

Table 5 – Analysis of the variance of performance by SC strategy clusters

	Cluster 1		**Cluster 2**		**Cluster 3**		**Cluster 4**		
	Mean*	SE	Mean*	SE	Mean*	SE	Mean*	SE	F Value
Commercial performance	3.71 (2,3,4)	0.06	3.41 (1)	0.11	3.36 (1)	0.07	3.45 (1)	0.06	4.92**
Economic/productiv performance	5.25 (2,3,4)	0.11	4.75 (1)	0.17	4.58 (1)	0.12	4.67 (1)	0.09	7.48**
Product innovation performance	4.88 (2,3,4)	0.10	4.49 (1)	0.10	4.26 (1)	0.13	4.34 (1)	0.09	7.49**
Process innovation performance	5.05 (2,3,4)	0.08	4.58 (1)	0.10	4.28 (1)	0.13	4.55 (1)	0.08	10.19**

SE = standard error; * Based on a seven-point Likert scale; ** p<0.001; Numbers in parentheses indicate the cluster from which this cluster is significantly different at 0.05 level of significance based on the Scheffe pairwise comparison.

These results show that companies with a leagile SC strategy achieve the best performance among the clusters in the four parameters analyzed. It can be said that this group is the most well-prepared to face different types of environments, as they are able simultaneously, and depending on, different challenges, to reduce waste and improve efficiency and respond quickly to changes in demand (Qi et al., 2017). Companies with an agile SC strategy present relatively high levels of economic and productivity performance, as well as product and process innovation performance, but a lower level of commercial performance. Companies that follow a lean paradigm presented higher levels of commercial, economic and productivity performance compared to innovation performance. The group of companies that adopt a traditional SC strategy has the lowest levels of performance in all the parameters observed.

Implications and conclusions
The aim of this paper was to discuss and test the antecedents and consequences of the adoption of different SC strategies. The study replicated and confirmed previous studies (especially Qi et al., 2009) in some respects and added to the existing knowledge in others. The hierarchical cluster analyses carried out demonstrated that the four types of SC strategies observed by Qi et al (2009) in Chinese companies are also adopted by the companies analyzed in the Portuguese and Brazilian context. Significant differences among the clusters were found in a variety of aspects.

Product characteristics and environmental uncertainty were analyzed as antecedents of the adoption of SC strategies. The results confirmed previous studies regarding product characteristics, clearly showing that companies with primarily functional products tend to adopt a lean strategy, while those with primarily innovative products adopt an agile strategy. Companies with traditional and leagile SC strategies present both functional and innovative products to a similar degree, although leagile has higher levels of innovative products. These results confirm the model proposed by Qi et al. (2009), contributing to provide validity and credibility to this previously developed theory.

Environmental uncertainty was assessed with a view to adding to the present knowledge about the factors driving the adoption of SC strategies. According to the results, companies that compete in environments characterized by high levels of complexity and dynamism tend to adopt an agile SC strategy, while those in environments with higher munificence adopt leagile and lean strategies. These results help to explain the strategic choices made by companies, along with product characteristics, as the

analysis was able to support and extend the theory regarding the relationship of the different SC strategies to the different internal and external features of companies, especially concerning the various aspects of uncertainty.

The results showed that the companies that adopt a leagile SC strategy present better business performance, contrary to previous studies, especially Qi et al. (2009), who do not find significant differences among the performance of lean, agile and leagile ones. Moreover, the group using a leagile strategy also perform better in terms of innovation, which had not been tested before. According to the results, a traditional SC strategy leads to the worst results, confirming the results obtained by Qi et al. (2009). The similarity of the performance between lean and agile, also verified in previous studies confirms the idea that there is no best SC strategy.

This study makes a theoretical contribution to the literature on the characteristics of companies with a lean and agile SC strategy and presents a variety of managerial implications. Companies need to adopt not only the right SC strategies related to their product characteristics, but also to the variety of features of their environment. The results can be used to guide managers in the adoption of their SC strategy as it clearly demonstrates that each strategy fits better with different characteristics of companies and environments, and produces different results.

Although this study provides interesting findings on the relationship between strategy, business conditions and performance, the limited sample size and geographical coverage of the sample means that any generalization of the conclusions should be made cautiously. Future research using data from different countries could contribute to discussing similarities and differences among different cultures further, following a logic of replication, as advocated by Goldsby and Autry (2011). Considering the significative lower level of commercial performance compared with economic and productivity performance in all the clusters, future research could use different scales and metrics (such as primary data) to explore and discuss the reasons and effects of this characteristic.

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Reference Modelling: A Solution for Current Sales and Operations Planning Challenges?

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Abstract

Sales and Operations Planning (S&OP) is an emerging topic, as reflected by the increasing interest of both practitioners and academics. Current studies highlight that many companies are experiencing challenges in implementing and executing S&OP processes successfully. This paper offers a first investigation on the applicability of reference modelling, a concept from the Information Systems community, as a novel approach to address current S&OP challenges. The analysis builds on a systematic literature review and interviews with three executives. The paper identifies benefits and challenges for applying reference modelling to S&OP and offers an overview of existing reference models in S&OP-related areas.

Keywords: S&OP, Reference Model, Information Systems

Introduction

Sales and Operations Planning (S&OP) is a business process, which has the aim to synchronise demand and supply, by connecting different functional areas within a company, and to bridge the strategic business plans with the operational plans of a company (Blackstone, 2010; Thomé et al., 2012). S&OP has become a topic of great importance for academics and practitioners, as indicated by an increasing industrial interest and a growing body of research (Tuomikangas and Kaipia, 2014; Kristensen and Jonsson, 2018). Despite the seemingly simple S&OP process, many companies are

currently experiencing challenges in implementing and executing S&OP processes successfully (Tuomikangas and Kaipia, 2014; Scavarda et al., 2017; Kristensen and Jonsson, 2018). Qi and Ellinger (2017, p. 1320) state that a reason for this is that "the process is not well understood". Although different aspects of S&OP have been investigated and the literature provides a variety of frameworks, a complete characterisation of the process is still missing (Pedroso et al., 2016). This is associated with a lack of detailed guidance to implement S&OP (Pedroso et al., 2016; Danese et al., 2017). A complete process characterisation could help companies in implementing and designing their S&OP processes.

This paper introduces reference modelling, an approach from the Information Systems community, as a possibility to address this issue. Reference models are information models constructed with the intention to be reused to support the development of company-specific models (Becker et al., 2007). They can serve as an initial point for process implementations, but also as a template for improvements by showing how processes can or should be designed (Fettke and Loos, 2007; Rehse et al., 2017). Reference models have been successfully applied in Operations Management, for example, SCOR in Supply Chain Management (Supply Chain Council, 2012). However, to the best of the authors' knowledge, a reference model for S&OP does not exist in the literature, and an analysis of the reference modelling approach to address current S&OP challenges has not been carried out yet. Therefore, the purpose of this paper is to conduct a first analysis in this regard. Furthermore, the paper aims to identify existing reference models in S&OP or its related functional areas and to analyse their application potential for the design and support of S&OP processes. Consequently, the following two research questions are investigated:

- *RQ1: Can the reference modelling approach support S&OP design and implementation challenges and provide complete process characterisation?*
- *RQ2: Which reference models exist in S&OP-related areas and in how far can they be applied to S&OP?*

To answer the first question, the authors of this paper conducted three interviews with industry executives, who have a long experience in working with S&OP. Furthermore, to identify reference models and to answer question two, a systematic literature review is conducted. By this, the paper takes an initial step for investigating reference modelling as a potential solution for S&OP challenges.

The paper is structured in the following way: In the next section, the literature background on S&OP and reference models is presented. Afterwards, the methodological approach for the interviews, literature search and reference model classification is explained. This is followed by a presentation and discussion of the findings. The paper finishes with a conclusion in the final section.

Literature background

Sales and Operations Planning

S&OP is a "cross-functional and integrated tactical planning process within the firm" (Thomé et al., 2012, p. 2). According to the APICS definition, it "brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans" (Blackstone 2010, p. 133). S&OP combines horizontal with vertical integration (Tuomikangas and Kaipia, 2014; Kristensen and Jonsson, 2018). While horizontal integration refers to an alignment between different functions within a company as well as across several actors within a supply chain, vertical integration relates to the alignment of objectives and plans throughout the different levels in a company (Kathuria et al., 2007; Thomé et al., 2012; Tuomikangas and Kaipia, 2014).

S&OP usually follows a five-step process that is conducted in a monthly cycle (Wallace and Stahl, 2008), as depicted in figure 1.

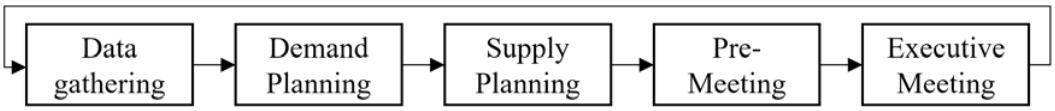

Figure 1: S&OP process (adapted from Wallace and Stahl, 2008)

Wallace and Stahl (2008) describe the five S&OP steps as follows: (1) Data Gathering, in which files are updated with the most current data and generated information; (2) Demand Planning, in which the sales and marketing department uses the information to generate the demand forecast; (3) Supply Planning, in which the operations department creates a supply plan that is based on the forecast from step three; (4) Pre-Meeting, in which conflicts are addressed and decisions to balance demand and supply are taken; (5) Executive Meeting, in which executives review the results from the previous step and change or verify the S&OP plan. Although the S&OP steps are often described similar to the ones presented in figure 1 (e.g., Lapide, 2004; Ivert et al., 2015; Hulthén et al., 2016), many studies report that how the detailed process is designed and executed depends on several contextual factors like industry, company size, or manufacturing strategy (e.g., Thomé et al., 2012; Ivert et al., 2015; Kaipia et al., 2017; Dreyer et al., 2018; Kristensen and Jonsson, 2018).

Reference modelling

A reference model represents "a special form of information models" (Becker and Schütte, 1997, p. 428), and can be used for the development of other, specific information models (Hars, 1994; Becker and Schütte, 1997; Fettke and Loos, 2007). Reference models can be seen as the result of the construction of a developer, who describes information on universal elements and relationships of a system by means of a formal language and thus creates a point of reference (Schütte, 1998). On the one hand, reference models could lead to "off-the-shelf-applications" (Fettke and Loos, 2007, p. 5) and be applied completely. On the other hand, it is also possible to reuse the reference models only partly, extend them in various aspects, aggregate their different parts, or transfer several of their patterns to analogous situations (vom Brocke, 2007).

Even though a large body of literature has been published on reference modelling, no unanimous definition of the term "reference model" exists (Thomas, 2005; Fettke and Loos, 2007; Rehse et al., 2017). Several authors present different characteristics that reference models should embrace, which are debated in the literature. Reference models should, for example, be reusable to create organisation-specific models and have a certain degree of universal applicability (e.g. Fettke and Loos, 2007). To apply reference models in different, more specific application contexts, Becker et al. (2007) highlight the importance of reference models to be adaptable. Moreover, reference models should provide recommendations for the modeller and can offer examples of actual implementations and best practices (Schütte, 1998; vom Brocke, 2003; Becker et al., 2007).

Several benefits are associated with the use of reference models. They offer a general description of a company (Fettke and Loos, 2007), and can thus foster a common understanding of the modelled objects. For the creation of company-specific models, the reuse of existing knowledge can lead to a decrease in development time and costs (Hars, 1994; Thomas, 2005; Becker et al., 2007). Furthermore, the quality of a model can increase when constructing it based on a reference model (Hars, 1994; Thomas, 2005).

Besides, the risk of failure can be reduced when applying an already proven solution presented in a reference model (Hars, 1994; Fettke and Loos, 2007). An adapted or partly usage of reference models could also yield the described benefits.

Research methodology

This paper follows a two-step methodological approach. In the first step, interviews with three S&OP executives were conducted to obtain empirical insights regarding the use of the reference modelling approach for S&OP. The executives were chosen because they have long experience in working with S&OP in different manufacturing industries in Germany and Brazil. The interviews were conducted in a semi-structured form, following the guidelines of Myers and Newman (2007).

In the second step, a systematic literature review was conducted, based on the approach of Tranfield et al. (2003). ScienceDirect was selected as the database and searched with the following keywords: “reference model” AND (“S&OP” OR “sales” OR “operations” OR “marketing” OR “product development” OR “manufacturing” OR “production” OR “sourcing” OR “financial” OR “finance”). The search terms were chosen to represent all functional areas described in the APICS S&OP definition presented in the second section. Moreover, “production” was added as a synonym of “manufacturing” and “finance” as a synonym for “financial”. The term “product development” was chosen instead of “development”, as otherwise, many reference model development techniques appeared in the search, which is not the focus of this paper. For the study selection, two exclusion criteria were defined: (i) studies not presenting a reference model (i.e., only superficially touching the topic); (ii) conference papers that present similar contents, which are later published in a journal. As this paper is not intended to contribute to the debate regarding formal reference model definitions, it is, therefore, referring to a “reference model”, when it is declared as such by the authors of the analysed papers.

The search was conducted in December 2018 and without time restrictions. It returned 517 papers in total, which abstracts were read. After reading the abstracts and applying the exclusion criteria, 44 papers were selected for a full-text review. After the full-text reading, 29 papers remained for the final analysis. To classify the reference models in these publications, the following criteria from the reference model classification methodology by Fettke and Loos (2004) have been adopted: origin, modelling language, construction method, application method, evaluation, and application domain.

Findings

The following section firstly presents the findings from the interviews, and the secondly offers the investigation of the studies from the systematic literature review.

Reference modelling as a potential solution for S&OP challenges

The interviews with the executives confirmed that companies are often struggling to implement, maintain, and execute successful S&OP processes, and that one reason for this is a lacking homogeneous understanding of the S&OP process. All three executives are not aware of a reference model for S&OP. However, they acknowledged that such a model could potentially provide benefits for the current S&OP challenges, and support the implementation and execution of S&OP processes. Executive 1 highlighted that “a reference model for S&OP could be very useful and add value, as it could help to overcome some challenges and difficulties”. Executive 2 confirmed this view and stated that a reference model could serve as “best practice” for the S&OP application and “could help to make the process more effective and cost-efficient”.

However, despite the potential benefits, all three executives emphasised that they see

difficulties with the development of a reference model for S&OP, which are mainly related to its context-dependent nature. The executives stressed that, according to their experience, S&OP processes are highly company-specific and that their design can be influenced by many contextual factors. Examples of such factors that were mentioned during the interviews include the industry sector, company structure, type of products, amount of stock keeping units, available information technology (IT), or outsourcing decisions. Additionally, "the state of the S&OP implementation plays an important role", as indicated by Executive 3.

Even though the interviewees expressed the contingent specificity of S&OP, they believe that the contextual influence depends on the level of detail of the S&OP process. Executive 1 pointed out that "the five core S&OP steps stay the same for different companies, but looking onto the lower level could become a 'nightmare', as there will be an extremely high number of contextual variables". Executive 2 confirmed this by stating that "the question is, how detailed you want to describe the S&OP process. I think you will fast reach a level, where it will be very company specific." The executives expect S&OP processes to be comparable across different contexts on a higher level, which has been emphasised especially by Executives 1 and 2.

Furthermore, the executives highlighted that solely presenting the S&OP process in a reference model would not be sufficient to describe S&OP completely and address its challenges. Executive 2 often used the expression "S&OP management" in this regard, indicating that a successful implementation embraces more than simply introducing a well-structured business process. All three executives accentuated the importance of people for a functioning S&OP process. Executive 1 stated that "considering the role of people is especially important for S&OP as different stakeholders are working together, who often have conflicting motivations and goals." To have a functioning process, the different S&OP actors need to have the "competency and understanding" (Executive 3), but also the "commitment" (Executive 1). The communication among each other is vitally important to solving the conflicts, which cannot directly be depicted in a model, as Executive 2 stated. Another factor that is crucial for S&OP is the supporting role of IT, as stressed by the executives. IT can influence the S&OP process in several ways and be an important enabler for a successful S&OP, as it can, for example, increase the forecasting process or make scenario planning possible (Executive 1). Other examples of the positive effects of IT on the S&OP process that were mentioned in the interviews are data management support and the provision of a "communication platform" (Executive 2). Besides describing the process, a complete characterisation of S&OP should, therefore, embrace these two dimensions.

Reference models in S&OP-related areas

The systematic literature review revealed no S&OP reference model. The 29 selected papers present 23 different reference models from S&OP-related areas. Seven of these papers focus on the Supply Chain Operations Reference (SCOR) and are therefore summarised under the term "SCOR" in the following.

The results of the classification according to the criteria of Fettke and Loos (2004) show that the identified reference models are highly diverse in nature. Despite SCOR, all reference models are developed in scientific publications and hence do not have their origin in practice. Only some of the models are developed by applying a modelling language such as flowcharts (Kovacs et al., 1994), Petri Net (Mendéz et al., 2000), IDEF0 (Kalpic and Bernus, 2002), or eEPC (Molina and Medina, 2003). Models in other publications are mainly described textually. Furthermore, only a few authors specify the construction method, by which the reference model is developed. While Gerosa and

Taisch (2009) apply the construction method of Fettke et al. (2005), Kovacs et al. (1994) and Brilhuis-Meijer et al. (2016) develop and apply their own approaches. Kalpic and Bernus (2002) and Zapp et al. (2012) use information gained by companies to construct their reference models and thus develop their model inductively. Other authors develop the reference models in a deductive way based on literature (e.g. Brilhuis-Meijer et al., 2016). Regarding the application method, most authors do not suggest an approach on how to use the reference model for developing company-specific ones. Only SCOR, Eversheim et al. (1997) and Wang et al. (2004) provide concrete suggestions for the application of their model. Moreover, not all of the presented reference models are evaluated. Most of the evaluations are conducted through practical case studies (Mendez et al., 2000; Kalpic and Bernus, 2002; Ng and Jiao, 2004; Oztemel and Tekez, 2009; Brilhuis-Meijer et al., 2016). SCOR is a step further and considered an established reference model that is often applied in practice (Supply Chain Council, 2012).

The identified reference models cover a wide range of application domains, e.g. Supply Chain Management (SCOR; Pereira et al., 2018), product development (Eversheim et al., 1997; Kalpic and Bernus, 2002; Brilhuis-Meijer et al., 2016), or capacity planning (Zapp et al., 2012), Most of the reference models focus on the manufacturing context. However, in terms of goals and concepts, even these reference models are highly diverse. Chalmeta et al. (1997) use an object-oriented perspective to develop a manufacturing system, whereas Macedo (1994) and Oztemel and Tekez (2009) describe the use of artificial intelligence techniques to design a manufacturing system. Kovacs et al. (1994) focus on designing and operating a computer-integrated manufacturing system. Wang et al. (2004) deal with integrating enterprises based on a business logic perspective. Biemans and Vissers (1989) have another focus and describe specific tasks of components in a manufacturing planning and control system.

Most of the identified reference models have a functional-specific intention (e.g. manufacturing or product development) and do not address cross-functional issues between different departments. Three reference models address the synchronisation of the demand and the supply side. SCOR aims to model, analyse, and improve the communication between supply chain partners and the supply chain management activities of a company (Persson, 2011; Supply Chain Council, 2012). Pereira et al. (2018) develop a reference model to handle a demand-supply synchronisation in omnichannel retailing environments, and Zapp et al. (2012) construct a reference model for a collaborative capacity planning between two supply chain partners.

Discussion

The statements during the interviews, based on the executives' practical experiences, reinforce several issues that are currently discussed in the S&OP literature. The mentioned challenges related to S&OP implementations are in line with several studies (e.g., Pedroso et al., 2016; Danese et al., 2017) and emphasise the need for practical support. By highlighting the context-dependent nature of S&OP, the executives confirmed the findings from the literature (Ivert et al., 2015; Kaipia et al., 2017; Dreyer et al., 2018; Kristensen and Jonsson, 2018). Furthermore, the necessity to view S&OP from a more holistic perspective and consider the people and IT together with the process to characterise S&OP corroborates Kristensen and Jonsson (2018, p. 21), who state that one should also consider "the human, technological and organisational (HTO) characteristics, which can ease or hinder the use of S&OP".

Regarding the application of the reference modelling approach to S&OP, the executives believe that the features of reference models can help to address current S&OP challenges. The potential benefits of a reference model for S&OP, that were highlighted

during the interviews, are in line with the generic benefits described in the literature (Hars, 1994; Thomas, 2005; Becker et al., 2007; Fettke and Loos, 2007). All three executives state that currently no reference model for S&OP exists, which corroborates the systematic literature review results. Also, the identified reference models from S&OP-related areas have limited applicability to S&OP. None of the reference models covers the five steps of the S&OP process described by Wallace and Stahl (2008). Furthermore, most of the models are either too function-specific or have largely operational planning foci. Thus, they do not combine vertical and horizontal integration and match the cross-functional and tactical planning characteristics of S&OP. Most of the authors do not raise the issue of their models being adaptable or applicable to other contexts than the ones for which they were designed. Even those models that address demand and supply synchronisation do not appear to be directly applicable for an S&OP reference model. The SCOR model found in the literature review was also mentioned during the interviews, but it was described as being "too generic to serve as a reference for S&OP" (Executive 1). The model from Pereira et al. (2018) is too specific, with a focus on omnichannel retailing. Zapp et al. (2012) specifically focus on the planning between the automotive and the semiconductor industry and provide recommendations instead of a process model.

Regarding the comparison of the identified reference models, it is important to highlight, that many authors of the papers have a significantly diverging understanding of what a reference model is. This leads to the fact that their developed reference models are highly heterogeneous. While some provide detailed process model (e.g., Kalpic and Bernus, 2002; Brilhuis-Meijer et al., 2016), others only describe more general recommendations verbally (e.g. Gerosa and Taisch, 2009; Zapp et al., 2012). Also, the degree of detail to which the reference models are described varied significantly. While most of the reference models were just described in a few pages (e.g., Macedo, 1994; Méndez et al., 2000), SCOR comes along with an extensive and detailed description (Supply Chain Council, 2012). These differences among the models made their comparison challenging.

Despite the potential benefits of an S&OP reference model, its development appears to be a very challenging task. This has mainly to do with the fact that the design of S&OP processes is highly context-dependent. Even though a model could serve as a reference for different companies at a high level of detail, it would need to be severely adapted to address company-specific needs, which are particularly important on a more detailed level. Executive 1 highlighted that the development of an S&OP reference model would have to be conducted "in close collaboration with practitioners to capture challenges from real-life", indicating that it would have to be conducted inductively to a large extent. Executive 3 highlighted that especially for S&OP a reference model could and should not be used dogmatically, as it would be very important that the practitioners have the possibility to shape the process according to their specific needs. Furthermore, a process model alone could not capture the essential S&OP dimension as especially the people and IT play a crucial role for S&OP. Therefore, a reference model for S&OP would need to be highly adaptable to different contexts and able to embrace the dimensions of people and IT. Another possibility could be to apply reference modelling as part of a bigger, more flexible solution for S&OP management.

Conclusion

By borrowing the reference modelling approach from the Information Systems community, this paper offers a novel approach to address current S&OP challenges. The paper aimed at investigating if reference modelling can support S&OP design and implementation challenges and provide a complete process characterisation (RQ1), and

identifying existing reference models in S&OP-related areas and examining their applicability to S&OP (RQ2). To address the research questions, firstly, interviews with three executives were conducted, and, secondly, a systematic literature review was carried out.

Concerning RQ1, the executives emphasised that a reference model could help to address the S&OP design and implementation challenges and provide a process characterisation. However, it was highlighted that more dimensions than just the process would need to be considered for a complete S&OP characterisation and management. The role of people and IT are essential factors in this respect. Furthermore, in regards to the importance of contextual factors for the design of S&OP, findings from the literature were reinforced in this study, emphasising that a comparison on a more detailed level of the process appears difficult. Concerning RQ2, an S&OP reference model was not identified, as indicated by the executives and the results of the systematic literature review. Twenty-three reference models from S&OP-related functional areas have been identified and classified according to the methodology of Fettke and Loos (2004). The analysis revealed that none of the reference models can solve the S&OP implementation and design challenges or provide a process characterisation. The three identified models that address demand and supply synchronisation, have either generic (SCOR) or too narrow foci (Pereira et al., 2018; Zapp et al., 2012). The development of a reference model for S&OP is considered to be a beneficial, but highly challenging endeavour, especially due to the context-specific nature of S&OP.

This paper has some limitations and offers directions for future research. For the literature search process, only one database was used. Searching more databases could have led to an identification of further reference models. Furthermore, the search was focused on identifying reference models in S&OP-related areas based on the APICS definition. Keywords such as “integration”, “collaboration”, “coordination” or “alignment” might be promising as well, but were outside the scope of this paper. Analysing the papers identified in the systematic literature review demonstrated the wide variety of interpretation of what a reference model is and what goals it should achieve. Further research should be conducted to develop a common understanding of the term reference model in the investigated areas. Moreover, as only three executives were interviewed for this work, a deeper investigation to validate the findings appears promising for future studies. In spite of the limitations, the insights gained from this paper could be used as a starting point for the development of an S&OP-specific reference model. This would address current research gaps and at the same time be of high practical relevance. As it is challenging to address the context-dependent aspects of S&OP and at the same time embrace the dimensions of people and IT with a reference model, the application of reference modelling as part of a bigger, more flexible solution should be investigated further. The examination to combine other concepts with reference modelling would, therefore, be helpful. Especially the investigation of other approaches from the Information Systems community appears promising, as IT plays an important role for S&OP management.

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Balancing Supply and Demand and its Impact on Operational Performance: Evidence from Complex Retail Operations

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Abstract

Matching supply and demand is an important aspect of the supply chain management discipline. Yet, there is little research focused on validating the primary claim that improvement of such matching leads to operational performance benefits. This research addresses this lacuna by exploring the impact of the Bullwhip Effect Coefficient (BEC), a proxy of supply and demand matching, on Gross Margin Return on Inventory (GMROI) in the complex setting of cruise ship retail operations. The findings show that in this setting BEC has only a limited effect on GMROI, which can be partially attributed to the complexity of the case organisation.

Keywords: Retail Supply Chain, Bullwhip Effect, Supply Chain Performance

Background

It is widely acknowledged that the concept of Supply Chain Management (SCM) encompasses a network of interrelated entities involved in flows of materials, finance, and information in order to deliver customer value at the optimal network-wide cost (Ellram and Cooper, 2014). However, from its inception in the 1980s it has been emphasised that the balancing function of supply and demand is the key objective of SCM (Oliver and Webber, 1982). Subsequent thinkers have confirmed the importance of this function (Cooper et al., 1997; Christopher and Ryals, 2014).

In order to fulfil this balancing function a number of general ideas have been adopted by management practitioners, such as Lean (Womack et al., 1990), Agile (Nagel and Dove, 1991), and Leagile (Naylor et al., 1999); followed by more specific frameworks, including Virtual Organisations, Six Sigma, and Total Quality Management. These developments were expected to provide the supply chain participants with tangible improvements in terms of operational and organisation wide performance (Tan et al.,

1999). It can be argued, therefore, that a level of matching supply and demand in a supply chain should be directly linked to operational performance (Lee et al., 1997).

Research Purpose and Setting

Researchers generally agree that the SCM approach provides an added value for all involved partners, such as suppliers, focal companies, and customers (Lambert and Enz, 2017). These benefits are expected to be manifested in improved operational performance and achieved competitive advantage. Regarding performance the literature discusses both generic metrics such as quality, delivery, cost, and flexibility (Hallgren et al., 2011), and more specific metrics such as fill rate, on-time delivery, and lead time (Beamon, 1999).

In retail organisations it is particularly important to recognise that traded goods are assets which provide the means for those organisations to operate. Traditionally, therefore, the main performance measures in the retail industry include stock turns, return on investment (inventory), and cash-to-cash cycle. It has been acknowledged, however, that there is no single unified set of SCM performance measures which are able to completely assess operational performance (Anand and Grover, 2015).

There is still relatively little research focused specifically on validating the main premise of the SCM concept that balancing supply and demand leads to improved operational performance (Geary et al., 2006). Furthermore, existing studies focus predominantly on settings with relatively stable and predictable patterns of demand and supply, such as manufacturing and retail (Lee et al., 1997; Jin et al., 2015). The research reported in this paper attempts to extend existing knowledge by analysing if there is a link between supply and demand disparity, represented by the bullwhip effect coefficient (BEC), and Gross Margin Return on Inventory (GMROI) in a more complex and dynamic setting – cruise ship retail operations. These two measures have been selected purposely because of their significance for the retail industry (Gaur et al., 2014; Jin et al., 2015). The BEC enables one to measure how strongly supply and demand are matched in any given period of time, and in general it is a result of the quality of supply chain management practice (Lee et al., 1997). GMROI, on the other hand, combines two important aspects of performance, Gross Margin and Average Inventory Investment, and it has been long recognised as an important factor for retail organisations (Sweeney, 1973; Levy et al., 2012).

By analysing if there is a correlation between BEC and GMROI over prolonged period of time we aim to explore how matching of supply with demand affects the performance of a company operating in a dynamic and complex retail setting.

The research follows the principles of the case study approach, which is suitable for in-depth exploration of contemporary phenomena in a real life context (Yin, 2014, chap.1). A retail organisation operating in the cruise ship industry was selected as the case study. The main motivation for selecting this particular firm is that their supply chain has characteristics that make it highly complex and unusual. The case study design is seen as particularly suited to examining unique settings (Eisenhardt and Graebner, 2007; Yin, 2014, p.52).

The uniqueness of the chosen cruise ship retail organisation is manifested in several characteristics. Firstly, the firm is part of a complex supply chain consisting of three distribution centres located on three different continents, over 200 shops located on

board more than 50 sailing ships and selling products sourced from over 600 suppliers. Secondly, the case organisation manages a very wide variety of products ranging from food, cosmetics, and clothing, to jewellery and gifts. Furthermore, the number of unique items sold by the case organisation exceeds 150,000, which is considered significant compared to manufacturing organisations, or even many large land-based retailers. Thirdly, a unique feature of retailing on cruise ships is the requirement to deliver goods in tightly fixed delivery windows, which demands a specific focus on delivery system robustness. It has to be emphasised that failing to deliver goods to a ship in the specified delivery window is likely to result not only in significant commercial losses but also reputational damage. Fourthly, unlike in many other types of businesses, in the case study organisation two critical aspects of the supply chain replenishment system vary significantly, namely lead time and the reordering cycle. This is a result of the fact that the ships are sailing around the world, which means that the delivery ports are changing, and the lengths of voyages are changing. Furthermore, the case study organisation faces other challenges in its management of the supply chain, including uncertainty regarding law and regulations in different parts of the world, fast changing customer profiles, and very limited storage space on board the cruise ships.

Methodology

The process of the research consists of three parts: selection of units of analysis, data collection and preparation, and statistical analysis of the data.

For this study 'product groups' were selected as the unit of analysis. Each product group consists of two elements: a category and a supplier. This reflects an entity used by the case firm to manage their replenishment processes. The selection of the product groups followed the theoretical sampling approach (Eisenhardt and Graebner, 2007), with particular focus on those product groups that 'can bring the greatest theoretical return' to the study (Strauss and Corbin, 1998, p.202). A main criterion used to select the product groups was their contributions to the firm's revenue. Twenty-one product groups have been selected, with a combined contribution to the company's revenue in 2014 in excess of 40%. Moreover, the selected product groups contain a wide variety of products such as food, clothing, jewellery, watches, and beauty products.

Numerical data required to calculate the BEC and GMROI for these product groups were collected from the case organisation's Enterprise Resource Planning (ERP) systems for a four-year period (2012-2015), but for each year separately. These data included ERP records regarding:

- purchase orders
- sales orders
- gross margin
- inventory levels.

The authors adopted a commonly used formula for calculating the bullwhip effect coefficient (Chen and Lee, 2012; Bruccoleri et al., 2014):

$$BEC = \frac{VO}{VD}$$

where:
VO - variance of purchase orders
VD - variance of sales orders
These measures have been calculated using standard formula for statistical variance (Field et al., 2012):

$$s^2 = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

where:
x_i - individual observation: for purchase orders it is monthly cost of purchased goods, for sales orders it is monthly cost of sold goods for a specific product group
$\bar{x}$ - mean of observations: mean of monthly purchase costs, and costs of sold goods respectively
n - number of observations: twelve per year for each product group
GMROI, on the other hand is calculated using the following formula:

$$GMROI = \frac{GM}{I}$$

where:
GM - gross margin
I - average inventory at cost

Table 1 shows an extract from the data format used in the study for four product groups. Lower values of BEC indicate better match between supply (purchase orders) and demand (sales orders). Even in this short extract it can be observed that there is substantial variability of this measure. For example, for Cigarettes - V01977 in 2012 the BEC value was 17.1 (poor match), dropping to 1.8 (good match) in 2014. Even greater discrepancies can be observed between product groups, with highest for Accessories - V02046, and lowest for Cigarettes - V01977. GMROI values also vary on yearly basis within product group, and although the differences might not look large they have significant effect on profitability. However, much greater dispersion can be observed between product groups, for example, for Accessories - V00727 GMROI ranged from 1.45 to 1.98, whereas for Cigarettes - V01977 its values were higher and achieved between 4.99 to 6.97.

Table 1 Data extract for BEC and GMROI

Product group	Period	BEC	GMROI
Accessories - V00727	2012	11	1.71
Accessories - V00727	2013	19.2	1.87
Accessories - V00727	2014	14.9	1.45
Accessories - V00727	2015	19.1	1.98
Accessories - V02046	2012	32.3	2.08
Accessories - V02046	2013	30.6	3.89
Accessories - V02046	2014	82.1	2.12
Accessories - V02046	2015	55.7	2.34
Cigarettes - V01977	2012	17.1	4.99
Cigarettes - V01977	2013	2.9	5.82
Cigarettes - V01977	2014	1.8	5.46
Cigarettes - V01977	2015	2.9	6.97
Clothing - V00384	2012	12.6	1.92
Clothing - V00384	2013	6.8	2.38
Clothing - V00384	2014	32.6	3.14
Clothing - V00384	2015	18.1	2.91

Based on the BEC and GMROI data and using R Language software (R Core Team, 2019) to conduct correlation analysis, the strength of association between the supply-demand matching (bullwhip effect coefficient), and operational performance (GMROI) was examined.

Findings

The results of the correlation analysis are presented in the scatter plot shown in Figure 1, where each point represents a product group in each year. There are 83 points, because 1 outlier due to an error in the ERP data has been removed from the analysis.

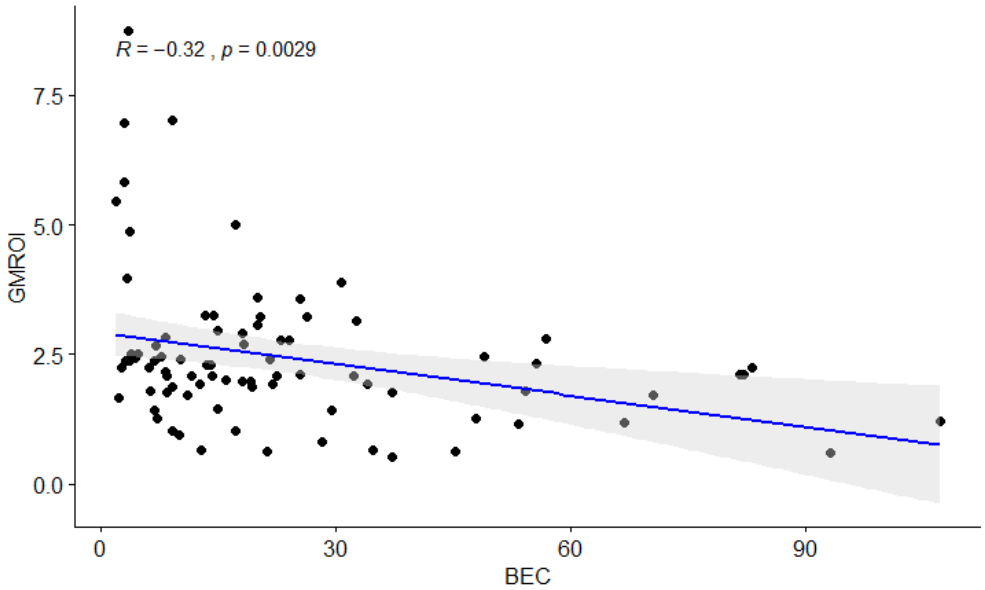

Figure 1 Correlation analysis - scatter plot

It can be observed that for GMROI most product groups are located between 1.25 and 3.75, with relatively few achieving a score of 5.0 or above (Table 2).

Table 2 High GMROI product groups

Product group	Period	BEC	GMROI
Spirits - V01977	2013	9.1	7
Spirits - V01977	2012	3.5	8.74
Cigarettes - V01977	2015	2.9	6.97
Cigarettes - V01977	2013	2.9	5.82
Cigarettes - V01977	2014	1.8	5.46

From Table 2 it can be seen that the product groups with a GMROI above 5.0 belong to categories that traditionally are associated with a high profit margin. Furthermore, these products were delivered by one vendor (V01977) and they achieved low BEC scores, which indicate a relatively close match between supply and demand.

On the other hand, there are a number of product groups where BEC scores are quite high, even exceeding 60 (Table 3).

Table 3 High BEC product groups

Product group	Period	BEC	GMROI
Fashion Watches - V00853	2014	177.8	1.86
Fashion Watches - V00621	2014	107.2	1.22
Fashion Watches - V01165	2012	93.3	0.61
Logo - V00120	2014	83.2	2.25
Accessories - V02046	2014	82.1	2.12
Fashion Watches - V00621	2012	81.7	2.11
Fashion Watches - V00853	2013	70.5	1.71
Fashion Watches - V01165	2015	66.8	1.19

Most of the product groups with high BEC scores are what Fisher (1997) described as 'innovative products', which are inherently affected by high variability of demand. Furthermore, almost all of these product groups (with exception of Fashion Watches - V00621) are sourced from overseas, mainly from the US or China with long delivery lead times. Therefore matching supply and demand for those products is likely to be more challenging.

The scatter plot (Figure 1) also shows an inverse linear relationship between the BEC and GMROI. However the slope of the regression line is rather shallow, which indicates only a moderate negative correlation. Further statistical analysis of the correlation between BEC and GMROI was conducted using R Language software (R Core Team, 2019) to determine the precise strength between these variables and the statistical significance of the results. The outputs of the analysis are presented below in Table 4 (R Language code is included in the Appendix).

Table 4 Pearson's product-moment correlation

Parameter	Value
Data	bullwhip_data$bullwhip_coefficient and bullwhip_data$gmroi
Statistics	t = -3.0746, df = 81, p-value = 0.002873
Alternative hypothesis	true correlation is not equal to 0
95 percent confidence interval	-0.5038393 ÷ -0.1156573
Sample estimates	correlation: -0.323282

The low p-value (0.002873) reported in Table 4 indicates that the analysis is statistically significant - below the level of 0.05 recommended for social science studies (Silver, 1997, p.100). The correlation coefficient value -0.323282 confirms our interpretation of the scatter plot and regression line, that the negative relationship between the BEC and GMROI is only moderate for the product groups analysed (Field et al., 2012). These results suggest that although improvements in operational performance can be achieved by matching supply and demand more closely, these improvements may not be significant in complex supply chain settings like that examined in this study.

Conclusion and Limitations

This research provides new insights into an important aspect of the supply chain management concept of the relationship between supply and demand matching and operational performance, measured in this study by the BEC and GMROI respectively. The correlation analysis undertaken in this study allowed us to draw the conclusion that there is a statistically significant link between these two variables, but that the strength of this link is only moderate in the case study organisation. We suggest that these results can be explained to some extent by the complex and highly dynamic characteristics of cruise ship retail operations, such as rigid delivery windows, variable lead times and replenishment cycles, changeable customer profiles, limited storage space.

Fixed delivery windows demand from the organisation to deliver goods to ships on specific days, which from one side requires robust distribution and from the other reliable supply process. Although the company operates dependable delivery system the supplier base varies in their delivery quality, which in turn negatively impact stock availability and its level, further affecting both BEC and GMROI measures. Variable lead times and replenishment cycles are unique to the cruise industry. In addition to experiencing difficulties with forecasting and planning inventory levels and demand, there are also challenges with short term replenishment especially for products with long lead times, resulting with stock-outs and overstocks. Unlike other 'land' retailers, where customers base is rather consistent, in the case of cruise ship industry there is greater variability of customer profiles, which is further reinforced by increasingly frequent price discounts and promotions offered by cruise liners, which disturbs the regular pool of passengers from a demographic perspective. As a result, cruise ship retailers have greater difficulties with planning their offerings and providing sufficient level of stock. Finally, an important aspect of retail operations is a storage space in shops, which should allow to temporarily warehouse stock for which there is no sufficient space on shelves. In the cruise industry the main focus is on providing

passengers with primary services such as accommodation, entertainment and retail experience. Other spaces, including storage backrooms are limited to minimum, which inevitably affects stock availability, especially of products with high demand variability, causing stock shortages. There are several other challenges the retail operations of the cruise ship industry face, however those listed above significantly affect both BEC and GMROI measures.

We argue that the scope to generalise our findings to other less complex and dynamic supply chain settings is likely to be limited therefore. More empirical research comparing the relationship between supply and demand matching and operational performance in different kinds of supply chain settings is needed, however, to evaluate this argument.

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Appendix:

R Language code for statistical analysis:

```
bullwhip_data <- read.table("<file path>", header=TRUE, sep=",")

library("ggpubr")

ggscatter(bullwhip_data, x = "bullwhip_coefficient", y = "gmroi",
      add = "reg.line", conf.int = TRUE, cor.coef = TRUE, cor.method = "pearson",
      xlab = "Bullwhip Coefficient", ylab = "GMROI", add.params = list(color = "blue", fill = "lightgray"))
+ theme(axis.title.x=element_blank(), axis.text.x=element_blank(), axis.ticks.x=element_blank())

res <- cor.test(bullwhip_data$bullwhip_coefficient, bullwhip_data$gmroi,  method = "pearson")

res
```

Early supplier involvement in the automotive industry: a study from the supplier perspective

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Abstract

Product Development (PD) is a critical process in the automotive industry. The Supply Chain Management (SCM) practice of Early Supplier Involvement (ESI) may provide a competitive advantage for the sector, but to obtain its benefits it is necessary to meet prerequisites and overcome challenges. This article seeks to understand, through a case study, how the ESI is conducted from the perspective of a Brazilian auto parts supplier. Results indicate that the benefits from ESI are beneath its potential, application of SCM and PD practices is still incipient and there is a gap in ESI theory concerning to the supplier's perspective.

Keywords: Early Supplier Involvement, Supply Chain Management, Automotive Industry

Introduction

Product development has become a critical process within Supply Chain Management, especially in the automotive industry, which carries a high degree of complexity and usually involves a significant diversity of materials and technologies. For such, the involvement of key suppliers in the early stages of the product development process, by the practice of ESI, can promote reduction of development time, quality improvements, and innovations into the products and the production processes, as well as can leverage costs and time-to-market reductions to the entire supply chain, by incorporating into the project the knowledge and skills of suppliers. Therefore, the ESI can strengthen the integration between company members of the supply chain. However, in order to properly carry out the development process and to effectively obtain the benefits of ESI, it is necessary to meet a series of prerequisites, such as technological capability, open communication, management structure and performance measurement systems of the companies involved. Additionally, the challenges encountered in the process must be overcome, such as lack of trust between the companies, unawareness of the advantages of ESI and lack of sharing of gains from its implementation. In this context, an extensive review on the ESI literature showed that the vast majority of reported studies was conducted from the perspective of the customer companies and that the implementation and management of ESI analysed from the perspective of suppliers is still an incipient

subject in the literature. Therefore, this article reports on an empirical research carried out in a supply chain of the Brazilian automotive industry, conducted from the perspective of a supplier of casting aluminium components for engines and automotive transmissions, and that had as main purpose to investigate how the practice of ESI has been conducted from the perspective of this supplier company.

Supply Chain Management

According to Pires (2009), a supply chain (SC) can be understood as a set of interlinked organizations. From the standpoint of a focal company within the supply chain, organizations located upstream are the direct suppliers, also known as tier-1 suppliers, and sub-suppliers (tier 2, tier 3, etc.). The companies downstream are the customers, the dealers and the final consumer.

The Council of Supply Chain Management Professionals (CSCMP, 2015) considers the SCM as a model that integrates key functions and business processes along the supply chain, seeking high performance of the supply chain and its members. Lambert & Schwieterman (2012) identified eight business processes in SCM: (1) Customer Relationship Management; (2) Supplier Relationship Management; (3) Customer Service Management; (4) Demand Management; (5) Order Fulfilment; (6) Manufacturing Flow Management; (7) Product Development and Commercialization and (8) Returns Management. Each of these processes is divided into strategic and operational sub-processes that relate to the other processes, involving cross-functional teams with representatives from the areas of sales & marketing, purchasing, logistics, operations, product design, finance and information technology, as well as customers and suppliers (Rogers, Lambert, & Knemeyer, 2004).

Pires (2009) states that the effective implementation of Supply Chain Management (SCM) involves the development of initiatives and managerial practices, such as: restructuring and consolidation of supply chains; suppliers development; planning and collaborative management, including electronic data interchange (EDI), efficient consumer response (ECR), vendor managed inventory (VMI), continuous replenishment (CR), collaborative planning, forecasting and replenishment (CPFR); outsourcing; in plant representatives; postponement; and early supplier involvement (ESI).

Product Development Process

The Product Development (PD) process is critical for the SCM effectiveness (Matos, Pires, & Vivaldini, 2014) and may provide sustainable competitive advantage for organizations, since the reduction of time-to-market is a key element to the success in innovation and product profitability. PD requires a multidisciplinary approach and integration with customers and suppliers as well as the increasing integration of services and products, a practice currently used as a way of adding value to the product and a valuable source of market differentiation (Rogers, Lambert, & Knemeyer, 2004). Like other SCM processes, PD consists of strategic and operational sub-processes, which relate to the other processes and are developed by multifunctional teams, including managers from the areas of product engineering, research and development, marketing, finance, purchasing, logistics, and representatives of customers and suppliers, which permits the alignment of objectives across the different functions involved in the process (Tsai, Fang, & Hsu, 2012).

The PD in the automotive industry is part of a strategic effort to enhance the SCM performance through the establishment of best management practices (AIAG, 2012). The instrumentalization of the PD process occurs mainly through the application of product quality planning methodologies, especially the Advanced Product Quality Planning

(APQP), which involves the various levels of the supply chain and starts even before the formal closing of the purchase order. One of the APQP premises is concurrent engineering, which is a process carried out by cross-functional teams of supplier, customer and sub suppliers, who must work together in order to develop quality products in the shortest time possible. In concurrent engineering design phases overlap over time, rather than being performed sequentially. The APQP is aligned with the concepts and practices of SCM, especially the ESI, since it advocates the involvement of supply chain members in the PD process and considers not only aspects of product design, but also the production process and logistics issues (AIAG, 2008).

Early Supplier Involvement

The PD process requires the integration of an internal development team with other members of the supply chain (Rogers, Lambert, & Knemeyer, 2004). ESI is a practice of SCM that suggests the involvement of the supplier with the customer since the early stages of PD so that supplier's skills are incorporated into the project with the goal of developing higher-quality and lower-cost products more quickly (Pires, 2009). ESI is also aligned with the principles of lean manufacturing, as both aim to reduce waste, risk, cost, and time-to-market (Forno, Forcellini, & Bornia, 2013).

In order to be successful, the ESI program must be structured to integrate tactical and strategic operational factors. Dowlatshahi (1998) proposed a conceptual framework to support the implementation of the ESI that includes four blocks: (1) Design, that recommends the participation, beyond the project area, of other areas and functions of the company and of the suppliers in the definition of critical project tasks. (2) Procurement, where the role of the purchasing area should not be restricted to be a mere facilitator in the implementation of the ESI. Purchasing should also be involved in product design so that their concerns are considered in the product development process. (3) Suppliers, since the development of a long-term strategic relationship between the organization and the supplier enables the achievement of mutual gains. (4) Manufacturing, to ensure that the products can be easily manufacturable.

The degree of involvement of each supplier in the PD depends on a series of factors, among which stand out the degree of responsibility of the supplier in the project and the degree of risk involved. The interaction between customer and supplier in the development phase is a function of the risk and responsibility of the supplier in the project (Calvi, Le Dain, Harbi, & Bonotto, 2001). The interaction may be classified as black box, when the product project has integral responsibility of the supplier and is divided into two involvement types: (1) global development based on specifications, when the supplier has technical knowledge and autonomy to integrally develop the product based on the required performance expected by the customer; (2) strategic co-development, a critical situation that requires greater interaction between customer and supplier, as in the case of systems and modules manufacturers. In the gray box involvement, also called (3) critical co-development, neither the customer nor the supplier has the total knowledge required and demands strong interaction between the customer and the supplier, which share responsibility for the project. In the white box involvement, the supplier follows the customer specifications and also is divided into two types of involvement: (4) classical subcontracting based on technical specifications, where the suppliers role is limited on defining the productive and logistic processes necessary to meet specifications at the lowest possible cost and (5) coordinated development based on technical specifications, where the product design is responsibility of the customer that has a strong influence and controls the development process. In this case the supplier must absorb the project changes during the development (Pires, 2009).

After the establishment of ESI management structure and determination of the degree of supplier involvement in the project, the implementation phase of ESI begins, when the effective integration of the supplier to the project occurs. If the program prerequisites are met and the challenges overcome, the expected benefits of the practice are then obtained. The interaction between customer and supplier in PD can occur in different phases of the project, and it is a function of several factors, among which the degree of responsibility and autonomy of the supplier on the project and the degree risk involved in the project (Petersen, Handfield, & Ragatz, 2008).

In medium or high complexity products, the benefits of ESI tend to be greater when the integration of the supplier occurs at the beginning of the project. The leverage effect of investments on profits is due to the fact that design changes are generally more costly and complex when investments are made closer to the beginning of the mass production (Eisto *et al*., 2010).

Although the benefits of ESI practice have been widely documented through qualitative and quantitative studies, a successful ESI implementation depends on a number of prerequisites, without which the expected benefits will not be fully achieved, what makes the application of ESI to be below its potential. This gap is due, among others factors, to the difficulties and challenges found in the implementation. The main benefits, prerequisites and challenges in ESI implementation are shown in Figure 1.

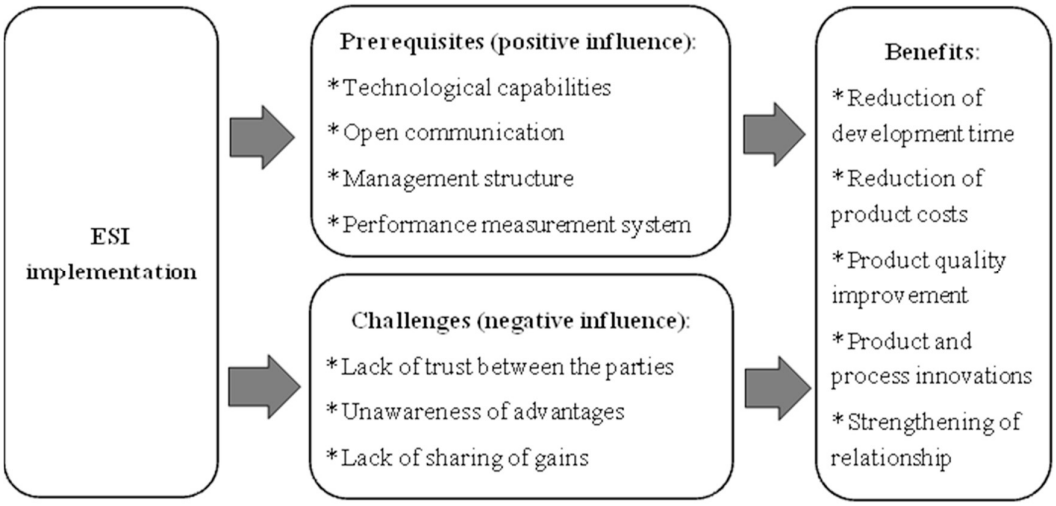

Figure 1 – Benefits, Prerequisites and Challenges in ESI Implementation (Source: Authors)

These benefits, prerequisites and challenges in ESI implementation were identified after an extensive review of ESI literature, summarized in Table 1, that includes the authors consulted, the classification of the articles analysed regarding the perspective adopted (customer or supplier) and the research method (qualitative or quantitative). Concerning the research methods, there is a balance between qualitative and quantitative studies. Most of the studies are conducted from the customer's perspective and studies that consider the ESI from the supplier's perspective are still uncommon.

Table 1 – ESI Categories of Analysis (Source: Authors)

Authors	Classification				Benefits					Prerequisites				Challenges		
	Customer perspective	Supplier perspective	Qualitative research	Quantitative research	Reduction of development time	Reduction of product costs	Product quality improvement	Product and process innovations	Strengthening of relationship	Technological capabilities	Open communication	Management structure	Performance measurement	Lack of trust between the	Unawareness of advantages	Lack of sharing of gains
Cerra, Maia, & Alves Filho (2011)	●		●		●	●	●	●		●		●				
Chavran, Mahajan, & Sarang (2012)	●		●		●	●	●		●	●	●	●				
Comerlato, Costa, & Luciano (2013)	●		●		●	●	●	●		●	●	●				
Dowlatshahi (1998)	●		●		●	●	●			●		●	●			
Eisto *et al.* (2010)	●	●	●		●	●	●			●	●	●	●	●	●	●
Huang & Mak (2000)	●		●		●	●	●	●			●	●				
Klioutch & Leker (2011)		●		●	●	●	●	●	●	●	●	●				
LaBahn & Krapfel (2000)		●		●	●	●	●	●	●	●		●		●		
Lau, Tang, & Yam (2010)	●			●	●	●	●	●			●					
Lau (2011)		●		●	●	●	●	●				●				
Lawson & Potter (2012)	●			●	●	●	●	●		●	●	●				
LeDain, Calvi, & Cheriti (2010)	●		●		●	●	●	●	●	●		●				
Luo, Mallick, & Schroeder (2010)	●			●	●	●	●		●		●	●				
Luzzini *et al.* (2015)	●			●	●	●	●	●		●		●				
Matos, Pires, & Vivaldini (2014)	●		●		●	●	●	●				●			●	
McIvor & Humphreys (2004)	●			●	●	●	●				●	●				
Petersen, Handfield, & Ragatz (2005)	●			●	●	●	●		●	●		●	●			
Pires (2009)	●			●	●	●	●	●	●			●		●		
Santos & Forcelini (2012)	●		●		●	●	●	●	●	●	●	●				
Schiele (2010)	●		●		●	●	●	●		●		●			●	
Severino, Peixoto, & Godinho Filho (2011)	●		●		●	●	●	●	●	●	●	●				
Smets, Oorschot, & Langerak (2013)	●			●	●	●	●			●		●	●	●		
Toledo *et al.* (2008)		●		●	●	●	●	●				●				

Among the evaluated publications, a representative case stands out (Eisto *et al*., 2010). The case deals with the ESI practice in casting customers and suppliers – as is the business focus of this research – proposes a framework for ESI implementation and considers the supplier's perspective in more depth than the other works consulted.

Methodology

The research was conducted through the in-depth unique case study using a multi-tier approach within the supply chain, what allows the researcher to capture more fully the context in which the phenomenon under study occurs (Yin, 2010). Nowadays there is a growing trend to use qualitative methods in operations management studies due to its contribution to the development of the theory and construction of knowledge, because these methods examine concepts in terms of its meaning and interpretation in specific

contexts of research (Barratt, Choi, & Li, 2011) and beginning from the confrontation of theoretical propositions with the idiosyncrasies of the analysed case, there may be theoretical implications that contribute to the creation of knowledge in the chosen field of study (Ketokivi & Choi, 2014; Siggelkow, 2007). One of the main aspects that make the case chosen unique is the fact that the focal company is a manufacturer of aluminium castings for the automotive industry, what requires a high-quality level and technical knowledge of casting process that few companies worldwide currently have, making the company a strategic supplier to its customers. Besides the focal company, its three main customers (which together account for about 90% of its revenues) and its three main suppliers were also investigated, as shown in Figure 2.

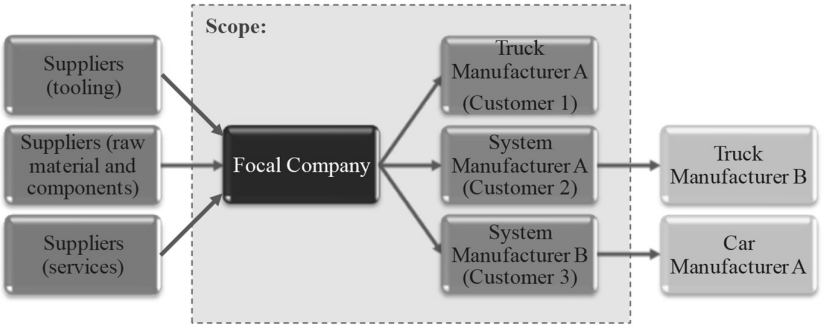

Figure 2 – Scope of the Case Study (Source: Authors)

Data were collected through interviews with key executives involved in SCM, PD and ESI in the focal company. To guide the case study a semi-structured questionnaire was developed, covering issues related to SCM, PD and ESI in the investigated companies and for the data assessment were established, based on the literature review, twelve variables divided into three categories of analysis: benefits, prerequisites and challenges of ESI. The empirical data collected in the interviews were complemented with visits to the company' facilities and the company's documentation available were gathered and analyzed. Moreover, in order to increase reliability, transparency and replicability of the case study, a research protocol was previously established.

Case Study

The case study was conducted in a Brazilian medium-sized company, supplier of components for the automotive industry, its three main customers and three suppliers involved in PD process, whose main characteristics are shown in Table 2.

Most of the products produced by the focal company can be classified as gray box and the projects are customer responsibility, but with the growing participation of the focal company, consulted to ensure product manufacturability, since the increased use of aluminium in vehicles is a global trend, due to its low density, high strength and virtually unlimited recycling. The tooling is customer property, as usual in the automotive industry, what introduces an important variable to the process, because the supplier should be transparent to the customer, but also protect its know-how. The PD process is based on APQP manual and closely monitored by the customer. The project is developed by a cross-functional team with members from Project, Process Engineering, Tooling, Manufacturing and Quality areas. The design and construction of the casting tooling are considered critical activities to the success of the project and consume most of the time and program resources, having a major impact on product quality and productivity. The Engineering area develops the projects of the moulds using technological tools in line

with global best practices, such as CAD, CAE and CAM systems. Engineering simulations using CAE system are outsourced.

Table 2 – ESI Categories of Analysis (Source: Authors)

Company	Product	Origin	Size	Capital
Focal Company	Casting parts for engines and transmission systems of vehicles	Brazil	Medium (130 employees)	100% Brazilian closed capital
Customer 1	Trucks and bus chassis	Europe	Large (about 10,000 employees in Brazil)	Multinational open capital
Customer 2	Engines for trucks and generators	USA	Large (about 1,000 employees in Brazil)	Multinational open capital
Customer 3	Electronic systems for vehicles	Europe	Large (about 2,000 employees in Brazil)	Multinational open capital
Supplier 1	Software and engineering simulation services	Europe	Small (about 20 employees in Brazil)	Multinational closed capital
Supplier 2	Tooling construction	Brazil	Small (about 20 employees in Brazil)	100% Brazilian closed capital
Supplier 3	Machining services	Brazil	Small (50 employees)	100% Brazilian closed capital

The results from the interviews and documentation review in focal company related to SCM indicate a number of important gaps in the management system, which does not meet fully and consistently the requirements of the SCM processes, and the main gaps are in the processes of supplier relationship management, demand management and product development and commercialization. Regarding the SCM practices, none of them are fully implemented in the company or its suppliers and has not even been considered in a systemic way in the development of internal processes of the company. The practices that were found in the company were implemented by imposition of customers.

The results of the PD process indicate a high degree of compliance with the requirements of the sector, particularly with APQP process, but still with gaps in the processes of generation and selection of ideas, design and prototyping, decision make-or-buy, performance indicators system, implementation of concurrent engineering with participation of suppliers and treatment of logistical issues. A positive point is the intensive use and exchange of electronic data, especially CAD, CAE and CAM.

The results of ESI practice also indicate several important gaps. The development time, one of the main benefits of ESI, had no significant gains in last developments, due to the late involvement of the company on the projects and to the customer's resistance to design modifications suggested by suppliers. The reduction of costs and improvement of product quality can be considered together as they are due to the same factors, like geometry or materials changes of the product that allow gains by reducing failure rates and increasing productivity. Implementation of changes to the product are more difficult when they occur later in development, because once a product concept has been approved, changes require new validation, which can be extremely time consuming and costly. No product innovations were identified, but an innovation in PD process was observed in one project, that is the stress simulations made by the customers in parallel with the simulation of casting process by focal company. Strengthening the customer-supplier relationship is also positively affected by the practice of ESI, but it is necessary to the company to be represented by technically trained staff, with negotiation skills and decision-making power sufficient to respond to the project and the customer's demands.

The prerequisites to ESI were also investigated. In the current environment of the automobile industry the intensive use of technology is an imperative for product

development, with major impact to its success. The exchange of electronic data between supply chain members shortens the process and reduces the amount of errors and design changes. The technological capability is not restricted to the availability of systems such as CAD, CAE and CAM, and requires the necessity of trained professionals and the continuous monitoring of technology trends to identify opportunities and risks resulting from rapid technology obsolescence. New trends, such as rapid prototyping and 3D printing, have potential to quickly and dramatically change PD process. Communication plays a central role in ESI and the focal company has established a cooperative communication with its customers and suppliers. The main deficiency of the process is the little emphasis on strategic and commercial issues, staying focused on technical issues. As the management system of the focal company is not structured to the practice of ESI, significant shortcomings were found. APQP procedure includes simultaneous engineering, but does not establish criteria for development risks analysis, or to determine the degree of involvement of suppliers, nor to seek a proactive participation in product design phase. The performance measurement system is insipient and current indicators do not measure the impact of ESI on the results of developments. It is noteworthy that neither the literature of PD establishes suitable indicators for ESI.

Finally, the challenges in ESI implementation are presented. As customers do not establish any formal contract with suppliers that provides a minimum of certainty of return for supplier participation in the project, the business confidence level is low, what reduces the supplier willingness to share the expertise with customers. However, the focal company often takes the risk to participate without guarantees, because their participation increases the chances of winning the purchase order. The awareness of ESI benefits is widespread in the supply chains of the automotive industry, but only in relation to its potential benefits. The lack of clarity about the prerequisites and implementation challenges is one of the factors that make it difficult to obtain the desired benefits, because the process complexity requires a structured approach, including support from higher hierarchical levels, so that they can overcome the barriers and difficulties inherent in the process. The lack of sharing of gains is another feature clearly identified in the research. As the customers' PD process is structured considering the traditional method of sequential development, where engineering area designs the product and purchasing area selects the supplier based on final product specifications and quality requirements, logistics and price, the ESI is not included in the procedures and purchase contracts, so the sharing of gains with suppliers of gains from ESI practice is not considered. On the other hand, the focal company also has a passive attitude and does not include the issue of sharing of gains or development cost recovery in negotiations with customers in cases of application of ESI.

Final Remarks

Within the scope of the SCM the results show that the supplier relationship management processes conducted by the focal company are relatively undeveloped, presenting several opportunities for improvements, and the definition of its supplier base is carried out based mainly on assessments of the quality and the production processes systems. Regarding the PD process, the focal company practically does not have a formal framework to develop proactively products on its own initiative. The company develops products only when it is triggered by a customer company and it does not have even a structure for the development of prototypes, which is becoming a supplier’s qualifying criteria in the sector. Somehow, this seems paradoxical because the focal company has a recognized expertise in auto parts of casting aluminium, whose global demand has grown significantly during the last years, especially due to the processes of engines downsizing.

Regarding the practice of ESI, despite being increasingly applied in the PD of the focal company, it is still performed in an unstructured and passive form, i.e., always seeking to meet customer needs. Also, when carried out, the focal company does not usually have a contract that guarantees that it will be later the supplier of the component to the customer company, and it has no guarantee that its expenses will be reimbursed if it does not become the component supplier. This makes the ESI practice a "risky operation" to the focal company, but the company considers it would be worse nowadays if it does not get involved in ESI of its major customers. The creation of opportunities for developing new business and of a privileged channel of communication with the customer companies are the two main reasons identified for such procedure. Another remarkable point is that there is no formal, or even informal, compromise (between the focal and customer companies) concerning the sharing of benefits arising from the ESI implementation, and they mostly stay with the customer companies. To the focal company usually is only possible to obtain gains in technological development and reduction of production costs arising from the better manufacturability of developed components. Another noteworthy fact identified is that, from the perspective of the focal company, the ESI tends to be more easily implemented and managed in the case of customers who are "systemists" (key first tier suppliers), than the case of customers who are automakers.

The results indicate mainly that the benefits arising from the application of ESI for the focal company, its customers and suppliers are below the potential of the practice, which are due to not fully meet the prerequisites and the difficulties to overcome the challenges of its implementation. Furthermore, the research found and sought to contribute to fill a significant gap in the literature about ESI, which deals with the practice predominantly from the customer's perspective, with little consideration from the supplier's perspective, as would be required for the development of a truly and win-win collaborative practice as it has been contended in the basic tenets of SCM.

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Impact of supply chain on the competitiveness of the automotive industry

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Abstract

One hypothesis identified as cause for the traditional automotive companies to become unable to compete with new incoming assemblers is an inefficient supply chain. This paper aims to crosscheck the supply chain structure of the traditional automotive industry installed in Brazil with South Korean and Chinese supply chains. Based on strategic decision making and transaction cost theory, this comparison exploits the factors that lead to the inefficiency of traditional automotive supply chains. It was used a multi-method research, leading to the proposition that automakers recently installed have lower transaction costs than traditional ones due to their vertical supply chain structure.

Keywords: Supply chain management, Supply network design, Operations strategy

Introduction

The automotive industry is very strong in the Brazilian economy: it represents 23 per cent of industrial GDP and 5 per cent of total GDP (Anfavea, 2015). Brazil is the fourth largest market and the seventh largest manufacturer in the world, with 31 automakers installed, 64 industrial plants, more than 500 direct automotive parts (first tier of the supply chain), 5,533 resellers spread throughout Brazil, involving almost 200 thousand companies directly or indirectly linked with the automotive supply chain. This industry contributes to the national economy by generating around 1.5 million direct and indirect jobs; tax collection of approximately US$58 billion; and annual revenues of roughly US$110.9 billion (Anfavea, 2015).

There are some hypotheses that may explain the inability of the Brazilian automotive sector to compete with imported or newly locally produced vehicles, such as outdated product technology; delayed manufacturing technology; inefficient supply chain; low skilled labor in the development of high technology products and processes (Agénor, Canuto, & Jelenic, 2012; Eichengreen, Park, & Shin, 2011; Felipe, Arnelyn, & Utsav, 2012).

This research aims to explore one of the hypotheses listed above: supply chain inefficiency is a cause for the low competitiveness of the domestic automotive industry. Supply chain is a set of companies that continuously relate to the goal of delivering products or services to the consumer market (Lambert, Stock & Ellram, 1998). The focus company considered in this research is the automaker. Direct suppliers are called Tier 1, and suppliers of automakers' suppliers are called Tier 2.

Starting in the 1970s, the automakers installed in Brazil started a vertical disintegration movement stimulated by the need to reduce production costs, made necessary to face the Japanese model (Vanalle & Salles, 2011). As a result, there was an increase in suppliers in the supply chain, replacing domestic production, which reduced production costs, but increased the incidence of transaction costs. The South Korean and Chinese automobile factories recently deployed in Brazil present a different arrangement of the supply chain, with a strong verticalization. These new incoming assemblers took over the development and production of the main parts, outsourcing some of them to suppliers that they have stock control or shareholding.

Given this context, in which there are different supply chain arrangements with different results, the question that we intend to answer herein is: What are the factors that differentiate the structure and management of the supply chain of the national automotive industry from countries such as South Korea and China?

The objective is to evaluate the impact of the supply chain structure of the national automotive industry on its competitiveness, crosschecking it with supply chains of other two countries that have stood out in the automotive industry over the past decade, South Korea and China. This comparison allows to highlight the similarities and differences that can contribute to the understanding of the problem, and thereby redirect the long-term competitiveness of the national industry. The research is based on supply chain, strategic decision making, and transaction cost theory literatures. A multi-method methodology based on a qualitative approach is used.

The next sections detail the theory and methodology used, to finally present the results and conclusions of the research.

Literature Review

Supply chain management as an integrated discipline gained force in the 1980s, mainly due to the successful implementation of the lean program developed by Toyota (Holweg, 2007). At that time, Toyota and Honda outsourced about 80% of the value of the cars they produced, using collaborative relationships with few suppliers for each automotive part, while US automakers outsourced only about 30%, denoting a high vertical integration (Corrêa, 2010). The American automakers followed the original model of the automotive industry, based on an intense verticalization. This example shows how the supply chain arrangements can be different within a single industry.

In this research, we will emphasize the decision of the supply chain arrangement using strategic decision making and transaction cost theory.

Strategic decision-making

The boundaries of a company are a long-term strategic commitment, which has consequences in its performance (Novak & Stern, 2008). The decision about the organizational boundaries can be divided into making internally (vertical integration) or buying in the market (outsourcing or horizontal integration). To make or to buy a determined product or service is not only an economic decision based on the best cost; it is a strategic decision for the company (Prahalad & Hamel, 1990; Quinn & Hilmer, 1994).

There is a diversity of research that explores the nuances and consequences of vertical integration and outsourcing (Nickerson & Silverman, 2003; Baker & Hubbard, 2004; David & Han, 2004) with different points of view. Some companies consider outsourcing a critical element of their strategy (Holcomb & Hitt, 2007), since outsourcing can be a way to reduce costs and improve performance, leaving the activity in the hands of experts (Gilbert, Xia and Yu, 2006). However, outsourcing should always be viewed from a strategic perspective. The eagerness to reduce costs can lead to the loss of company skills (McIvor, 2009, Prahalad and Hamel, 1990).

Outsourcing facilitates access to state-of-the-art technology and the use of performance contracts. On the other hand, vertical integration allows companies to adapt to unforeseen contingencies and customer feedback to maintain incentives that are more balanced and develop company specific capabilities. These effects suggest that outsourcing will be associated with higher levels of initial performance, and that vertical integration will be associated with improved performance over the product life cycle, enabling the development of specific capabilities (McIvor, 2009).

Decision based on the theory of transaction costs

The transaction costs theory is based on the premise that one must analyse not only the economic costs of production but also the transaction costs in intercompany operations (Coase, 1937). A transaction cost occurs when a good or service is bought or sold from one company to another in well-delineated processes, surrounded by several sources of inefficiencies as limited rationality, opportunism, uncertainty and complexity, and information asymmetry (Williamson, 1975, 1979, 1983).

Transaction costs are the expenses that companies face when they buy and sell in the market. Some examples are the process of seeking the best technical and economical option, the preparation and negotiation of contract terms and the control of delivery performance in the required time and quality, among others (Williamson, 1985).

Williamson (1979, 1983) draws attention to the fact that the expansion of company boundaries tends to increase the costs of administrative coordination, reaching a point where, with high levels of coordination costs, the internal execution of activities becomes practically prohibitive. Phenomena such as bureaucracy and isolationism from competitive market pressure are other difficulties experienced (Geyskens, Steenkamp, & Kumar, 2006). In this case, the company can use the external market and obtain the same product or service at a lower cost through an outsourcing movement.

On the other hand, there are situations in which transaction costs with suppliers are high. Williamson (1975, 1985) considers three dimensions that combined indicate the timing of integrating an activity: frequency of transactions, specificity of assets, and uncertainties related to the environment before the contract and with the behavior after the contract.

The central issue of transaction cost theory is whether a transaction performs more efficiently within the firm (vertical integration) or by autonomous third parties (market governance) (Geyskens, Steenkamp & Kumar, 2006).

Dyer (1997) makes an important counterpoint, suggesting that transaction costs do not necessarily increase with the growth of specific investments in one supplier. In his study, the Japanese automakers present high specific investments with suppliers, but still have lower transaction costs than US automakers.

Methodology

The methodology of the research is qualitative, using a multi-method approach (Minger & Gill, 1999). Data were collected through interviews and secondary data, allowing the

identification of aspects that support the clarification of the research objective (Guerin & Runfola, 2008; Yin, 1994).

The context of the automotive industry justifies the use of a multi-method approach, since it is a complex environment, highly competitive and globalized, with great secrecy of information, which also grounds a four-stage process (Minger & Gill, 1999):

(1) First stage: Secondary data were used to understand the current structure of the automotive sector, supply chains and financial performance, with a focus on three countries, Brazil, China and South Korea. Data were collected from automakers and Anfavea (National Association of Automotive Manufacturers in Brazil) reports and published by the press in the internet.

(2) Second stage: At this stage the authors developed a semi-structured interview script, based on literature review and findings from the first stage to deepen data analysis. The script was validated by one of the authors, who has more than 25 years of experience in product development and interface with suppliers in the automotive industry, and by two other executives in the industry. The main interest of the authors was to understand the structure of the supply chain and how each assembler relates to its first and second tiers. Six executives with extensive experience in the automotive market were interviewed, with two executives working in newly installed assemblers in the country, while the others work in traditional assemblers in the Brazilian market. The interviews lasted about 80 minutes. For reasons of confidentiality, it is not possible to name the assemblers interviewed.

(3) Third stage: The authors organized a workshop with executives and specialists from assemblers, automotive suppliers and universities to discuss the automotive industry. The workshop brought together 145 representatives from distinct sectors of the automotive and academic industry (Fórum de Inovação, 2015). In addition to collecting general information compiled in the discussions, individual interviews were conducted with eight executives who participated in the event. These executives occupy positions of management or board of directors in assemblers installed in Brazil or new incoming.

(4) Fourth stage: In this last stage, we worked on tabulation of results, organization of tables and establishment of relations with theoretical aspects.

Results and discussion

As a result of the fourth stage, the authors tabulated a summary of the analysis of the secondary data (first stage) and information collected in the interviews with the executives of the assemblers and the individual discussions of the workshop (second and third stages) (Table I).

We compare the financial results of some automakers to discuss their competitiveness (Table II). Through the global profit margins, we highlight some trends:

. U.S. automakers (GM and Ford): they have average profit margins around 4%, with standard deviations higher than other companies;

. Japanese automakers (Toyota and Honda): Honda has a constant value of 4% while Toyota consistently exceeded 7%;

. Korean automaker (Hyundai): a global competitor with recent global expansion systematically shows a profit margin above all other world competitors (around 9%);

. Chinese automaker (Geely and SAIC): new entrants to the global competition, Geely has a profit margin close to 8% and SAIC a constant margin of 4.5%.

It is possible to highlight some differences between the characteristics of the traditional assemblers in Brazil and the newly installed Korean and Chinese assemblers. The analysis of the primary data allowed its correspondence with the literature concepts and their comparison among the different structures of supply chain (Table III). It was possible to

compare the same concept from the perspective of each supply chain model, qualifying it according to the perception of the interviewees and connecting theory and findings. Below it is presented a discussion of the findings by nationality of the assembler:

South Korea

According to the executive of the Korean company, Korean automakers follow the concept of chaebol, which can be defined as a large business group that is controlled by a family or by members closely related to that family. Government support is common to leverage business growth (Choi, Michell, & Palihawadana, 2008). The main characteristics of a chaebol are centralized planning; the vertical structure of the organization; family participation in each chain business and high capital investments (Choi et al., 2008; Jwa, 2002).

The assembler interacts with all major first tier suppliers through stock or equity control. These suppliers have autonomy to supply their auto parts to other customers and especially to competitors, thus obtaining economies of scale that result in lower costs for the parent company.

The centralized governance in the supply chain provides high reliability between the automaker and its suppliers, providing conditions that reduce transaction costs: the long-term relationship and the possibility of expanding the return on investment of specific assets reduce opportunism; in turn, the greater exchange of information reduces the uncertainty and asymmetry of information, minimizing transaction inefficiencies (Williamson, 1979, 1985; Gulati & Singh, 1998; Dyer & Chu, 2003). Economy of scale and, especially, transaction costs minimization along the production chain are factors that make South Korean companies more profitable than the industry average.

China

Automotive companies in China are nationalized, as well as a large part of the supply chain, with a strong fiscal incentive and investments in research and development, so they can develop high value-added products quickly.

The entire supply chain operates cooperatively with parent companies (assemblers). Both first and second tier suppliers are under control of the automaker (fully nationalized control; mixed control between government and private sector; or stock control of the automaker), ensuring a relationship with centralized governance (Williamson, 1979, 1985). The stability of the relationship ensured high reliability between the automaker and its suppliers, providing conditions that reduce transaction costs (Dyer & Chu, 2003; Gulati & Singh, 1998). Long-term relationships imply long-term return on investments in specific assets, thereby eliminating opportunism in negotiations (Dyer, 1997). In addition to consistent information exchange, inefficiencies in transactions and consequently transaction costs are minimized. Western and Eastern (Japanese and Korean) companies, to gain access to the Chinese market, must necessarily constitute a joint venture with a local state-owned enterprise, conducting all steps from project development to full manufacturing internally at the Chinese enterprise, thereby transferring all technology and expertise.

There is a government policy focused on technological development in two ways: incentives for investment in research and development and joint venture policy in the country. The internationalization of the company tries to follow this same model. In Brazil, the main Tier 1 suppliers are Chinese, with state or mixed stock control, ensuring greater stability in the relationship and a verticalization of the supply chain. Chinese companies with shareholder control of the automaker or with state or mixed investment form the layer of the second-tier suppliers, whenever possible.

Table I – Summary of research results

	BRAZIL	SOUTH KOREA	CHINA
Market	4° World Market (2015)	12° World Market (2015)	1° World Market (2015)
Local Production	3,802,701 vehicles (2012)	1,534,889 vehicles (2012)	19,306,435 vehicles (2012)
Characteristic of market	Segmented; under crises	Stagnant and small market	Growing market
Brands marketed in the country	27 brands (2015)	Few brands (Korean brands)	More than 130 national brands and JVs
Import	All segments; significant quantities	Small quantity	Small quantity
Export	Mercosur and Asia emergents	High quantities (Europe and USA)	Internationalization policy in progress
Source:	**secondary data**	**secondary data**	**secondary data**
Production Characteristics	High fixed cost	Medium fixed cost	Low fixed cost
	Instability of demand	Stagnant demand	High local demand
	High level of idle capacity	Low level of idle capacity	Very low level of idle capacity
	Difficulty for investments	Easiness for investments	Easiness for investments
	Difficulty in launching new products	Easiness in launching new products	Easiness in launching new products
Existence of natural resources	High	Low	High
Processing capacity of natural resources	Low	High	Medium - growing
Quality of digital infrastructure	Low - growing	High	Medium - growing
Skilled labor	Low	High	High
Quality of secondary educated labor	Medium	High	High
Basic infrastructure	Low	High	Low - growing
Availability of strategic input	Limited	High	Limited
Tier 1 suppliers: quality and availability	Low	High	High
Tier 1 suppliers: competence and capacity	Limited	High	High
Tier 1 characteristics	Multinational companies	National companies - same corporation	National - same corp. & independents
Relationshio with Tier 1	Cost	Equity control	Equity control, State control, or mixed
Logistics costs	High	Low	Low
Transaction costs	High	Low (same corporation)	Low
Tier 2 characteristics	National companies (usually familiar)	National companies	National companies
Tier 2 relationship	None	Partnership	Equity control, State control, or mixed
Public policies influence	High	High	Low (State-owned companies)
Exchange rate impact	High	High	High
Country infrastructure impact	High	Low	High (State-owned companies)
Taxes impact	High	Low	Low (State-owned companies)
Science and technology policies impact	High	High	Low (State-owned companies)
Tax incentives impact	High	High	High (State-owned companies)
Main bottleneck	Political instability	Opening to the external market	Opening to the external market
Source:	**primary data (interviews)**	**primary and secondary data**	**primary and secondary data**

Table II – Comparison of global profit margins (profit on net revenue) (source: Orbis database)

AUTOMAKER	PROFIT MARGIN					
	2015	2014	2013	2012	*Average*	*SD*
FORD	4.9%	0.1%	8.1%	4.2%	*4.3%*	*3.3%*
GM	6.4%	1.8%	2.4%	3.2%	*3.5%*	*2.0%*
TOYOTA	8.1%	8,0%	7.1%	4.4%	*6.9%*	*1.7%*
HONDA	2.4%	3.8%	5,0%	3.7%	*3.7%*	*1.1%*
HYUNDAI	7,0%	8.2%	9.8%	10.1%	*8.8%*	*1.4%*
TATA MOTORS	4,0%	5.3%	5.6%	5.2%	*5.0%*	*0.7%*
SAIC	4.5%	4.5%	4.4%	4.4%	*4.5%*	*0.1%*
GEELY	7.2%	6.3%	8.9%	7.9%	*7.6%*	*1.1%*
FCA	0.3%	0.6%	1,0%	0.1%	*0.5%*	*0.4%*

Brazil

Brazil has a sui generis automotive sector as it has only multinational automakers. Tier 1 suppliers are also mostly multinational. The choice of these suppliers has a strong dependence on the values of transacted products. There is no shareholder relationship between automaker and suppliers, and there is no participation of the national government in these companies. As there are few good suppliers in the country, there is a strong dependence on first tier suppliers.

Tier 2 is formed mostly by small and medium-sized domestic companies with family control. Respondents said that this is a weakness of the local industry. It is common that second tier suppliers have financial difficulties, affecting the production of the automaker. Such distancing hinders the exchange of information and knowledge in a fluid way in the chain, negatively affecting transaction costs (Dyer, 1997; Dyer &Chu, 2003).

The creation of local models of the productive chain, such as modular consortium and industrial condominiums, sought to bring the automaker closer to the main first tier suppliers. The modular consortium was implemented by "Volkswagen Caminhões" (trucks) in the city of Resende (Rio de Janeiro State). Industrial condominiums are characterized by the proximity of Tier 1 suppliers, who provide modules directly on the assembly line.

Discussion

The traditional assembly plants installed in Brazil for many years have a production structure focused on the assembly line with a high level of outsourcing. This outsourcing led to a predominance of multinational suppliers in Tier 1 in the last two decades, due to the lack of competitiveness of the national auto parts industry.

Tier 1 assumed the responsibility for Tier 2 suppliers, which are predominantly domestic and family-owned companies with many management problems and unable to cope with the country's frequent economic and political instability. As a result, they generate supply problems, costs and sometimes culminate in bankruptcy. Also, Tier 2 has a low level of innovation. This is a weakness of the traditional automotive supply chains in Brazil pointed out by the research: the detachment of the automakers from their Tier 2 suppliers, which are much smaller and unable to absorb large variations in demand, has affected the automaker's relationship with Tier 1 and increased costs in the supply chain.

On the other hand, the automakers that settled later tried to adopt different strategies:

. Hyundai has been introducing the Korean model in the country, with a strong vertical integration in the supply chain. The company has equity control of suppliers that develop and produce the main auto parts and components. Tier 1 suppliers are part of the chaebol;

. Chinese assemblers are building their first factories in Brazil, bringing the mode of operation from the country of origin: assemblers and suppliers are companies under the economic domain of the government, with an intense connection between them.

The outsourcing of productive competencies of most Western automakers enabled the development of these competencies in multinational suppliers, driven in recent years by the accelerated advance of information technology, electronics, telecommunications, among other technologies. The benefits of the new technologies are undeniable, but the required levels of investment have been growing at a rapid pace. At the same time, the obsolescence of these technologies happens at a faster rate than the return of the investments, forcing a transfer of investment costs from supplier to the automaker in shorter terms.

Two of the executives interviewed pointed out that the technological developments of suppliers generate several intellectual properties and patents, essential for the development of new vehicles; however, the investment costs in specific assets are passed on to automakers within short periods. Thus, there is an increase in transaction costs between suppliers and automaker (Dyer, 1997), strongly affecting the performance of horizontal supply chains. It is possible to notice there is a pressure from patent holders, which is one of the forces driving a company to consider vertical integration (Cacciatori & Jacobides, 2005).

Companies with a higher level of vertical integration in the supply chain had the best financial results and have been expanding their operations to other countries over the past decade, such as the supply chains controlled by Korean and Chinese automakers. High investments in research and development in these countries, as a result of their macroeconomic policies, support the development of competencies in technology.

Table III – Findings and connection with literature

Concept	Brazil		South Korea	China	Link with Literature
	Traditional Model	***Modular Consortium, Industrial Condominiums***			
Supply Chain Governance	Medium to Weak	Medium	Strong	Strong	Unilateral/unified governance reduces transaction costs involving specific assets (Williamson, 1979, 1985)
	Bilateral governance - relational contract. Focus on business relationship	Bilateral governance - relational contract. Mostly based on business relationship.	Unilateral governance - bilateral contract. Centralized in the automaker (chaebol)	Unilateral governance - bilateral contract. Centralized in the automaker (shareholding control, State or mixed)	
Reliability	Medium	Medium to High	High	High	Reliability is an alternative safeguard that reduces transaction costs (Williamson, 1979, 1985; Gulati & Singh, 1998; Dyer & Chu, 2003)
		Physical installation near or inside the automaker gives greater long-term relationship reliability	Belonging to the same nationality and the same economic group reinforce reliability	Belonging to the same nationality and the same economic group reinforce reliability	
Information Exchange	Medium to Weak	Medium to High	High	High	Greater exchange of information reduces asymmetry of information and opportunism, reducing transaction costs (Dyer, 1997; Dyer & Chu, 2003)
			Lower number of members in the chain and centralized planning facilitate the exchange of information	Lower number of members in the chain facilitates the exchange of information	
Long-term Relationship	Medium to Long-term	Long-term	Long-term	Long-term	The longer the relationship between a buyer and a supplier, the greater the likelihood of consolidating social relationships, generating reliability (Gulati & Nickerson, 2008)
	There is a tendency to prioritize the value of the transaction in the negotiations (decision based on cost)	Physical presence ensures long-term relationship	Belonging to the same economic group ensures long-term relationship	Belonging to the same economic group ensures long-term relationship	
Return Period for Specific Investments	Medium	Medium to High	High	High	Longer return periods on specific investments reduce transaction costs (Dyer, 1997)
	Investment based on specific project, with amortization period fixed by the supplier (usually a minimum period guarantee by contract with automaker)	Investment based on specific project, with amortization period fixed by the supplier (physical proximity ensures longer terms)	Investment based on specific project, with a longer amortization period determined by the automaker	Investment based on specific project, with a longer amortization period determined by the automaker	
Number of Suppliers Belonging to the Chain	Medium	Medium	Low	Medium to Low	Lower number of vendors reduces transaction costs (Dyer, 1997)
	Concentrated on multinationals	Concentrated on multinationals	Belonging to the chaebol	State control, stock control or mixed control	
Competences of the automaker in auto parts, subsystems, systems and modules	Low	Low	High	High	Loss of important competences affects competitiveness (McIvor, 2009; Prahalad & Hamel, 1990)
	Developed by suppliers (third parties)	Developed by suppliers (third parties)	Developed within the chaebol, high investments in R&D and qualified labor facilitated by the country policies	Developed within the supply chain using joint ventures with Western companies and government support on R&D investments	
Intellectual Properties/ Patents for auto parts, subsystems, systems and modules	High	High	High	High	High volume of Intellectual Properties generates vendor opportunism (McIvor, 2009) - it also generates a force for vertical integration (Cacciatori & Jacobides, 2005; McIvor, 2009)
	Large majority belongs to Tier 1	Large majority belongs to Tier 1	Large majority belongs to the automaker	Large majority belongs to the automaker	
Economy of Scale	Medium	Medium	High	High	
	Dependence on global projects	Dependence on global projects	Suppliers under stock control provide parts to other automakers (competitors)	Due to the production volumes involved (supplier can provide parts to more than one Chinese automaker)	
Supply Chain Organization	Horizontalization	Horizontalization	Vertical integration with Tier 1 suppliers and eventually Tier 2	Vertical integration with Tier 1 and Tier 2 suppliers	

To adapt to the new competitive arena, some aspects indicate the need for a change: a globalized and extremely competitive market, new low-cost competitors vertically integrated, new technological skills overlapping traditional ones, heterogeneity of countries regarding economic and political stability and wealth generation.

Based on the results of the research and the qualitative analysis of each concept, we make the following proposition: automakers recently installed in Brazil have lower transaction costs than traditional automakers due to their vertical supply chain structure.

The structural reorganization of the traditional automotive industry in Brazil requires the reduction of transaction costs through the integration of activities upstream of the supply chain. It is not necessary to follow the oriental models analysed herein, which are based on intense vertical integration. One cannot affirm, as in the model proposed by Lin et al. (2014), that vertical integration will always be beneficial. However, one can opt for hybrid models, integrating vertically the items whose competence is essential for the company's competitiveness, and outsourcing other items in the market (David & Han, 2004; Williamson, 1985). It is necessary to focus on identifying the necessary competencies to stay technologically up-to-date and at the same time reduce the current problem with the cost pressure of suppliers that hold patents (Cacciatori & Jacobides, 2005).

Conclusions and final considerations

This research compares the traditional automotive industry installed in Brazil with the automotive industry of two other countries, South Korea and China, recently installed in the Brazilian market and examples of growth over the past decade. The aim is to understand the factors that differentiate the structure and management of the supply chain of the traditional automotive industry in Brazil with those countries, which may pave the way for understanding the problems and for the long-term competitiveness of the Brazilian industry.

We conclude that horizontal automakers must rethink the limits of their company and study a plan of re-verticalization, focusing on the parts whose competence is important for their competitiveness. It is an opportunity to identify competencies in automotive parts that have a high impact on cost and especially on rapidly evolving technologies, which, being absorbed internally, can reduce transaction costs and improve quality. This is a practical contribution of this study, which is to encourage managers of the automotive chain to rethink the current management model of the supply chain.

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Exploring the moderation relationships among supply chain integration, procurement performance, and the buyer-supplier trust.

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Abstract

Procurement is a key function within Automotive supply chain, especially during the Brexit period. Supply Chain integration has been widely applied with in manufacturing/automotive industry. However, the extant literature lacks exploration of its impact on procurement performance. And this relationship closely correlated with trust between suppliers and buyers. This research explores a three-way moderation effect among supply chain integration, supplier-buyer trust and procurement performance empirically via 126 responses by UK automotive manufacturers.

Keywords: Supply Chain Integration, Procurement Performance, Supplier-Buyer Trust.

Purpose

The automobile manufacturing industry comprises the manufacture of components, bodies and trailers for cars and commercial vehicles (Brown and Rhodes, 2018). It has become an essential part of the UK economy, accounting for more than £82 billion turnover and £20.2 billion value added (SMMT, 2018b). As one of the most crucial features of supply chain management (SCM), supply chain integration (SCI) has been widely researched and tested from different perspectives (Armistead and Mapes, 1993; Das et al., 2006; Ebrahimi, 2015; Marquez et al., 2004; Rosenzweig et al., 2003; Sezen, 2008; Vickery et al. 2003). Also, Van der Vaart and Van Donk (2008) indicated that the SCI plays a sustainable role in improving the competitive edge of organizations. Therefore, SCI has been widely applied with in manufacturing/automotive industry, which plays a foundation role to guarantee the fluency of the Just-in-Time implementation. Within SCI, trust between suppliers and customers is a key role, which could significantly affecting the collaboration, communication, and engagements among suppliers who are in the same supply chain networks, and further affect the benefits of stakeholders (Darma, 2016; King and Burgess, 2008; Zhu and Sarkis, 2004). In addition,

procurement is a key function within automotive supply chain as well, especially during the current Brexit period. Nowadays, more than half of the sales turnover is spent on purchased activities in companies, hence, procurement performance (PP) has become a crucial and strategic significant dimension of performance measurements, which closely involved in the SCI and the cooperation and activities among suppliers (Van Weele, 2010).

However, most research to date has focussed on exploring the relationship between SCI integration and overall business performance (Das et al., 2006; Germain et al., 2008; Gimenez et al., 2012), lacks exploration of its impacts on procurement perspective. And these impacts could be closely correlated with trust between suppliers and buyers, which is a blank area within the extant literature. Therefore, this research aims:

To explore a three-way moderation effect among supply chain integration, supplier-buyer trust and procurement performance.

Conceptual Framework and Hypotheses

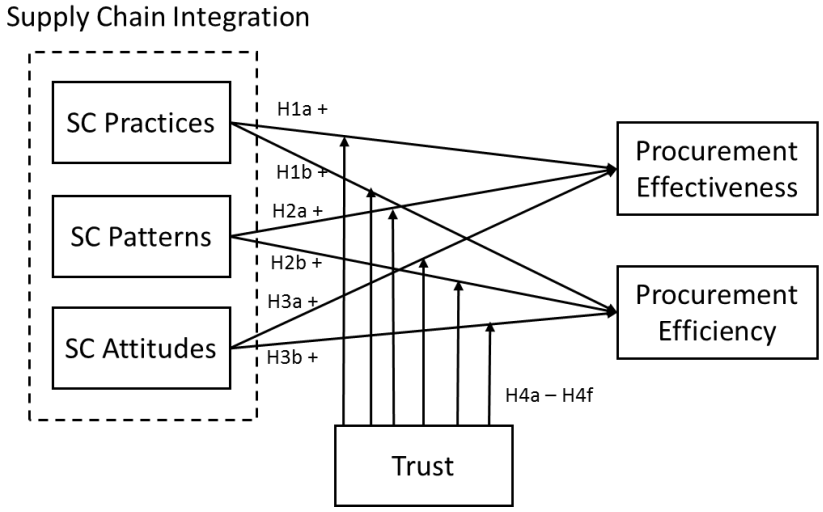

Figure 1 Conceptual Framework

Through the systematic analysis, Flynn et al., (2010) classified SCI into three dimensions, customer integration, supplier integration and internal integration (manufacturer), which can ultimately be accepted as the commonly recognized SCI dimensions (Alfalla-Luque et al., 2014; Boon-itt and Wong, 2011; Gimenez et al., 2012; Kim, 2013; Zhao et al., 2011). However, whether or not to regard external and internal integration as having the same level of significance has engendered strong debate in this SCI dimension research. Therefore, Vander Vaart and Van Donk (2008) raised SC practices, patterns and attitudes based on the external factors of integration. In this research, the SCI focuses on the external integration which is more about interaction of suppliers. Therefore, the dimensions of Van der Vaart and Van Donk (2008)'s c on SCI has been adopt in this research.

As shown in Figure 1 the conceptual framework, even though the extant publication did not justify the relationship between SCI and procurement performance, but the it does show a clear positive collaboration between SCI and financial performance (Das et al., 2006; Germain et al., 2008; Gimenez et al., 2012). For example, Vickery et al. (2003) recognized SCI as an essential strategy to integrate supply chain, meanwhile, examining the customer service and financial performance. As the key interactive activity among suppliers and customers, this research assume the SCI would have a positive correlation

with procurement performance.Saad et al. (2016) proposed a comprehensive model and provided insights into procurement performance for manufacturers in automobile industry, including efficiency and effectiveness two dimensions, which have been adopt in this research. Therefore, as shown in Table 1, the main hypotheses (main effect) have been displayed in detail to illustrate the proposed relationship between SCI and procurement performance.

Looking for a long-term and stable cooperative relationship is largely based on trust between buyer and supplier, which has been acknowledged as a key objective in different business. Following to the theory of resource-based view that to utilize and balance unique firm resources, such as capital assets, specific capabilities, or processes, to enable a firm a well executive of their strategies and thus assist to better efficiency (Barney, 1991), the buyer-supplier trust is an acknowledged firm resources as well. Even it is physically invisible, it plays a significant role and place great impacts on operations. Moon et al. (2017) suggested that trust enables to lubricate social friction and facilitate collaboration, the area with strong demand of collective actions in particular. Accordingly, Ahimbisibwe, et al. (2012) found that cooperation based on trust enables partners to accumulate accessible resource, and Ryu et al. (2008) justified the companies usually have a more positive outcomes with collaboration with partners is also involved in trust, rather than there is no interference between each other. Therefore, in order to achieve an effective relationship with suppliers and higher procurement performance, trust is an essential precondition in this base. Therefore, this research hypotheses the trust would moderate the relationship between SCI and procurement performances. As shown in Table 1, the moderations hypotheses (interaction effect) have been displayed in detail to illustrate the proposed relationship that the Buyer-Supplier Trust moderate the correlation between SCI and procurement performance.

Therefore, a summary of all the hypotheses were presented from Table1, aiming to build the connection and make sense of multiple research concepts based on established model.

Table 1 - Hypotheses Summary

Hypotheses Summary	
Main Effect	H1a: The supply chain practices positively affect procurement effectiveness
	H1b: The supply chain practices positively affect procurement efficiency
	H2a: The supply chain patterns positively affect procurement effectiveness
	H2b: The supply chain patterns positively affect procurement efficiency
	H3a: The supply chain attitudes positively affect procurement effectiveness
	H3b: The supply chain attitudes positively affect procurement efficiency
Interaction Effect	H4a: The buyer-supplier trust moderates on the relationship between supply chain practices and procurement effectiveness
	H4b: The buyer-supplier trust moderates on the relationship between supply chain practices and procurement efficiency
	H4c: The buyer-supplier trust moderates on the relationship between supply chain patterns and procurement effectiveness
	H4d: The buyer-supplier trust moderates on the relationship between supply chain patterns and procurement efficiency
	H4e: The buyer-supplier trust moderates on the relationship between supply chain attitudes and procurement effectiveness
	H4f:The buyer-supplier trust moderates on the relationship between supply chain attitudes and procurement efficiency

Methodology

Data Collection

Informed by the conceptual framework, a survey approach was adopted in order to collect the primary data and test the statistical relationship among the variables in Figure 1. As the dependent variables of this study, PP is the key research sector to examine, and hence, the participants for this survey are procurement-related staffs in manufactures in the UK automobile industry. And the suppliers from different tiers are also contained into the investigation due to the numerous repeated cross-border transactions existing in the international trade, automobile industry in particular, and the suppliers might also import the raw materials from the Continental Europe. The survey adopts 7 Likert-scale, and all the measurement items for each variable are adopt from the previous research. The survey is conducted through an online questionnaire statistics system, enabling to collect and manage information efficiently. Moreover, social medias, (such as Linked), is the may channel to search for the appropriate participants and collect the primary data from. In addition, the author also collect data for this survey via industrial visitings and industrial conference, social activities, targeting the UK automotive manufacturers covering tier1, 2, 3 and OEM. The collection starts from April 2018 and end up with 126 as the sample available to use for further statistical analysis.

Measurements

All the measurements related to the variables within the moderation model were adopted from previous research. For the three independent variables (IVs), there are seven items to measure SC Practices: schedule deliveries together with key suppliers, key suppliers deliver to us at short notice, key suppliers deliver to us frequently, share information electronically, share information about the production plans and forecasts to key supplier, high degree of strategic partnership with suppliers, high degree of joint planning, key suppliers are involved in our product development processes (Boon-itt and Wong, 2011; Flynn et al., 2010; Gimenez, 2011); three items to measure SC Patterns: high-corporate level communication on important issues, face-to-face communication frequently, online communication frequently (Vallet-Bellmunt and Rivera-Torres, 2013; Gimenez, 2011); four items to measure SC Attitudes: the parties are willing to work out a new deal when some unexpected situation arises, jointly treat problems when they arise, always jointly responsible for making sure that tasks are completed, be open to modifying their agreement if unexpected events occur (Gimenez, 2011). For dependent variables, there are seven items to measure procurement effectiveness: the materials quality fit to precise production requirements, receive order within request time; suppliers are able to fulfil an urgent unexpected demand, have a globally integrated procurement process, procurement process is mainly integrated to the Continental Europe suppliers, suppliers are able to help company to reduce procurement cost, suppliers have awareness of available prices for a product or service all the time (Kim et al., 2015; Saad et al., 2016; Wen-li et al., 2003); five items to measure procurement efficiency: supplier has a good network of known contract and reputation in automobile industry, able to keep continuous supplier collaboration, development and evaluation since supplier selection, we use e-procurement and paperless systems to manage procurement processes, we have achieved a great success from the utilization of e-procurement or digital system, suppliers and the company develop environmental friendly procurement with less resource wastage or CO2 emissions (Abolbashari et al., 2018; Kim et al., 2015; Saad et al., 2016). In terms of the moderator buyer-supplier trust, the measurements include: both parties are willing to make mutual adaptions, our firm can count on the supplier to be sincere, we believe that the supplier will be ready and willing to offer us assistance and support, we will

endeavour to keep original suppliers even in the stage of external environment change, (e.g.post-Brexit) (Ahimbisibwe et al., 2012; Fynes and Voss, 2002; Ryu et al., 2008).

Analysis Methods

To begin with, the descriptive analysis attempts to illustrate the demographic of target respondents in the UK automobile industry, enabling to reflect visible patterns, and probably, it is also accessible to detect the potential connection between the targeted factors. Furthermore, factor analysis, validity test and multiple linear regression are conducted step by step. Through the exploratory factor analysis (EFA) examining, unreasonable measures have been eliminated for the six variables, which confirm the convergent validity and discriminant validity for the data sample. The Cronbach's coefficient α of the scale, SCI, buyer-supplier trust and PP is ranging from 0.712 to 0.901. Hence, these results confirm that this scale is reliable, and the theoretical variables are acceptable. Following, the multiple linear regression aims to detect the correlation relationship between variables as well as the moderation effect (Schumacker and Lomax, 2010).

Findings

After data cleaning, the descriptive analysis, factor analysis, correlation analysis and multiple linear regression has been conducted step by step. The key results and findings have been shown below

The background characteristics of samples and descriptive demographics were briefly introduced in Table 2. It can be seen the samples have a good varieties and diversities, even though not able to get responses from Northern Ireland.

Table 2 – Descriptive Analysis Result

Sample characteristics	Classification	Total	%	Explanation
Respondent position	Senior Management	39	31	Senior Management (e.g. CEO)
	Middle Management	52	41	Middle Management (e.g. Procurement / operation manager)
	Junior Management	35	28	Junior Management (e.g. buyer/analysist)
Locations	England	86	68.25	Four different parties of the United Kingdom.
	Scotland	29	23.02	
	Wales	11	8.73	
	Northern Ireland	0	0	
Ownership (property)	British company	79	62.7	Foreign company (e.g. subsidiaries; joint venture, etc.)
	Foreign company	47	37.3	

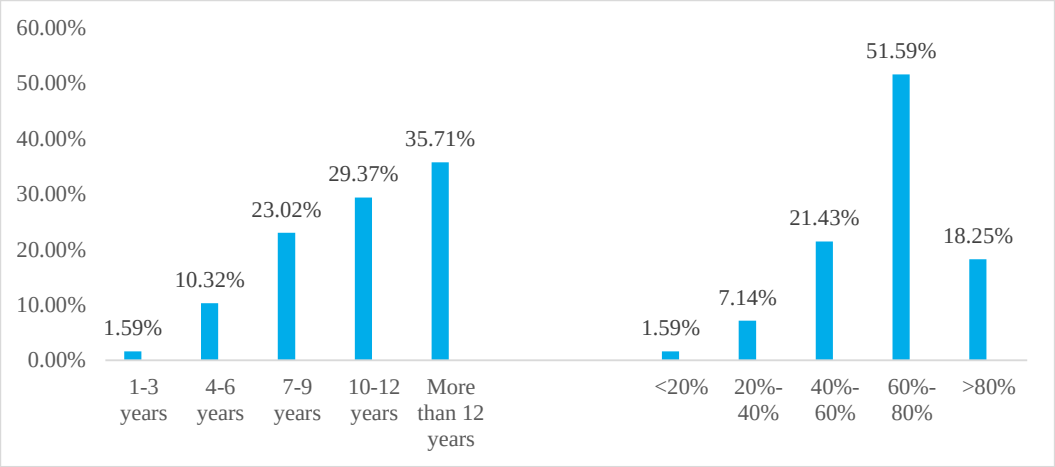

Figure 2 Results for Collaboration years and Procurement amount from European Suppliers

As the truth that majority UK automotive manufactures have close businesses with European suppliers, therefore the survey ask how long and the procurement amount from Continental European suppliers. The Figure 2 displays the connection between UK companies and Continental Europe suppliers. Nearly 90% samples have long-term cooperation with European suppliers and most companies import more than 40% of total volume from the EU.

The regression analysis results of main effects between SCI and PP have shown in the Table 3 below. If taking the significant level at 0.05, it can be clearly see that all the hypotheses about main effects (H1, H2, H3) have been supported. It means the SCI (including SC practices, patterns, and attitudes) does have a positive correlation with procurement performance (including effectiveness and efficiency). This result is alignment with the current literature that the effect of SCI on performance has been extensively recognized in different industries (Das et al., 2006; Germain et al., 2008; Gimenez et al., 2012).

Table 3 – Results for Main Effect (SCI-PP Relationship)

Dependent variable	R^2	Adjusted R^2	Durbin-Watson	Independent variable	β coefficient	t-value	Sig.t
Procurement Effectiveness	0.516	0.504	1.513	Practices	0.241	2.757	0.009
	ANOVA			Patterns	0.431	5.452	0.000
	df	F	Sig.	Attitudes	0.177	2.247	0.026
	3	43.298	0.000				
Dependent variable	**R^2**	**Adjusted R^2**	**Durbin-Watson**	**Independent variable**	**β coefficient**	**t-value**	**Sig.t**
Procurement Efficiency	0.449	0.435	2.168	Practices	0.234	2.505	0.014
	ANOVA			Patterns	0.379	4.491	0.000
	df	F	Sig.	Attitudes	0.184	2.189	0.030
	3	33.111	0.000				

In terms of the moderation effects, as shown in Table 4 below, not all the hypotheses have been justified, however, three clear significant results have been defined, which justify that the buyer-supplier trust significantly moderates on the relationship between SCI (practices, patterns, attitudes) and procurement effectiveness. This clear shows the close correlation of SCI and Trust on the effectiveness. This could due to that the trust will directly affect on the information sharing among different suppliers and avoid "Bull

whip" effect (Carnevale and Isen,1986; Li et al., 2006), which will positive improve the accuracy, timeliness and the integrity of purchase effectiveness. In addition, Dyer and Chu (2003)'s study on 344 automobile buyer-supplier relationship from the US, Japan and Korea, and they found that trust enables to decrease the cost of transactions, which is relevant to the information sharing in procurement. This outcome is consistent with Krause et al. (2007)'s study, that buyer-supplier trust tends to improve the length and depth of integrative relationships. Therefore, with a good trust, the integrity and cost reduction of purchase effective will be clearly improved.

Table 4 – Interaction Results

Dependent variable	Model		β	R^2	$\triangle R^2$	Sig.
Procurement Effectiveness	1	Practices	0.588	0.377		0.000
		Trust	0.132			0.068
	2	Practices	0.469	0.064	-0.313	0.000
		Trust	0.190			0.007
		Practices * Trust	0.284			0.000
	1	Patterns	0.679	0.491		0.000
		Trust	0.259			0.000
	2	Patterns	0.581	0.027	0.464	0.000
		Trust	0.284			0.000
		Patterns * Trust	0.195			0.010
	1	Attitudes	0.493	0.274		0.000
		Trust	0.120			0.125
	2	Attitudes	0.399	0.053	0.221	0.000
		Trust	0.173			0.026
		Attitudes * Trust	0.252			0.002

Dependent variable	Model		β	R^2	$\triangle R^2$	Sig.
Procurement Efficiency	1	Practices	0.580	0.344		0.000
		Trust	-0.154			0.038
	2	Practices	0.552	0.004	0.340	0.000
		Trust	-0.140			0.066
		Practices * Trust	0.069			0.403
	1	Patterns	0.594	0.359		0.000
		Trust	-0.037			0.614
	2	Patterns	0.576	0.001	0.358	0.000
		Trust	-0.032			0.666
		Patterns * Trust	0.037			0.666
	1	Attitudes	0.512	0.267		0.000
		Trust	-0.169			0.032
	2	Attitudes	0.446	0.026	0.241	0.035
		Trust	-0.132			0.097
		Attitudes * Trust	0.175			0.037

From the results, however, buyer-supplier trust has no moderation impact on the relationship of SC practices, patterns and procurement efficiency. This could due to the efficiency was defined by selection and purchases decision in this research, which is a more complete process and may be affect by more factors in practice, and trust may not be the significant one. In details, for SC practices, one possible explanation for this is

associated with the definition of procurement efficiency. For example, E-procurement is an approach that focal companies choose to simplify their procurement activities. It depends on companies' decisions through the evaluation of investment and outcomes. Although SC practice can facilitate procurement efficiency by developing limited system and ensuring the reliability of information sharing with joint efforts, focal companies can choose the appropriate system based on their practical demand and it will not be impacted by buyer-supplier relationship. Common sense suggests that buyer-supplier relationship will be impacted on mutual trust. Nevertheless, it is necessary to detect the relationship between trust and joint efforts. If the relationship is significant, it confirms that trust plays an indirect impact on procurement efficiency, if not, the relationship between SC practices and procurement efficiency will not be influenced. In addition, SC patterns focuses more on the communication between buyer and suppliers, including the negotiation, regular meeting and revisit, conference in special period and order in daily business. Trust significantly relates to buyer-supplier relationship, reflecting and functioning on the outcome of transactions. In SCI, buyer and supplier can share more information or technology support based on mutual trust, facilitating to satisfying transactions, whereas procurement efficiency, associated with procurement approaches, seems to be impacted less. Because procurement efficiency concentrates more on the company's willingness of appropriate procurement, and it will be adjusted according to the practical situation in SCI. Therefore, buyer-supplier trust has almost no influence over the study result. More interpretation on the moderation effect may need to draw and review the plots based on the results from Table 4. However, due to the time limitation, the plots have not been included in current work, which will be further improved in the future journal paper publication.

Conclusion and Contributions

From a theoretical standpoint, this work contributes to the extant literature by covering the gap between SCI and procurement performance, as well as the moderation effect of Trust on the correlation between SCI and procurement. When it comes to practice, this research will provide several implications for automobile manufacturers in the UK. First of all, the buyer-supplier trust still plays an important role in maintaining supply relationship. Closer connection within SCI enables partners to share information on the basis of seamless and multiple-channel communication, and this is crucial for enhancing procurement effectiveness, especially understand the JIT system. Due to the practice that around half of the UK automotive manufacturers buy in from European suppliers, faced with the potential uncertainties of the outcome of Brexit negotiations, mutual buyer-supplier relationship might be changed because of risks of cost increasing, commutative barriers, etc., and further, the PP probably is influenced along with the procurement activities transformation. Therefore, enhancing trust could also be a fundamental solution that company could do as an approach to mitigate the uncertainties brought by Brexit.

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Understanding Value of Social Media in Supply Chain Management

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Abstract

The purpose of the paper is to extend the social media analytics frameworks reported in the existing literature to create value from the data captured from heterogenous social media and IoT sources in a global supply-chain. The paper will aid the practitioners to understand the importance of focussed analysis and the key requirements for this analysis by offering a guide to organisational needs. The framework and requirements proposed in the paper will aid managers to capture value from the data (i.e. gain key insights) and augment human decision-making.

Keywords: Social Media, Analytics framework, Value creation

Introduction

Social media has become a major phenomenon for different organisations globally, and the field of supply chain management has slowly recognised its value for organisations (Chae, 2015). Companies are creating their own online platforms to interact with customers (Correia Loureiro, Serra, & Guerreiro, 2019) or collecting information to use it to enhance customer loyalty (Gamboa & Gonçalves, 2014) and to improve the products offered to consumers. The purpose is to "win with data" (Hopkins & Lavalle, 2010). This perspective is very appealing because technological advances and the increase use of social media by customers.

How to properly harness the benefits of social media in supply chain management, however, it is still a growing area. Information from a multitude of sources is collected and analysed to take advantage of it, but that can become a complex and time-consuming task because of the large volume, variety and velocity of the data, along with its unstructured state (Singh, Shukla, & Mishra, 2018). This is an important consideration because poor quality of data can render the data useless (Hazen, Boone, Ezell, & Jones-Farmer, 2014). This paper states that a different approach is required. Instead of only looking at the volume and the quality of the data, it is important to start looking at the question that the data is trying to answer.

Current analytics frameworks assume that value is created at the final stages, once analytics are applied to the information to find some trends/insights. This article presents a review of two case studies in supply chain management to identify the important elements that create value from the use of social media and redefine current analytics framework. From a more practical perspective, this paper is looking at the most beneficial approach to create value for decision-makers. The objective is to offer a conceptual framework that can be used by stakeholders to take advantage of social media for value creation.

The contribution of this paper is to change the current paradigm from a more "exploratory" analysis of social media data to a focused process introducing "value creation" as a stage defining and guiding the analysis. This shift can become beneficial to address several of the shortcomings identified in the literature about the use of social media in organisations. The paper is also providing a guide with the value creation requirements and organisational needs to exploit the benefits of social media.

Cases

Currently, the role adopted by the social media is increasing world-wide with the advances of cross-platform Web 2.0 applications and services (Palen, Starbird, Vieweg, & Hughes, 2010). To analyse the impact of social media in the supply chain and to identify the needs to exploit its potential impact, this research is looking at two different supply chains: retail and humanitarian. Both supply chains have similar components, but the objectives and strategy of each one of them exhibit significant differences, allowing the authors to identify the common elements to exploit social media in supply chain management.

Case study: Zara

Zara has been a very interesting case in operations for a long time because of the fast response and flexibility stemming from their practices (Kasra Ferdows, Machuca, & Lewis, 2015). The concept of fast fashion and the high level of vertical integration applied by this company has shown the value of staying at the forefront of operations and its impact on performance. Zara is part of the Inditex group, with more than 650 stores over 50 countries (K. Ferdows, Lewis, & Machuca, 2004) which has led them to achieve nearly 75% of sales of the whole group (Kasra Ferdows et al., 2015).

Speed is an essential quality in the fashion industry. Responsiveness is one of the goals of different companies, but Zara is able to claim achieving responsiveness because of the agility embedded in its supply chain (Kasra Ferdows et al., 2015; Martínez, Errasti, & Rudberg, 2015) as a result of the high level of control rom the supply of materials until the customer purchases the garments (K. Ferdows et al., 2004). For instance, Zara has

been able to introduce new items of clothing to its different stores in around two weeks, from design until delivery (Kasra Ferdows et al., 2015).

Zara has been able to thrive by leveraging new technologies to support its fast fashion approach. The high degree of control over the different links of the supply chain has allowed Zara to have better information sharing as part of their supply chain. Knowledge from the links directly in contact with the customer in the supply chain have allowed the company to be more responsive, using private systems to reduce delays, and enhance the quality and attractiveness of the garments.

With the development of Web 2.0, e-commerce has become a valuable channel to sell products and services. Zara has taken advantage of that opportunity to make their products available to consumers (Fondevila Gascón, Del Olmo Arriaga, & Bravo Nieto, 2012; Gamboa & Gonçalves, 2014) and leveraging from brand enhancement from electronic word of mouth (Correia Loureiro et al., 2019). Similarly, consumers are taking a more prominent role through new communication channels opened by Web 2.0. The introduction communication channels supporting many-to-many interactions have allowed consumers to participate and even collaborate with companies (Gamboa & Gonçalves, 2014). Therefore, several companies are using online platforms in which customers can take part to become closer to the company (Correia Loureiro et al., 2019)

Social media has become a new battlefield for fashion companies because it has become essential to shape the reputation of the brand and achieve customer loyalty (Fondevila Gascón et al., 2012). Zara is the example of an organisation that has embraced social media, as it is one of the fashion companies with the highest number of fans on Facebook (Gamboa & Gonçalves, 2014), which allows them to enhance the engagement with consumers (Fondevila Gascón et al., 2012) and advertise new products and relevant updates about the brand (Correia Loureiro et al., 2019).

Zara's engagement in social media involve constant interaction with customers and posting photos and videos with relevant content (Correia Loureiro et al., 2019), which has paid-off with an increased level of customer loyalty (Gamboa & Gonçalves, 2014) and improved advertising strategies, but it has also carried some challenges. For multinational organisations it is important to consider decentralisation, language, culture and campaign coordination across markets (Fondevila Gascón et al., 2012). The evolution of the content provided and aligning social media to the strategy of Zara is essential to continue enjoying the benefits of social media.

Occupy Sandy: Social media for disaster relief

U.S. Congresswoman Susan Brooks stated in 2013 the importance of social media and technology in disaster management, as well as the value of digital volunteers to enhance the potential of social media and increase situational awareness (Kirac & Milburn, 2018).

A good example of the potential of social media in disaster management is the situation occurred after Hurricane Sandy hit the US. Hurricane Sandy has been one of the costliest disasters that have affected the United States of America. The disaster had devastating impact in several states of the country after growing into a category 3 Hurricane (Yoo, Rand, Eftekhar, & Rabinovich, 2016), striking the East coast in October 2012. It was challenging for FEMA to cope with the situation because of the scale of the disaster, which allowed a small group stemming from the Occupy movement to show the potential of social media to support disaster management with their activities in Brooklyn (Feuer, 2012). In fact, disaster response from the Occupy movement was quicker than larger and more established organisations such as FEMA and Red Cross (Kavner, 2012).

Social media has been heavily linked to disseminating information in disaster situations and to target search and rescue activities (Panagiotopoulos, Barnett, Bigdeli, & Sams, 2016), but the potential of these tools go beyond that. FEMA has recognised the value of social media have a two-way conversation with people and to look at them as resources (Tobias, 2011). This was experienced after Hurricane Sandy hit the US, because the occupy movement was able to set-up communication hubs to re-establish communication and use it to create an emergent supply chain.

Procurement was performed appealing at donations from citizens in two ways. Financial donations using Webpay (Webpay, 2012) were collected to finance response activities and projects, with a total tally of $1,361,337.19 (Occupy, 2013). On the other hand, in-kind donations were also encouraged through the use of Amazon's wedding registry (Occupy, 2012) . In this alternative, an updated list of the most needed items in ravaged areas was posted online for donors to but the items directly and use Amazon retail services to deliver the items to one of the outposts from the movement (Feuer, 2012). The collection of in-kind relief was successful as well, as shown by the delivery of over 35,000 items in few weeks after the storm hit (Islam, Vate, Heggestuen, Nordenson, & Dolan, 2013). They used Sahara Eden to request assistance, to print waybills with items and delivery areas, and to track requests (Homeland_Security, 2013)

Exploiting both supply channels represented operational challenges to manage the relief. The relief was delivered to Occupy Sandy distribution sites split between two churches in Brooklyn, which were the facilities used to deploy relief end volunteers to affected areas (Kavner, 2012). Coordination of these volunteers and relief can become problematic task, especially with numbers between 5,000 and 10,000 volunteers (Homeland_Security, 2013). The Occupy movement used communication systems to enable collaboration by matching human resources with the required activities (Kavner, 2012; Occupy, 2012). That way, a set of borrowed cars and trucks were used to move items and people from the distribution hubs to the affected areas (Feuer, 2012) with the purpose of providing further support to the victims and distribute the relief available.

The size of the occupy movement, however, was not enough to supply all the affected areas. The integration of different organisations and initiatives quickly became a priority to manage operations. That is the reason a link between formal and informal response efforts was essential. Geeks without Bounds became that link for Occupy Sandy, allowing them to coordinate with FEMA and other formal organisations to make operations more efficient (Homeland_Security, 2013). Additionally, they provided situational awareness through crowd mapping. They worked with Hurricane Hackers NYC to provide a map of the affected areas (Homeland_Security, 2013). Therefore, the Occupy movement was able to use public social media as an enabler to create an emergent organisation to provide support online and on the ground (Kavner, 2012). Overall, Occupy Sandy was able to leverage social media across different parts of the supply chain to support disaster affected areas. The collaboration among different links of the supply chain, the constant monitoring of physical and financial aid, the ability to match supply and demand to coordinate different stakeholders, and the use of crowdsourcing to enhance information during the event are some of the examples of the potential of social media in these situations.

Framework

In this section, we extend the existing social media analytics framework (Figure 1) to include a value creation stage, which will aid the decision-makers and relevant supply-

chain entities to understand the purpose of using the analytics for processing the big data captured from social media sources. The key challenge with the voluminous and heterogenous data collected from different sources are lack of focussed analysis (i.e. what do we want from the data) and trying to find a pattern (generate insights without knowing what exactly we are exploring). Thus, the proposed framework extends the existing social media analytics frameworks reported in the extant literature (Lee, 2018; Stieglitz et al., 2018; Holsapple et al., 2018; Chae, 2015)

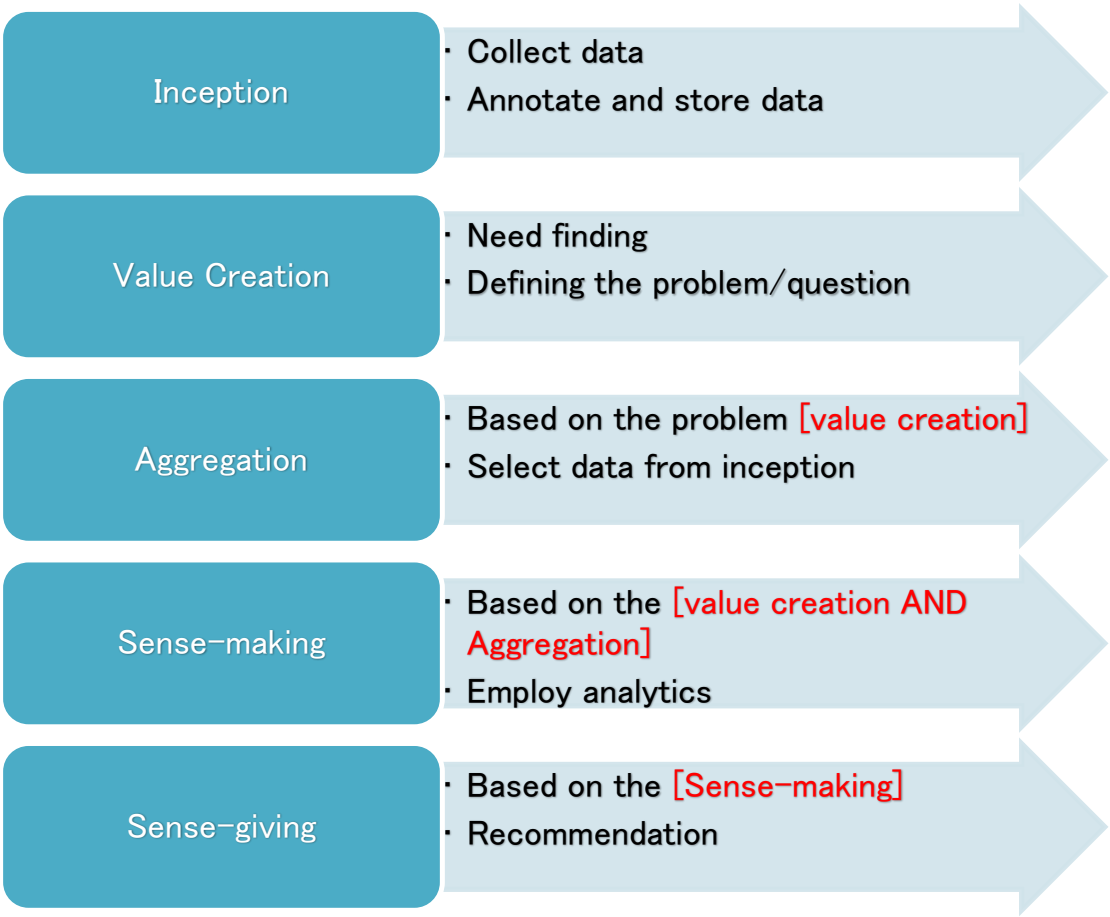

Figure 1: Analytics process to create and capture value from social media data

- ***Inception:*** The primary activities in this stage are collecting the data, followed by cleaning it (i.e. formatting with suitable annotations), then storing it in a structured-way for future use. The primary deliverable is not only a data repository but a report that can guide the next stage, where managers will identify the value of the stored data for purposeful use.
- ***Value Creation:*** This stage is essential to the outcome of the analytics and a component that has seldom been considered in the existing analytics frameworks. The main idea is for managers to use the inception report to understand what data is available from various social media sources and define the questions that they would like to pose to make the analysis focussed. The focussed analysis will aid in capturing value from the process and aid human-decision making.

- ***Aggregation:*** The relevant data from the inception stage will need to be integrated into a consistent format suitable for analysis (basic analytics and advanced analytics). The data selection will depend upon the problem (questions posed by the decision-makers), thus making the both the analysis and outcome focussed and purposeful (Govindan et al, 2018).
- ***Sense-making***: The sense-making stage will employ algorithmic procedures depending upon the questions posed by the managers (in the value creation stage). This stage will include two deliverables: (1) a summarised snap-shot of the data which will help to gather suitable information from the data (which is likely to be voluminous and gathered from heterogeneous sources); (2) output of the analytics employed (such as predictive, prescriptive) using machine learning techniques (Fan and Gordon, 2014). The summary and output will help the managers to capture value from the data, i.e. gain suitable insights for the problem/question identified in the value creation stage, which in-turn will aid in formulating recommendations thus reducing the information and cognitive overload.
- ***Sense-giving:*** This final stage will present the information (summary and output of the analytics) in a visual form, which is intuitive and easy to understand using suitable pictorial representation (such as linked-graphs, trees, filters). The visual representation will help the mangers to have a high-level understanding of the output and offer further drill—down to understand the rationale behind the recommendations (for a recommender system), which ought to depend upon historical information (data bias), heuristics used in the analysed (factor weighing) and source as well as type of data (textual, numerical values, audio and videos).

Overall, the proposed framework demonstrates the importance of value creation stage, which drives all the other stages in the analytics framework towards a focussed analysis. The outcome of the analysis will aid managers to understand the value of the data and have the potential to optimise business processes.

Organisation Needs

This section will discuss the key needs for an organisation to use the proposed framework for creating value and eventually capturing it through the analytics process. The key elements comprise of resources and activities that will aid organisations to build capabilities (such as technology, tools, skills) for successful deployment of the initiatives. The key elements (Figure 2) for consideration are as follows.

- ***Organisation culture:*** This represents the willingness and attitude of the business organisation (managers and team) to invest in contemporary initiatives (data-driven vale creation), appreciate the associated long-term and short-term risks, and evolve the process over time (i.e. remain agile to the advent of technology and novel data contribution platforms). The mindset of the organisation will determine the keenness to take risks, make changes and evolve to create and capture value using data-driven initiatives.

- ***Skills requirements:*** This element pertains to the ability of the organisation, decision-makers, and key employees to understand, manage and align the value creation process to deliver the business needs of the organisation. Additionally, ability to create strategies that will co-ordinate and streamline business and

technical capabilities is pivotal for value creation and capture. It also requires managers to interpret and recognise the information presented in the sense-giving stage to make decisions.

- ***Identifying relevant data sources:*** This relates to identifying, capturing and storing real-time data obtained from social and physical sensors that will aid the organisation in creating value, which requires understanding of the data and business needs of the organisation. This element will require domain expertise (i.e. understanding the business needs to identify relevant sources) and knowledge about the analytics framework (not necessarily technical but conceptual).
- ***Relevant Tools:*** This represents the technological needs of the organisation to harvest relevant insights from the data, i.e. transform data into knowledge using suitable analytic tools, and infrastructure to support such techniques. It requires making decisions for purpose of the analytics to capture value, a strategy to identify and invest in the resources.

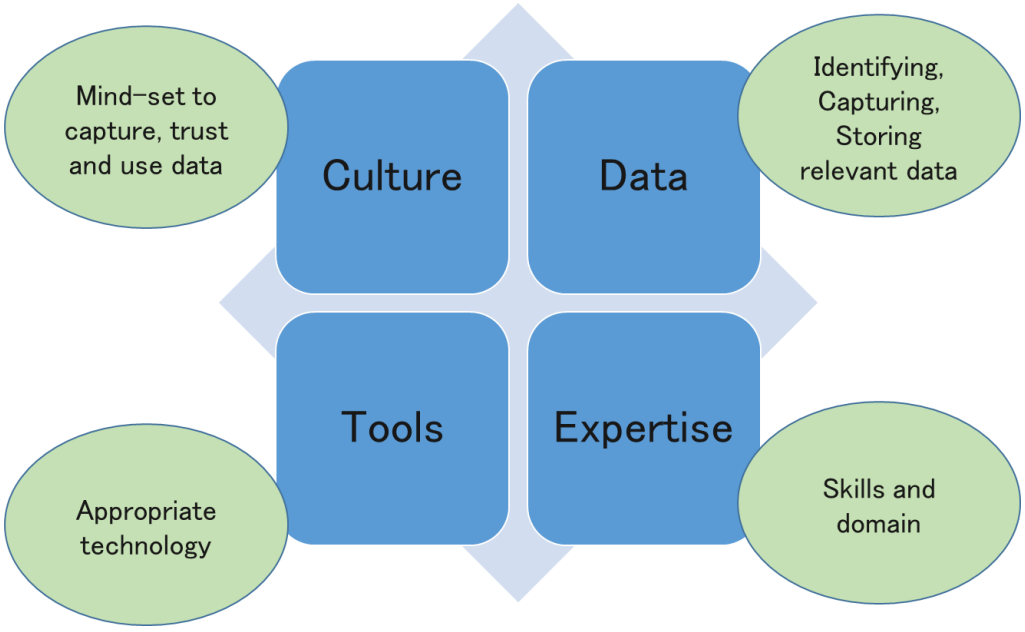

Figure 2: Needs of the organisation to employ the proposed analytics framework

Value creation process

Business organisations in a supply-chain need to understand the key elements involved in the value creation stage, to formulate suitable questions that will be posed to the analytics process. The quality of the output derived from the automated analytics process will depend upon the quality of the question (or the problem formulated by the managers). This section provides and overview of the key elements *(Figure 3)* that managers will need to consider in the value creation stage of the proposed framework taking into account an array of factors preceding this stage.

- ***Purpose:*** It is necessary for the organisations (key decision-makers) to use their domain knowledge, understanding of the business needs, and knowledge of the data sources to outline the purpose of the analytics, i.e. what is the question the automated process will aid in answering. This will streamline and eventually co-ordinate the business needs, data availability, analytics process and value creation (Sanders, 2016). The purpose will also determine which social media streams should be used depending on the nature of the query, quality and type of data available from the stream, and organisational trust in the data stream.

- ***Question:*** The question (i.e. definition of the problem) is a critical element to guide the aggregation and sense-making stages of the analytics framework (Shah et al., 2012). The relevance of the question should be critically assessed considering four key factors: (1) whether the question can be answered, or key insights can be gained by employing analytics; (2) whether the organisation has relevant access to the data streams that will aid in answering the question; (3) how answering the question/ gaining insights will add value to the business needs of the organisation; (4) whether the question is relevant to the contemporary needs of the organisation, i.e. relevance and alignment to business needs, objectives and existing strategy.

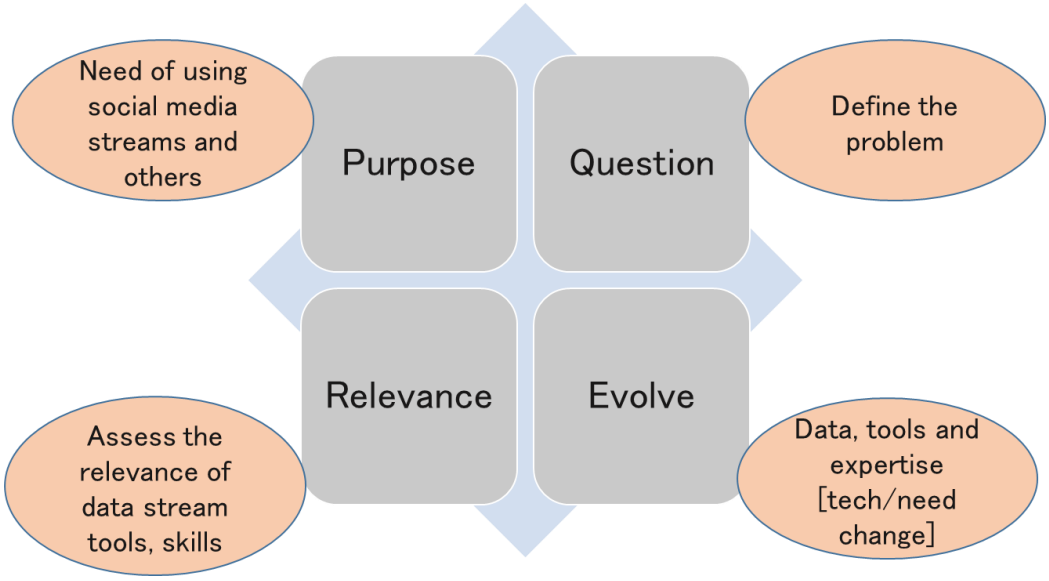

Figure 3: Key elements to consider in the value creation process

- ***Relevance:*** It is key for the organisation to assess the relevance of data stream, i.e. how much the data source can be trusted after the pre-processing, given the veracity involved in the data collected from social sensors. It is critical to assess the key features of the data which will include capturing platform, times-stamp, location, author, motivation to create the data and event associated with the data. Additionally, relevance of technology, expertise to use the technology, and suitable tools need to be considered as well, which should again streamline with the purpose of the analytics and potential intended benefits.

- ***Evolve:*** This is a critical consideration for the organisation to the evolving needs pertaining to technology turbulence and the supply-chain (at all levels – both upstream and downstream). The whole analytics process is evolutionary both in terms of value creation requirements and needs of the organisations. Organisations need to be agile to manage and respond to market movements and make changes dynamically, which will involve taking risks and strategically tackle the uncertainty. Therefore, organisations will be required to revisit their strategy and reflect on it, instead of sticking to a one-stop solution, which is unlikely to reap benefit over a period of time.

Conclusion

This paper demonstrates the need to include a value creation stage in the existing social media analytics framework, so that organisations can streamline the technological and business needs in a suitable manner, which will aid in reaping the benefits from social media data. In this context, organisation will need to adopt an agile strategy that will respond to changes in market as well as the technological turbulence in this digital era. The conceptual framework reported in this paper is yet to be validated in a practical business setting through a longitudinal study. In the future, we aim to conduct multiple case-studies with organisations (both small and large businesses) to validate the framework and identify the barriers stemming from the adoption of this framework. Nonetheless, the value-creation stage in social media framework is non-trivial because in a real-life business setting, organisations often delve into analytics (both social media and IoT data), without having substantial knowledge of the process and randomly searching for patterns in the hope of capturing some insights (which eventually becomes a barrier due to uncertainties stemming from an non-focussed analysis).

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Towards a seamless supply chain: A systematic literature review of influencing factors

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Abstract

The core rationale of supply chain management envisages an integrated supply chain as key to enhanced performance. However, this "end-to-end" approach has not been fully realized. The aim of this paper is to provide a comprehensive review and analysis of factors influencing integration in the supply chain. This is achieved through an exhaustive systematic literature review. From the analysis of 74 articles, a three-path influencing factors model is identified at internal, supplier and customer scopes. Subsequently, influencing factors are categorized into enablers, inhibitors, and dual according to behavioural patterns. The proposed framework provides an all-encompassing overview of factors influencing integration.

Keywords: supply chain integration, enablers, inhibitors

Introduction

Integration is the underlying perquisite to effective supply chain management (SCM). Hence, the study of supply chain integration (SCI) is central to SCM. Approaches to SCI suggest an emphasis in collaboration, coordination and integration in the flow of materials, services, processes and information through the entire SC with the ultimate objective of achieving an end-to-end supply chain (Chang et al. 2016; Childerhouse and Towill, 2003; Flynn et al.2010). Despite the large number of publications exploring SCI, very few firms have yet materialized the *seamless* supply chain (Towill, 1997). In this view, the industrial challenge of planning integration processes among SC partners is still a major source of poor performance (Richey et al. 2009). Thus, there is a need to identify a novel approach for improving performance across the entire SC beyond the realm of the individual firm.

The present paper focus on the first part of this challenge. Accordingly, the purpose of this paper is to investigate and explain both, sources of poor integration and opportunities to enhance SCI. The aim of this paper is to identify the corresponding roles of different influencing factors in enabling and/or inhibiting SCI. This is achieved through an exhaustive and inclusive systematic literature review (SLR).

Methodology

This paper adopted a five-step improve methodology prescribed by Denyer and Tranfield (2009) to systematically reviewing papers in the field of SCI. This methodology encompasses the five-steps of question formulation, location of studies, selection and evaluation, analysis-synthesis, and report of results. The present research design aims to provide rigor and transparency while minimizing bias. In addition, it benefits from enabling replicability.

Formulation of over-arching research question followed a process of setting the scope of the study, identifying emerging literature and further discussions with members of the review panel. The review question is derived as:

- What are the factors that influence the performance of SCI?

The over-arching question suggested the following sub-research questions:

- What are the sources that lead to poor integration?
- What are the sources that provide an opportunity to improve integration?

Two types of keywords relating to the concept of supply chain and integration were used in developing search strings with Boolean operators. Construct search strings are shown in Table 1:

Table 1: Specification of key words used as search strings

Supply Chain		Integration
("Supply chain" OR "Supply network" OR "Value chain" OR "Value network" OR "Logistics" OR Logistic*)	AND	("Integration" OR Integrat* OR "Alignment" OR align*)

In order to allow access to all relevant literature search strings were applied across four databases: Emerald, ScienceDirect, Scopus and Web of Science. These were screened for title and abstract publications in English language, including academic journals, chapters of edited books, and reports published between 2000 and 2018. From initial search, 23.940 papers were retrieved. Following elimination of duplicates, title and abstract of remaining papers were screened against inclusion and exclusion criteria.

Subsequently, the remaining papers were read in full. In order to identify most relevant publications studies were evaluated against a set of specific quality criteria based on subject matter and quality assessment. These included papers providing a comprehensive understanding of the research are of SCI. Then, studies that contributed to the increasing knowledge of factors influencing the performance of SCI were selected. As a result, 66 papers from the original search were identified as relevant for this research. In addition, 8 publications were included from cross-referencing that were not originally identified in the primary search. In all, 74 papers were analyzed for descriptive and thematic findings. Full selection process is detailed in Figure 1:

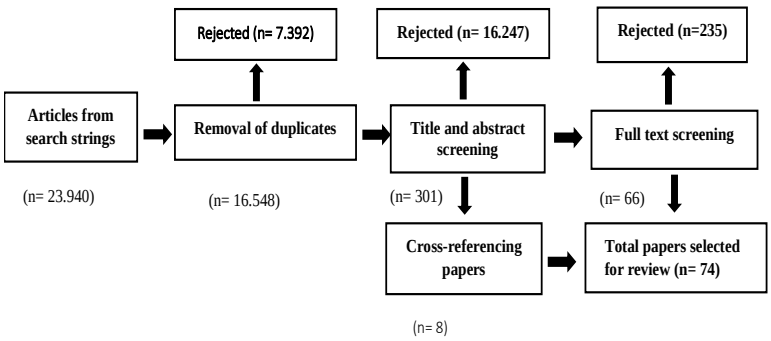

Figure 1. Summary diagram of systematic selection process

Descriptive Findings

The 74 papers selected for review are descriptively analysed in this section in respect of year of publication, research methodology, journal, field of study and industry. The aim of the descriptive analysis is to identify the research trends in the field of SCI.

Figure 2 indicates a gradual interest over the years, with a dramatic increase between 2009 and 2017. During this time 55 papers were published, which amounts to 75% of papers included in this study. A surge in recent publications clearly indicates an increased interest of academics in SCI within the operations management field.

Accordingly, 88% of studies were empirical of which 57 (87%) employed survey and fewer 8 (12%) a case-study method. This confirms the advance mature stage of SCI field, emphasizing a high degree of theoretical development through validation.

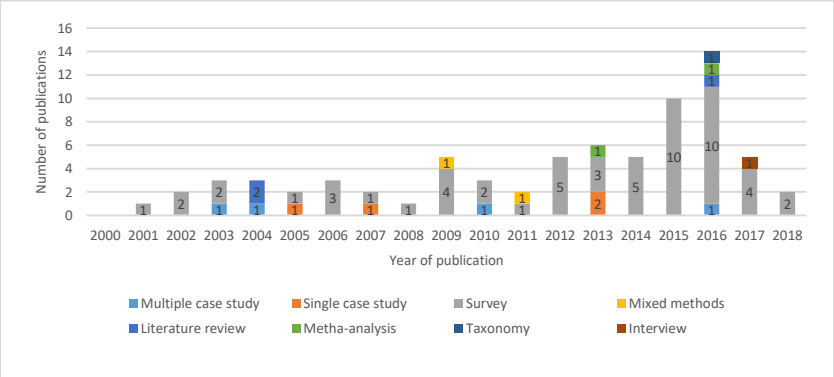

Figure 2. Publications according to year and research methodology

The studies selected for this review were exclusively published in academic journals. Once again, this illustrates the mature stage of this area of research. Likewise, most papers were published in operations management and technology journals (82%), operations research & management science (7%), information management (7%), marketing (1%) and social sciences (1%). This indicates the predominance of studies in operations and technology with little interest from other fields of research.

Finally, the presence of industry sectors is fairly represented across SCI studies. Manufacturing/Machinery (23%), consumer products (19%) and electrical/electronic are predominantly the most discussed industries.

Thematic Findings

This section identify and explain a three-path influencing factors model at three different scopes including internal, supplier and customer.

Types of influencing factors to SCI

Factors are classified as inhibiting, enabling and dual. Inhibiting factors have an exclusive inhibiting influence to a particular scope. Enabling factors have an exclusive enabling influence to a given scope. In contrast, dual factors may act as both enablers and inhibitors at any scope.

At internal scope financial and risk are classified as inhibiting factors. Technology, human intervention, communication, alignment, culture, uncertainty, strategy and

organizational are dual factors, while commitment is a single inhibiting factor. At supplier scope, financial is classified as single inhibiting factor. Correspondingly, technology, human intervention, communication, alignment, culture, uncertainty, strategy, organizational, trust, commitment and risk are dual factors. Dependence and power are single enabling factors. In addition, financial and risk are inhibiting factors to customer integration. Technology, human intervention, communication, alignment, culture, uncertainty, strategy, organizational, trust and commitment are categorized as dual factors. In contrast, dependence and power are classified as enabling factors. The following section identifies influencing factors across different scopes. Figure 3 depicts SCI influencing factors model.

Influencing factors: inhibiting forms

Common across all scopes (internal, supplier and customer)

Influencing factors inhibiting integrative practices across all dimensions include lack of access to high-class technology (Leuschner et al. 2013); lack of a supporting platform/and or practices for technology (Cousins and Menguc 2006); management resistance to change(Bernon et al.,2013; Frohlich, 2002); lack of management support to assist SCI practices (Zhao et al, 2015); management minimizing sharing of sensible strategic information (Trkman et al. 2007; Wang et al., 2014) ; management lack of understanding of SCI; poor SCI- Issue fit Strategic Alignment (Flynn et al. 2016); lack of communication (Forslund and Jonsson, 2009; Pagell, 2004) ; low levels of environmental uncertainty (Wong et al., 2011) ; high levels of market, demand and supply uncertainty (Childerhouse and Towill, 2003; Lu et al. 2018); financial and supply risk (Leuschner et al. 2013; Zhao et al. 2013); independent functionality (Richey et al. 2009) ; lack of technical and business skills, and fragmented planning system (Frohlich, 2002); poor strategic alignment (Flynn et al. 2016); time constrains (Alfalla-Luque et al. 2013); lack of external perspective (Richey et al. 2009); and increased cost associated with acquisition of supporting infrastructure for SCI (Terjesen et al. 2012)

Specific to external scope (supplier and customer)

Influencing factors specific to the external scope include continued use of low performance logistic tools that are outdated and/or incompatible and management "know-best" decision-making (Forslund and Jonsson, 2009); Management hindering integration practices to avoid personal risk (Villena et al., 2009); lack of trust (Revilla and Knoppen, 2015); absence/poor commitment (Yuen, 2016); partners lack of alignment (Das et al., 2006); deviation from the "optimum level" of integration (Swierczek, 2014); restricted share of knowledge or information sharing (Zhu e al., 2018); formal communication channels encouraging transmission but not proximity (Alfalla-Luque et al., 2013); SC partners organizational culture differences (Trkman et al., 2007); lack of governance structure to handle integration (Cousins and Menguc, 2006); centralised hierarchical structures that minimize employees involvement (Flynn et al., 2016); poor understanding of SCI (Leuschner et al., 2013); complexity of processes and materials requirements (Lockström et al., 2010); use of indiscriminate integration practices (Das et al., 2006; Gimenez et al., 2012); shared resources (Van Donk and Van Der Vaart, 2005) ; excessive intensity of SCI (Swierczek, 2014) ;and cost focused firms (Van Der Vaart and Van Donk, 2004)

Specific to internal scope

Influencing factors specific to the internal scope include employee use of soft skills to avoid undesirable jobs (Wang et al., 2014); poor functional, departmental and systems

alignment; poor quality of information hierarchical cultures that promote distance and remove power (Pagell, 2004); internal politics that are not inclusive of SCM practices (Zsidisin et al., 2015); and organizational resistance to change (Gimenez and Ventura, 2005).

Specific to supplier scope
Inhibiting forms include management cultural differences and a lack of cultural understanding (Lockström et al., 2010); and poor quality of information (Alfalla-Luque et al., 2013)

Specific to customer scope
Influencing factors specific to customer scope include instrumental commitment (Zhao et al., 2008); hierarchical cultures (Cao et al., 2015); high levels of demand risk (Zhao et al., 2013); and partners use of coercive power in the relationship (Zhao et al., 2008).

Influencing factors: enabling forms
Common across all scopes (internal, supplier and customer)
Influencing factors enabling integrative practices across all dimensions include logistic tools (Alfalla-Luque et al., 2013); processes supporting its functioning (Arun et al., 2006); top management support (Zhao et al, 2015); human capital (Huo et al.,2016a); high levels of communication (Bernon et al.,2013); supporting communication structure (Kim and Narasimhan, 2002); information and knowledge sharing, and knowledge capability supporting structure (Prajogo, and Olhager, 2012; Richey et al., 2009; Turkulainen et al., 2017a; Zhu e al., 2018); commitment to the relationship and identification with the firms' common norms and values (Huo et al.,2016a); alignment of SCI to the type of performance indicator aimed to improve and alignment of enabler and degree of SCI (Wong et al., 2011); development and group cultures (Cao et al., 2015); high environmental uncertainty (Terjesen et al., 2012); an external strategic orientation (Yunus and Tadisina, 2016) ; pursue of both internal and external integration jointly as they beneficially influence one another (Gimenez and Ventura, 2005); strategic processes and practices that support SCI (Terjesen et al., 2012); closer location to the customer order decoupling point (CODP) (Van Donk and Van Doorne, 2016); supporting management and information processing infrastructure (Srinivasan and Swink, 2015); and use of common platforms (Ralston et al. 2015).

Specific to external scope (supplier and customer)
Enabling forms of factors specific to the external scope include the use of inter-personal relationships (Wang et al., 2016); information integration (Prajogo, and Olhager, 2012); equal levels of dependence among SC partners (Zhang and Huo, 2013) ; trust (Chang et al., 2016); a reliable and genuine interest in the relationship (Vijayasarathy, 2010) ; desire to move from traditional to strategic collaboration (Yuen, 2016); open-minded and honesty (Zhang and Huo, 2013); appropriate use of power (Wang et al., 2016); partners alignment (Li et al., 2009); externally focused culture (Yunus and Tadisina, 2016); high Specification and volume uncertainty (Van Donk and Van Der Vaart, 2005); internal integration approach as key to achieve further integration (Gu et al., 2017); an evolutionary process approach to integration (II->SI->CI) (Chen, 2016); strategic collaborative practices (Frohlich, 2002); information integration strategy (Prajogo, and Olhager, 2012); pursue of coordinative practices (Wiengarten and Longoni, 2015); a simplification approach (Childerhouse and Towill, 2003); use of intangible/inimitable resources (Xu et al., 2014); a low "proactive" strategic orientation (Stonebraker and Liao,

2004) ; an “inside-out" removal of integration obstacles strategy (Frohlich, 2002); a socialization strategy (Cousins and Menguc, 2006); a continuous improvement approach to integration “not a one-time thing” (Trkman et al., 2007); joint influence of both interpersonal relationships and inter- organizational relationships (Wang et al., 2016); and a long-term relationship approach (Yuen, 2016).

Specific to internal scope

Enabling forms of factors at the internal scope include an open communication climate (Zsidisin et al., 2015); real time cross-functional communication that is informal (Arun et al., 2006); employee commitment (Alfalla-Luque et al, 2015); goal alignment (Turkulainen et al., 2017a); inter-departmental alignment (Alfalla-Luque et al., 2013); cultures that promote collaboration (Pagell, 2004); an innovative orientation (Lii and Kuo, 2016); the “optimal timing" of Integration efforts must precede the practice intended to improve or being applied at a nascent stage (Narasimhan and Das, 2001); flatter/ de-centralized organizational structures (Flynn et al., 2016); and inter-functional and Inter-departmental integration (Moyano-Fuentes et al., 2016).

Specific to supplier scope

Enabling forms specific at supplier scope include alignment of SCI efforts-environment (He et al., 2017); collectivism Culture (Chang et al., 2016); risk management practices (Villena et al., 2009); technological uncertainty (Huang et al., 2014); joint decision-making (He et al., 2017); and imitation of peers (Turkulainen et al., 2017b)

Specific to customer scope

Specific enabling forms at customer scope include high quality and consistent information (Chavez et al., 2015); and planning systems integration (Bernon et al.,2013).

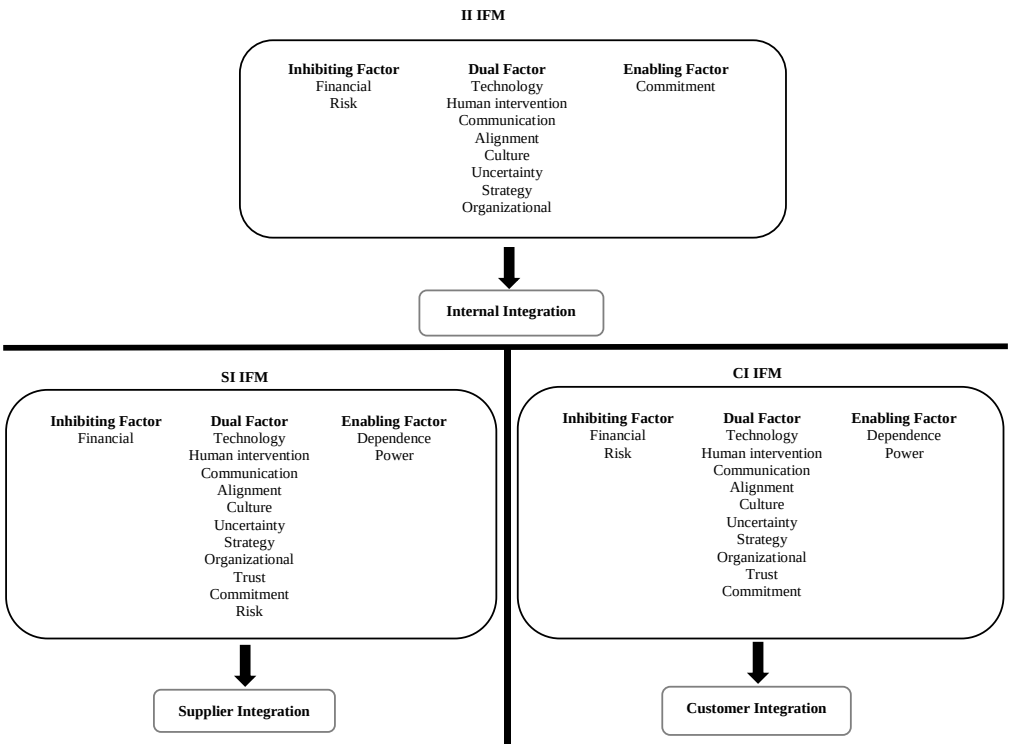

Figure 3. SCI Influencing Factors Model

Conclusion

This paper investigates factors that influence realization of SCI. From the analysis of 74 papers a three-path influencing factors model is identified at internal, supplier and customer scopes. Subsequently, influencing factors are classified as enabling, inhibiting, and dual according to behavioural patterns. The main outcome of this study is the establishment of a framework that explains the relationship between influencing factors and integration at specific scope levels. Hence, influencing factors to SCI act at scope level, with all three scopes influenced differently resulting in factors variation across scopes. This illustrates the complexity to understand SCI in practice and to achieve realization of the seamless SC. This framework should be used as a foundation to develop hypothesis and further empirical work.

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Buyer-supplier relationships in Industry 4.0 – A comparison across industries

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Abstract

Industry 4.0 implies a future digitalized and interconnected industrial value creation and has the potential to transform buyer-supplier relationships. These relationships differ among industry sectors because of industry-specific circumstances. This paper sheds light on future buyer-supplier relationships in the context of Industry 4.0 focusing on industry differences. Qualitative semi-structured expert interviews with 65 experts from German industrial enterprises serve as empirical basis of the exploratory multiple case study. The results reveal how future buyer-supplier relationships differ among various industries. The paper contributes to the current state of research from a management perspective triggering further research in this area.

Keywords: Industry 4.0, Buyer-Supplier Relationships, Industry-comparison

Introduction

"Industry 4.0", also known as the "Industrial Internet of Things", indicates a de novo change in industrial value creation based on digitalization and interconnection (Kagermann et al., 2013). People, machines, objects, and information and communication technology systems get intelligently, horizontally, and vertically interconnected (Schneider, 2018). Given its far-reaching technological developments along with its revolutionary character for value creation, Industry 4.0 provides numerous opportunities and potentials, e.g., efficiency, quality, and flexibility improvements (Kagermann et al., 2013).

Industry 4.0 implies a digitized, real-time capable, and intelligent interconnection of value creation chains, networks, and ecosystems (Bienhaus and Haddud, 2018; Kiel et al., 2017; Tu, 2018; Wang et al., 2006). Technological developments enable collecting, processing, analyzing, and sharing data (Thun, 2010; Wang et al., 2006). In this context,

digital technologies may create new forms of collaboration, cooperation, and integration and change buyer-supplier relationships (Obal and Lancioni, 2013). A more intense collaboration, further integration of partners, usage of platforms, and cross-company systems transform the shape of future competition. Given substantial industry specific differences in terms of value creation, analyzing buyer-supplier relationships requires a separate consideration.

Buyer-supplier relationships in the context of Industry 4.0 have scarcely been analyzed so far and consequently little is known about particular differences in various industry sectors (Haddud et al., 2017). However, analyzing the interconnection of companies, cross-company cooperation, and shared value creation is relevant for several reasons. Firstly, analyzing these aspects is vital to unveil how to further develop and improve industrial value creation (Vanpoucke et al., 2013). Secondly, buyer-supplier relationships represent a great source of competitive advantage, e.g., reducing sourcing costs, especially against the backdrop of decreasing value creation depth (Tan et al., 2002; Wang et al., 2006). Thirdly, cross-company interconnection represents a central element of Industry 4.0 and thus asks for an investigation (Büyüközkan and Göçer, 2018).

Whereas it is expected that companies cooperate and interact more closely in the future (Vanpoucke et al., 2013; Wang et al., 2006), it is unknown how buyer-supplier relationships are characterized in the context of Industry 4.0. Both research and practice show great interest in discovering setting levers for future buyer-supplier relationships (Schneider, 2018; Tu, 2018).

For this reason, the study addresses the following research questions:

RQ 1. How are present buyer-supplier relationships characterized in various industry sectors?
RQ 2. What are the distinct characteristics of future buyer-supplier relationships in the context of Industry 4.0 dependent on companies' industry sectors?
RQ 3. What drivers and causes can be identified why buyer-supplier relationships are transformed in the context of Industry 4.0?

The study sheds light on industry-specific differences in buyer-supplier relationships in the context of Industry 4.0 and indicates areas for future research. Aside from contributing to research, the derived recommendations and implications serve managers and corporate practice, which in turn ensures the study's practical relevance.

Theory

Industry 4.0

Based on an ongoing digitalization and interconnection, Industry 4.0 implies a new paradigm shift of industrial value creation. Cyber-Physical Systems and the Internet of Things form its technical basis. Cyber-Physical Systems are characterized by physical objects being complimented with communication systems and technologies that exchange digital data and allow an autonomous and independent coordination (Blau, 2014; Kagermann et al., 2013; Lasi et al., 2014). By means of information and communication technologies, the Internet of Things interconnects physical and virtual objects and systems alike, and in so doing, enables comprehensive communication and vast interactions (Kagermann et al., 2013; Lasi et al., 2014). Applying these technologies paves the way to merge and interconnect the physical and virtual world in industrial value creation. The inclusion of Internet of Things solutions and applications in industrial value

creation is also referred to as Industrial Internet of Things, why this term can synonymously be used to Industry 4.0.

Given its far-reaching implications for industrial value creation, Industry 4.0 provides both strategical and operational potentials for individual companies. First, it paves the way for new, data-driven business models, e.g., platforms, and it may also transform existing business models (Kiel et al., 2017). Second, modular product designs and flexible production processes help to produce individual products nearly in a similar quantity and efficiency like mass production ("mass customization") (Kiel et al., 2017). Third, value creation efficiency and productivity can be improved, for instance via optimizing capacity utilization and turnaround time. Fourth, Industry 4.0 can decrease overall risks by increasing transparency of the value creation process and fasten responsiveness to adapt to changes (Rong et al., 2015).

Aside from affecting individual companies, Industry 4.0 has the potential to reshape entire value creation processes forming integrated cross-company value creation chains and networks (Hofmann and Rüsch, 2017; Kiel et al., 2017; Vanpoucke et al., 2013). Against this backdrop, a broad and comprehensive horizontal and vertical interconnection represents a key to tap Industry 4.0's full potential (Kagermann et al., 2013; Müller et al., 2018a).

Industry 4.0 in Supply Chain Management

Supply Chain Management aims at optimizing the performance of the value creation process, for instance improving quality, time, and cost, and building up competitive advantages (Tan et al., 2002; Vanpoucke et al., 2017). Supplier Management's objective is to create, manage, and develop buyer-supplier relationships in order to efficiently organize and manage value creation (Choy and Lee, 2003). Being a central element, supplier integration represents a form of vertical cooperation. It is a set of strategies to design buyer-supplier relationships in a collaborative and cooperative manner, combining resources and capabilities to conduct common activities (Bienhaus and Haddud, 2018; Schoenherr and Swink, 2012; Tan et al., 2002; Thun, 2010; Vanpoucke et al., 2013).

Buyers and suppliers alike benefit from collaboration, cooperation and integration (Bienhaus and Haddud, 2018; Haddud et al., 2017; Tan et al., 2002; Vanpoucke et al., 2017). Intensifying cooperation allows conducting joint activities, for instance, carrying out common research and development projects (Bienhaus and Haddud, 2018; Tan et al., 200;). Integrating new or unrelated partners ensures access to further resources and expertise (Rong et al., 2015; Vanpoucke et al., 2013). On an operational level, closely working together reduces costs of value creation. First, it decreases process complexities and in turn increases process efficiency, e.g., via lower coordination efforts and less manual reworking. Second, it reduces inventory levels following greater information transparency. On an output level, it increases flexibility, agility, and responsiveness of value creation chains. Further, cooperation helps to address customers' demand providing individual solutions and services (Bienhaus and Haddud, 2018; Dweekat et al., 2017; Vanpoucke et al., 2017; Wang et al., 2006).

Industry 4.0 affects Supply Chain Management and transforms buyer-supplier-relationships intensifying the interconnection of value creation chains. Technologies, such as the Internet of Things, Big Data, and Cloud Computing, enable real-time data analysis and data management across company boarders (Bienhaus and Haddud, 2018; Büyüközkan and Göçer, 2018; Dweekat et al., 2017; Thun, 2010; Wang et al., 2006). Thus, Industry 4.0 increases information transparency improving efficiency of Supply Chain Management functions, decision-making, and overall business performance (Bienhaus and Haddud, 2018; Dweekat et al., 2017; Vanpoucke et al., 2017; Wang et al.,

2006). In addition, the supply chain is improved as for robustness, flexibility, responsiveness, and agility, for instance, using smart products that advance traceability and further automating processes (Wang et al., 2006). Furthermore, digital technologies pave the way to create new forms of collaboration, cooperation, and integration, for instance transferring value creation to digital platforms, and subsequently change buyer-supplier relationships (Obal and Lancioni, 2013). Intense vertical integration and ongoing collaboration does not only apply for first-tier suppliers, but includes suppliers of further value creation stages (Dweekat et al., 2017; Müller et al., 2017). Consequently, future competition will no longer be amongst individual companies, but between corporate network structures and ecosystems (Kiel et al., 2017).

Methodology

Using a qualitative explorative empirical research design and applying a multiple case study approach, the study analyses how buyer-supplier relationships differ in various industries in the context of Industry 4.0 (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007). Exploratory case studies are used to investigate complex, novel, and evolving, phenomena (Yin, 2009). Multiple cases increase the results' accuracy, reliability, generalizability, and robustness (Eisenhardt and Graebner, 2007; Yin, 2009).

The empirical data comprises semi-structured interviews with 65 experts from German and Austrian companies of heterogeneous firm sizes and different industry sectors conducted between August 2018 and March 2019 (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007). The companies' characteristics vary in sales volume (av. = 29,200 million EUR) and number of employees (av. = 83,000). They were analyzed in their role as buyers and stem from the automotive (n = 8), automotive suppliers (n = 15), consumer goods (n = 4), electronic and electrical engineering (n = 13), mechanical engineering (n = 13), and raw materials processing (n = 12) industries. All experts hold management positions with an average company tenure of 8.55 years and they are involved in or responsible for Industry 4.0-projects. The experts' names and companies are anonymized for confidentiality reasons. The sample's heterogeneity enables generalizing results and counteracts potential negative effects of sample biases (Yin, 2009). Selecting competent and knowledgeable experts strengthens the findings' reliability (Huber and Power, 1985).

The interview guideline was informed by literature but followed the principles of openness and flexibility. The first part deals with questions about personal facts and company contexts. The second part focuses on current buyer-supplier relationships and the third part deals with future buyer-supplier relationships. To concretize some aspects and to reveal further information, individual questions slightly deviated from the original guideline. All interviews were audio recorded and transcribed which reveals more than 820 pages of text material. Whenever possible, secondary data was used to verify the experts' statements for triangulation purposes, which increases validity and reliability (Eisenhardt and Graebner, 2007; Yin, 2009).

In order to answer the research questions, a qualitative content analysis was used to identify pattern, themes, and categories in the empirical material (Miles and Huberman, 1994). The study follows an inductive coding procedure that facilitates theory building but the categories were partly informed by literature to allow new aspects to emerge (Edmondson and McManus, 2007; Eisenhardt and Graebner, 2007; Krippendorff, 2013). In a first step, first-order (informant-centric) categories were developed. Second, the categories were synthesized into second-order themes. Third, the themes were distilled into general dimensions. The process was conducted in a research team consisting of three authors to ensure validity and objectivity of the coding procedure (Weston et al., 2001).

Results

The results are divided into three subsections addressing the paper's research questions in a buyer-to-supplier perspective: First, it is described how present buyer-supplier relationships are characterized in differing industry sectors. Second, we describe to what extend buyer-supplier relationships change in the context of Industry 4.0 and how future relationships vary in several industries. Third, drivers and causes are presented why buyer-supplier relationship are transformed. Given the limited space of the paper, the chapter does only present and discuss those categories that are predominantly named to be relevant for the industries regarded in the sample. Table 1 depicts the results differentiated by industry sectors:

Table 1 – Aspects of buyer-supplier relationships differentiated by industry sectors

	Present buyer-supplier relationships	Future buyer-supplier relationships	Drivers and causes for transformation
Automotive	▪ Digital, automated data exchange ▪ Low level of trust	▪ Real-time data ▪ Relationship of trust ▪ Selection criteria for suppliers	▪ Improving competitiveness ▪ Customer demands and value offering ▪ Market dynamics and volatility
Automotive suppliers	▪ Non-automated data exchange ▪ Personal and direct contact ▪ Dependent on suppliers ▪ Low level of trust	▪ Digital platforms ▪ External expertise, support of start-ups ▪ Relationship of trust ▪ Personal contact	▪ Optimization ▪ Customer demands and value offering ▪ Information sharing and transparency ▪ Market dynamics and volatility
Consumer goods	▪ Personal and direct contact	▪ Direct contact remains important ▪ Lower supplier base	▪ Improving competitiveness ▪ Information sharing and transparency
Electronic & electrical engineering	▪ Positive and well established relationships	▪ Digital platforms and cloud computing ▪ Automated processes	▪ Optimization ▪ Technological changes
Mechanical engineering	▪ Long-term oriented relationships	▪ External knowledge ▪ Earlier integration of partners ▪ Concentration on strategic suppliers	▪ Optimization ▪ Cost pressure ▪ Technological changes
Raw materials processing	▪ Positive and well established relationships	▪ Integration in product development ▪ External knowledge ▪ Selection criteria for suppliers ▪ Automated processes	▪ Market dynamics and volatility

Present buyer-supplier relationships

Interviewees from the automotive industry state that automated data exchange is how they share data with suppliers. Interestingly, automotive suppliers predominantly use non-automated data exchange with their respective suppliers in contrast.

Automotive suppliers and companies from the consumer goods industry indicate that personal and direct contact to their suppliers is of utmost importance in the present. In the automotive supplier industry, however, the frequency of direct contact with their suppliers is largely dependent on the respective suppliers' importance.

For mechanical engineering companies, in the present long-term relationships with their suppliers play a crucial role. Those relationships are of close nature, for instance integrating suppliers in innovation and product development processes from early on.

As far as level of trust is concerned, especially representatives from the automotive industry and from automotive suppliers perceive a rather low level of trust in their present buyer-supplier relationships. In contrast, representatives from mechanical engineering and electronic and electrical industries predominantly describe their current buyer-supplier relationships to be positive and well established.

Future buyer-supplier relationships

Automotive suppliers and raw materials processing companies name digital and automated data exchange to be part of their future buyer-supplier relationships. Foremost companies from electronic and electrical engineering state that the importance of platforms and cloud computing increases. In contrast, automotive suppliers indicate that direct and personal contact still remains important in the future, which is also true for the consumer goods industry. In the automotive industry, real-time data exchange is a central characteristic of future buyer-supplier relations. Representatives of raw materials processing enterprises name an enhanced traceability as crucial for future collaboration in their industry. In the electronic and electrical engineering and raw material processing industry major manual activities, e.g., procurement processes, are automated in the future.

Mechanical engineering enterprises predominantly focus on strategic suppliers and companies from consumer goods industry keep a smaller supplier base in the future. Mechanical engineering enterprises and companies from raw materials processing aim at further integrating external knowledge, especially IT-related expertise. Representatives from automotive suppliers as well as raw materials processing companies apply different selection criteria to choose suppliers in the future.

Companies from the automotive industry and automotive suppliers predominantly aim at intensifying buyer-supplier relationships in the future. In addition, automotive suppliers try to intensify and broaden cooperation with start-ups. Companies from raw materials processing intend to cooperate more closely with their suppliers when it comes to new product development. Representatives from the mechanical engineering industry state that they prospectively integrate their suppliers at an earlier stage compared to the present.

Drivers and causes for transformation

Industry 4.0 and accompanying technological developments play a central role in the transformation of buyer-supplier relationships according to all interviewees' statements. Various interviewees express that well-established and smooth buyer-supplier relationships are required to successfully implement Industry 4.0 across companies and subsequently profit from its entire set of potentials.

Several drivers can be observed why buyer-supplier relationships are transformed that differ in various industry sectors. First, companies from mechanical engineering, electronic and electrical engineering, and automotive suppliers see potential for

optimization in reshaping buyer-supplier relationships. In addition, competitiveness, both on an individual and a supply chain level, is strengthened through enhanced buyer-supplier relationships foremost for companies from the automotive and consumer goods industry. Apart from this, representatives from the automotive industry and automotive suppliers indicate that demands from their customers, e.g., higher flexibility, reliability, and product availability, drives changes in their buyer-supplier relationships. Transforming future buyer-supplier relationships enables companies from those industries to create new forms of value offerings for their respective customers. Data exchange across the supply chain, for instance via platform solutions and horizontal and vertical data exchange, requires new relationships between buyers and suppliers. Especially interviewees from automotive suppliers and consumer goods industry state that the possibility to share information and to increase transparency drives the transformation of their future buyer-supplier relationships.

External causes why buyer-supplier relationships are transformed can be found manifold as well. Representatives of automotive, automotive suppliers and raw materials processing companies name an increased market dynamic and volatility as well as an increasing competition as influence factors for a transformation of buyer-supplier relationships. Especially companies from mechanical engineering face increasing cost pressure they address with transforming their buyer-supplier relationships. Technological changes, e.g., digital technologies for digital data exchange and analysis, pave the way for future transformations, mainly in the industries of mechanical engineering and electronic and electrical engineering.

Discussion

As far as present relationships are concerned, the study uncovers that significant industry differences in buyer-supplier relationships can be observed. Among others, the results show that present buyer-supplier relationships in the automotive industry and automotive suppliers are built upon rather low levels of trust. In contrast, buyer-supplier relationships in the mechanical engineering and electronic and electric engineering industries are characterized by higher levels of trust. For the majority of industry sectors, present buyer-supplier transactions and information sharing are mostly conducted via non-automated, analogue, and manual processes. In this context, personal and direct contact are frequently used and are very important in present buyer-supplier relationships.

Our study reveals that buyer-supplier relationships are transformed in the context of Industry 4.0, but the extent of transformation varies among industry sectors, given differing status quos and intensities of changes. The automotive industry and their suppliers prospectively aim for improving current rather mediocre relationships with suppliers, whereas other industries aim at deepening and intensifying already well-established relationships, for instance, further integrating suppliers. In this regard, the paper contributes to the current state of literature emphasizing that well-established relationships are a prerequisite for successful supplier integration. Further, the paper confirms that intense buyer-supplier relationships pave the way to streamline value creation and to provide a superior value proposition that is aligned on end customers' demand which in turn serve to build up a competitive advantage (Schoenherr and Swink, 2012; Tan et al., 2002; Thun, 2010).

Extant research has shown that the automotive industry and its suppliers perceive Industry 4.0 rather from an operational, than from a strategic perspective, in contrast to, for instance, mechanical engineering and electrical and electronic engineering companies (Kiel et al., 2017; Müller et al., 2018b). Our paper partly confirms these results revealing that for instance, companies from mechanical engineering and raw materials processing

concentrate on strategical aspects of buyer-supplier relationships, e.g., integration of partners in product development.

The results show that prospectively information sharing will increasingly be conducted via digital and automated processes in all regarded industry sectors. However, the extent and the forms differ as indicated by the results. For instance, in the automotive and automotive supplier industry, especially real-time data plays a crucial role. Digital platforms become relevant predominantly in the electronic and electrical engineering and automotive supplier industry. Sharing information increases productivity and decreases inventory levels, maintenance efforts, and value creation costs (Vanpoucke et al., 2017; Wang et al., 2006). Whereas on an operational level, information sharing might increasingly be conducted digitally (Hofmann and Rüsch, 2017; Müller et al., 2018a), the results indicate that on a strategic level, personal communication remains important in the future. The paper extends literature in adding that direct personal contact will remain of high importance in buyer-supplier relationships in the context of Industry 4.0.

Responsible for a great proportion of value creation, small and medium sized firms keep on working with manual and semi-digitized solutions in many cases for technical and financial reasons. Subsequently, this requires a strategy that both strives for digital data exchange and develops buyer-supplier relationships on a personal level to unfold the entire potential (Dweekat et al., 2017; Müller et al., 2018a).

Changes in future buyer-supplier relationships can be referred back to several drivers and external causes. Literature has revealed that collaboration, cooperation and integration provide several benefits (Bienhaus and Haddud, 2018; Haddud et al., 2017; Tan et al., 2002; Vanpoucke et al., 2017). Our study adds to the current state of research differentiating between industries and providing an industry comparison.

Our paper extends studies that highlight the importance of buyer-supplier relationships for smooth supply chains in the digital era (Tu, 2018; Wang et al., 2006). Information and communication technologies and digital supplier integration efforts pave the way to establish digital value creation networks in the context of Industry 4.0 (Vanpoucke et al., 2017; Thun, 2010).

Conclusion

Industry 4.0 has the potential to transform future buyer-supplier relationships. Despite its importance for research and corporate practice, there is still little research about Industry 4.0 from a Supply Chain Management perspective. Using a unique sample of empirical data comprising interviews with 65 experts from German industrial companies, the study analyzes how buyer-supplier relationships in the context of Industry 4.0 differ in various industry sectors.

The study entails some limitations as for the data sample and its method that are worth to discuss. First, the data sample exclusively includes German companies that may limit the results' generalizability. Second, the study focuses on selected industry sectors, which must be kept in mind when transferring its implications to other contexts. Third, the study does neither differentiate between different levels of value chain stages, e.g., first-tier versus second-tier suppliers, nor does it analyze differences that stem from various company sizes, e.g., small and medium sized versus large companies. Fourth, the study solely analyzes buyer-supplier-relationships from buyers' perspectives. As far as methodical limitations are concerned, developing solid theoretical implications from explorative, qualitative research is rather difficult. However, the study consolidates empirical data from individual cases while keeping relevant content, and in so doing, is able to work out theoretical contributions. In addition, various biases, e.g., key informant

and retrospective bias, are addressed by our methodological approach and discussed along with measures to reduce their impact.

In the course of the analysis, the study uncovers space for future research. Given the study's limitations and contributions, further research could shed light on the following aspects. Quantitative research may complement the study and, for instance, may quantify and statistically prove the discussed effects. Future research can add the supplier's perspective to analyze buyer-supplier-relationships, focus on small and medium sized firms, and differentiate between levels of value chain stages. Going beyond the study's scope, research could focus on the following further aspects. Research could investigate the incentives to integrate suppliers and incentives to intensify cooperation and collaboration. Future research studies are ought to analyze how supplier integration is to be conducted operatively, what efficiency gains and economical outputs can be expected, and which implications for future value creation can be derived. In addition, platforms possess the potential to revolutionize buyer-supplier-relationships and therefore call for special attention leaving great space for future investigations.

The study and its findings reveal several implications for management and corporate practice. First, well-established buyer-supplier relationships can be regarded as a prerequisite for close cooperation and supplier integration in the digital era, which is why establishing such relationships, is of utmost importance. Second, cooperating and collaborating is crucial in the context of Industry 4.0 to acquire knowledge about IT-processes, especially for traditional industry sectors, such as mechanical engineering. Third, companies are advised to consider present relationships with suppliers and to harmonize digital information sharing and transactions across the supply chain. Fourth, the role of digital data exchange across a supply chain, particularly by using digital platforms, must be supported in future buyer-supplier relationships, given their potential for value creation. Keeping these aspects in mind, may help to prepare companies for future challenges and unfold the potential Industry 4.0 poses for industrial value creation and Supply Chain Management.

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Supply Network Design

The Configuration and Evolution of Korea Automotive Supply Network: An Empirical Study Based-on K-core Network Analysis

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Abstract

The purpose of this study is to analyze the Korea automotive industry supply network based on the K-core method, not the traditional tier perspective. The analysis shows that the core structure is barrel-shaped and that even the same tier suppliers can belong to other core. From the analysis of network evolution from 2007 to 2017, most of the newly emerging nodes are entering 1-core, while nodes located in the 4-core are maintaining more than 80%. This study suggests theoretical and practical implications that a focal company should manage and care about nodes with high core on the network.

Keywords: Korea Automotive Industry, Supply Network, K-core method

Introduction

Traditionally, supply chain management has focused on vertical and linear relationships between buyers and suppliers. However, due to the development of industries and the globalization of enterprises, multi-tier supply networks have been formed, which does not explain the complexity of the supply chain from an existing perspective (Lamming, 2000; Borgatti and Li, 2009).

Recently, there have been a lot of studies on the supply network, but most of them are limited to theoretical and descriptive studies. Research to analyze the real supply network through social network analysis is still lacking. Because it is difficult to collect data for network analysis, and the theoretical basis for interpreting the various measurements used in social network analysis from the perspective of the supply chain is not clear (Harland et al., 2001; Kim et al., 2011).

The supply chain of the automotive industry consists of 1st, 2nd, and 3rd suppliers based on the automakers and the structure of the automotive industry was generally described as a tier structure (Nishiguchi, 1994). In reality, however, most suppliers do not belong to only one supply chain, so the automotive industry has a very complex network structure. Therefore, using social network analysis, the supply chain of the automotive industry can be understood at the entire network level.

The purpose of this study is to investigate the complicated multi-tier supply network of the Korean automotive industry, through *k* -core network analysis. *K*-core is a beneficial way to find the core group in a complex network. Research questions are proposed as follows.

RQ 1. What is the configuration of the Korean automotive supply network when applying the K-core method?

RQ 2. How does the Korean automotive supply network configuration evolve?

K-core analysis

K-core, the primary analysis method of this study, can be defined as a maximal subgraph in which all nodes are connected to at least *k* number of other nodes (Seidman, 1983; Scott, 2012). That is, all nodes in the *k* -core have degree centrality greater than or equal to *k* (Prell, 2012).

Small *k* means the big size of the subgroup as it includes nodes having a low degree. On the other hand, the increased *k* means a relatively small size of the subgroup as only the nodes having a high degree will be included. This is the way of forming a hierarchical structure according to the value of *k*, and nodes including a high-level *k* -core are the vital node that makes the network cohesive(Tong, 2002).

K-core analysis has recently been applied to many real networks (Internet, WWW, a cellular network, etc.) and is used as an essential tool for visualizing and interpreting complex networks (Dorogovtsev et al., 2006).

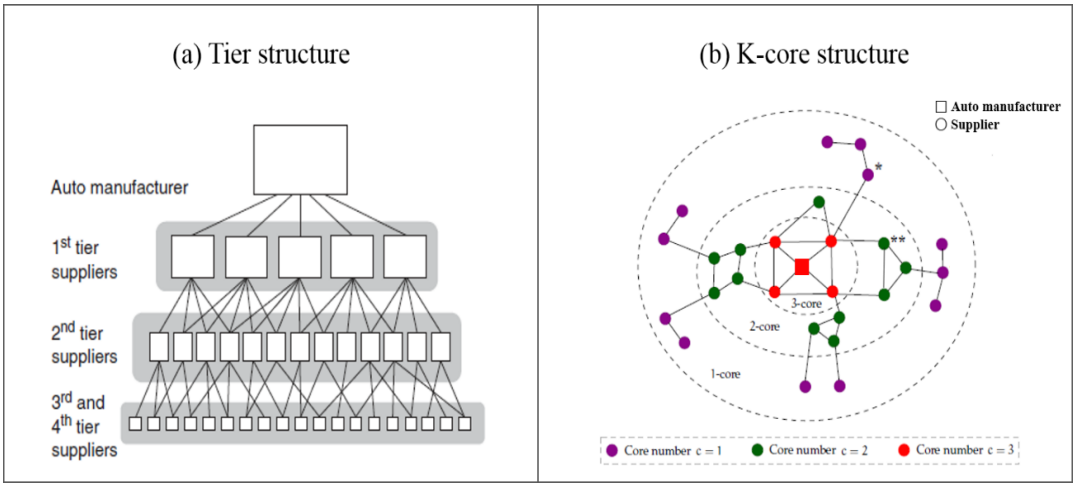

Figure 1 – Tier structure vs. k -core structure
(a) from Clark and Fujimoto, 1991, p. 139, (b) from Tixier et al., 2016

The Korea automotive supply network is a highly cohesive, forming a hierarchical distribution relationship with a small number of the automaker (e.g., Hyundai, Kia, and GM) in the center. Therefore, by using *k* -core analysis, it is possible to find the core group by analyzing the cohesion structure of a complex network. It was common to explain the supply network of the automotive industry based on the tier structure. Tier was first introduced to describe the pyramid-shaped supply chain of Japanese automotive and electronics industry (Nishiguchi, 1994).

As Figure 1 (a) shows, the tier can be measured as the distance from the automaker to several steps away. However, in reality, the supply network looks rather close to Figure 1 (b). Suppliers' links forms complexed shapes, they are not just connected vertically

(from lower-tier supplier to higher tier supplier); connected within the same tier, or between the 1st and the 3rd tier.

As shown in Figure 1 (b), node ** is a 2nd tier supplier based on the distance from an automaker, but node **, differentiating itself from node *, is higher degree because it is also connected to other 2nd tier suppliers. In the tier structure, the node * and the node ** are the same tier, but the degree is different. Therefore, in the *k* -core structure, the node ** belongs to a higher core than the node * and more influential in the network (Kim et al., 2011).

For the analysis, supplier information is gathered using the "Automotive Industry Guide" issued by the Korea Automotive Industry Cooperative bi-annually. For the first research question, *k* -core analysis was conducted using the most recent 2017 supply network data, and the network structure was identified by measuring the geodesic distance to a specific supplier based on the automaker. For the second research question, from 2007 to 2017, we observed how the *k* -core of nodes in the supply network changes over two years. We classified all the nodes into three categories: a new entry into the network, same core compared to the previous period (two years ago), and core moving (rising or falling) and analyzed the drivers of change. *UCINET6*, a social network analysis tool, was used for data analysis.

Tier structure vs. Core structure

First, *k* -core analysis was conducted using data from 2017 to compare the tier structure and core structure of the Korean automotive industry network. As a result, the network is divided into four cores as shown in Figure 2. In 4-core, 55 firms including the automaker, 116 firms in 3-core, 71 firms in 2-core, and 113 firms in 1-core can be found.

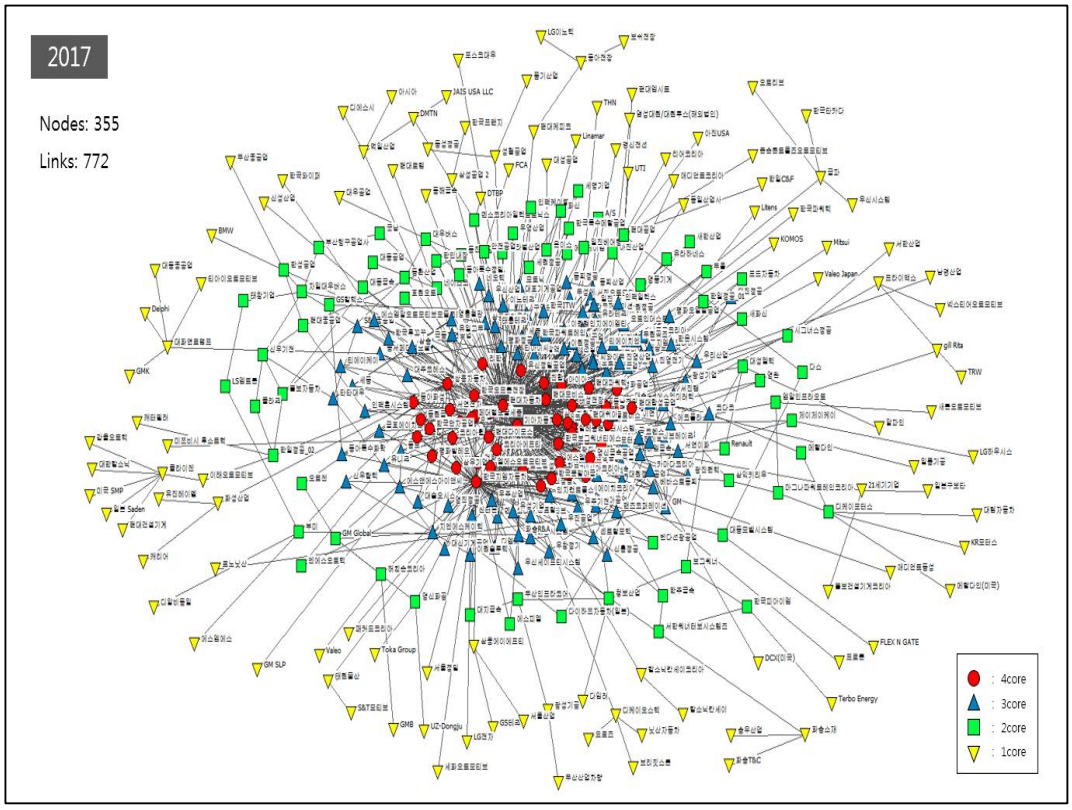

Figure 2 – Network visualization of the 2017 Korean automotive industry

We also measured the *'geodesic distance'* from the automaker to the specific supplier to identify the tier structure. The *'distance'*, which is commonly used in a network, means the shortest path among a plurality of paths between two nodes (Wasserman and Faust, 1998).

There are five automakers; Hyundai, Kia, GM, Renault Samsung and Ssangyong in the Korean automotive industry network. When we measured the geodesic distances to specific suppliers based on the five automakers, the tiers appeared mixed. For example, there are 2nd tier suppliers of Hyundai, Kia, and GM as well as 1st tier suppliers of Renault Samsung and Ssangyong. In this case, it was measured as a 2nd tier supplier, because it is the 2nd tier to more than half of the automakers in the network. As a result, we confirmed that there were third-tier suppliers in the network.

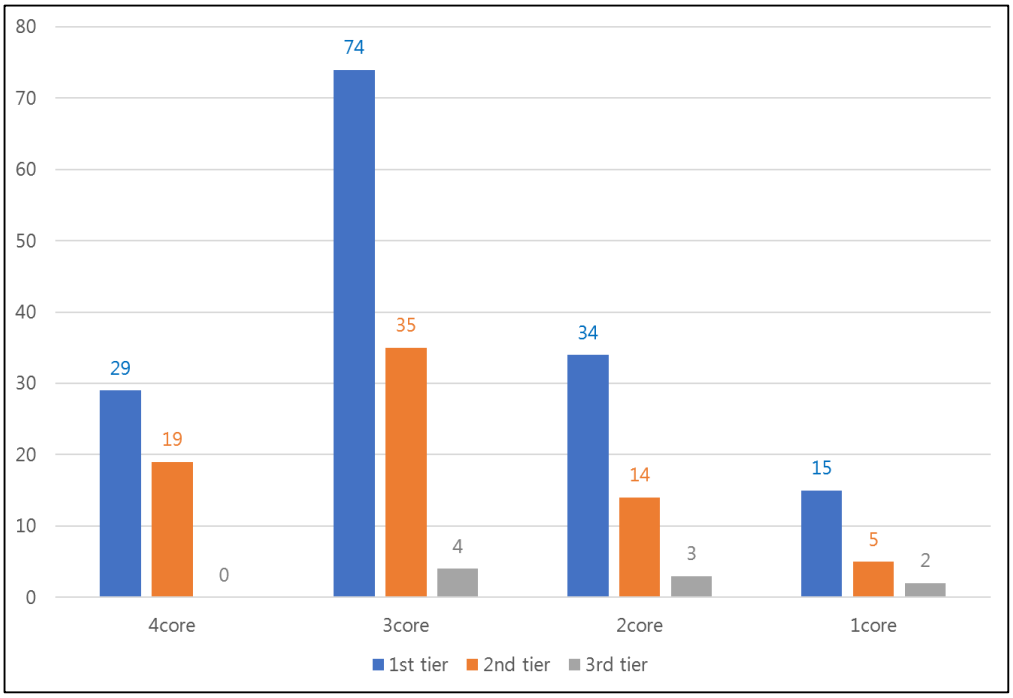

Figure 3 – Tier distribution by core

Figure 3 shows the distribution of tiers by the core. For the 4- core, which is the most central part of the network, 29 1st and 19 2nd tiers belong together. Unlike the hierarchical structure of the tier perspective, in a core-based network, different tier suppliers can be located in the same core.

Similar to the study by Kito et al.(2014), which revealed that the supply network of Toyota is a barrel-shape with a more significant number of 2nd tier suppliers than the 1st tier suppliers, it is confirmed that the core structure of the Korean automotive industry is also a barrel-shape. However, the difference is that the network is analyzed by the core structure and the tiers of the suppliers are mixed in each core.

Evolution of Korea automotive supply network configuration

Regarding the second research problem, Figure 4 visualizes the results of analyzing the supply network of the Korean automotive industry every two years from 2007 to 2017 using *k* -core. The network was divided into four cores in all periods. It can be seen that there is no dramatic change in the number of nodes and links in the entire network.

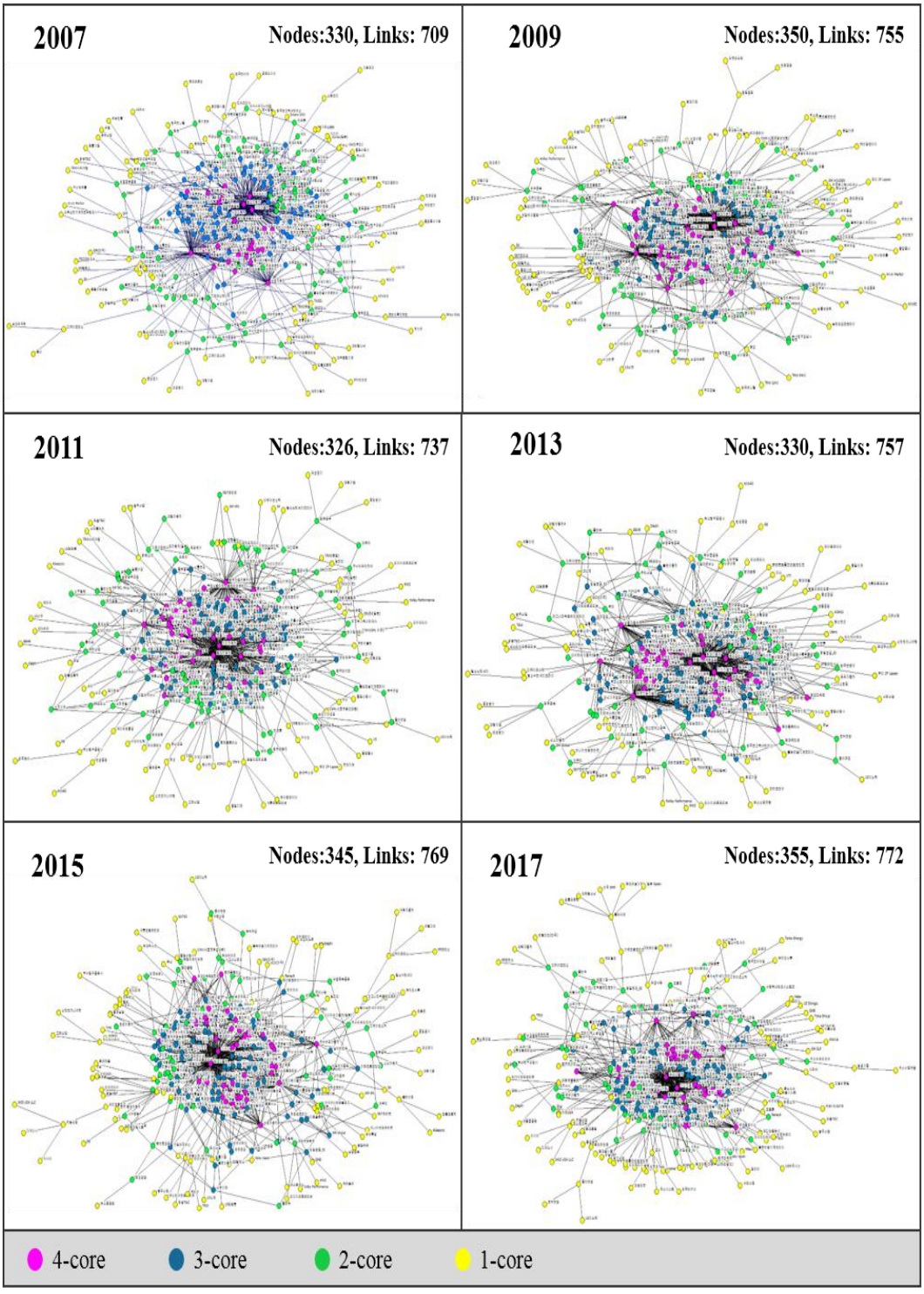

Figure 4 – Evolution of Korea automotive supply network

First, as shown in Table 1, most of the new nodes are entering at 1-core all the period. As expected, it can be confirmed that new entry into the lower core is relatively easy.

Table 1 – Number of new nodes per core

K-core	2009	2011	2013	2015	2017
4-core	5	2	3	0	0
3-core	16	6	9	3	5
2-core	9	3	6	3	5
1-core	43	55	19	23	37

Second, we measured the percentage of nodes in each core that remained the same compared to the previous period and Table 2 shows that the remaining ratio of the nodes increases with the upper core. It is related to the supplier certification of the automotive industry.

For the automotive industry, most automakers have a supplier certification system because the quality of the parts directly affects the performance of the finished car (Cho et al., 2007). In the case of Hyundai-Kia Motors, only the 1st tier suppliers that have received the "5star" certification can participate in the bidding process, and the 2nd tier suppliers can also deal with the first tier suppliers only if they are certified as SQ (Supplier Quality) (Hyundai · Kia Motors 2012). These certified first and second suppliers are likely to maintain their existing high cores, and it is challenging for new suppliers to enter 3-core or 4-core.

Table 2 – Remaining ratio (compared to the previous year)

K-core	Remaining rate (compared to last year)					
	2009	2011	2013	2015	2017	mean
4-core	88.6%	82.4%	82.4%	96.6%	84.5%	86.9%
3-core	74%	85.5%	80.4%	92%	81.7%	82.68%
2-core	72.9%	82.3%	76.3%	86.2%	74.7%	78.48%
1-core	67.8%	62.9%	75.5%	87%	70.4%	72.72%

Third, it is confirmed that the remaining ratio changes depending on the performance of major automakers. Compared to 2013, the remaining ratio was increasing in all cores in 2015. At this time, Hyundai Kia Motors, a major player in the Korean automotive industry, was in a period of growth and the supply network has also stabilized. On the other hand, it confirmed that the remaining ratio in all cores decreased in 2017, which is closely related to the poor sales performance of Hyundai Kia Motors due to a decline in sales volume in China.

Fourth, as shown in Table 3, for 14 suppliers in 4core for ten years, the production rate of auto parts is very high, and most of the production items; chassis, suspension spring, door frame, radiator grille, interior lamps, steering wheel, engine parts, drive axle,

modules and A/S parts are related to modules. Therefore, suppliers that produce critical components (or modules) are more likely to remain in 4-core.

Finally, we observed the rise and fall of the core for 196 suppliers in the network for ten years. Among them, we examined the sales of 30 suppliers whose core is steadily rising or maintaining core after ascending, which confirms the tendency of the sales increase. However, companies with core declines could not find a connection with sales.

Table 3 – Suppliers in 4core for ten years

Name	K-core	Production ratio (Auto parts))	Main item
KunHwa	4	99.0%	Chassis
Daewon Kang Up	4	95.00%	Suspension Spring
Dong-A Hwa Sung	4	43.00%	General rubber products
DongWon Metal	4	100.00%	Door Frame
MAHLE Donghyun Filter Systems	4	100.00%	Air Cleaner
SamShin Chemical	4	95.00%	Radiator Grille
LS Automotive	4	99.00%	Electric field switch
IlHung	4	100.00%	interior Lamps
JinHap	4	100.00%	Fastener
Korea Fueltech	4	100.00%	Canister
SECO Komos	4	100.00%	Steering Wheel
Korea Powder Metallurgy	4	95.50%	Engine Parts
Hyundai Transys	4	100.00%	Drive Axle
Hyundai Mobis	4	100.00%	Modules and A/S Parts

Conclusion

The results of the study will be summarized as follows. Firstly, by measuring the geodesic distance from an automaker to a supplier, we confirmed that there are even 3rd tier suppliers in the network. Secondly, as a result of sub-group analysis with K-core, the network was divided into four sub-networks. The core structure is a barrel-shaped; the tiers of the suppliers are mixed in each core. Thirdly, as a result of analyzing the supply network evolution from the year 2007 to 2017, in most cases, new nodes in the network enter as 1-core.

On the other hand, more than 80% of the nodes located in the 4-core have remained the same core, and the remaining ratio changed significantly depending on the performance of major automakers. Fourthly, suppliers that specialize in auto parts and

produce major components such as modules are constantly in the 4-core. Lastly, suppliers whose cores have risen are continuing to increase their sales.

Unlike previous studies, which used behavioral analysis of dyadic relations or specific parts supply networks, this study is meaningful in that it empirically analyzes the entire supply network of the Korean automotive industry using actual transaction data. Also, this study complements tier structure-based studies by applying the K-core methodology for the first time in the supply network research.

This study suggests theoretical and practical implications that an automaker or a focal company should be careful about and manage nodes which have high K-core away from directly connected dyadic relations. In future research, it is necessary to examine the drivers of network evolution through the reinforcement of methodology.

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Industrial resilience in automotive supply networks – A case study of product recalls

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Abstract

While there is substantial research about consequences of supply chain complexity on disruption risks, little research focused on the root causes of product recalls. Recall rates in the automotive industry have seen a severe increase in recent years. This research addresses the relations between supply chain design and product recalls in the automotive industry from a product-, process and location perspective. The results of this study suggest that higher supply chain complexity contributes to increasing recall rates. A mitigation approach consisting of multiple action fields is provided, tackling recalls arising from increasingly deep, broad and dispersed supply chains.

Keywords: Supply Chain Design, Decision-making, information processing

Introduction

Product recalls in the automotive industry have seen a severe increase within the last decades. This trend is observable for different markets. Analysis of data from the National Highway Traffic Safety Administration (NHTSA) and the Driver and Vehicle Standards Agency (DVSA) shows evidence that increasing recall incidents are not a national phenomenon, but an international development that affects the whole industry (DVSA, 2019; NHTSA, 2019).

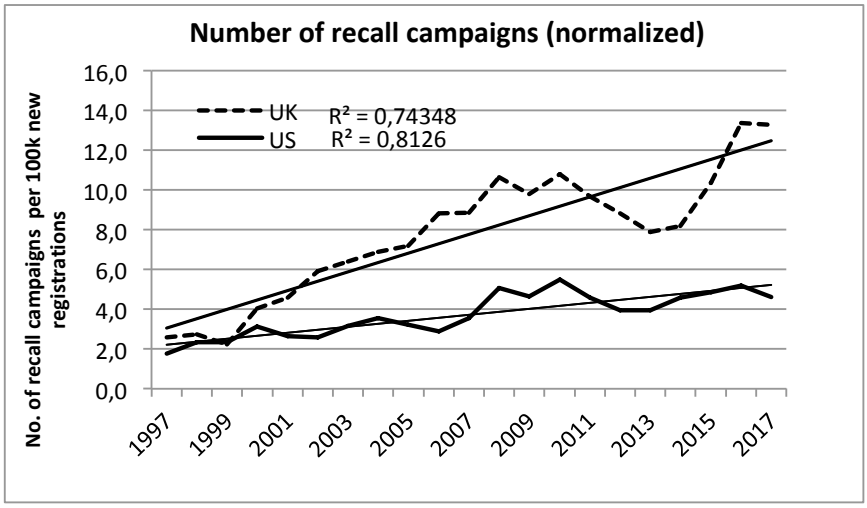

Figure 1 – Number of recall campaigns in the USA and UK (normalized)

The Takata airbag scandal further showed the reputational and financial damage that OEM and suppliers faced because of malfunctioning products. The malfunctioning airbags from the supplier Takata led to unintended ruptures, which caused at least 16 deaths and over 100 injuries (Bomey, 2017). Moreover, the product malfunction resulted in a recall of over 100 million inflators and over 42 million cars until the end of 2017 ("ADAC," 2018). Although the effects of recalls are discussed in multiple facets, such as the effects on shareholder wealth or future product reliability, there is limited understanding of the underlying causes concerning the vulnerability of manufacturer's supply networks (Kalaignanam et al., 2012; Ni et al., 2016).

Supply chain complexity

(Lyles et al., 2008) conceptualized the role of supply chains in China's product recall problems and highlighted the challenges of supply chain depth and complexity in a globalized industrial environment. Deep supply chains are characterized by a large number of subsequent upstream tier stages. In this context, traceability refers to the obligation for a documentation that proves that the supplier has followed the instructions previously agreed upon throughout the entire process chain from origin to point of sale. In deep supply chains, it is often difficult to provide a sufficient traceability of the products (Marucheck et al., 2011; Tse & Tan, 2012). Reduced traceability can cause issues such as poor supplier material, product contamination or non-conformance incoming inspections that lead to compromised quality (Marucheck et al., 2011; Tse & Tan, 2012). Accordingly, among the most frequently mentioned risks in supply chain processes are more complex supply chains (Bode & Wagner, 2015; Lyles et al., 2008; Marucheck et al., 2011; Sheffi & Rice, 2005; Speier et al., 2011). Bode & Wagner conceptualized supply chain complexity as vertical, horizontal and spatial complexity, which refers to the number of upstream tier stages, the number of tiers on one stage, and the geographic dispersion of the supply chain. It was found that increased supply chain complexity increases the risk for disruptions. The causes of these disruptions in deep supply chains are rooted in an unforeseeable interaction of small failures in the upstream supply chain, which can cause disruptions downstream (Bode & Wagner, 2015). It was not further elaborated what causes these failures and more precisely, how product, process and location based attributes foster the complexity of supply chains. Furthermore, the relations between product modularity and the

fragmentation of value adding processes are yet partly unexplored. (Novak & Eppinger, 2001) examined, how product complexity influences sourcing decisions, but made a major simplification for sourcing as being a binary variable (make or buy). Hence, it was not assessed how product architecture and complexity influence the supply chain depth and breadth. Therefore, this research bridges the gap between the findings of Wagner & Bode (2015) and Novak & Eppinger (2001) by examining how product architecture influences supply chain complexity and how this complexity relates to product recalls. Moreover, prior research identified proximity of first tier suppliers in production networks as essential to ensure design compatibility and avoid lack-of-fit risks by reinforcing inter-firm knowledge exchanges (Bode & Wagner, 2015; Frigant & Layan, 2009). Accordingly, following prior research about the geographic re-configuration of automotive supply networks, geographic supply chain dispersion is examined as a further contributor to recalls (Sturgeon et al., 2008).

The findings of this research were used to create a decision support framework for supply chain design to mitigate recall related risks. The research aims to answer the following research questions:

1. How do product-, process- and location related supply network design decisions of a firm affect its product recall rate?

2. How can product recall related vulnerabilities in these networks be effectively mitigated?

To systematically capture the characteristics relevant for supply chain decision-making, an academic framework was developed. The domains capture product, process and location related supply chain characteristics. These are defined by the characteristics of the component to be bought, the processes involved in producing this component, and the location where the component is to be bought as well as the location of the end product to be sold. The decision areas following from these characteristics are shown in the framework. The result of the supply chain decision-making process is the supply chain complexity. The complexity can relate to spatial complexity, which describes the spatial dispersion of the supply chain, and the vertical and horizontal complexity, representing the depth and breadth of the supply chain.

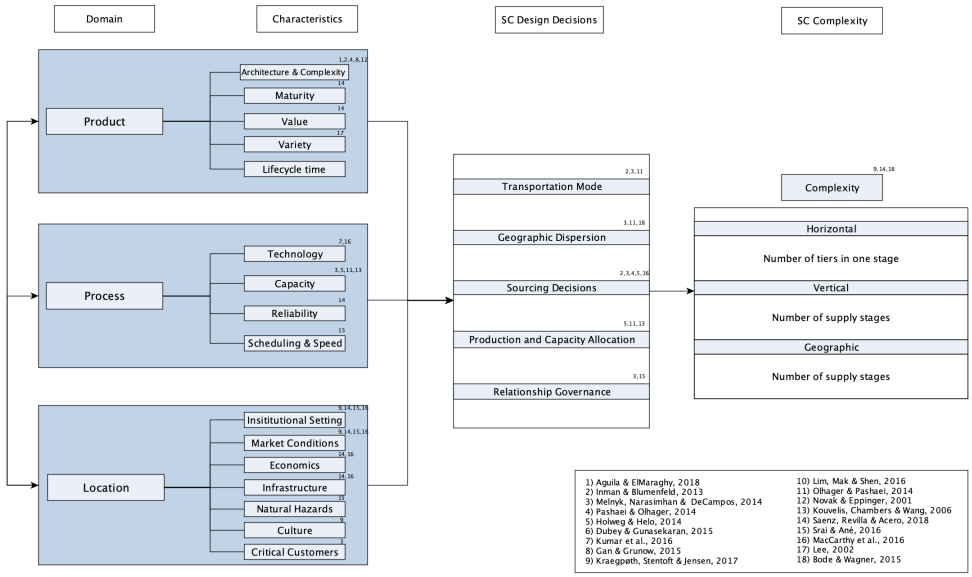

Figure 2 – Supply chain design framework

Method

This research relies on empirical data. This is due to the limited understanding of the relationship of supply network design decisions and resulting risks. A qualitative research approach was chosen, as the research questions to be investigated suggest an exploratory nature of the phenomenon (Yin, 2014). Hence, case study research was chosen to accommodate for the exploratory nature of the research questions.

Data collection

Semi-structured interviews were chosen to allow for enough flexibility during the interview process (Yin, 2014). The interviews were conducted with OEM and suppliers in the automotive sector. The questionnaire was handed to the interviewees prior to the interview to allow for preparation. In total 12 company representatives were interviewed The units of analysis in this case study were supply chain design strategies. Multiple companies and accordingly multiple units were analysed, hence the case study design followed an "embedded" approach (Yin, 2014). Moreover, the focus in these companies was set on the Supply Chain, Purchasing and Quality Management departments in Europe and the USA in order to ensure that the data obtained in the case study was received from sources, which are familiar with the topic and relate to the markets of reference in the data analysis. Interviewing different departments involved in the supplier selection process allowed to identify differences in priorities with respect to selection criteria. Within the study, 24 purchased components used for the assembly in cars were analysed according to their product architecture, their supply chain breadth and supply chain depth. Information about supply chain design were matched with the framework to identify sources of network vulnerabilities that increase the recall risk. The list of participants is shown below:

Interviewee list

Nr.	Type of Industry	Vertical Position Supply Chain	Size	Type of Product	Position Interviewee
IP 1	Automotive	OEM	> 100 bil. US$	Automobiles: engine components, finished goods	Senior Manager Supply Chain & Production Management
IP 2	Automotive	OEM	> 100 bil. US$	Automobiles	Risk Manager Supplier Selection
IP 3	Automotive	OEM	<100 bil. US$	Automobiles: finished goods	Senior Manager Supply Chain Management (Finished Goods)
IP 4	Automotive	OEM	> 100 bil. US$	Automobiles	Head of Purchasing, Quality & Strategy
IP 5	Automotive	Tier 1 (upstream)	> 20 bil. US$	Mechanical components for automobiles	Head of Sourcing & Qualiy, Head of Requirement Management, Teamleader Escalation
IP 6	Automotive	OEM	> 100 bil. US$	Automobiles: electronic head units	Purchasing Specialist Electronic Components
IP 7	Automotive	Tier 1 (upstream)	> 20 bil. US$	Mechanical components for automobiles	Director Product Development, Platform Integration
IP 8	Automotive	OEM	> 100 bil. US$	Automobiles: exterior components	Purchasing Specialist Exterior Components
IP 9	Automotive	OEM	> 100 bil. US$	Automobiles: software	Purchasing Specialist Software
IP 10	Automotive	OEM	>100 bil. US$	Automobiles: powertrain	Head of Global Quality Management, Systems Integration Powertrain
IP 11	Automotive	OEM	> 100 bil. US$	Automobiles: software	Purchasing Specialist Software
IP 12	Automotive	OEM	> 100 bil. US$	Automobiles: software	Head of Product Development: Software

Figure 3 – List of interview participants

Analysis & results

The data gained in the collection phase was analysed using a pattern-matching method. The academic framework was used to match the feedback received from the interviewees with the characteristics, which were identified as relevant in the framework.

Interviewees	IP 1	IP 2	IP 3	IP 4	IP 5	IP 6	IP 7	IP 8	IP 9	IP 10	IP 11	IP 12
A. General Information												
A1. Assumptions made when discussing supply chain design	•	•	•	•	•	•	•	•	•	•	•	•
A2. Central Tasks in the daily business												
– Managing concurring goals in supply chains	•		•		•	•		•	•		•	
– Choice of suitable suppliers for collaboration	•	•		•	•	•	•	•	•	•	•	•
– Ensuring reliable supply of parts	•	•	•	•	•	•	•	•		•		
B. Relevant factors for supply chain design												
B1. Product characteristics												
– Cost of the component	•	•		•	•	•	•	•	•	•	•	•
– Size of the component		•		•						•		
– Lifecycle time of the component	•									•		•
– Architecture: modular / integral	•			•	•	•	•	•	•	•		
– Variety of the component: options	•	•		•	•	•						
– Maturity of the component												
B2. Process characteristics												
– Speed: replenishment cycle time and lead time	•	•	•	•	•							
– Production capacity & flexibility	•	•	•		•	•	•	•	•	•	•	
– Innovative technologies for production			•		•	•	•	•	•	•	•	•
B3. Location characteristics												
– Institutional setting		•		•	•	•	•	•	•	•	•	
– Market conditions in the country of sourcing	•	•			•							
– Economics in the country of sourcing	•					•		•				
– Transport infrastructure: availability of alternative routes		•	•		•					•		
– Educational infrastructure: skilled labor		•		•	•	•			•	•	•	•
– Natural Hazards: hurricanes / earthquakes / floods		•		•	•	•				•		
– Cultural factors: trust / ethical considerations		•		•	•	•	•					
– Critical customers												
C. Mitigation Measures												
– RFID Technology					•		•			•		
– Barcode tracking					•	•	•	•				
– Data Analytics					•	•	•	•	•	•		•
– Contractual Solutions					•	•			•	•		•
– Multi Sourcing				•	•	•		•		•		
– Additive Manufacturing								•				
– Others		•		•	•	•	•		•	•		•

Figure 4 – Interview feedback summarized

By analysing the feedback of the interview partners ("IP") regarding supply chain design decisions and the depth and breadth of supply structures of the components, which were purchased for the assembly in cars, patterns regarding decision-making and supply chain complexity were identified. The results of this study show several facts:

- The depth and breadth of supply chains are determined largely by the product architecture and the integration concept.
- Cost pressure significantly extends supply chains towards deeper structures (IP 5…8,10)
- Sub-components for many products are negotiated, cost pressure affects the content of components (IP 5…8,10,)
- Increased supply chain breadth and depth increases recall risks by worsening supply chain visibility, fragmenting value adding processes and increasing lack-of-fit risk
- The results suggest that geographic complexity is associated with stronger communication barriers and a higher lack-of-fit risk

Discussion

Prior studies have suggested increased supply chain complexity as a source of risk for disruptions (Bode & Wagner, 2015; Marucheck et al., 2011; Tse & Tan, 2012). The findings of the case study confirm that supply chain complexity increases disruptions and the scope is further narrowed down on automotive product recalls. In addition, a causal perspective on failures extends the predominantly logistical contemplation of

failure sources. During the case study, evidence for the relation between product architecture and supply chain complexity was collected.

Supply chain breadth & supply chain depth
Modular sub-systems such as oil or fuel pumps, electrical engines and electronics components have significantly broader and deeper supply chains than simpler, in most cases integral components. A great part of the integration efforts to create these subsystems is distributed among lower tiers (IP 2,5…8,10). Especially electronics components such as those for navigation systems, circuit boards and control units are so complex in nature, that most interviewees were not able to name the exact breadth and depth of the component, but indicated that it is very high (IP 2,6,7,10). It was found that supply chains become deeper and broader, the more electronic and electro-mechanical content is required, as confirmed by interview partners 2,5…8,10). This is due to a requirement for specialisation regarding development competences and technologies. Accordingly, requirements for competences in different technological fields lead to a fragmentation of supply structures. In contrast, supply chains become less complex when a large part of the value added can be generated with a single or several related technologies. This finding is somewhat contrary to the implications of (Novak & Eppinger, 2001) on product complexity and make-or-buy decisions. Whereas (Novak & Eppinger, 2001) found that increasing product complexity enhances in-house production, this research suggests that specialization of production and development capabilities lead to a more fragmented organization of supply and increases the breadth and depth of supply chains. Reasons for this discrepancy may be rooted in the change of product characteristics due to a higher degree of automization and electrification in cars and accordingly increased content of mechatronic, electronic and software units within the last two decades. Moreover, cost pressure was found to have an impact on the supply chain depth, but also on the content specification on lower tier levels (IP 5,7,8,10). More precisely, cost pressure encourages lower tiers to outsource their activities (IP 5…8) and determines the quality of sub components in the main component (IP 7,8). For components such as electronic control units, the sub-content is part of the negotiations and cost pressure reduces the quality of the end product (IP 7,8,10). The interviewees who were asked about the relation between supply chain complexity and recalls, confirmed that modular, often more complex products carry a higher inherent risk for malfunctions (IP 5,6,8,10). Reasons for higher failure probabilities for components with deep and broad supply chains were partly mentioned in prior literature. Worsened traceability in deep supply chain structures was identified as a source of risk for reduced quality (Marucheck et al., 2011; Tse & Tan, 2011). Multiple interview partners confirmed that traceability in general is guaranteed, but that informative value is lost when components cross firm boundaries (IP 2,5,7,10). Hence, supply chain depth is associated with worsened traceability. In addition, it was found that components that require particularly demanding manufacturing processes have a higher failure probability. For example, sub components that require particular manufacturing processes, like sintering, are more vulnerable for malfunctions, if the supplier is missing the know-how for specific steps, like the pressing or hardening of the part or if several difficult processing steps are done by different suppliers. This is why for certain components with high-tech production requirements, the failure probability is higher than for those with more basic requirements. More modular and complex components that have a high number of these critical parts are therefore more vulnerable for malfunctions.

Geographic dispersion

Multiple interview partners confirmed that product recalls in the automotive industry have its root causes mainly in design and layout failures (IP 5,8,10). Interview partner 10 is head of quality management and confirmed that approximately 80% of all recalls are due to design and layout flaws, whereas flaws in production and logistics cause the remaining 20% of the recalls. This implies that product design and development is the dominant contributor to product malfunctions and the identification and mitigation of root causes for lack-of-fit risks is highly relevant for product safety. (Marucheck et al., 2011) argued that increasing globalization in production networks reduces the traceability of components in the supply chain and therefore makes maintenance of product safety more difficult. The results of the case study confirm this argument. Multiple interview partners confirmed the importance of collaboration of design and development departments between OEM and first tier suppliers to ensure the compatibility of components (IP 5,7,8,10). The results of the case study confirm this argument. Multiple interview partners confirmed the importance of collaboration of design and development departments between OEM and first tier suppliers to ensure the compatibility of components (IP 5,7,8,10). This collaboration is compromised by spatial distance. Interview partners 8 and 10 highlighted problems with collaboration between OEM and FTS in cases where the FTS is located in rural areas, as direct communication for project based work is aggravated. Furthermore, language barriers in cases of collaboration with foreign partners make communication for joint development and design tasks more difficult (IP 6,8). This implies that more local collaboration in development may be a solution to reduce design flaws. However, an ongoing specialization process, technological constraints for production and strategic cost based considerations suggest that there is rather a trend towards more dispersed supply structures than towards local structures (IP 1,2,5…8,10). Multiple interview partners confirmed that competence for different key technologies are located in different regions of the world (IP 1,2,4,5…11). Therefore it seems unlikely that network structures will become less dispersed in the future.

Mitigation strategies

The case study revealed multiple action fields. Multiple research scholars highlighted the importance of traceability as an effective countermeasure to tackle issues such as poor supplier material, product contamination or non-conformance incoming inspections that lead to compromised quality (Lyles et al., 2008; Marucheck et al., 2011; Tse & Tan, 2012). As many interview partners pointed out, there is a trade-off between traceability costs and benefits, which determines the degree of the granularity of the data (IP5…8,10). RFID technology can improve data granularity, as it enables the traceability of the component within the production and assembly process. However, the associated costs for tracking and capturing field data from components that are used in cars in large numbers, which can easily reach several millions in case of car models that are sold in large quantities, imposes a significant cost factor for car manufacturers. It is questionable if a broad field data collection would be financially beneficial. Hence, an approach, which selectively collects data from a limited number of sold models would be more suitable (IP 7,10).

Production processes were identified as another field of high relevance for traceability (IP 1, 5…8,10). The interconnection of data flows across firm boundaries allows to capture important variables in all steps of the production process and to link the data of all steps to use it for the end product (IP 5,8,10). This interconnection enables the monitoring of process variables and a faster reaction in case of defective

production (IP 5…7,10). Moreover, root causes for product malfunctions can be detected more easily (IP 5,10). However, higher costs associated with the gathering and management of the data limits the applicability of production traceability. Accordingly, this requires an empirical evaluation of product categories and the scope of production traceability efforts should be focused on products and components with an empirically verified high failure probability (IP 6).

(MacDuffie & Fujimoto, 2010) anticipated the loss of control that automobile manufacturers will suffer due to products with a higher degree of digitization. However, they argued that older car manufacturers ("dinosaurs") will be able to manage greater product complexity in their supply chain due to their legacy better than younger companies. The results of this work suggest, however, that it is precisely this legacy that complicates the organizational learning of major manufacturers, thereby causing inertia in processes that compromise product safety. In order to establish minimum standards for software quality, legally binding conditions for tests should be defined for each safety relevant software component. In addition, several interviewees have argued that government authorities should consider a disclosure requirement for safety relevant software (IP 10,12).

Conclusion

As the first study to link product-, process and location characteristics with product recall rates, the findings of this study are highly relevant considering increasing product recall rates in the automotive industry. Prior literature identified trends towards a reconfiguration of supply networks in the automotive industry (Sturgeon et al., 2008). The results of this study suggest that the dispersion of supply networks is associated with higher recall rates as the compatibility of components is put at risks and collaboration is aggravated. The study further identified product complexity as a driver for product recall rates, as it fosters supply chain complexity and aggravates traceability. Cost pressure and capacity constraints exacerbate the supply chain complexity as outsourcing activities increase. In order to mitigate the consequences of increasing supply chain complexity, this research suggests the implementation of new technologies to increase the traceability of production and logistics processes. Data connectivity and production organization as well as new testing methods improve the product compliance and traceability along the supply chain. Moreover, the results reveal that the complexity of digital products require new ways of product testing and furthermore necessitate a re-assessment of governmental regulations regarding the disclosure and testing procedures

Implications and Contribution

By classifying supply chain design into three domains and matching the literature with empirical data, this study is the first to demonstrate how product-, process- and location based characteristics shape the complexity of supply chains. Furthermore, this study reveals new relations between product architecture and supply chain complexity that challenge findings of existing research regarding make-or-buy decisions. While prior research argued that product complexity fosters make-decisions, this research finds that higher product complexity leads to a fragmentation of value-adding processes and accordingly to deeper and broader supply chains. It was shown that the complexity of products has various effects on failure probabilities. Electronics, electro-mechanical components and software components are associated with a high number of sub-entities and functional interrelations within the components. At the same time, these components become increasingly important for modern cars. Hence, automobiles are expected to become more complex in the future.

To tackle problems associated with a higher product complexity, this research suggests a policy mix consisting of multiple fields of action for the implementation of mitigation strategies in practice. Accordingly, reducing recalls effectively is not straightforward, but requires actions in different fields regarding logistics, production and regulation. As technology in fields like autonomous driving is rapidly proceeding, the responsibility of car manufacturers to provide safe products despite increasing complexity gains an even greater importance. The results of this study show evidence that software related recalls are not an emerging issue for manufacturers, but already represent a significant fraction of recalls leading to potentially severe financial and human costs and are expected to increase further rapidly. This poses an urgent need for standardization of processes and regulations regarding the testing of new software. Inertia caused by the legacy of car companies has to be overcome quickly to cope with the transformation of the automobile from a purely mechanical to a highly digitized transport medium.

Limitations & further research

As with all studies, this research is subject to limitations and therefore provides possibilities for further research. Although several fields of actions have been identified by this study, further research should focus on implementation strategies with the aim to improve implementation strategies regarding data connectivity in supply chains and operations. Moreover, it should be specified, in which order the countermeasures should be implemented and if they should start upstream or downstream in the supply chain. Lastly, it should be mentioned that product recalls have only limited significance as a measure of product quality. Even though product recalls went up significantly within the last decades, there is little doubt that vehicles became significantly safer during this time. Hence, with new safety features there are more possibilities for malfunctions. This development certainly contributes to higher recall rates and puts the results in perspective. Nevertheless, we are convinced that this research provides valuable insights for theory and practice.

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Supply network configuration and capabilities for high-cost, small series textile/apparel: A TISM approach

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Abstract

The increasing emphasis on small series production in higher cost locations is particularly challenging in the textile/apparel industry due to global supply chain configurations. To support (re)configuration in this context, Total interpretive structural modelling (TISM) method is used to gain a deeper understanding of the inter-relationships among configuration/capability related aspects from the literature. TISM interviews were done with 24 industry practitioners producing/sourcing in the EU, or in the process of implementation. The findings validate extensive inter-relations, at the same time highlighting relational aspects, internal integration, and quality as significant drivers. Further in-depth research is required to understand these influences.

Keywords: Supply network configuration, Total interpretive structural model, textile and apparel industry

Introduction

Significant challenges to existing global supply chains include the need for faster development and delivery along with increasingly customised products. This demand for greater speed and responsiveness combined with rising wages offshore is leading to more reshoring or nearshoring production to higher-cost locations (Martínez-Mora and Merino, 2014, Benstead et al., 2017). These changes are especially relevant in the textile/apparel industry where demands for competitiveness and sustainability are leading to greater emphasis on agility, speed, and smaller-series/on-demand production (Andersson et al., 2018). However, in these industries, the current global structures and operations have resulted in decoupled supply chain stages due to locational separations (e.g. textiles in Ketokivi et al. (2017)), and thus are unable to deliver speed, quality and sustainability at the same time. For this reason, there is a need to re-design or configure these supply chains/networks in order to be able to deliver with respect to these demands. Therefore, context specific understandings are required regarding how the textile/apparel supply chain should be configured for competitive small series

production in high-cost locations, as there is no 'one size fits all' in supply chain design (Melnyk et al., 2014). Here, high-cost locations are defined in terms of GDP per capita (e.g. Ketokivi et al., 2017).

When designing and configuring the supply chain, there are many aspects that need to be considered related to configurations and capabilities. While several inter-relationships or associations between some of these aspects are touched upon in the literature, contributions focusing on these relationships are more limited. In particular, an emphasis on causality and understanding of how or why these associations exist is lacking. For example, literature has associated several aspects with high-cost production/sourcing locations such as product complexity and customisation (e.g. Grandinetti and Tabacco, 2015), quality, innovation and sustainability, and the need for fast delivery (Bryson and Taylor, 2010, Pal et al., 2018). However, the understanding of how these aspects individually, and in combination, influence products, production, relationships and the structure of the supply chain is lacking. This understanding is crucial for several reasons, as it may be necessary to focus on several aspects at the same time for competitiveness, as in the case of innovative, high quality and customised products (e.g. Bryson and Taylor, 2010). Additionally as competitiveness can require balancing these different aspects e.g. with respect to the level of product variety, customisation and speed required (e.g. Salvador et al., 2004). Further, the nature of these inter-relationships should be understood from the perspective of the decision-makers or practitioners, as their 'factual premises' are the basis for their decisions (e.g. Ketokivi et al., 2017), here regarding supply chain design. Crucially focusing on the textile/apparel industry as a relevant context to address for the reasons previously mentioned.

Thus, due to the numerous potential inter-relationships briefly discussed, there is a need for a deeper understanding of how these configurational and capability aspects (Table 1) relate to each other according to the practitioners within a particular context. Thus, the purpose of this paper is to examine the influences between supply network configurational aspects and associated capabilities with respect to small series textile/apparel production in high-cost locations.

Conceptual model development

As briefly discussed above, there are many potential inter-relationships suggested in the literature between aspects related to supply chain/network design and configuration. For brevity, the adopted view of configuration is mentioned, followed by the categorisation and presentation of the aspects from the literature that are included in the model. Thereafter, some inter-relationships between the categories are briefly touched upon.

The definition of supply network configuration (SNC) presented by Srai and Gregory (2008) is used here to categorise and understand the configuration and capability aspects generated from a review of the literature on small series production in a high-cost context (Table 1). According to the authors, SNC is composed of four elements: (1) network structures, (2) network relationships, (3) unit operations, and (4) the value structure. The value structure is encompassing the product related aspects, here including *PS* and *PV*. The unit operations including the type of operations- *SK* and how flexible- *OF*. The structure involving the shape and coordination of the network, here including *LO*, *SF*, *II*, *SI*, and *CI*. With network relationships relating to the governance and softer aspects of networks, including *RE*, *CM*, and *TR*. Further, Srai and Gregory (2008) address SNC in relation to capabilities and performance, with aspects such as customisation, quality and speed/responsiveness being included as strategic priorities, capabilities and performance. In line with this perspective, and due to the primary

importance of defining these objectives when designing or configuring the supply chain (Melnyk et al., 2010, Melnyk et al., 2014, Calleja et al., 2018), these aspects (*CU*; *IN*; *SU*; *QU*; *DE*) are categorised as capabilities in this paper. These aspects being crucial for evaluating a supply chain (Calleja et al., 2018) as the configuration defines the capabilities that are possible to achieve (Srai and Gregory, 2008, Melnyk et al., 2014).

Table 1 – Configurational aspects for interpretive structural modelling

Configurational Aspect		Description	Key References
Network Structures	Production/sourcing location (LO)	Reshoring to or located in high-cost production/sourcing location and competitiveness in high-cost location related to proximity (physical)	Bryson and Taylor (2010), Martínez-Mora and Merino (2014), Gray et al. (2017), Ketokivi et al. (2017), Pal et al. (2018)
	Structural flexibility (SF)	Complexity and modularity of the supply chain, related to the adaptability of the network	Dedrick et al. (2008), Cheng (2011), Gray et al. (2017), Macchion et al. (2017b)
	Internal integration (II)	Infrastructures, mechanisms, practices and systems to be coordinated internally between functions	Zhang et al. (2014), Van Donk and Van Doorne (2016), Gu et al. (2017), Zhang et al. (2019)
	Customer integration (CI)	Infrastructures, mechanisms, practices and systems to be coordinated with customers, related to co-design, etc.	Duray et al. (2000), Tu et al. (2004), Zhang et al. (2014), Zhang et al. (2019)
	Supplier integration (SI)	Infrastructures, mechanisms, practices and systems to be coordinated with suppliers, related to information systems and other ICT, collaboration, physical flows etc.	Jitpaiboon et al. (2013), Lyons et al. (2013), Marsillac and Roh (2014), Gu et al. (2017), Zhang et al. (2019)
Relationships	Close/long-term relationships (RE)	Characteristic of supplier or customer relationship with stability of relationships for long-term collaboration	Jitpaiboon et al. (2013), Van Donk and Van Doorne (2016), Um (2017), Zangiacomi et al. (2017)
	Communication and information sharing (CM)	Characteristic of supplier or customer relationship, supported by digital technologies	Dedrick et al. (2008), Liao et al. (2011), Shamsuzzoha et al. (2016), Ketokivi et al. (2017)
	Trust and mutual commitment (TR)	Relational governance related to long-term relationships and information sharing	Liao et al. (2011), Liao et al. (2012), Clauss and Spieth (2016), Um (2017)
Unit Operations	Specialised knowledge and production technologies (SK)	Importance of specific knowledge (specialisation/ variety) of employees and/or machinery and complementary competences in the network	Schonberger and Brown (2017), Yin et al. (2017), Zangiacomi et al. (2017), Vos et al. (2018)
	Operational flexibility and agility (OF)	Indicator of operational performance, capacity to adjust reactively and proactively	Jitpaiboon et al. (2013), Gu et al. (2017), Um (2017), Wiengarten et al. (2017), Pal et al. (2018)
Value Structure	Product structure (architecture) (PS)	Complexity of products, and modularity/ commonality of components as an internal variety management strategy	Duray et al. (2000), Salvador et al. (2004), Grandinetti and Tabacco (2015), Vos et al. (2018)
	Product variety (PV)	Variety related to volume and mix of products	Martínez-Mora and Merino (2014), Um (2017)
Capabilities	Customisation (CU)	(Mass)customisation defined in terms of customer involvement (postponement point) and product modularity, with Personalisation as a broader concept	Duray et al. (2000), Piller et al. (2004), Salvador et al. (2004), Bryson and Taylor (2010), Lyons et al. (2013), Zhang et al. (2019)
	Innovation (IN)	Indicator of operational performance, can be related to sustainability, characteristic of the products that change frequently with higher levels of customisation	Bryson and Taylor (2010), Jitpaiboon et al. (2013), Marsillac and Roh (2014), Clauss and Spieth (2016), Gu et al. (2017)
	Sustainability (SU)	Characteristic of the products that are possible to competitively produced in a high-cost location e.g. using local materials, related to quality	Fornasiero and Zangiacomi (2013), Fornasiero et al. (2016), Zangiacomi et al. (2017), Pal et al. (2018), Vos et al. (2018)
	Quality (QU)	Quality management and quality integration as relevant aspects focused on customers and continuous improvement and indicator of operational performance	Bryson and Taylor (2010), Kristal et al. (2010), Gu et al. (2017), Pal et al. (2018), Zhang et al. (2019)
	Delivery speed/reliability (DE)	Indicator of operational performance, requirement/motivation or benefit from proximity (physical or virtual)	Jitpaiboon et al. (2013), Martínez-Mora and Merino (2014), Gu et al. (2017), Macchion et al. (2017b), Pal et al. (2018)

As discussed above, there are many inter-relationships between these categories of aspects suggested in the literature. For example, *PS* and *PV* can have implications on the level of *OF* possible or required in relation to levels of *CU* (e.g. Macchion et al., 2017a, Salvador et al., 2004), thus highlighting inter-relationships between value structure, unit operations, and capabilities. With increased levels of customisation necessitating greater employee knowledge-*SK* and empowerment (e.g. Sandrin et al., 2018), as well as affecting or being related to the complexity and changeability of network structures-*SF* and the characteristics of relationships in the network (Dedrick et al., 2008, Lyons et al., 2013). Additionally, with the structural aspect of customer integration/involvement being inter-related with operational production and supporting technologies (e.g. Piller et al., 2004, Salvador et al., 2015). Beyond these inter-relationships several others are potentially relevant e.g. the need for fast delivery or high quality influencing various aspects of the overall configuration. Thus, these interactions, which must be considered, necessitate interpretation and evaluation within a particular context.

Methods

In this paper, the purpose is to model the influence between relevant aspects of network configuration and capabilities for small series production textile/apparel production in high-cost contexts. Through this process identifying the drivers, dependent, and tightly inter-related aspects with respect to this particularly relevant industry context. This is done with the Total interpretive structural modelling (TISM) method undertaken through in-depth interviews, thus providing evaluation and interpretation.

Interview process

Total interpretive structural modelling (TISM) was employed with practitioners from the European textile/apparel industry to evaluate the influences between the configurational and capability aspects. Respondents were chosen from firms currently undertaking small series production in Europe, or that are strategically planning to (soon to start). Twenty-four responses were gathered from companies ranging from small retail brands to larger international companies, operating in various stages in the textile/apparel value chain (e.g. fabric and/or garment manufacturers, branded retailers, etc.). As studies employing ISM/TISM have been conducted with smaller sample sets (e.g. Lamba and Singh, 2018, Mangla et al., 2018), this number of respondents can be considered reasonable. Some relevant company characteristics are presented in Table 2.

Table 2 – Demographics of the companies included in the sample

Company characteristics	**N=24** (%)
Size (Employees)	
Micro (<10)	**5** (21%)
Small (<50)	**8** (33%)
Medium (<250)	**5** (21%)
Large (>250)	**6** (25%)
Small series focus	
Less than 90% of offering	**14** (58%)
90 to 100% of offering	**10** (42%)
Product focus	
Fashion	**9** (38)
Function	**8** (33%)
Hybrid (Fashion/Function)	**7** (29%)

Total interpretive structural modelling approach

The TISM process quality was ensured in line with Sushil (2017), with TISM going beyond the ISM process by interpreting the relationships and highlighting relevant transitive links (Sushil, 2012). In this case, the respondents were asked to evaluate whether an aspect 'will influence' or 'influences' another aspect and how strongly (0-4). With the following answers possible:

- V- Aspect *i* influences aspect *j*;
- A- Aspect *j* influences aspect *i*;
- X- Aspects *i* and *j* influence each other;
- O- Aspects *i* and *j* do not influence each other.

Further, any explanations were elicited to provide a deeper understanding and contribute to a knowledge-base. Thus, explanations and evaluations of strength of the relationships for insights regarding 'how' and 'why' this influence takes place (Sushil, 2012), and to emphasise the most important direct and indirect links between the structural levels in the resulting diagraph.

In addition to partitioning the aspects into levels to generate the diagraph structure, MICMAC analysis can be used with the same data to classify the aspects according to driving power and dependence (e.g. Lamba and Singh, 2018, Mangla et al., 2018). Specifically, classifying the aspects into four clusters: Autonomous–with low driving power and dependence, Dependent–high dependence with low driving power, Linkage–with high driving power and dependence, and Independent–high driving power with low dependence.

For the aggregate ISM diagraph and MICMAC analysis, an initial reachability matrix was generated by including each relationship between two aspects *i* and *j* that a majority of respondents marked as valid, regardless of the strength. Transitivity checks were done to generate the final reachability matrix and resulting diagraph structure. Thereafter the respondents' interpretations regarding relationship strength were used to identify the most relevant inter-relationships for the TISM diagraph structure, with significant transitive relationships included. Thus, the final TISM structure highlighting the most significant drivers and dependent aspects by focusing on the strongest relationships.

Results and discussion

Following, the results are presented in aggregate, elaborated upon with some relevant explanations from individual respondents and discussed.

For the aggregate ISM results, relational aspects (*TR*; *RE*; *CM*), as well as *II* and *SI* are the strongest drivers, see the MICMAC and diagraph structure in Figure 1. There are many aspects that are classified as linkage with high levels of inter-dependence with each other, thus all being on the same level. The most dependent aspect is *CU*, which is influenced by all the other aspects.

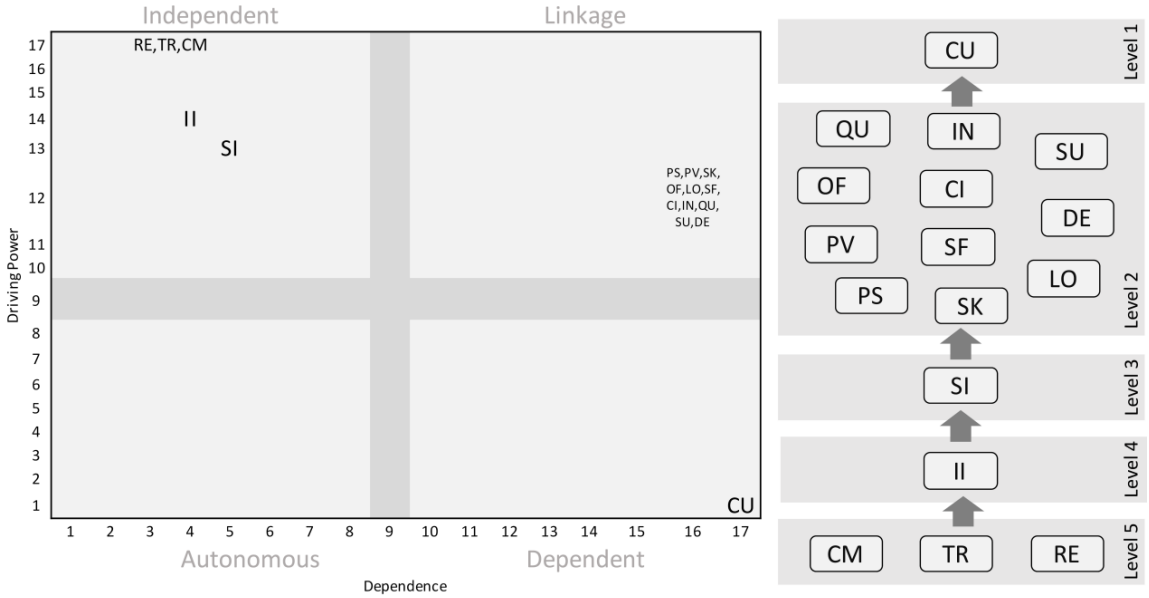

Figure 1 – Aggregate MICMAC (left); and ISM diagraph (right)

The extensive inter-relationships with many aspects at level 2 necessitates highlighting the most relevant relationships. Here the respondent evaluations regarding the strength of the relationships are used to create the TISM structure (Figure 2). Thus, emphasising the most significant driving and dependent aspects with respect to both the direct and transitive relationships.

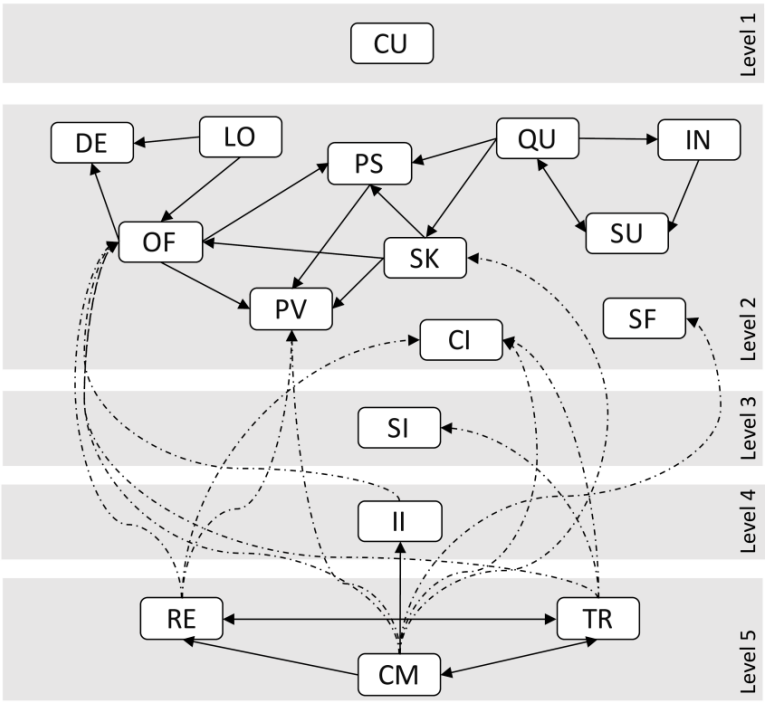

Figure 2 – Aggregate TISM diagraph with strongest direct and transitive relationships

The modelling of the relationships and strength of influence between configurational aspects and capabilities/performance has enabled the identification of context-specific

drivers (Melnyk et al., 2014) for high-cost textile/apparel. Specifically, the overall TISM process, interpreting the strength of the relationships with explanations has provided a deeper understanding of the configuration of supply chains/networks. Notably, there is a great deal of interdependence between the aspects, with many aspects classified as linkage and *CU* being driven by the other aspects (see Figure 1). Thus, many aspects must be taken into consideration when designing the network configuration individually as well as regarding how they inter-relate. Whereas relational aspects (*RE*; *CM*; *TR*) and *II* are drivers according to ISM, the TISM provides a more detailed picture of the strength and significance of these inter-relationships, with *QU* also found to be a driver in this context.

Some of these key drivers and their inter-relationships, according to the TISM/ISM structures, were explained by the respondents. Specifically related to *TR* and *RE*, one respondent said *"…if you have good trust, the stability of the relation will be better… you know how to react or act, so you can plan for the future"*. Additionally emphasizing that new activities are easier with stable and integrated customer relationships, validating the effect on agility as found by Um (2017). Further, another respondent stated that digital linkages support *CM* as people have greater trust in technology than they have in other people, thus emphasising the importance of internal and external information system integration (*II*;*SI*) for relationships in line with Gu et al. (2017). Another respondent described *II* as crucial although not easy, stating that *"…you can be internally very well integrated and it all works very well internally but you are not integrated to the customer. Because that's outside your control."* Additionally that *"…if you're not internally integrated then you cannot integrate with your suppliers"*; further emphasising *II* and *SI* as crucial for *OF*. Thus, validating the primacy of internal integration efforts to support external integration, e.g. for flexibility, quality and customisation (e.g. Zhang et al., 2019). Further, regarding *RE*, the stability of relationships, especially with suppliers, was described as a focus for several respondents in particular to maintain the *QU* and *DE* that is required to satisfy the customers.

According to the TISM, the aspects with the greatest driving power were *CM*, *TR* and *QU*. Regarding *QU*, one respondent explained that, *"Of course the speed is important but the quality and the environment is the most important."* Thus, highlighting the relationship between *QU* and *SU*. Along similar lines, another respondent stating that buying nearshore is about the speed and ability to order in-season and thus be responsive while maintaining their sustainability goals by not flying products. These motivations are in line with Pal et al. (2018), emphasizing the association between speed, quality and sustainability for competiveness of textiles/clothing production in high-cost locations. Further regarding *TR*, one respondent noted that *"…if we don't have the trust in what [suppliers] promised when it comes to delivery and production we can't guarantee to have 100 percent and customer satisfaction."* With another stating that without trust, it is not possible to share information; with an additional respondent highlighting the importance of information sharing between them and their customers to develop trust. In particular, several respondents described digital technologies and connections with suppliers for *CM* and *SI* as crucial for *TR* and *CM* with customers, in particular transferring detailed information about the product being produced on-demand. Thus, echoing the need for deeper information system integration with suppliers due to deeper integration with customers (e.g. Gu et al., 2017).

Additionally several respondents emphasised that they do not produce anything that is lower quality, in one case with no room for error due to the highly technical nature of the textile/apparel product. Thus, illuminating the relationship between *QU* focus and

the *PS*. While *PS* is one of the top three dependent aspects according to the TISM, *PV* and *OF* are the most dependent. Several respondents elaborated upon the relationships between these aspects, one describing the need to limit the variety of materials-*PS* for internal small series production, and another having limited fabric choices from external suppliers. Thus, using component commonality and some degree of modularity (e.g. Um, 2017) to offer sufficient *PV* while maintaining *OF*.

Conclusion

This paper has examined the influences between supply network configurational aspects and associated capabilities related to small series textile/apparel production in high-cost locations, in line with the need for context-sensitive supply chain design research (Melnyk et al., 2014). The TISM method with MICMAC has enabled the identification of drivers, dependent, and linkage configurational and capability aspects. Overall, the findings show a great deal of inter-relationships with many linkage aspects. With these aspects requiring significant attention due to being impacted by and having impact on many other aspects, thus adding strength to inter-relationships suggested from the literature. Relational aspects including stability, trust and information sharing, structural internal integration, and quality capabilities were some of the most significant drivers. Thus, validating quality as a significant motivator for reshoring/reconfiguring the supply chain in this way (e.g. Gray et al., 2017, Martínez-Mora and Merino, 2014). Additionally, the product aspects and operational flexibility were some of the most dependent. Notably, the indicated impact of the relational aspects on capabilities, structures, operations and products should be further addressed, in line with the call to understand the influence of the supply chain on the product by Pashaei and Olhager (2015). Further, while the stability of relationships has been emphasised as enabling greater agility there is a need to understand the implications on the complexity and adaptability of the supply chain. Thus, potentially involving a tension between trust and stability, with the overall need to adapt to changing competitive landscapes.

The TISM presented here can serve as a multi-element/criterion decision-making tool to address the configuration of supply chains/networks. For the textile/apparel industry, these models show the most significant driving and driven aspects which can provide understanding and thus guidance regarding SC design/configuration. Notably, the analyses have highlighted the importance of communication and information sharing, trust and stability within supply chain relationships and internal integration. Thus, highlighting some key opportunities for development, especially related to integration, as many textile/apparel companies have limited IT and process integration within their own organisations, with even lower levels of integration with suppliers.

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Supplier's contractual embeddedness and sales performance in uncertain environments

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Abstract

Literature offers limited knowledge on the online markets that consist of both open contractual and supply networks which are subject to environmental uncertainties. This study investigates how the environmental uncertainty dimensions and supplier's contractual embeddedness (as informed by the degree and closeness centralities) impact the supplier's sales probability in light of Complex Adaptive System theory, Social Network Analysis and the environmental uncertainty literature. Australian based Open Food Network data from 2012 to 2016 empirically validates that the supplier's contractual embeddedness generally improves its sales probability and uncertainty dimensions moderate this relationship with the help of panel logit regression model.

Keywords: Contractual embeddedness, environmental uncertainty, sales performance

Introduction

Scholars increasingly conceptualise the supply network as a complex adaptive system (CAS) where a network topology emerges over time rather than a purposeful design by a single firm (Choi et al., 2001; Park et al., 2018). CAS view further explains the coevolution between the embedded firms of the supply network and the environment (Nair et al., 2016; Park et al., 2018). Yet, how an open contractual network that resembles a CAS leads the consumers to derive the supply network from the open contractual network in each order cycle offers very limited knowledge in the literature. In a broader view, how much effort a supplier needs to put into being central in the open contractual network to increase their sales probability in the supply network while adapting the environmental uncertainties remains mostly unexplored in the literature. The current CAS

validation of the supply network coevolution does not consider the dual networks are coexisting with each other that is present in Internet-enabled supply chain platforms.

There are two types of networks that freely emerge in these online platforms that resemble a CAS. These include the open contractual network where any supplier can register and connect to each other based on their mutual understanding and the supply network as a collection of consumer designed supply chains for each order cycle using the suppliers of the open contractual network. Suppliers' contractual embeddedness (SCE), which is how they are linked with each other with open contracts, may influence their sales probability in online markets. The concept of SCE is vague because the current literature posits both linear and nonlinear effects of embeddedness on performance mostly based on subjective measures (Uzzi, 1996; Kim, 2014). Scholars popularly use perceptual measures to inform a supplier's network embeddedness and ignore the objective measures due to the network data collection difficulties (Uzzi, 1996; Kim, 2014). Nevertheless, social network analysis (SNA) matrices are now widely available to inform the SCE in different aspects such as degree, eigenvector, betweenness and closeness centralities (Borgatti and Li, 2009; Kim et al., 2011).

Also, suppliers change their contractual relationships in an online market to adapt to environmental uncertainty dimensions of dynamism, munificence and complexity over time (Gligor 2018), but this remains poorly understood in the literature. To explore these gaps, this paper investigates the impact of environmental uncertainty and SCE dimensions on the supplier's sales probability in the supply network. In doing so, this study integrates the CAS theory, Social Network Analysis (SNA) and the literature of environmental uncertainty, supply chain and performance. This paper addresses the following research question:

- How do environmental uncertainty and supplier's contractual embeddedness impact the supplier's sales probability in the supply network, over time?

The open contractual network of the Australian based open food network (OFN), the research context consists of small to medium scale farmers and food hubs who register to the OFN with their product and shipping options and connect with each other. When a consumer makes an online order and designs its food supply chain by picking the preferred suppliers from the open contractual network for each item, the chosen food suppliers stand a chance of joining the supply network. It thus enabled the analyses of the impact of environmental uncertainties and the SCE on the supplier's sales probability in the supply network in a panel data setting involving food suppliers that registered to the OFN from 2012 to 2016.

This longitudinal study makes generous contributions to the literature. It elucidates how the supply network emerges in each order cycle as a derivative of the open contractual network that resembles a CAS that received less attention in the literature. This study relies on the objective measures using the SNA matrices to provide a network understanding of the SCE than the widely used perceptual measures. The results reveal that the SCE generally improves the supplier's sales probability in the supply network context contradicting the beliefs that hold on to non-linear effects of the embeddedness on performance. This study graphically unveils the evolution of the open contractual and the supply networks from 2012 to 2016 using the SNA. This study further discloses that the environmental uncertainty dimensions have a moderating influence on the SCE and

the supplier's sales probability relationship which remain largely unexplored in the literature.

Hypotheses Development

Supplier's Contractual Embeddedness and the Sales Probability

The in-degree is the number of ties received by the supplier, and the out-degree is the number of ties initiated by the supplier (Borgatti and Li, 2009). In this study, the centrality calculations are based on the open contractual network where the value of a tie equals one for having a contract between two suppliers; otherwise, it is zero. When the supplier holds on to more ties, it can play a central role as a coordinator collecting the demand information from other suppliers and aligning the customer segments and innovative business strategies to achieve the greater supply network interests (Kim et al., 2011). The open contractual network exhibits complex multi-scale behaviour among the suppliers since a variety of food producers, restaurants and food hubs evolves and self-organises through a complex interplay of its structure and function (Choi et al., 2001; Pathak et al., 2007). Consumers prefer suppliers with high in-degree centrality who receive from many other suppliers and act as a food integrator (Kim et al., 2011). Those food hubs create vast opportunities for the consumers ordering a variety of food items ranging from meat, fish, egg, fruit, vegetables, winery, bakery and grain under one shelter and deciding the producers for each item from the available pool of suppliers that attached to the food hub. Hence, there is a high probability of consumers choosing them for their food supply chains. Accordingly, the suppliers with high out-degree centrality are the ones who promise to deliver food items to many other suppliers that act as a food allocator distributing its products across many suppliers, focusing on the economies of scale (Borgatti and Li, 2009; Kim et al. 2011). The food suppliers in the open contractual network also prefer to connect with such food producers/hubs who are readily available for the food supply to them and hence, there is a high probability of consumers picking them for the supply network.
Hypothesis 1: A supplier who holds a more significant number of contracts in the open contractual network has a high sales probability in the supply network over time.

The open contractual network consists of inter-supplier relationships that connect multiple food and beverages related industries in Australia. The consumers consider certain factors from multiple perspectives such as logistics cost, product costs, flexibility and quality in designing their food supply chains to fulfil their food requirements (Terjesen et al., 2011). The significant factors that a consumer might consider are the constraints of the open contractual network and the supplier's adaptivity to the environmental uncertainties including the past customer experiences (Pathak et al., 2007). The OFN consists of geographically concentrated clusters to satisfy the regional consumers. Hence, the closeness centrality, which indicates how close a supplier to all the other suppliers in a network, is a significant factor that determines the supplier's geographic and conceptual proximity (Borgatti and Li, 2009). The highest scores indicate more closeness. A supplier with high closeness centrality has more freedom from others' influence and higher capacity for the independent actions (Kim et al., 2011). Such suppliers get the consumers' attention in that region. Consumers might entertain less shipping and exchange fees by connecting original producers with the suppliers of high closeness to fulfil their orders. Since the high closeness suppliers hold on to shorter food

supply chains, they can optimally balance supply and demand with less inventory and lower operational costs (Borgatti and Li, 2009).
Hypothesis 2: A supplier who can quickly reach all the other suppliers in the open contractual network has a high sales probability in the supply network over time.

Environmental Uncertainties as Moderators: Dynamism, Munificence and Complexity

Dynamism refers to the level of environmental volatility or the unpredictable change within an industry that intensifies uncertainty (Gligor, 2018). The suppliers that possess more direct ties become more central and visible in the network, and they perceive a leadership role in coordinating the other suppliers due to its greater connectedness (Borgatti and Li, 2009; Kim et al., 2011). The dynamic rigour inlays unanticipated environmental fluctuations into the open contractual and supply networks which lead to the network transitions ensuring the embedded suppliers' survival. Hence, the suppliers with high in-degree centrality manage the incoming food supplies from the upstream suppliers by putting together or transforming different food items into a value-added product such as vegetable and fruit boxes, meat boxes and beverage cartons that ensure the product quality (Kim et al., 2011). Also, the suppliers with high out-degree centrality manage the demand flow by distributing consumer selected producer items focusing on the economies of scale. High degree centrality suppliers have a great impact on the operational decisions and the strategic behaviour of the other suppliers reconciling the differences in network members and aligning them with the OFN interests (Kim et al., 2011; OFN, 2018). The pressure on the high degree centrality suppliers is much higher during the dynamic events such as food surpluses and supermarket domination that prevent the regional farmers supplying beyond the restricted quotas (National Association of Retail Grocers of Australia, 2007).
Hypothesis 3: Higher dynamism leads to a stronger positive relationship between a supplier who holds a larger number of contracts in the open contractual network and its sales probability in the supply network over time.

Dynamism can bring adverse effects into the existing interrelationship structure thereby weakening the coordinated and shared supply chain strategies which may be obsolete in the face of emerging challenges. Nair and Vidal (2011) emphasise that long average path lengths between suppliers in a supply network are detrimental to its robustness against the disruptions while shorter average distances allow faster propagation of products and information. So, the closeness should enhance the responsiveness of the supply network in the event of environmental dynamics. Though the supplier's ability to remain in cliques by selectively connecting to the well-connected suppliers advances the regular supplier network operations, it is vulnerable to the environmental distractions due to the higher level of dependency on dominant suppliers (Borgatti and Li, 2009; Nair and Vidal, 2011). The consumers favour the suppliers that can quickly reach most of the other suppliers in a cluster in terms of logistics costs, but the product reliability and flexibility issues generated by the environmental disruptions may weaken customer loyalty. In adapting to dynamic situations, some ties and suppliers would disappear from the shortest paths, and new suppliers and ties enter the network and hence, the closeness centrality may decrease.
Hypothesis 4: Higher dynamism leads to a weaker positive relationship between a supplier who can quickly reach all the other suppliers in the open contractual network and its sales probability in the supply network over time.

Munificence refers to the resource abundance in the environment resulting in a higher capacity to support the sustained growth of a firm and thus focuses on an industry's sales trend (Terjesen et al., 2011). Network structure partially determines the opportunities and constraints to access valuable resources and information that would help the suppliers sustain competitive advantage (Burt, 1992). The suppliers with high degree centrality can influence their suppliers either to compete or corporate or both when developing value-added products by recognising, leveraging and deploying the market knowledge and demands (Kim et al., 2011; Bellamy et al., 2014). Since they experience high relational activity in the open contractual network that capture the potential transactional intensity or related risks, they can influence other connected suppliers' operational scope. High degree centrality suppliers are willing to absorb the opportunities generated by highly munificent environments to meet the diversified consumer requirements aligning with the anticipated actions of other connected suppliers.
Hypothesis 5: Higher munificence leads to a stronger positive relationship between a supplier who holds a larger number of contracts in the open contractual network and its sales probability in the supply network over time.

The environment interacts with the contractual relationships in ways that cause selective pressure and competition among the structural dimensions to create nonadditive effects on the supplier's survival (Gell-Mann, 1994). The OFN is more vital in munificent environments as its primary purpose is to become an alternative platform for the sustainable producers and hubs to sell their surplus produces to the consumers. Thus, the suppliers with high closeness centrality have the potential to deliver the produces promptly to consumers as they can quickly reach most of the other suppliers in the network (Borgatti and Li, 2009). The suppliers that are at a short distance from most other suppliers receive information and produces sooner than the suppliers that are far away from most others (Borgatti and Li, 2009). The other suppliers would like to join the short food supply chains to get more sales while consumers place orders assigning a pivotal role to the high closeness centrality suppliers to get the benefits of less operational and inventory costs (Lee et al., 2004).
Hypothesis 6: Higher munificence leads to a stronger positive relationship between a supplier who can quickly reach all the other suppliers in the open contractual network and its sales probability in the supply network over time.

An industry's complexity is implied by the number of firms and their composition in terms of size and perceived resources (Child, 1972). In a complex business environment, a supplier needs to satisfy the environmental expectations placed on it with the available resources, capabilities and products to remain operationally sustainable (Li et al., 2010). Having a higher number of direct contacts with other suppliers in the open contractual network enhances the supplier's ability to absorb the external knowledge in response to the increased information processing demands and open innovation. Also, suppliers that are unable to recognise and leverage the extensive information that can be accessed from other evolving suppliers are likely to face legal consequences and weak performances (Pathak et al., 2007). The new suppliers entering the open contractual network connects with high degree centrality suppliers than the isolated suppliers in a complex business environment to attract consumers. Further, consumers trust a high degree of centrality suppliers in a market spoiled by choice with a large number of physical establishments. Eventually, the OFN producers that start with fewer connections transform into high degree centrality food hubs over the years responding to the various market requirements.

Hypothesis 7: Higher complexity leads to a stronger positive relationship between a supplier who holds a larger number of contracts in the open contractual network and its sales probability in the supply network over time.

Food suppliers inescapably engage in a cycle of continuously changing inter-relationships to increase its internal fit to the supply chain and external fit to the environment (Choi et al., 2001; Park et al., 2018). It is even more critical in a CAS to find the strategic fit between the network structure and the collaboration patterns (functionality) (Li et al., 2010). Hence, the key interest of this study aligns with this interplay and the shorter food supply chains that cover a heterogeneous product range. Since the longer paths increase the operations costs and network disruptions, high closeness centrality suppliers are in relatively powerful positions in delivering a wide range of food items with shorter and flexible delivery times. Both the consumers and the embedded suppliers coevolving with the complex environment increasingly connect with the high closeness centrality suppliers that could reduce the logistics costs and improve on-time delivery.
Hypothesis 8: Higher complexity leads to a stronger positive relationship between a supplier who can quickly reach all the other suppliers in the open contractual network and its sales probability in the supply network over time.

Conceptual Model

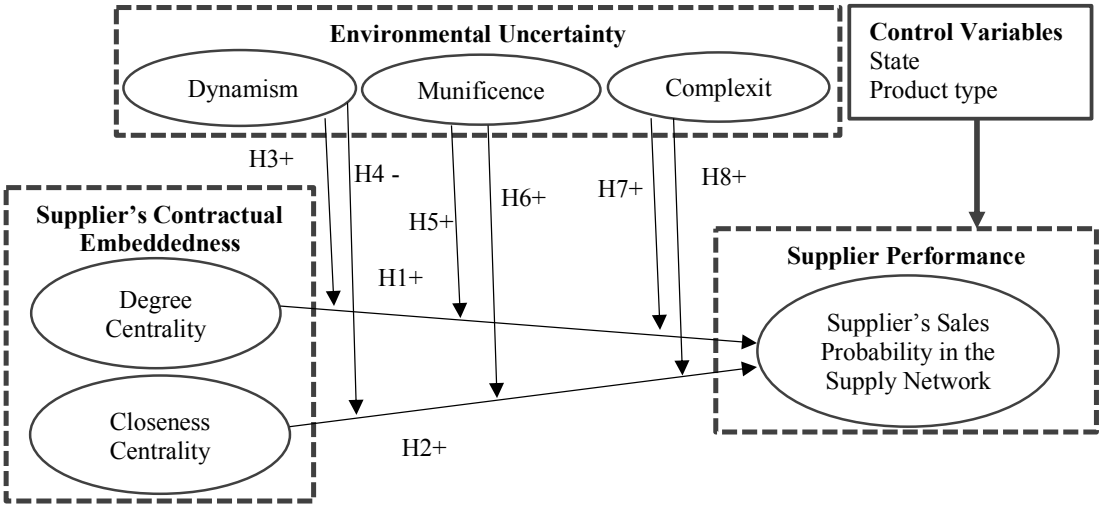

Figure 1: Conceptual model

Research Methodology

OFN dataset was used for the analysis which started in 2012 with 34 food suppliers and grew to 96, 234, 1033 and 1876 in each consecutive year up until 2016. The corresponding supply network started with 30 food suppliers and evolved by 71, 234, 395 and 503 in each successive year along with the open contractual network's evolution. The network deals with 52 main product categories. The IBISworld industry reports from 2008 to 2016 were used to measure the environmental uncertainty dimensions. SNA and panel logit regression modelling methods were used to test the proposed hypotheses.

In-degree centrality of a supplier is the number of ties received by the supplier and out-degree is the number of ties initiated by the supplier (Borgatti et al., 2002; Kim et al.,

2011). The log transformation of the sum of the in and out degree centralities of the supplier is used in this study for the degree centrality. Closeness centrality is the reciprocal of farness which is the sum of the lengths of the ties to every other supplier (Borgatti et al., 2002; Kim et al., 2011). As an alternative to taking the reciprocal after the summation, the reciprocals can be taken before. Since the data is directed, the average of both in and out closeness centralities was calculated after which the log transformation was obtained.

Munificence is measured as the five-year average growth in industry sales revenue and industry value added of the industries that the supplier is involved in (Keats and Hitt, 1988; Gligor, 2018). Measures were taken in $ millions. The basic equation followed is

$$y_t = b_0 + b_1 t + at$$

where y=natural logarithms of sales/industry value added, t=year and a=residual. Growth measure is the average of the antilog transformations of the sales and industry value added regression coefficients. Dynamism is the five-year patterns of the instability of the environment (Keats and Hitt,1988; Gligor, 2018). The measure is the average of the antilog transformations of the standard errors of each regression slopes (sales and income) measured for munificence (IBISworld, 2016; Gligor, 2018). Complexity is the breadth and variety of the industries' geographic markets that the supplier operates in (Child, 1972;). The five-year average growth of the number of physical establishments of the industries that the supplier operates in was used (Keats and Hitt, 1988; IBISworld, 2016). The basic equation followed is

$$y_t = b_0 + b_1 t + at$$

where y=natural logarithms of the number of physical establishments, t=year and a=residual (Gligor, 2018). The growth measure is the antilog transformation of the regression coefficient. The probability of sales is a binary variable. If the supplier generates sales in the supply network it is 1; otherwise, it is 0 (Lanier et al., 2010).

Descriptive Statistics

Table 1: Descriptive statistics and correlations

Variable	Mean	Standard Deviation	Minimum	Maximum	1	2	3	4	5	6
1.Degree	0.78	1.07	0.00	5.81	1.00					
2.Closeness	-2.41	0.18	-2.63	-0.85	0.48*	1.00				
3.Dynamism	1.01	0.01	1.00	1.12	0.01	0.10*	1.00			
4.Munificence	1.02	0.04	0.85	1.34	-0.09*	-0.07*	0.09*	1.00		
5.Complexity	0.99	0.03	0.74	1.36	-0.07*	-0.05*	-0.14*	0.56*	1.00	
6.Sales	0.37	0.48	0.00	1.00	0.63*	0.49*	0.02	-0.14*	-0.10*	1.00

*p<0.01

Table 1 provides descriptive statistics and the correlations between the variables.

Results

The analysis was conducted in two steps. SNA and the panel logit regression modelling procedures were used respectively. First, the SNA technique was applied using the UCINET software to visualise the network evolutions from 2012 to 2016 as shown in Figure 2 and to derive measures for our independent variables which are degree and closeness centralities. Second, the moderated panel logit regression modelling

methodology was used given the dichotomous nature of the dependent variable which is the supplier's sales probability in the supply network and it is unbalanced due to the unequal number of suppliers presented by the regional food network evolutions. The control variables; product type and the state, do not significantly vary over time and the suppliers in the OFN are a small representation of the Australian food suppliers in each category. Hence, the random effects panel logit model was used. The odd ratio was used to infer the true nature of the relationship between the explanatory variable and the dependent variable (Wiersema and Bowen, 2009).

Results are shown in Table 2. These results show the support for six out of the proposed eight hypotheses. The first model includes the effect of the control variables on the supplier's sales probability. The independent variables of centralities were added into the second model and the moderators of the environmental uncertainty variables into the third model. The fourth model includes the interaction terms, which are the product of each centrality variables with each of the mean centred environmental uncertainty variables. Since the odd ratios of the log transformations of degree and closeness centralities are greater than 1, they associate with higher sales probability supporting hypotheses 1 and 2.

In both highly dynamic and complex environments, the positive association between the supplier's degree centrality and its sales probability are very high as their odd ratios are significantly greater than 1 supporting hypotheses 3 and 7. Though the munificent environments increase the positive association between the closeness centrality and the sales probability with an odd ratio greater than 1 supporting hypotheses 4, dynamic environment diminishes that positive slope with an odd ratio less than 1, thus confirming the hypothesis 6. The relationship between the degree centrality and the sales probability is not evident in the munificent environment, thereby contradicting the hypothesis 5. This may be due to when most of the food suppliers have product surpluses, and they get motivated to directly sell the products for lower prices rather than from selling through food hubs. Therefore, consumers may reach both the individual food producers and hubs to get price advantages in munificent environments. Also, the relationship between closeness centrality and sales probability is absent in the complex environment. Consumers that are spoiled by the choices with a heterogeneous product range chase after local brands without concerning the distance in a complex environment and hence it is possible to have hypothesis 8 not being supported.

Table 2: Unbalanced panel logit regression results

Model	Model 1	Model 2	Model 3	Model 4	Hypothesis
Sales	Odd ratio	Odd ratio	Odd ratio	Odd ratio	
Constant	0.03*	$3.72x10^{10}$*	$2.13x10^{24}$*	$3.24x10^{30}$*	
State	Yes	Yes	Yes	Yes	
Product type	Yes	Yes	Yes	Yes	
Degree centrality		10.07*	14.99*	16.66*	H1: Yes
Closeness centrality		65241.54*	29794.79*	1994342*	H2: Yes
Dynamism			$3.93x10^{-5}$	$1.78x10^{-08}$***	
Munificence			$2.44x10^{-9}$*	$1.03x10^{-08}$*	
Complexity			0.02	0.23	
Degree *Dynamism				$1.12x10^{17}$**	H3: Yes
Closeness *Dynamism				$3.90x10^{-160}$*	H4: Yes
Degree * Munificence				0.01	H5: No
Closeness * Munificence				$5.41x10^{57}$**	H6: Yes

Degree * Complexity				$3.25x10^{07}$***	H7: Yes
Closeness * Complexity				$3.96x10^{32}$	H8: No
Wald chi2	21.16***	228.97*	201.57*	189.70*	

Observations = 3273, Groups = 1876, p<0.01*, p<0.05**, p<0.1***

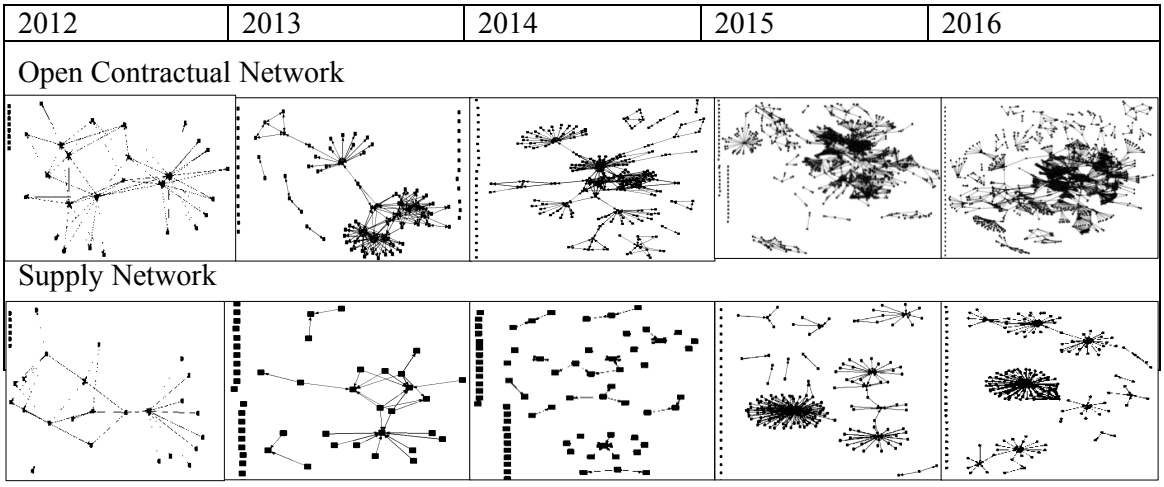

Figure 2: Network evolutions from 2012 to 2016

Discussion and Conclusion

This study primarily investigates how the open contractual network derives the supply network in each order cycle in response to the environmental uncertainties over five years by applying CAS theory. Results reveal that the SCE as informed by the SNA matrices of degree and closeness centralities generally improves the supplier's sales probability in the supply network. This contradicts the belief about the non-linear effects of the embeddedness on performance. Further, the study elucidates how freely emerging open contractual network interacts with the environmental uncertainties without any global controller to increase the embedded supplier firm's performance. This study discloses that environmental uncertainty dimensions moderate the relationship between SCE and the supplier's sales probability which is mostly unexplored in the literature. Both the dynamic and complex dimensions improve the positive association between the degree centrality and the sales probability as per the odd ratios. Munificence increases the positive association between the closeness centrality and the sales probability nexus, but dynamism lowers this positive relationship.

This study graphically unveils the simultaneous coevolution of the open contractual and the supply networks embedded in a single system over five years to adapt the environmental uncertainties. The geographically remotes network clusters that connected through the structural holes in the networks evolve into different network patterns over time. These network transitions and the changes in the SCE centralities aim at catering the local interests than the global optimum, and hence these networks exhibit the characteristics of a locally sufficient CAS. This study offers a more rigorous and scientific analysis elucidating how to foster the CAS and SNA views of the open contractual

network to develop the supply network and increase the embedded suppliers' sales probability.

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Sustainability in Operations and Logistics (including CSR)

Towards Circular Economy in Manufacturing: Identification of Barriers Seen by Norwegian Manufacturing Companies

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Abstract
Most companies include in their strategy, a commitment for sustainable growth which involves a switch towards a circular economy (CE). A CE transition is hindered by barriers that must be overcome to comply with sustainable growth. In this paper we identify barriers faced by industries, and we propose solutions for how to overcome these barriers. The main barriers were found to be complexities in supply chain, coordination problems, quality issues, little attention to CE in production and design, difficulties in disassembly of products and high start-up costs. To overcome these barriers, we present a model supporting life cycle information.

Keywords: Circular Economy, Sustainability, Barriers

Introduction
While globalisation gives both a larger market and an increased competition, the companies` supply chains have become more complex and critical than before (Majta 2012, Sheffi 2018). The worldwide consumption has increased over the last decades and it is expected that the resource use globally would increase three times more by 2050 (Lucas 2014). The effect of population growth and the following increase in consumption raise challenges to the environment, the overall society, and the depletion of scarce resources (Ellen MacArthur Foundation 2015). The resource consumption of the linear model follows the take-make-consume-dispose pattern which is not sustainable as its over-use scarce resources and contribute to pollution of the environment. The cities are generating 1.3 billion tons of waste each year and it will surge to 2.2 billion tonnes by 2025 (Masi et al., 2017). Waste and trash have a negative impact, our oceans are accumulated with plastics, marine life in endangered, animal kingdom and wildlife are affected by too many pollutants, persistent chemicals are causing diseases, depletion of

the ozone layer, global warming and trash landfills which have led to serious actions against waste. The electronic waste is another kind of waste that is increasing fast.
Businesses in need to satisfy their customers, must increase the prices of the materials due to the increasing scarcity of resources, which again might affect the progress and profitability of the companies in a negative way unless it is addressed. More pressure of environmental concern from customers are seen to result in more eco-friendly products. The CE model is based on the concept of changing the take-make-use-dispose pattern into closed-loops of material flows through processes such as maintenance, repair, reusing, refurbishing, remanufacturing and recycling (Masi et al., 2017). Supply chains are considered to be an important factor for implementation of the CE model because of the need for a joint effort of suppliers, manufacturers and customers. The co-operation and co-ordination between supply chain upstream and downstream partners are essential as upstream partners obtain eco-friendly inputs cooperating with downstream partners for environmental management practices such as product return, reuse and recycling (Zhu et al., 2010).

The transition to CE is not as easy as is evident from several studies that have identified many barriers. Due to these barriers, firms are slow to make a transition towards the CE (Masi et al., 2017; Preston, 2012). We claim that the transition to CE is only possible through the better management of information and the informational flow. We follow Rosén (2010) in defining the information needed for a product as "*all the information required in making decisions and taking actions in the whole life cycle of a product"*. Information technology is considered as a priority for managing the information flow across the supply chains, and standardization is helpful in providing rules and frameworks to support companies move towards the CE.

This study addresses the barriers to the CE in manufacturing industries and aim at shedding light on how these barriers can be overcome by applying information technology.

In this study, we refer to manufacturing industries as industries using highly equipped machines and digital instruments that are helpful in their production. Examples of such industries are construction industry, automotive industry, defence and arms, energy industry (electrical & petroleum), computer industry and aerospace industry. These industries work with tools such as massive machineries, heavy metals, digital and complex mechanical instruments, drills and cranes and other heavy transport equipment and appliances (GS1 2018). It is crucial for these industries to have a secure method to recycle or dispose of metal and electronics waste that can have hazardous effects on our environment. However, there have been challenges in recycling and disposing of these types of machinery and metals as elements and products that cannot be extracted easily.

Manufacturing Industries

The last couple of decades, we have seen an evolution from a traditional supply chain towards a green supply chain. Environmental-friendly production and consumption activities, reducing the negative effect on the environment, represents a major goal of green supply chains. The focus is not just on the reduction of negative consequences of production processes and residuals, but also on the repeated use of materials through such systems, where transformation is made through a relationship between ecological system and economic growth (Genovesea et al., 2017). In addition, the unique product identification is creating interesting opportunities for transparency in companies' supply chains (Karkkainen & Holmstrom, 2002).

Circular Economy (CE)

Adoption of CE concepts have been the focus of the food industry for several decades. Irani and Sharif (2018) explored the role of sustainable food security with the closed loop business models. CE can be seen as consisting of two parts, where the first part focuses on reducing the impact on the environment, and the second part focuses on creating business models that implement the first part (Torstensson, 2016). Regarding the first part, which concerns reducing the impact on the environment, the Ellen MacArthur Foundation (2015) has given a model of circularity showing which activity-cycles that gives the highest positive environmental impact. The cycles focus on a material's next use. The best next use i.e. most environmental-friendly, would be to close a cycle instead of going to a cycle with lower CE effect or end up in the waste-chain.

Figure 1 illustrates the CE cycles Maintaining, Reusing, Remanufacturing and Recycling (M+3R) and the waste-chain. Maintaining has highest CE-impact, followed by Reusing, Remanufacturing and Recycling respectively, and the waste-chain having the lowest CE-impact (Ellen MacArthur Foundation, 2015; Torstensson, 2016). The waist-chain consists of Waste collectors, Energy-from-waste operators, and Landfill operators.

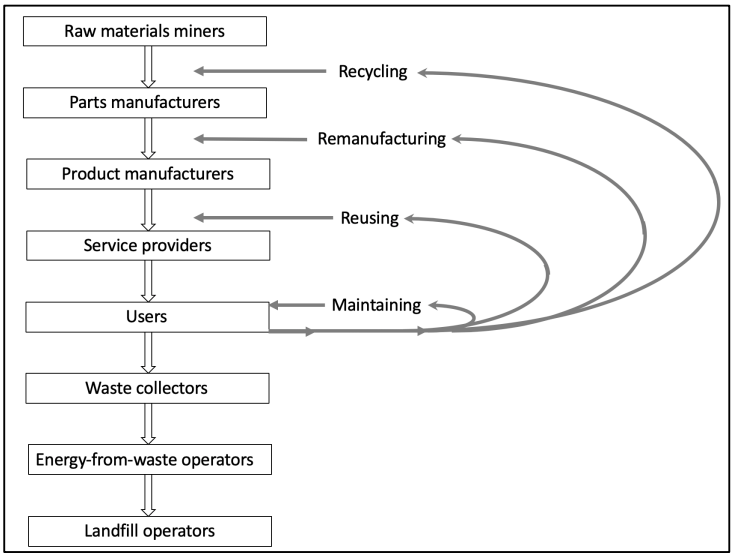

Figure 1 CE as a restorative system for technical products with the M+3R cycles in the upper part and the waste-chain in the lower part (adapted from (Ellen MacArthur Foundation, 2015)

According to Zhijun & Nailing (2007), shifting towards a CE model requires a deep focus on raw materials and energy. When producing a product, the focus should be on minimizing the entire product life cycles negative effects on the environment from the very early stage of material extraction towards the product disposal.

Barriers to CE

A shift to the CE model requires a dramatic change for the whole company involving all stakeholders. This shift is somewhat disruptive in nature because the current mode of working would be changed (Ritzéna & Sandström, 2017). In order to identify common barriers to CE, an exploratory review of existing literature was done using academic databases such as Google Scholar, ProQuest, ScienceDirect and Academia. Keywords such as "Circular Economy, Product Identification, Sustainability, and Barriers to Circular Economy" were used. In summary, the barriers found by (P) Preston, 2012; (LB) Liu & Bai, 2014; (E) Eijk, 2015; (T) Torstensson, 2016; and (BB) Berchicci and Bodewes, 2005) are, ordered by the authors: (P1): Resource-Intensive development models. Traditional models are highly resource intensive; less resource-intensive models

are lacking. (P2): High start-up costs. In the long run the CE model would show sustainable benefits and increase growth but in the short run, the start-up costs are high. (P3): Supply chain complexities. Multiple companies around the world are engaged to make a particular product for a global customer base. A challenge for the supply chain in the CE model is the alignment from the early design stage to consumption the durability and reparability of materials. (P4): Difficulty in coordinating companies. The coordination among companies is a barrier because it needs multiple companies to adjust their daily operations. (P5): Innovation diffusion challenge. It is critical that new breakthroughs rapidly find their way into the mass market, so that transition to the CE can contribute to tackling climate- and water-related goals in the necessary timeframe. (LB1): Structural. Innovation and flexibility are restricted by organizations` hierarchical patterns. Lack of budget towards the CE model innovation. CE`s strategies are affected by the managers' employment term restrictions. (LB2): Contextual. Competition in the market place restricts the movement towards CE. (LB3): Cultural. Managers are risk averse. (E1): Restricted supply chain. There is lack of enablers to improve cross cycle and cross- sector performance. Lack of exact knowledge of the composition and origin of materials used. (E2): Lack of industrial symbiosis. Industrial symbiosis is based on having good knowledge of material/energy flow within an industrial sector and geographical area. Thus, it requires exchange of information regarding inputs and output to optimize the processes, but this industrial symbiosis is a barrier towards CE because it's costly or difficult to obtain. (E3): Logistics. Information exchange systems in logistics are limited. Cargo flows are handled by logistics, which also includes the reverse logistics and supply chain management. For the CE transition, existing network design is a barrier. The design should support switching between transportation modes. (E4): Product design and production. Removing of toxic material and separation of biological from technical substance is lacking. Shortage of information regarding green suppliers. Current product design is given less attention towards the end phase of products. (E5): Recovery. The products are becoming more complex; the recovery of such products is a big challenge. (E6): Recycling. Recycled materials are sometimes more expensive than the new raw materials. Investing in recycling is seen to be risky on a larger scale. (R1): Lack of technical skills. A barrier is the lack of skills in small and medium-size enterprises. They don't realize the benefit of implementing more advanced technologies that reduce the negative impacts on the environment and would give them costs savings. (T1): Quality compromise. Companies' reluctant attitude towards CE is their concern regarding the quality of materials. They fear materials would be chosen based on the environmental aspects instead of quality of performance. (T2): Disassembly of products is time consuming and expensive. A product is made of many different components which are attached in a way that their disassembly is hard and time consuming and it seems much better to produce a new product than to recirculate the materials, and also it would be very expensive to mould the components in a way they could be available to use again. (T3): No sure recycling, remanufacturing and reusing would help the environment and save money. There is no surety to the companies that this process of CE would definitely save money or protect scarce resources, and it might be the case that producing a new product is less costly than reusing the old one. (T4): Quality assurance. A barrier is that it is difficult to know what has exactly been done with the material and whether the recycled material is handled in a manner that is good with respect to quality, and all these things involve costs. (BB1): Design irrespective of CE. The products that are produced lack a circular design which is the reason the reusing, disassembly, remanufacturing etc. is hard. (BB2): Hygienic issues. Some perceive that recycled or reused materials are not safe and hygienic.

Data Collection

In order to explore how manufacturing companies look upon the CE concept, and what barriers they see, we carried out semi structured interviews with three companies. since semi-structured interviews are one of the most used methods of data collection within the social sciences (Bradford & Cullin, 2012). The interviews were conducted in three companies A, B and C, working with technical issues and who focus on the idea of green supply chain and sustainability. In the interviews, we aimed at gaining information about their internal capacities, challenges and barrier that they encounter each day by handling their products. Two interviews were carried out face-to-face, while one of the interviews was carried through by sending the interview guide via email since the person available for a face-to-face interview. Company A is a technology-based company that delivers competitive solutions to meet the power needs of its customers. The company works within the marine and automotive industry, and deliver products and services encompassing power systems, nuclear and many more. The company aims at having a reputable rule to minimize the risk of climate change, low carbon global economy, reduction of environmental impacts from production as well as improving the environmental performance of its products. Furthermore, the company are strongly committed to health, safety and environmental management. The respondent said that they do not exactly use the term CE, but we have all the focus on environmental protection:

> '*We have the program called "Revert" which is about minimizing the demand for the new materials in which the metals are being recycled. This also helps in lowering the cost and reusing of finite resources i.e. rhenium, hafnium, nickel and titanium."*

Regarding the question about CE, the respondent said that almost 95% of the engine parts and equipment are recycled and have high quality but the main barrier is the cost of recycling. Through the "Revert" program tons of carbon dioxide are saved compared to using new materials. In addition to the cost of recycling, another barrier the respondent mentioned was the disassembly of the products.

Company B manufactures professional lighting solutions for global markets. Their goal towards a sustainable environment is:

> '*Through obligations to comply with local, global government requirements and self-imposed requirements, we will contribute to a lower environmental impact. This implies objectives to reduce waste; increase reuse and; as far as possible, use environmentally efficient transport solutions; reduced energy consumption prevent emission''*

The company complies the law that applies to follow the local and global standards and environmental policies, which is reflected in one of the answers of a former employee:

> *'The company's products also satisfy the WEEE Directives (Waste Electrical and Electronic Equipment), has ISO 14001 environmental certification and policy for Corporate Social Responsibility (CSR) to support a precautionary approach to environmental challenges, undertake an initiative to promote greater environmental responsibility and support the development of environmentally friendly technologies.'*

Company C is Global Standards 1 (GS1 2018) who is a not-for-profit company that develops global standards for business to business communication. GS1 was established in February 2005, by the merger of EAN International (European Article Numbering) and

UCC (Uniform Code Council). GS1 is a leading global organisation dedicated to the design and implementation of global standards and solutions to improve the efficiency and visibility of supply and demand chains globally. The best known GS1 standards are the barcode and RFID standards. The identification of components and equipment enables efficient processes manufacturing industries. The procurement, storage, assembly, maintenance, repair and disposal of products and their components can be optimised based on GS1 identification standards. GS1 Norway has fifteen employees. This interview was conducted in the Department of Delivery Standards where we interviewed Terje Menkerud, a senior advisor at GS1. GS1 Norway has more than 6300 registered companies in Norway. In response to the question about challenges to the company with respect to sustainability the respondent said:

> '*GS1 is not a logistics company, it came from the retail sector and not many companies see us as a logistics company. This is the biggest challenge to get the actors and the players in the field of logistics to know who we are and get aware our system and get to know how we could we help them in daily business by reducing the cost and solution towards environmentally friendly transportation.'*

He further explained that since a lot of players in the market have their own systems, they don't interact effectively. If you receive some material from another market you have to re-label it. To get the entire community into the same global standardized way of trace and track with unique identification is a big challenge in a way of sustainability. The reason is that if there are globally standardised system all the information about a particular product would be shared which is not the case in most of the countries. Further details of the questions and answers can be found in Naz and Rahim (2019).

Barriers identified to the CE in technical industries

Based on our findings, it seems that Norwegian companies in technical industries know the concept of "circular economy" and that they have a with a high focus on environmental sustainability. Even if they do not use exactly the word "Circular Economy", all their efforts towards environmental protection have the base in this concept. The results indicate that large Norwegian technical companies have special attention towards regeneration of resources, and they have special programs to implement such thought as illustrated by the "Revert project", the "sunshine program" etc. mentioned by the respondents. Company B's move towards a sustainable environment is pushed added by charging their customers a small recycling fee that is transferred to the recycling funds to handle recycling. Company B has a membership in an association of recycling companies that make sure the electronic product waste is handled carefully and that products are reused instead of new raw materials. By doing this energy consumption is saved, and environmentally friendly products are produced by reducing the global waste. The company is also certified with ISO 14001:2004. This makes the company to comply with the rules and regulations of the environmental management system thereby reducing the negative effects on the environment. There are several barriers to CE adoption as identified by the literature review part.

The companies interviewed identified the six barriers: coordination problem, quality issue, disassembly of products, design and production, supply chain complexities and high start-up costs.

In end-of-life management, the disassembly of products is considered to be an important element. It is considered that almost every product has some amount of disassembly i.e. irreversible joints, maintenance and up gradation and degradation during

use. It is not actually the reverse process of assembly. If the instructions of disassembling are available with other relevant information such as design and life cycle information, it will ultimately help in product disassembly automation and decrease in disposal or components (Parlikad et al., 2003). All the respondents said that the disassembly of products is not easy and it expensive and time consuming because of complex nature of products and this fact is also supported by the literature (Torstensson, 2016). The complexity comes due to different aspects. The number of materials has increased, and many small materials are used with significant importance as well as the multiple components of different nature and connections assemble together and affect the transition towards a CE. If the resources contained in these materials and components are taken back through repair, upgrade or remanufacture can benefit the overall world (Peiró et al., 2017).

Another barrier which the companies have mentioned the technology sector is less attention towards the end-phase of product (Eijk, 2015)**.** One of the problems is the production of cheaper goods, shorter-life expectancy and low cost and unsustainable products in today's corporate culture. The culture of companies is, when they make a product, they don't feel the need about how the product will end its life. Once the manufacturers produce the product and send it off for sale, they are not usually responsible for the end-phase of the products' life. Furthermore, they report lack of information when recycling or reusing any product in their end phase of life, because product information is necessary to identify and know about the product parts. This has concerned governments and organizations to make strategies to pressurize companies and the corporate world to be more responsible while producing and have strict environmental considerations & policies (Hesselbach et al., 2001).

Recommended model to overcome CE barriers

We provide recommendations to the companies in technical industries for overcoming the CE-barriers based on an information model built on top of international product information standards by global Standards 1. The GS1 Standards being used by the retail sector for decades are currently being developed to fit the manufacturing industries. GS1 provides standards for identifying, capturing and sharing information about unique products, parts, components and assets, business locations, and documents that enable industries to achieve visibility and life cycle management including the maintenance and repair processes (GS1a 2019).

By uniquely identifying products and components companies can use the identifiers to look up information about the product in a database provided by the manufacturer. E.g. during the end-phase of product life dis-assembly can be eased by scanning the product identifier to use it for lookup of dis-assembly information provided by the manufacturer. The unique identifiers, therefore, needs to be attached in the initial design and engineering stage of components and products. To illustrate this, we use a crane as example. In the model, the crane has different components namely, trolley, hook, sewing bearing, cab, wedges and counter weight. Each component is given a different Serialized Global Trade Item Number (SGTIN) to be attached to the component. The unique identifier can be encoded in e.g. a UPC barcode or an RFID tag. When these components are assembled, the final product "crane" gets another unique SGTIN identifier linking the crane SGTIN to each SGTIN of its components. The SGTIN attached to each of components would help in the later stages of disassembly such as maintenance, reuse, remanufacturing and reuse. The SGTIN information related to a unique crane is stored in the company data base. SGTIN will have information about manufacturing companies, the suppliers and material used e.g. master data and information about bill of materials. The sharing of

information is under the control of the manufacturer due to the security issue and threat from competitors. When the authors asked respondents, they argued that threat of copying of our components and material used inside the component is a big challenge they cannot share it publicly. In our model, we propose that the master data of company to be saved in the GS1 data base i.e. GS1 cloud and GDSN (Global data synchronization network). GDSN allows GS1 to be connected to different companies that want to exchange product data with their supplier or recycling companies. The information sharing of GS1 include data standards for master data, business transaction data, and physical event data, as well as communication standards for sharing this data between applications and trading partners (GS1 2018). Master data are valuable information about products of any company, it is stored in GDSN. In order to obtain information, the companies should register in the global register data pool by GS1.The GDSN can automatically share the business data with their trading partners (GS1 2018). This means that the required information regarding the product or its components will be shared and updated between the actors, i.e. the technical company and recycling company. In particular, to the company and GS1, GDSN will be a connecting network that will help the company to share and exchange their data in order to recycle and reuse its products and attain sustainability. For the sustainability of products, companies need to identify, measure, compare and transform the factors that improve production and consumption. Many of these factors inhabit the supply chain, as it is common having problems in complexity and problem in disassembling the parts. Using GS1 standards will help systematize supply chain data, ease its exchange and make efficient reporting against a sustainability profile (GS1 2018). In the GS1 Cloud, the data maintained in the GDSN database about brand-sourced data and the member organizations product catalogues are combined together with six new features about GTIN, Brand, label description, target market, product classification, company name. The data about crane components will be shared with the GS1, GDSN and GS1 cloud with permission from the producer and the information would only be given to the recycling companies i.e. Norsk Gjenvinning and Romerike Avfallsforedling IKS, by allowing access only by using the passwords and encryption of data. The recycling companies if get all the necessary data related to components and their material content. It would help companies in disassembling of components and recycle efficiently. For the privacy of information of manufacturing companies and their confidential data about product components there can be passwords, encryption that would be allowed to its users only. In a complete CE transition waste should be designing out always providing a next-use of materials. Products such as machines, electric equipment and other products with harmful substances, the substances should be extracted and reused. Hence, GS1 standards can help companies in extracting the harmful substances by giving company a specific identifier to each of their product and components. The *lack of product information about product design and production* is a barrier and this barrier can be removed by providing more accurate information. For this purpose, product information must be exchanged with product designers for later use in recycling, reusing and repairing. Consequently, another strategy to overcome this barrier can be, by formulating regulations for manufacturing industries to make them obliged to share product design information to the concerned recycling companies. The GS1 Global Data Synchronization Network (GDSN) concept can help in advancing the overall quality of the product information by automating exchange of master data information with trading partners. The GDSN concept has already been successfully deployed in health care by implementing unique device identification (UDI) in pharmaceutical companies. This implementation has increased the efficiency and flexibility, while also supporting regulatory requirements (GS1, 2018). We propose a

model for the technical industries based on the same principles applied in the health sector. See Figure 6.3 for the general concept. For details see (Naz and Rahim 2019).

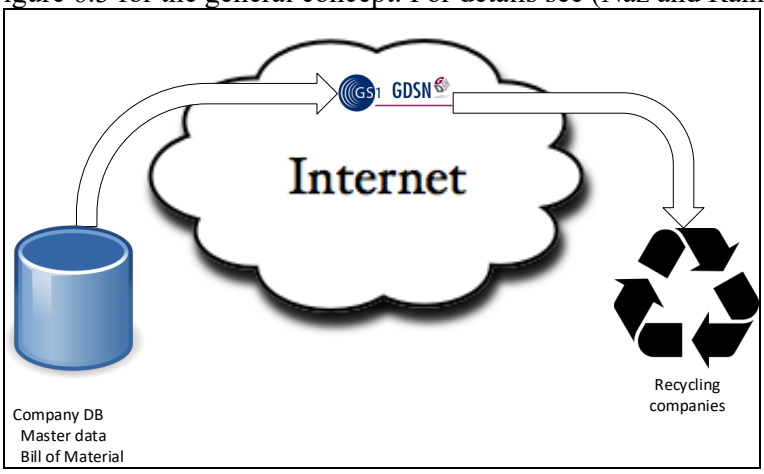

Figure 6. 3: Recommended Model for shift towards circular economy

Supply chain complexity and co-ordination problems depends on the information system used and differs from company to company. GS1 provide the standard EPCIS (Electronic Product Code Information Systems) for information systems that handle trace and track of products across their life cycle and across companies. Following the standard, companies can have a shared view of information related to each other's businesses. This would *reduce supply chain complexity, give more visibility and support coordination*. In addition, sharing of information about products and components with following GS1 standards would help recycling companies to disassembly products for reuse and recycling. Hence, through identification standard with EPCIS code, sharing would be possible with all the recycling companies and other relevant partners to overcome the barriers of complexity and cooperation in supply chain, disassembly of products by the recycler and product design and production by the engineers and producers.

Conclusion

In this paper we have identified barriers to the CE transition of manufacturing companies by doing a literature review. By carrying out case studies of three Norwegian companies, we found that the major barriers for implementation of CE were a quality issue in recycled materials, supply chain complexities, coordination problem between companies, design and production of the product, disassembly of products and high start-up cost. These barriers are a sub-set of what we found in the literature on barriers. Our findings show that the companies are well aware of the challenges of moving towards the CE. To help companies to overcome the barriers we proposed a model for a product information management system to be used by companies.

Limitations

The main limitation is the limited amount of data collected due to companies' confidentiality concern. Another limitation is that this study only focuses on one standard "identification" due to time constraint. Companies in this research have answered about CE and barriers in implementation but they, in reality, have only started on the CE adoption. Our proposed model should be tested to assess its applicability, and the use of GS1 standards should be contrasted with other standards.

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Operationalising circular economy business models: a three-level approach

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Abstract

Circular economy (CE) has been proposed as a possible solution for the unsustainable take, make, dispose mentality of linear economy. Circular business model (CBM) is a company approach to CE. The purpose of this manuscript is to discuss CBM implementation on company, supply chain, and community levels. Triple bottom line with environmental, economic, and social aspects of sustainability is used to analyse sustainability on each level. Through multiple case study method implementation is analysed in six CBM firms from the clothing and textiles industry. The results may help other firms in their CBM designs, as well as authorities in policymaking.

Keywords: Circular economy, Circular business models, Implementation

Introduction

In the recent years, the circular economy (CE) has received attention from governments, NGOs, companies, and consumers to contribute to the fight against global warming. The CE, also called the 'closed loop' economy, is an economic model which aims for environmental, economic, and social gains through the underlying culture of zero-waste (De los Rios & Charnley, 2017; Murray et al., 2017). The potential of CE includes creation of new businesses and job opportunities, savings on materials costs, decreased risks in supply chains, and reduced negative impacts on the natural environment (Kalmykova et al., 2017). In Europe a CE could benefit resource productivity by 3% annually, therefore enabling annual benefits of €1.8 trillion by 2030 (MacArthur, 2015).

The circular business model (CBM) is a company approach to the CE by the strategies of slowing and closing materials loops in production and consumption (see e.g. Bocken et al., 2016). Several types of CBMs applying these aims have been identified (Bocken et al., 2016) and frameworks for CBM innovation and implementation have been provided (Antikainen & Valkokari, 2016; Lewandowski, 2016; Nußholz, 2017). However, there is no common knowledge of how CE has been applied to company operations (Murray et al., 2017; Merli et al., 2018), company's supply chains (Masi et al., 2017; Geissendoerfer et al., 2018) and in the society.

This study explores CBM implementation from the firm perspective through a three-level lens adopted to CE from industrial ecology (Murray et al., 2017); micro (company), meso (supply chain), and macro (community) levels. Triple Bottom line (TBL) model, which defines the three aspects of sustainability (environmental, economic, and social) is

used as a tool to gain holistic understanding of sustainability on each of the three levels. In-depth multiple case study approach including six firms from the clothing and textiles industry is chosen to generate insight on this unexplored angle on the CBM. Companies born to CE (natives) and companies transitioned/transitioning to CE from linear economy (adopters) are taken into account to comprehend whether a company's foundation to the CBM influences its implementation. The research question is: How do companies implement CBM on company, supply chain, and community levels?

Theoretical background

Circular business model

The CBM is closely connected to the theories of sustainable business model, circular economy (CE), and industrial ecology. The CBM is considered to be one type of sustainable business model (Bocken et al., 2014). The origins of the CE are in economics and ecology, and industrial ecology is often seen as the closest antecedent of the concept (Murray et al., 2017). In the literature the terms circular economy business model and circular business model seems to be used interchangeably. This study employs the latter term. The CBM is also connected to the theory of business model. A business model is a description of the economic value creation, capture, and delivery logic of an organization (Osterwalder, 2004). A business model is further defined as a blueprint for strategy implementation through organizational structures, processes, and systems (Osterwalder & Pigneur, 2010).

Whereas the business model focuses only on economic value creation, the CBM considers value on a wider spectrum. Thus, value creation in the CBM connects to the aims of closing (Nußholz, 2017; Bocken et al., 2018) and slowing/extending resource loops (Nußholz, 2017; Bocken et al., 2018). The existing CBM studies focus on closing materials loops, whereas slowing materials loops has been given a marginal attention (Merli et al., 2018).

The CBM is typically based on environmental and economic sustainability. Social sustainability has been mentioned in several studies (e.g. Antikainen & Valkokari, 2016; Lewandowski, 2016; Rizos et al., 2016; Bocken et al., 2016; Merli et al., 2018; Geissendoerfer et al., 2018; Bocken et al., 2018), however, no study has taken it as an integral part of the definition of the CBM. Geissendoerfer et al. (2018) deploy a Triple Bottom Line (TBL) approach in the CBM, however, they do not seem to systematically utilize TBL in the analysis. In this study we define the CBM as: *The logic by which an organization creates, delivers, and captures environmental, economic, and social value by slowing and/or closing materials loops. The CBM includes the key structures, processes, and systems which are involved in translating the strategy into value*.

Theoretical background: circular business model implementation

One significant area of the literature on CBM implementation are frameworks for design and implementation. As a basis for frameworks, the business model canvas (Osterwalder & Pigneur, 2010) is typically used (Antikainen & Valkokari 2016; Lewandowski, 2016). To the original framework, some important elements added include: take-back systems and adoption factors (Lewandowski, 2016), as well as sustainability impact with environmental, social and economic requirements and benefits (Antikainen & Valkokari,

2016). However, it can be questioned whether adding CE elements to a canvas designed for a linear economy business model correctly reflects the CBM.

Another dominant area of the literature is challenges in the CBM implementation. Stål & Corvellec (2017) studied adaptation of take back systems, one type of a CMB, in linear economy companies within the apparel industry. They identified a horizontal decoupling between the take back system and the linear business model which still dominates the business. The contradiction between the linear BM and the CBM seems to be a hindrance in the CBM implementation.

A few case studies have identified challenges, enablers, and practices in the CBM implementation. In a study with 52 cases, Rizos et al. (2016) identified important challenges in SMEs' transition to a CBM from a linear business model: "*lack of support from supply and demand network"* and *"lack of capital*". Based on them, a successful CBM implementation depends on a "*green*" company culture, regional SME networks for raising awareness, and benefits of a "*green*" image (Rizos et al., 2016). Furthermore, Masi et al. (2018) identified challenges from the focal firm perspective in a survey with 77 cases: "major up-front investment costs", "higher cost for making and planning", "lack of clear, standardized, quantitative measurement and goals," "lack of awareness and sense of urgency," and "limited attention for end-of-life phase in current product". The most common CBM practices were: "taking back products from consumers after the end of their functional life" and "taking back products from consumers after the end of their usage" (Masi et al., 2018). Therefore, the focus on challenges indicates a lack of knowledge of the CBM implementation.

In the CBM literature it is frequently acknowledged, that in CE, cooperation with other actors beyond company boundaries is important (see e.g. Antikainen & Valkokari, 2016; Nußholz, 2017; Masi et al., 2018). However, most of the CBM studies focus on the scope inside the company, an exception being Masi et al. (2017) who also take the firm's supply chains into account. Furthermore, it is recognized that elements from macro (global trends and drivers), meso (ecosystem and value co-creation) and micro (company, customers, and consumers) levels should be integrated in the CBM innovation (Antikainen & Valkokari, 2016) and implementation (Lewandowski, 2016). However, only Geissendoerfer et al. (2018) have considered micro level influence on meso and macro levels. Each of their four Case firms had a proactive approach towards not only their shareholders but also internal and external stakeholders. They studied what value is captured by different stakeholders rather than how companies create, deliver, and capture value. As the micro, meso, and macro levels of the CBM implementation are not holistically studied in the CBM literature, a look on the CE implementation literature is taken to further comprehend the CBM implementation.

Theoretical background: circular economy implementation

In the CE implementation literature, the role of micro, meso, and macro levels is defined. CE implementation can be framed with three levels: micro (single firm or consumer), meso (eco-industrial parks, industrial symbiosis), and macro (city, province, region, nation) (Ghisellini et al., 2015; Merli et al., 2018). Firms, together with society, legislation, and policy, can be argued to have a central role in the CE implementation (Lieder & Rashid, 2016). This implies a concurrent top-down national effort and bottom-up company effort (Lieder & Rashid, 2016). A successful transition to CE requires collaboration and support from all the actors involved (Ghisellini et al., 2015). Therefore, CE implementation should include the micro, meso, and macro level initiatives with companies' bottom-up effort and the national top-down effort.

Ghisellini et al. (2017) divide the literature on the three levels to themes. The micro level includes: "*cleaner production", "green production and green public procurement*", "*product recycling and reuse, scavengers and decomposers*," and "policy". The meso level consists of: *"eco-industrial systems and industrial symbiosis districts and networks," "waste trade markets,"* and *"policy."* The macro level has: *"regional eco-industrial networks and productions, eco-cities, urban symbiosis", "collaborative consumption", "zero waste programs, innovative solid waste management systems,"* and *"policy."* They further write: "*CE implies the adoption of cleaner production patterns at company level, an increase of producers and consumers responsibility and awareness, the use of renewable technologies and materials (wherever possible) as well as the adoption of suitable, clear and stable policies and tools*."

The literature on CE implementation has focused on identifying evidence of the environmental and economic benefits (Ghisellini et al., 2015). Alongside with environmental and economic sustainability, social and institutional implications of CE are marginally considered (Merli et al., 2018). However, social sustainability is increasingly acknowledged as an important part of CE (Ghisellini et al., 2016; Lieder & Rashid, 2016; Murray et al., 2017). It is yet to be researched how companies in the CE adopt this value creation logic with economic, environmental, and social sustainability principles in practice on micro, meso, and macro levels.

Method and data

Multiple case study method (see e.g. Voss et al., 2002) is used to analyse CBM implementation on micro, meso, and macro levels. The method helps to guard against observer bias, therefore enhancing reliability of the method, and augmenting external validity (Voss et al., 2002). The clothing and textiles sector is selected as the industry because it creates more pollution than international flights and maritime shipping combined (MacArthur, 2017). In the industry value of more than USD 500 billion is estimated to be lost yearly due to the lack of reutilization and recycling (MacArthur, 2017). The textile production has also significant negative effects for the natural (Fletcher, 2008) and human environments (Turker & Altuntas, 2014). Life-cycles of the products can be as short as two weeks (Niinimäki & Hassi, 2011), which greatly contradicts the principles of closing and slowing materials loops.

Firms with CBMs were selected from Finland. Finland was chosen as the Finnish government has set the target of Finland to become the forerunner in CE by 2025 (Ministry of the Environment, 2018). The case selection was based on the literature (Patton, 1990): each selected business model is employing slowing and/or closing the materials loop principles (Bocken et al., 2016). As an additional sampling criterion, the firms with frontline CE achievements were selected (third party awards, sustainability acknowledgements, and/or placements in sustainability rankings). The cases include mainly SMEs. Two types of firms were selected. A half of the firms were natives, i.e. firms which' initial business models are based on the slowing and/or closing materials loops principles of the CBM. Another half of firms are adopters transitioning to CE i.e. those which have their origin in the linear economy (see Table 1). Semi-structured interviews were conducted with the founders of the companies or the persons officially or unofficially in charge of sustainability. Each interview protocol was formulated around the topics of drivers, values, and sustainable operations in the CE. Sustainability was discussed with the help of TBL model (Elkington, 1997). The interview questions were slightly modified during the data collection to take advantage of the emerging data (Spradley, 1979). The interviews were recorded and transcribed, and the accuracy of

information was verified by the company representatives (Voss et al., 2002). Validity of the interview data was enhanced by triangulating the data with information gathered from the companies' websites, brochures, sustainability reports, and emails with the interviewees (Voss et al., 2002). In the analysis the study employs an inductive approach, combining within-case with cross-case method (Eisenhardt, 1989).

Table 1 – Case descriptions

Firm	Employees/ Revenue (M€)	Description
Case A (Adopter) Founded 1820	155/ 36.33	Case A is a B2C home textiles firm, which started its transition to CE in 2014. It has approached CE e.g. by launching products made from recycled materials and emphasizing quality and long lifecycles of products. Motivation for CBM implementation was to gain competitive advantage by differentiation from competitors and the eagerness to break the silence about sustainability issues in the industry. The company operates accordingly to its three values: "*we are responsible,"* "*we are interested in the world*," and "*we are brave*." It has had several campaigns on social issues; inequality of salaries between men and women.
Case B (Adopter) Founded 1848	3500/ 176.06	Case B provides interior, workwear and personal protective equipment solutions for companies (B2B) of different sizes (workwear rental model is the focus of this study). The textiles rental service was implemented in the 1950's to gain competitive. In the firm's workwear solution model, the ownership of products stays at Case B during the whole life cycle. The firm chooses the right kind of garment care for each cloth to lengthen product life-cycle. The products proceed through four-use categories based on their condition during their lifecycles. Company values are *"profitable growth," "long-term customer relationships," "enthusiasm and the joy of learning," and "responsibility."*
Case C (Adopter) Founded 1983	105/ 6.98	Case C is a B2C women's garment manufacturer. In the company, responsibility has been important since founding of the company in 1983, but it has started the transition to CE in the recent years. Quality is essential in Case C's products and emphasis is placed on consistent quality and materials rather than variability of the selection. The CE efforts of the company include for example a garment collection in which recycled blended cotton and wood fibres are used, product transportation bags for own use from unsold products, and the redesign of processes to eliminate waste. Values of the company include "openness," "courage," "trust," and "responsibility."
Case D (Native) Founded 2003	10/ 1.12	Case D (B2B/B2C) was founded in 2003 on its values of "ecology," "ethics," and "aesthetics" with the aim of making a difference into a more sustainable world. The firm aims at minimizing the negative environmental impact of its products throughout the supply chains for example by aiming to minimize geographical distances and therefore also the emissions from transportation in supply chains. In 2018 the company's B2C product selection was revamped to consist of bags and accessories produced from recycled and left-over textiles materials and organic cosmetics. Case D also produces collections to B2B customers by commission from recycled materials, for example pack bags from the customers' old ad banners.
Case E (Native) Founded 2014	3/ 0.77	A casual wear producer (B2B/B2C) Case E was founded in 2014. Some of the founders had experience of running a CBM in the past. The need for the business idea emerged due to the lack of as sustainable textile as possible. The company uses fabrics mainly from left-over materials of sewing factories and materials are 100% recycled. The company factory was designed to be as good place to work as possible, and the company

		wants to show a sustainable example to other companies by its own actions.
Case F (Native) Founded 2008	18/ 1.66	Case F (B2B) produces workwear and PR products from surplus, recycled, and other sustainable materials and operates by the culture of no-waste. This study focuses on the firm's workwear business. The motivation for Case F to be founded was that a business can both be responsible and profitable. The company constantly aims to develop its sustainability and challenges consumers to do that as well. The company operates by its values of "quality," "trustworthiness," "openness," "innovativeness," and "responsibility."

Findings

Company level

It is evident the natives and the adopters have distinctive approaches to sustainability. Adopters emphasize long-term decision making in relation to financial stability. Two adopters, Case B and Case A, consider gaining competitive advantage from CBM implementation to be important. Case A also aims to find a "win-win situation" between the aspects of sustainability in its actions. Case C considers sustainability to be a part of everyone's tasks in a sustainability-oriented company. The natives have sustainability as the basis for all decision making. Case F and Case E seek to develop their businesses and consider economic motivations to be important, however not on the cost of environmental and social sustainability. Case D sees economic sustainability as an enabler for ecology and ethics. To summarise, the setups for decision making greatly differ, particularly if the natives and the adopters are compared. Whether a company emphasizes economic or environmental and social standpoints in decision making affects all CBM activities in a firm. The economic and environmental aspects of sustainability are identified as the most prominent ones. All the cases also take social sustainability into account to some extent. The extent of environmental and social sustainability action seems to be vaster in the natives.

The CBM suggests alterations to the company operating logic. In particular, in the firms utilizing recycled materials, materials based design influences operations. Case F and Case D reutilize customers old textiles which is an integral part of their business models. Case E utilizes cutting waste from textile factories as its main material. In the adopters, Case A has had projects where recycled materials has been used. Common is that recycled materials flows are not standard in their form and timing compared to materials in the linear economy. In adopters these characteristics of materials based design are still somewhat viewed as a risk factor. However, the natives see handling uncertainty of unstandardized materials flows as a part of the business expertise.

Quality of products and materials is emphasized across the cases. Quality is seen as one of the key features to long life-cycles and environmental sustainability. In Case B's workwear rental business model, quality is essential to keep the product in rental for a long time. Case A offers, for example, a 50-year guarantee for one linen sheet set and a five-year guarantee for duvet covers, pillow covers, and terry towels. At Case C, the emphasis is on consistent quality of materials and selection rather than on variability selection. The firms manufacturing from recycled materials also note that quality of materials needs to be good. For instance, Case D cannot use current consumer textiles as materials in its production due to poor quality. Additionally, functionality and design value of sustainable products were emphasized in several firms; they need to fulfil the customer needs in functionality and design. Case F mentions, that looking and feeling

good in a garment is important in workwear. Case D notes, the firm does not produce luxury, but aims to keep the prices in the reach of an average consumer. Several cases acknowledge that sustainable option is never the cheapest one. Particularly Case A and Case D feel their responsibility to educate customers about the price aspect.

Supply chain level

On supply chain level the companies are out to form requirements for sustainable operations. These include partners with shared values. Several firms mention that collaboration with companies with very different value bases would be difficult. Case B and Case A bring forth that they had to end collaboration with unethical partners. Based on the analysis, natives seem to have more partnership type of collaboration in their supply chains. The natives have chosen sustainable partners from the start, while the adopters are ensuring and improving their sustainability with their partners. The firms have formal and/or informal sustainability requirements for instance for working safety and waste management. Case B has a code of conduct which partners need to comply with. Case E only uses 100% recycled textiles, and this statement guides the criteria in their production; fulfilment is monitored by audits or visits to partners' premises. Case A, Case B, and Case F monitor more actively the places with higher risk, e.g. human rights violations in distant locations. Case D and Case F visit their suppliers' premises in Finland and Estonia, and Case E and Case C have their own factories. Values alignment in supply chains is seen as important for reaching the set sustainability targets.

Sustainability is present in the supply chain location decisions and transportation choices in some firms. Case D and Case F have a majority of their supply and manufacturing in the neighbouring areas. Based on them having geographically short supply chains decreases the negative environmental impacts of transportation. Case C has a large portion of the regular production at its subsidiary manufacturer in Estonia to ensure responsiveness and to minimize environmental impact of transportation. Case E found a sustainability-oriented shareholder in India and chose to locate its factory there in an area with expertise on fibre and textiles production, which for example Finland does not have.

The firms take into account sustainability of the product use period and end of life cycle. Garment care is a large part of the item's environmental impact, and Case E, Case F, and Case C have created garment care instructions which are available for customers. Case B has its own laundries and choosing for example the right washing temperature and interval are important consideration. Optimizing garment care contributes to lengthening product life cycle. Case F also has a take-back-policy for their products. The ownership of Case B products stays within the firm, the company takes responsibility of reutilizing or disposing the products. Already in the product design phase Case E considers the recyclability of a product for example in their own collection as they use water-based prints instead of oil-based.

The importance of openness as a way to spread sustainability knowledge also came up in the analysis. Case D, Case E, and Case F proactively share information about supply chain sustainability to its stakeholders. In some products Case F has a QR code where origins of the product can be viewed. Case F has also had some customers to visit their production sites to ensure that, for example, working safety is in order. Case A is also mapping their supply chain networks as a part of adopting a CBM and sharing information about supplier locations on country level on their web site. Case B has its sustainability policy available for its stakeholders as the company believes that they are better taken to practice when they are brought visible. To Case A and Case B one reason for mapping

their vast supply chains is also risk control. Negative surprises in SCs are less likely to surface when more is known about the SCs.

To summarise, ensuring supply chain sustainability is seen as a responsibility in several of the firms, especially in natives. The firms which have strong environmental and social considerations on the company level also actively implement these aspects in SCs.

Community level

On community level all firms have sustainability efforts. Some of the firms have the efforts rooted in their ideologies and therefore integral parts of the CBM. Being a sustainable example, voicing out social and environmental issues, and participating in industry sustainability initiatives aim for change making in the respective community of each firm. Case A, Case D, Case E, and Case F aim by their actions to be sustainable examples to others. They aim to wide impact, for example, from their example large companies and consumers learn about sustainability. Case F also mentions that its large customers who openly talk about sustainability projects they have created together increases the company's sustainability impact. Interestingly, the sustainability impact of these firms can potentially be much vaster compared to focusing on developing only operations. Particularly Case A and Case D have had campaigns and projects for voicing out environmental and social issues. Both of these companies have also had product lines to support these initiatives. Case D has been campaigning for example for transparency, human rights, fair trade, and lesser use of chemicals in manufacturing even before the legal and societal frameworks started to favour sustainability. Case A has had campaigns for social issues such as inequal salary for men and women, girls' rights issues, and racism.

Case A, Case D, Case E, and Case F have participated or are participating in industry sustainability initiatives. The focus of a couple of projects initiated by the government together with companies has been to develop CE solutions for the clothing and textiles industry. In fact, several firms have worked together in these projects. Case A, Case D, and Case E are also part of the group of the organizations initiating corporate sustainability law change in Finland to obligate companies to attend human rights by United Nations guidelines (ykkösketju.fi). Hence, many CBMs seem to include efforts for a legal framework change for sustainability. Overall, community level change making seems to be an integral part of the CBMs of the natives. In adopters the extent differs by company. The natives' objective to create social and environmental value can be seen to translate to community level in the actions described above.

Discussion and conclusions

The research question was: How do companies implement circular business models on company, supply chain, and community levels? The findings indicate that on company level standalone environmental and social value creation, competitive advantage, quality, design and functionality, producing for the need, materials based product and process design, recycling, and employee well-being were important CBM implementation practices. On supply chain level collaboration with partners with shared values, setting sustainability standards in supply chains, location choices, garment care, product end-of-life considerations, openness, responsible pricing, and risk control were identified as important CBM implementation practices. On community level being a sustainable example, voicing out social and environmental issues, charity, participation in industry sustainability issues, and rehabilitative working programs were important practises.

On company level the focus has been mainly on economic and environmental sustainability implementation, whereas on supply chain level social sustainability rose to more of an equal importance with the other two aspects. On community level social and environmental aspects were the most prominent ones; firms truly seems to aim for impacting behavioural change towards sustainability. The company level sustainability also reflects on the other two levels. In natives, sustainability has been integrated to all decision making from the day one, whereas adopters are implementing it piece by piece. CBM implementation focus and extent seem to differ based on whether a company is a native or an adopter. A lot could be learnt from natives of effective CBM implementation; they can be seen as vanguards. They are also eager to spread knowledge of sustainable values and operations. Adopters seem to expect a benefit from CBM implementation, but natives implement CBM because it has standalone value for them.

To conclude, neither CBM or CE implementation have been studied in the holistic context of three levels before, neither taking into account the three TBL aspects of sustainability. By increasing knowledge of more sustainable ways of implementing CE, the study contributes to acting against global issues such as global warming, overuse of natural resources, increasing pace of production and consumption, and social issues in the supply chains. The second contribution is that we study also natives in the CMB context; the current literature has focused on the CBM adopters. The results may provide guidance to other firms in their considerations of what to value in CE operationalization and what CE actions to implement. Also, findings can be helpful to authorities for policy making purposes by clarifying the incentives of CE companies. However, the CE operations discovered in this study are by no means an all-inclusive description of the key CE practices in firms, They rather provide some insights of the direction of CE implementation in CBM companies.

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Maximising loop flows in food supply chains: A circular economy perspective of analysis

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Abstract

This paper presents a methodological approach that combines circular economy perspectives with core industrial ecology concepts in order to specify a qualitative method to map food waste flows and the different industrial configurations across a food supply chain. The mapped waste flows and industrial linkages depict two time-related scenarios: 1. Current scenarios showing the status quo of existing food waste flows, and 2. Future scenarios pointing out circular economy alternatives along the supply chain. The framework provides a practical referential basis to inform benchmarking analysis and strategic alternatives for the reduction of waste in food supply chains.

Keywords: food supply chain; food waste mapping; circular economy

Introduction

The environmental sustainability of the food industry and its supply chain activities is a complex issue calling for sustainable practices that can be effectively achievable by the organisations operating in food value chains. In this context, food waste represents a major problem that remains to be addressed more effectively. The Food and Agriculture Organization (FAO) of the United Nations acknowledged that approximately a third of the global annual production of food ends up in landfill as waste (Mourad, 2016). An aggravating problem is that vital resources used in the production of food that is wasted are used in vain.

In order to improve its accountability and responsibility towards new expectations of customers and the society, the food sector needs to develop sustainable supply chains that minimise food waste across a wider spectrum of organisations from diverse sectors operating in different geographical contexts (Vermeulen, Campbell, and Ingram, 2012; Ghosh *et al.*, 2016).

Many managerial concepts, frameworks and approaches are grounded on the notion of 'waste' as a valuable 'resource' and they consider the extended scope of supply chains when addressing sustainability issues concerning production and consumption systems (Pandey, Surjan, and Kapshe, 2016; Steeneck and Sarin, 2017). Yet, extant literature reveals some criticism on the practical implementation of the quantitative methods they involve, which present operational barriers in terms of cost, access to customised quantitative data, involvement of expert know-how and interpretation of outcomes by managers (Lake *et al*., 2015; Scheepens, Vogtlander, and Brezet, 2016).

This paper addresses these limitations by providing a qualitative methodological approach to mapping current scenarios of food waste in food supply chains, as well as identifying alternative circular scenarios that can potentially replace disposal flows. We report preliminary findings of a study where the framework was empirically tested. The paper brings circularity perspectives advocated by the circular economy into the framework, this way expanding the methodological basis to support initial analysis of food waste and recovery scenarios in circular economy based approaches. Key questions addressed in the paper are: 1. How can we capture industrial configurations and related food waste flows in a food supply chain without engaging with too complex and costly methodological approaches? 2. How can we identify circular industrial linkages that can minimise food waste disposal in a supply chain?

In the next section we highlight key aspects concerning the analysis of food waste and organisational synergies. This is followed by a presentation of the theoretical basis underlying the proposed methodological framework of analysis. In the sequence, we briefly discuss the methodology of the empirical study developed to test the framework. The main research findings and conclusive thoughts are discussed in the subsequent sections.

Food waste and organisational synergies

To derive food waste scenarios and potential organisational synergies from supply networks is not a straightforward task. Previous studies have pointed out that approaches to analyse and mitigate the environmental impact of food supply chains without proper consideration of the interconnections that exist between organisations and sectors in the chain are likely to fail (Cellura, Ardente, and Longo, 2012). To deal with the environmental complexity of food supply chains, it is necessary to have the support of analytical framework methods that take into account the array of industries involved as well as their geographical configurations and potential cross-industry linkages in different regions across the supply chain.

In general, food waste can be a valuable input material for organisations inside or outside the supply chain they were originally generated. Finding food supply chain gaps where such valuable resources are being wasted into disposal flows rather than being absorbed in further production processes is a core concern of this study. In essence, this represents a major concern of the circular economy, which advocates production systems that are restorative by purpose, shifting production value chains from linear ('take-make-use-dispose') to circular ('take-make-use-recover') cycles (Webster, 2015). The transition to a circular economy predicated on production systems that take into account opportunities for circular cycles and cascading of products, by-products and waste outputs calls for a more comprehensive consideration of the potential circularities linking different supply chain actors (Dervojeda *et al.*, 2014; WEF, 2014; Nasir *et al.*, 2017). This complexity posits methodological challenges to analyse food waste scenarios.

For instance, the implementation of circular flows comprising closed- and open-loops of food waste materials increases the complexity and expands the scope of supply chain

operations in the circular economy context. Following the call for more integrative approaches to designing sustainable supply chains (Bals and Tate, 2018), the design of supply chains for the circular economy should take into account more holistic perspectives integrating the different types of circular flows that maximise the recovery of materials. A wider perspective of industrial linkages is therefore a fundamental methodological approach adopted in this study.

Methodological framework for qualitative food waste mapping

In this section we introduce a methodological framework for the qualitative analysis of food waste and potential organisational synergies in food supply chains. The framework synthesises core concepts and approaches from previous studies and knowledge areas into a more practical and less complex analytical method. For this, we draw from a methodological approach developed by Ardente *et al*. (2009), combining the initial steps of their approach with a standardised classification of food waste proposed by Darlington, Staikos and Rahimifard (2009). Food waste synergy scenarios are considered with basis on the food recovery hierarchy model specified by the U.S. Environmental Protection Agency (EPA, 2014) and core industrial ecology/symbiosis concepts (Chertow, 2007; 2000) encouraged by the circular economy. Figure 1 shows the key supply chain stages from which waste synergy scenarios are derived from. The scenarios are the main outcomes of the analysis process and they ultimately describe potential food waste synergies not only within and between the industrial activities of the supply chain considered, but also potential industrial linkages with organisations outside the supply chain in focus.

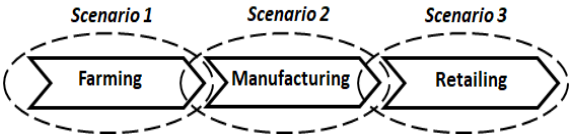

Figure 1 – Key industrial sectors from which food waste synergy scenarios are derived

Phase 1: Scope definition

The initial phase of the analysis involves specification of 'systems boundaries'. In this phase, we specify the unit of analysis and the systems-in-focus that are going to be investigated. The unit of analysis refers to the specific food supply chain in focus from which food waste and synergy scenarios are going to be drawn. The systems-in-focus refer to the organisations in each of the supply chain stages being analysed. As illustrated in Figure 1, the system-in-focus in each stage of the food supply chain that will be analysed are: 1. farming in the initial food production stage; 2. manufacturing in the food processing stage; and 3. retailing in the food gateway to consumption market stage. Organisations in the external environment of the systems-in-focus, i.e. outside the supply chain, will be taken into account regarding their potential to be involved in potential food waste synergies. With basis on Ardente *et al.* (2009), activities in this phase include: a. Specification of the unit of analysis, b. Definition of system boundaries and c. Identification of main industrial processes.

From an industrial ecology perspective, steps b. and c. above refer to the 'industrial inventory' process of the analysis, which in practice comprises the identification of local organisations in a specific region and their related resource flows. According to Chertow (2012), data concerning the inputs and outputs of relevant industrial processes are collected generically to form a base analysis from which further assessments can be developed.

Phase 2: Inventory of waste outputs

This phase of the analysis focuses particularly upon the identification and classification of the main waste outputs generated by the companies in the supply chain. For this, we apply the waste model for the food sector defined by Darlington, Staikos and Rahimifard (2009) as a basis to categorise, in a standardised way, the food waste and key by-product outputs identified in Phase 1. We adapt their model to specify a clearer differentiation among the five general types of waste in the food sector, namely: 1. *Processing waste* (material losses from the production process due to poor handling or processing failure); 2. *Wastewater* (water at the end of food processing or cleaning processes, which usually carries dirt or debris); 3. *Packaging waste* (materials disposed from packaging and re-packaging processes); 4. *Nonconformity waste* (edible food generated in the production process that have not achieved required market specifications); and 5. *Overproduction waste* (food that meets industry specifications but has to be scrapped because it no-longer has a consumer).

Phase 3: Scenarios specification

This phase involves the description of waste destination flows from each of the companies under study. The scenarios have two time-related perspectives, one portraying **current** waste destination flows and the other portraying **future** waste destination scenarios which involve industrial synergies that can potentially take place if circular economy practices are implemented. Ultimately, the future scenarios point out potential alternatives for supply chain transitions from linear to circular value chain ecosystems that divert valuable resources from disposal. Such initiatives are based on a fundamental principle of the circular economy, which advocates the implementation of sustainable production and supply chain systems that seek to prolong the lifespan of products, by-products and waste (Lovins and Braungart, 2014). This can be achieved through the purposeful design of restorative processes and supporting circular supply chains (De Angelis, Howard and Miemczyk, 2018).

The waste flows identified are classified according to the 'food recovery hierarchy' model of the U.S. Environmental Protection Agency (EPA, 2014), shown in Figure 2. The model provides a helpful referential basis to classify, in a standardised way, the current food waste destination flows and the future circular food waste destinations through which the environmental sustainability of the food supply chain can be improved.

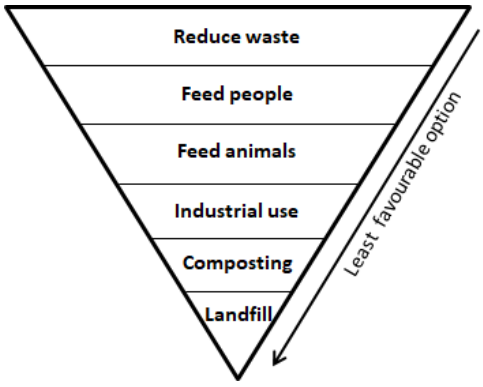

Figure 2 – Food recovery hierarchy model. Adapted from EPA (2014)

The hierarchy model also indicates an order of preference for processes that should be targeted as better alternatives for food waste to landfill (disposal). Accordingly, the future waste destination scenarios identify potential industrial connections that move current

food waste flows up in the hierarchy pyramid, and most importantly out of landfill destinations. This is done by matching food waste streams from one organisation with inputs at other facilities inside or outside the supply chain in focus. From a circular economy perspective, this represents identification of industrial linkages through which supply chain transitions from linear to circular systems can be achieved.

The identified waste flow scenarios are classified according to the spatial scale typology of industrial symbiosis proposed by Chertow (2000). Industrial symbiosis is a specific stream of the industrial ecology area that is concerned with the flow of materials that may involve industrial linkages between organisations or institutions from diverse industries engaged in physical exchanges of waste, by-products, water and energy (Chertow, 2007). This classification provides helpful insights regarding the geographical distances concerning waste flows, as distinct geographical configurations demand different logistics operations for the materials exchanges/flows envisaged. Table 1 describes the general types of materials exchange through industrial connections from a spatial perspective.

Table 1 – Spatial dimensions of industrial linkages

TYPE	INDUSTRIAL LINKAGES
Type 1: Through waste exchanges	Materials exchange involving third-party brokers or dealers that create trading opportunities for waste and by-products
Type 2: Within a facility, firm or organisation	Exchanges occur inside the scope of one organisation, without involving outside parties, e.g. between departments
Type 3: Among firms co-located in a defined industrial park	Exchanges involving organisations located within a determined industrial park
Type 4: Among local firms that are not co-located	Exchanges involving organisations that are not necessarily in the same industrial park; however, they are located in physical proximity within a specific geographical area
Type 5: Among firms across a broader region	Exchanges involving organisations that are not necessarily in geographical proximity; however, they can get engaged in materials exchange by capitalising on existing logistics systems

Source: Chertow (2000; 2012)

Methodology

The methodological framework above specified was empirically tested in a case study of a food supply chain. Following recommended data collection methods and techniques adopted in qualitative approaches, besides field observation and analysis of documents, semi-structured interviews comprised the major activity for the collection of primary data conducted in the study (Bryman and Bell, 2015). The interviews were conducted with the founders or CEOs of the companies in the supply chain studied. The interviewees therefore had a comprehensive understanding of their respective suppliers, customers and key input/output materials necessary for their operations. The case study approach allowed a comprehensive understanding food waste flows and identification of potential food waste synergies in the food supply ecosystem considered.

The unit of analysis for the case study comprised a supply chain of vegetables, and related derived products, comprising local companies in the UK. The supply of vegetables was targeted due to the increased challenges that products with fast perishability and short ‘shelf life’ bring to supply chain operations. Their production is usually associated with intensive use of water and re-packaging processes across the supply chain that represent additional sustainability challenges.

Research findings

Phase 1: Scope Definition

The supply chain analysed involved three key agri-business players in the production and commercialisation of vegetables and derived products, namely: A food grower, a food manufacturer and a food retailer. These specific operations represent the systems-in-focus of the study and they are typical production and service ecosystems in food value chains, with systems boundaries clearly defined at the level of farming, food processing and food retail service respectively (Figure 1). Table 2 provides a qualitative industrial inventory (Chertow, 2012) of the organisations in terms of generic input-output mapping of the main production and service operations involved. The real names of the companies are not shown due to non-disclosure agreements.

Table 2 – Qualitative inventory of the systems in focus

COMPANY A: FOOD GROWER – FARMING		
Main input materials	**Main operations**	**Main outputs**
- Water - Fertilizers - Seeds - Plastic sheets - Packaging materials	Cultivation of broccoli, carrots, runner beans and broad beans. Supplier of major UK supermarkets and open markets in the greater London region.	- Washed, trimmed and packed vegetables in small packs for supermarkets. - Large packs of vegetables for wholesale in open markets.
COMPANY B: FOOD PROCESSING – MANUFACTURING		
Main inputs	**Main operations**	**Main outputs**
- Water - Vegetables - Herbs/spices - Vegetable oil - Packaging materials	Manufacturing of vegetable soups, sauces and salad dressings. Supplier of major UK supermarkets.	- Fresh vegetable soups packed in Tetra Pak packaging - Sauces and salad dressings packed in Tetra Pak packaging
COMPANY C: FOOD SERVICE – RETAILING		
Main inputs	**Main operations**	**Main outputs**
- General groceries, including fresh fruits and vegetables.	Grocery retail Large chain of convenience shops in the UK.	- General groceries, including fresh fruits and vegetables, sold to end consumers.

Phase 2: Inventory of waste outputs

In this phase an inventory of waste materials was produced. The production waste created by each supply chain actor was identified and classified according to standard categories to facilitate qualitative analysis of the main types of waste generated across the supply chain. The results are presented in Table 3. The table shows that '**processing waste**' is by far the predominant type of food waste across the supply chain analysed. It is particularly critical at manufacturing level. This might be explained by the higher degree of complexity involved in the input transformation processes that take place in the food manufacturing context considered. '**Overproduction waste**' is an evident issue at farming and retail levels, suggesting difficulty of growers and retailers to match volume capacity with demand. While '**packaging waste**' is present across all stages in the supply chain, '**wastewater**' is more localised at farming and manufacturing levels. Indeed, vegetable washing processes are much more substantial in these two operational instances

when compared to retail operations. Finally, '**nonconformity waste**' is an issue of more concern for growers, which in fact have more difficulty to produce on a regular basis vegetables with the aesthetic specifications required by retailers due to varying climate circumstances that are out of their control.

Table 3 – Inventory of waste outputs

Company	Main waste material	Waste classification
A	**A1**. Vegetables that do not meet customer specifications (aesthetic requirements, labelling/packaging errors)	*Nonconformity waste*
	A2. Vegetable cuttings from trimming processes	*Processing waste*
	A3. Surplus vegetables (over supply quota)	*Overproduction waste*
	A4. Plastic, paper and cardboards	*Packaging waste*
	A5. Water from washing processes	*Wastewater*
B	**B1**. Vegetable, herbs and spices (spills, handling errors, machine failures)	*Processing waste*
	B2. Vegetable oil used on cooking processes	*Processing waste*
	B3. Packed vegetable soups, sauces and salad dressings (labelling errors, machine failures)	*Processing waste*
	B4. Tetra Pak packaging	*Packaging waste*
	B5. Water from washing and cooking processes	*Wastewater*
C	**C1**. Packed fresh vegetables (not sold by expiry date)	*Overproduction waste*
	C2. Packed fresh vegetables (packaging damaged)	*Processing waste*
	C3. Packed vegetable soups, sauces and salad dressings (not sold by expiry date)	*Overproduction waste*
	C4. Packed vegetable soups, sauces and salad dressings (packaging damaged)	*Processing waste*
	C5. Plastic, paper and cardboards	*Packaging waste*

Phase 3: Scenarios specification

Current destination flow scenarios for the main types of waste identified above are presented in Table 4. They are classified according to the EPA food recovery hierarchy model (Figure 2) and the spatial scale typology related to the organisations involved.

Most of the waste generated at the farming level (company A - grower) is destined to further industrial processes. More specifically, nonconformity waste A1 (vegetables that do not fulfil aesthetic requirements specified by retailers or present labelling/packaging errors after going through packaging processes) are currently sent to commercialisation in the wholesale market. This is the same destination of overproduction waste A3 (surplus vegetable produce), which is not under exclusive contracts with customers. Packaging waste (A4) go to recycling organisations located within the farmer's region area (type 4 spatial scale) and wastewater (A5) is treated within the farm (type 2 spatial scale) and used to reinforce its irrigation systems. From a circular economy perspective, waste A2 (processing waste resulted from vegetable cutting/trimming processes) represents a major concern, as it currently goes to landfill. The grower disposes A2 for collection by government contractors that provide waste collection services (Type 1 spatial scale).

At manufacturing level (company B), waste B3 presents highly recommendable flows in circular economy terms, as they are donated to NGO organisations running food banks and shelters in the region. The spatial linkage through which B3 flows is Type 4. However, the manufacturing company is not performing well in implementing sustainable waste flows for wastes B1, B4 and B5, which are currently destined to landfill.

Used vegetable oil (waste B2) is currently taken by a recycling operations in the region which refines cooking oil into biofuel for power generation and heating.

The current waste flow scenario at retail level presents good circularity capability, as there is no waste flow to landfill. While food not sold by the expiry date (wastes C1 and C3) is sent to local recycling operations that produce compost, food not sold due to packaging damage (wastes C2 and C4) is removed from the shelves and made available to local small farmers for animal feed purpose mainly. Finally, packaging waste (C5) is sent to local recyclers.

Table 4 – Current waste destinations in the supply chain

Company	Main waste material	Waste destination	Spatial scale
A	**A1**. Vegetables that do not meet customer specifications (aesthetic requirements, labelling / packaging errors)	*Industrial use*	*Type 5*
	A2. Vegetable cuttings from trimming processes	*Landfill*	*Type 1*
	A3. Surplus vegetables (over supply quota)	*Industrial use*	*Type 5*
	A4. Plastic, paper and cardboards	*Industrial use*	*Type 4*
	A5. Water from washing processes	*Industrial use*	*Type 2*
B	**B1**. Vegetable, herbs and spices (spills, handling errors, machine failures)	*Landfill*	*Type 1*
	B2. Vegetable oil used on cooking processes	*Industrial use*	*Type 4*
	B3. Packed vegetable soups, sauces and salad dressings (labelling errors, machine failures)	*Feed people*	*Type 4*
	B4. Tetra Pak packaging	*Landfill*	*Type 1*
	B5. Water from washing and cooking processes	*Landfill*	*Type 2*
C	**C1**. Packed fresh vegetables (not sold by expiry date)	*Industrial use*	*Type 4*
	C2. Packed fresh vegetables (packaging damaged)	*Feed animals*	*Type 4*
	C3. Packed vegetable soups, sauces and salad dressings (not sold by expiry date)	*Industrial use*	*Type 4*
	C4. Packed vegetable soups, sauces and salad dressings (packaging damaged)	*Feed animals*	*Type 4*
	C5. Plastic, paper and cardboards	*Industrial use*	*Type 4*

The current scenario analysis pointed out areas in the food supply chain where linear open flows of waste to landfill represent sustainability main issues of concern. The specification of future waste destination scenarios allowed identification of alternative industrial linkages that can potentially promote the shift of waste flows from open (linear flows to landfill) to circular (more sustainable) processes. Further improvements of waste flows can also be done through the identification of industrial linkages that bring food waste flows up the food recovery hierarchy. Figure 3 points out the areas in the supply chain where such improvements could occur. For example, the figure shows that circularity improvements at farming level could be achieved through the implementation of alternative flows for A1, A2 and A3 wastes. For instance, to improve social sustainability part of the A1 vegetables that are currently going to wholesale markets could be destined to feed people through NGOs running food banks or shelters. Vegetable cuttings and trimmings (waste A2) could be made available to local farmers for animal

feed purposes. Improvements on farming techniques and better demand forecasting would allow reduction of overproduction waste (A3). Further improvements are shown at manufacturing and retailing levels.

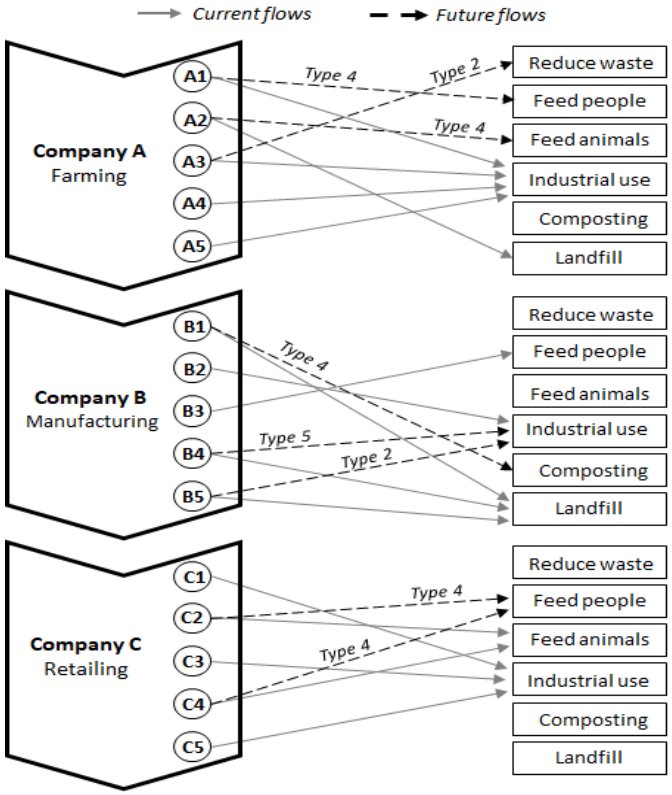

Figure 3 – Potential food recovery improvements in the supply chain

Conclusions

This paper introduces the theoretical and methodological basis of a qualitative framework of analysis that brings circular economy perspectives into the core of key knowledge areas supporting analytical tools applied in research concerned with the environmental sustainability of food supply chains. In the paper, our main intention is to put forward a qualitative methodological framework of analysis that is, in practice, realistically straightforward and simple to apply without being simplistic in terms of its conceptual basis and supporting antecedent frameworks.

We encourage future research that involves complementary quantitative data in mixed method approaches that expand the analytical contributions of the framework here developed. For example, the different contexts of waste hierarchy processes, categories of food waste, and spatial scale of industrial linkages can all be numerically scored. Depending on the availability and access to data from the organisations being analysed, this can be combined with figures related to cost reduction and revenue enhancement enabled by potential exchanges of food waste materials that can take place in the future. Such quantitative perspective can be applied to facilitate comparative analysis and to support simulation applications showing how emergent industrial ecosystems influence the potential costs and revenues of the organisations involved.

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Conceptualising peer-to-peer support for sustainable manufacturing advance

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Abstract

The sustainable manufacturing literature informs how to technically change but is weak on how an organisation should facilitate the change. We know that organisations learn quickly from external sources, especially peers, but that technical practices and tools alone are insufficient to replicate and sustain improvements. Communities of practice could frame how organisations make use of sustainable manufacturing knowledge and how learning is shared within and beyond manufacturing sites through peer-to-peer support. This research seeks to capture how organisations share knowledge beyond site boundaries and how sustainability leaders in companies, often without dedicated teams, engage in sharing for mutual benefit.

Keywords: Sustainability, peer-to-peer support, communities

Introduction

The sustainable manufacturing literature can inform how to technically change but is weak on how an organisation should facilitate the change, especially when working across site boundaries. Lean manufacturing (Womack & Jones, 2005) shows us that technical practices and tools alone are insufficient to replicate and sustain improvements (Drew et al., 2004). Advancing sustainability (Mejías et al., 2016) demands tacit knowledge that will be impacted by the willingness to share and receive (Dudley, 2006).

We know that organisations learn quickly from external sources (Cummings, 2004) and adopt new organisational routines (Argote & Ingram, 2000) through organisational learning theory. Additionally, communities of practice (Bodrožić & Adler, 2018) allows us to frame how organisations make use of sustainable manufacturing knowledge and how learning is shared within and beyond manufacturing sites. Whilst these theories have the potential to address peer-to-peer support, there is little work in sustainable manufacturing (e.g. Davies, 2012) and knowledge on the barriers focus on the individual and neglect the organisation (Ball & Lunt, 2018).

The purpose of this research was to conceptualise how organisations share and receive knowledge beyond site boundaries and how sustainability leaders in companies (who often operate without dedicated teams) engage in sharing for mutual benefit. Whilst it is known that companies of the same type, in similar supply chain positions and potential competing in the same market may share (MacBryde & Ball, 2018) little is known about how different companies share and support, especially through community and peer-to-peer exchange. The motivation for better understanding is driven by the urgency to

address the impact of manufacturing on global resources. Through better understanding of sharing it could be possible to support manufacturers in faster and more extensive change for their own and global benefit.

This paper first considers the literature on sustainable manufacturing and how knowledge sharing and communities of practice could influence the adoption of better practice. The methodology followed by the findings detail how two different industrial networks shared knowledge between peers and the analysis to derive a conceptual framework that is underpinned by a community for sharing. The ongoing work is briefly presented before the contribution is restated.

Literature

Manufacturing operations need to reduce their environmental impact by considering input cost, waste cost, regulation and 'doing the right thing' (Giunipero et al., 2014). One way forward is to adopt lean thinking. The links between lean and green have been well documented with, in general, those implementing lean having better green performance (King and Lenox, 2001). Whilst Martínez-Jurado & Moyano-Fuentes (2014) see the link between lean and sustainability as the "new frontier", Yang et al. (2011) working on practice bundles argue that lean is insufficient to improve environmental performance.

Claro et al. (2013) assert that leadership is key for implementing practices and this leadership must be an organisational commitment to properly motivate those designing products and services (Pagell & Wu, 2009). It is likely that the skills learnt for lean achievements help with the skills for environmental achievements (Hajmohammad et al., 2013). Mollenkopf et al. (2010) argued for collaboration to share knowledge and build capability by working across the supply chain.

The willingness to share knowledge and the willingness to receive knowledge are two key aspects of how knowledge within and across supply chains can propagate. Dudley (2006) recognised the importance of relationships for smooth knowledge transfer. For sharing, a sense of identity (Bresman et al., 1999) is important for knowledge exchange, so too is physical interaction, e.g. through meetings and visits (Kohlbacher & Krähe, 2007). For receiving, motivation is important for absorption (Minbaeva et al, 2014) as well as similar understanding and language (Cohen & Levinthal, 1990). Underpinning this transfer, especially for tacit knowledge, is trust (Dyer & Nobeoka, 2000). In summary, knowledge, especially tacit knowledge, sharing is enhanced through physical interaction of individuals who identify with one another through common language, common understanding and a shared sense of identity. Peer-to-peer sharing therefore offers an effective conduit for the dissemination of sustainable manufacturing practices.

Knowledge exchange between companies in pursuit of sustainable operations is emphasised by Gavronski et al. (2012) for organisational learning. Apart from a few works (e.g. Davies, 2012), there is an absence in the sustainable manufacturing literature. The relevance here is that organisational learning theory (Argote, 2011) can be used to understand routines which include rules and procedures (Levitt & March, 1988). Davies (2012) presents a conceptual framework detailing the flow of learning from a trigger to change through to people learning that improves understanding and in turn new methods that results in improved eco-performance. The focus on routines is important to distinguish between the knowledge of an individual and the knowledge embedded within an organisation independently of the individuals. Inter-organisational learning (Gieskes et al., 2002) offers a conduit to move expertise and practices from one organisation to elsewhere in the community.

Communities to support this could endorse knowledge to encourage others to adopt practices and promote the 'stickiness' of those practices (Brown & Duguid, 1998). They

focus on the socially embedded knowledge that allows both the 'what' as well as the 'how' of the practice to be transferred. Cox (2005) see the theory of community of practice as defining the facilitation of a group (virtual or informal) to share with one another and learn from one another. The evolution of technology revolutions has seen the transition from strategic integration to one of networks (Bodrožić & Adler, 2018) that emphasise knowledge management in which we "cultivate the communities of practices needed to sustain innovation in … dispersed value-chain activities". The knowledge of a practice and the actual practice itself is different (Gherardi, 2009) and so communities of practice to foster the exchange of tacit knowledge aids communication of practices beyond accessing practice repositories, literature on practice types, etc.

Whilst a focus on people and their communities would be advantageous, barriers may occur. A barrier hinders the achievement of improved efficiency (Jaffe & Stavins, 1994) and may describe fear of change, lack of urgency, lack of tools, lack of knowledge, absence of vision, etc (Lunt et al., 2014). Overcoming these barriers through 'remedies' or enablers will permit advance. Overcoming the barriers in the context of communities that share practices and support one another offers a means to advance sustainable manufacturing using existing practices.

The sustainable manufacturing literature has significant work what practices companies are using and in turn what they are achieving as a result. With the organisational learning and communities of practice literature there is significant work on how knowledge is embedded with organisations and how communities are able to share that knowledge within and between organisations. What is absent is how sustainable manufacturing practices are shared. The literature tells us what has been shared but not the underlying mechanisms of exchange and what helps and what hinders that exchange. In particular there is an absence of work conceptualising the exchange between peers. A better understanding of such peer-to-peer exchange through communities, especially beyond the boundaries of individual companies, could inform how to facilitate wider and faster spread of practice to reduce the impact of manufacturing operations.

The research objective is therefore to understand how communities of practice can capture exchange and be used to foster sustainable manufacturing advance. In particular, what motivates peer-to-peer sharing and how it can be supported.

Methodology

The research sought to understand how sustainable manufacturing practices are shared across operations. We know what practices can be adopted and the corresponding typical performance improvement. What is less well understood is how those practices are shared across networks, whether within the same enterprise or across multiple enterprises. This research was therefore exploratory to inductively characterise how manufacturing organisations share knowledge.

The research draws empirically from UK manufacturers. The work reported here sought to understand how they adopted sustainable manufacturing practices with the support of networks and communities. Data was gathered from companies within two UK manufacturing sectors. The unit of analysis was a company including its sustainability lead and local improvement team. Whilst supply chain interactions beyond the company boundary were acknowledged they were not investigated.

Firstly, a single company with a formal sharing network operating across its 11 sites that formed an internal supply chain was examined (Network 1). Secondly, 26 companies from the same tier of a distinct sector who interacted in an informal collegiate way was considered (Network 2). Companies approached were those motivated to improve their sustainability work and were self-selecting for inclusion. A grounded approach was used

to capture the enablers for sharing, apparent barriers and actions to remove those barriers to aid further sharing. Of interest was how sharing took place from transactional information transfer to learning through joint activity.

A process thinking mindset in line with lean manufacturing thinking was used to capture and structure interactions. Data analysis was by coding and clustering to capture characteristics. Codes (e.g. a type of barrier or practice) were refined into final codes which are shown as the barriers, practices, etc). Clusters were formed around how the sharing took place. Two separate networks were investigated so further consolidation of results was carried out as a second phase.

Findings

Industrial networks

Two industrial networks are used to characterise the practice sharing in pursuit of sustainable manufacturing advance. The first is a formal network that was created across a multi-site, multi-country enterprise. The second is an informal network that exists within a specific industrial sector that grew out of shared passion for the products produced and sold.

The first network (Network 1) was a European aerospace manufacturer that initiated an industrial energy efficiency network to engage multiple sites in energy and other resource reduction. The programme of reduction consisted of a lead (or champion) in each site responsible for reducing consumption against agreed targets and connected together by a network lead. The network lead did not have line management responsibility for the site leads and the site team members were not necessarily line managed by the site leads. Each site used a common improvement method that had been incorporated within the enterprise lean production system. Site leads and their teams were trained on the methods to deploy and would maintain regular contact with the network lead and in turn the other network teams. The contact between the teams consisted of day-to-day informal direct contact, formal virtual sharing on a monthly basis and regular, less frequent assembly at a given site. The teams were also virtually and physically supported by the network lead. The achievement against target was reported formally in the site management reporting and collated by the network lead. Through observation, document analysis and interview, data was collected on performance achievement, practices implemented, enablers to success and barriers hindering or preventing success.

The second network (Network 2) was a UK beer brewing network that had grown from years of mutual support. Breweries have multiple strong brewery-to-brewery links, often within a locality as well as openness new links from any brewery. The community had formed out of smaller brewery shared interest in production of high quality ‘craft ale’ and selling in competition to the ‘goliath’ multinationals (although no significant barriers to exchange were overt for such parties in workshops). The improvement lead for a brewery tended to be the head brewer reflecting production knowledge and the small size of most breweries. Brewers tended to come from within the brewing industry or business outside of manufacturing. So, whilst brewers would use language, descriptions and motivations that could be recognised by a manufacturing engineer, the language was not typical of manufacturing hence lean thinking and sustainable manufacturing were not cited explicitly. Sharing could be by email, messaging apps, etc. but was more typically combined with mutual interest for the product within a brewery. Such sharing could therefore arise from scheduled workshops or site tours or more ad-hoc meetings resulting from a challenge a particularly brewery was seeking help on. Through observation, workshop output and interview, data was collected on the typical metrics used, the practices implemented, enablers to success and barriers hindering or preventing success.

Barriers

A barrier is used to describe a condition that may hinder or prevent an improvement process taking place. It could refer to something related to process (the first six lines in table 1) such as absence of supporting techniques, to people (the next five lines in table 1) such as a lack of knowledge or to tools (the last three lines in table 1) such as insufficient metering to gather data. Such tools (inc. hardware), processes and people categorisation draws on the technology, management and people categorisation used by Sarkis (2001). Using Lunt et al. (2014) as the reference point for barriers to progress in energy efficiency projects in manufacturing, evidence for the presence of barriers was sought in the two industrial networks.

In Network 1 numerous barriers were evidenced from observation of difficulties in progress on projects in the enterprise manufacturing sites and from project documentation (meeting minutes and final reports). Checks for the barriers revealed many existed that hindered the progress of the improvement projects. During the period of data capture some barriers remained throughout, some were removed, and some grew stronger. Key barriers captured in Network 1 are displayed in Table 1 against the bands of process, people and tools. For the process barriers, accountability was referred to disconnect between the local improvement objectives and corporate strategy. This disconnect with strategy was tolerated for a while as site managers site emphasised the priority of the resource reduction projects. Some projects could have been easier to manage had the team making the improvement seen benefit of the cost savings realised as well as them, rather than others, being the beneficiaries. For the people barriers, two key problems were identified. Firstly, insufficient staff were allocated to some projects and, in a few cases, staff were later redeployed on unrelated projects. Secondly, it took time for staff to have confidence in their decision making because of the training. For the tool barriers, initially there were problems access funds for capital acquisition and that the information needed for decision making was either not in a suitable form or data needed to be collected first with portable metering.

Table 1. Barriers reported for the two industrial networks

Generic descriptor	**Network 1**	**Network 2**
Accountability	Metrics and reporting not aligned	*(absent)*
Priority	No link to key metrics	No internal/external pressure
Principal-agent	Beneficiary elsewhere in company	Beneficiary not company
Split incentives	No reward for advance	*(absent)*
Selection	*(not significant)*	No available methods/techniques
Urgency	No link to strategy	Motivation to focus. Water cheap
Resourcing	Staff not allocated / redeployed	Lack of available people
Training	*(not significant)*	Time to do, ability to access
Knowledge	*(not significant)*	Competence to analyse & adapt
Bounded rationality	Making decisions confidently	Prioritisation of spend
Quality fear	*(absent)*	Fear of product quality impact
Capital	How to access funds	Small breweries, poor cash flow
Form of info.	Ability to obtain useful reports	*(absent)*
Incompletion info.	Ability to collect data	Lack of metering

In Network 2 similar barriers were reported and also appear in Table 1. For process barriers, priority was highlighted due to the lack of pressure from consumers or regulators to improve. In a few cases saving water or separating wastes did not benefit the brewery

due to tenancy or municipal arrangements. Additionally, the lack of methods and techniques available were low, in part resulting from a view by some that resources such as water were cheap. For people barriers, the small size of many breweries meant time, additional resource and competence hindered sustainability improvements. This was amplified by a caution towards product quality and the difficulty in judging where to spend funds most effectively. Finally, for tool barriers, the lack of data for decision making was further hampered by small cash reserves to fund decisions.

In Network 1, the site leads each experienced many of barriers cited. Through the guidance of the network lead, these barriers were shared to make each other aware of what may cause problems for future projects as well as trigger actions to mitigate these barriers through 'remedies' or enablers. In Network 2, the leads detailed the barriers they faced, many of which were people related. The people related challenges could explain why the network was openly helpful to each other which leads onto how the companies enabled their improvement work.

Enablers

An enabler is used to describe a positive condition supports improvement activity. It could refer to something related to process (the first three lines in table 2) such as a clearly articulated vision, to people (the next four lines in table 2) such as a mutually supportive community or to tools (the last two lines in table 2) such as enough equipment to gather necessary data.

Network 1 was a formal network in a multi-national hence guided by a distinct vision and strategy. Through incentives and accountability, the company was able to align activities to objectives and create a sense of urgency. Training was developed and delivered early in the network life and was built around a standard methodology (adapted from one developed by a previous project collaborator in another industrial sector) that had been piloted in the same site as the network lead. Through brokerage with site managers, a site lead and associated teams were formed from competent members of different site functions. The network lead fostered the interaction between the network lead and the site leads and encourage site to site interaction. Using standard company reporting the teams evidenced their activities and used the mechanism to share knowledge within and across the sites. Finally, by improving the metering and the subsequent software reporting of the data captured the site teams were able to utilise the standard methodology to make decisions more quickly and more confidently. The sharing that took place across the network of how to use the methodology, how to overcome problems, how to rationalise sometimes conflicting requirements enabled the teams to overcome barriers and achieve significant improvements in resource utilisation. It was observed that collegiate team members would help those in other sites unprompted out of a shared imperative without direct benefit to themselves. These enablers are summarised in column one of Table 2.

Network 2 was an informal community of like companies in the same sector and same supply chain position as each other. The vision therefore was not a formal corporate one but based on core company values and development of their individual brands. The small size of many of the companies meant that improvement activities to reduce resource use or increase production intensity had a meaningful direct link to profit. Many of the individuals had not received formal training but informally mentored one another through mutual support and direct knowledge sharing. It was observed that sharing was more detailed than would be acceptable practice in other industry sectors, illustrating the level of trust and shared endeavour that exists here. Interestingly, within brewing the level of cooperation goes well beyond knowledge sharing and with many formal and informal

practices from sharing facilities to cask swapping (for selling each other's beer) and from short term help on raw materials to co-developing products. Whilst Network 1 was data driven, Network 2 company leaders had line of sight and intimate knowledge of their entire process and therefore would readily connect own operational metrics and own visual observations with the practices of other companies to support decision making. Standard metrics reported across the sector allowed ease of interpretation as well as benchmarking. All companies used site level metrics and those that used more localised metrics reported immediate behaviour changes that in larger companies would typically need analysis prior to process change. Demonstration and endorsement of practice strongly influenced knowledge transfer and practice acceptance. Communities formed out of physical visits to breweries and continued virtually (e.g. WhatsApp groups). These enablers are summarised in column two of Table 2.

Table 2. Enablers reported for the two industrial networks

Network 1	**Network 2**	**Generic descriptor**
Vision and strategy	Values, brand focus	Vision
Incentives and accountability	Activity linked to profits	Operational responsibility
Objectives and urgency	Operational metrics (input, process, output)	Objectives and targets
Training and experience	Informal mentoring	Training
Standardised methodology	Resource efficiency mindset, replication of proven ways	Methods
Available and competent staff	Knowledge sharing, cooperative attitudes	People
Network sharing and learning	Virtual networks, physical visits	Community
Company standard reporting	Industry standard reporting, visual	Data provision
Metering and reporting software	Metering	Equipment

The Network 1 and Network 2 enablers show strong similarities in what guided motivation to change, how performance was captured, how people shared knowledge and where part of virtual and physical community interaction. The enablers from both networks are aligned within Table 2 and common generic descriptors are used to capture the generic enablers of: Vision, Operational responsibility, Objectives and Targets, Training, Methods, People, Community, Data provision and Equipment.

Conceptual framework

Drawing from the network barriers and enablers findings, a conceptual framework to capture the overall behaviours has been derived and is presented in Figure 1. The enablers and barriers are drawn from Table 1 and Table 2 respectively and categorised into process, people and tools as before. The linkages are drawn from the work of Davies (2012) work on organisational learning for sustainable manufacturing cited earlier. The associations between the barriers and the enablers are derived from the network data on what actions leaders and teams took to mitigate against the barriers they are faced with. The flow from left to right exists to illustrate the journey from having the justification to make changes, the people and process to approach change and the practices changed leading to improvements captured by the site and process metrics.

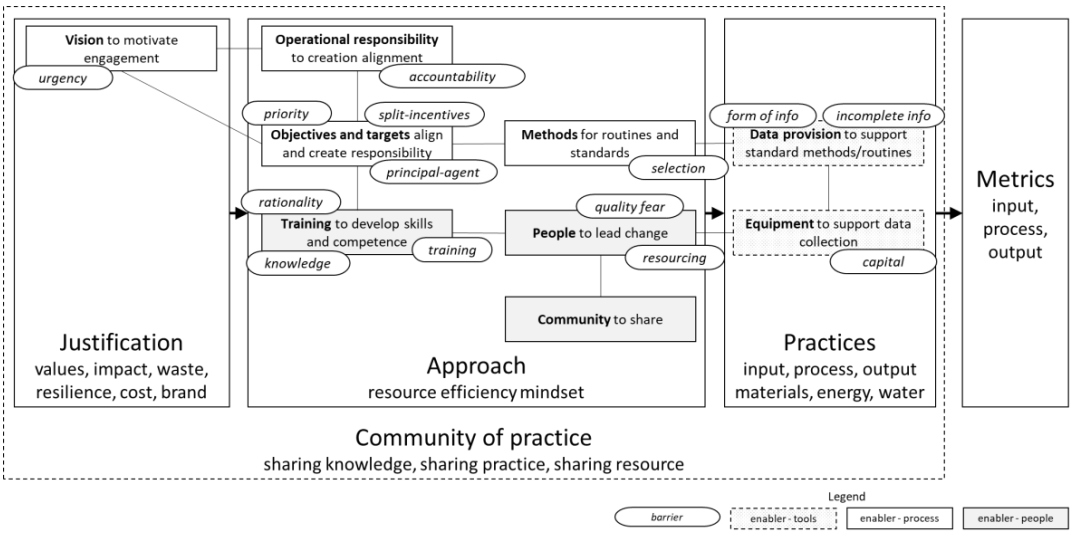

Figure 1. Enablers and barriers for advancing sustainable manufacturing

The community aspect was a prominent conduit for the sharing of knowledge, sharing of specific practices and, in some cases, providing help to others. It is significant that this sharing takes place across boundaries for which there is no command and control structure. Individuals did not have to share but saw mutual benefit in meeting (physically and virtually) to help one another. The practices being shared were not new to the field but can be considered new to each individual site. The community of practice therefore offers a means to explain and foster the advance of sustainable manufacturing practices across the companies.

The research captures how clusters of companies engaged in sharing sustainability knowledge with others on a mutual basis. The work differs from existing forms of digital exchange (through knowledge portals), verbal presentations and 'industrial tourism' as it engaged those in the cluster to actively help one another beyond simply exchange of information. Whilst good practice was revealed through presentations and tours, the communities are not just sharing high level knowledge but willing to trust in peers and assist one another.

There is little peer-to-peer learning and communities of practice literature focused on manufacturing operations and in particular sustainability programmes within them. Whilst there are different interpretations of how a community is defined (Cox, 2005), there is commonality in the language of collective learning, informal groups, membership cutting across boundaries and improvisation/unstructured pathways. Whilst some works see the community as one of equals others cite a more master-apprentice type relationship. In the research here, all were willing to learn from others who have particular knowledge but the exchanges identified were between equals in terms of general expertise and standing. The research outcome here provides context for the community specific to manufacturing operations. In particular it links the behaviour of the community with the activities of the community.

Ongoing work

The learning as led to the set up of two formal peer-to-peer networks involving non-competitive companies. The first from sub-sectors of food and drink for sustainable manufacturing, second looking at sharing new product introduction good practice with a geographic region. Acknowledging the barriers and enablers, the network addresses a shared ambition to seek further advance in improvement beyond individual company

current trajectories. The networks are made up of peers who are responsible for leadership of sustainability and design respectively, driven by their own company strategies. They have similar levels of achievement and target improvements and have a similar level of (advanced) competence. They are able to marshal teams within their companies and have experienced community and network sharing previously. Importantly, the interactions are at each site in turn with the visits split between the sharing of achievements and the presentation of challenges. The mix of "give and take" provides immediate gain for all, especially the host, prior to rotation to the next company in the network. The visits seek to provide consultancy-like input into each company in turn. This draws on the advantages of the formal single enterprise Network 1 and the informal multi-company community of Network 2.

Conclusion

The research has revealed the common barriers and enablers for sustainable manufacturing improvement for multiple sites of a single enterprise and multiple similar enterprises within a single industrial sub-sector. The community support and sharing of knowledge and specific practices reveals the willingness to help peers and others in the absence of immediate reward or fulfilment of line management expectation.

The research therefore contributes to the communities of practice literature by characterising how sustainability practice is shared from a manufacturing operations perspective. What motivates individuals to participate in peer-to-peer exchange and how it is justified to colleagues has been absent from the sustainable operations field. Capturing how tacit and explicit information is transmitted and received between organisations that may not have a formal relationship provides new insights to how sustainable manufacturing can be advanced. The characterisation focuses on how peer-to-peer sharing can foster advance through a community perspective on barriers and enablers.

From a practice perspective, such decentralised sharing offers an opportunity to enable organisationally 'lean' companies to advance through learning with trusted peers without incurring significant cost. From a policy perspective, this could have potential for facilitating rapid, cost effective change in manufacturing.

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Purchase intention towards remanufactured products: A systematic literature review

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Abstract

Remanufacturing is one of the processes to extend products' life cycle in closed-loop supply chain. The process runs by OEMs, certified firms or third parties and flows as receiving used products, making them function at least the same as brand new one and selling them again with warranty. Despite highlighted economic and environmental benefits, the remanufacturing industry is still underdeveloped with great opportunities. Due to the nature of the process, understanding customers' perception and purchase intention are vital for further and faster development of the industry. This paper reviews 26 journal articles.

Keywords: Remanufactured product, purchase intention, systematic literature review

Introduction

Remanufacturing is a closed-loop supply chain (CLSC) strategy that aims to recover the residual value of returned products (Wang *et al.*, 2013; Bittar, 2018; S. Wang *et al.*, 2018). It is a process that brings used-products to like new condition with warranty and at least the same quality, functionality, and performance as brand new ones (Jiménez-Parra *et al.*, 2014; Bittar, 2018; Vafadarnikjoo *et al.*, 2018). The process involves stages of product acquisition, disassembling returned products, cleaning, repairing or replacing worn-out parts, quality testing, reassembling and remarketing (Wang *et al.*, 2013; Bittar, 2018; Vafadarnikjoo *et al.*, 2018) that is an industrial process (Wang and Kuah, 2018). Remanufacturing is fundamentally different from repair, recycle, and reuse due to the requirement of converting the product to like a new one (Xu *et al.*, 2017; Matsumoto *et al.*, 2018a; Vafadarnikjoo *et al.*, 2018). The difference between these is not well understood in the market (Wang and Kuah, 2018). Therefore, these terms cannot be used interchangeably. On the other hand, the term refurbished means the same as remanufactured (McKie *et al.*, 2018).

Due to global sustainability issues, many countries took legal actions to promote sustainable actions (Qu *et al.*, 2018) and reduce carbon footprint such as the Paris Agreement. Also, customers become more sustainability-conscious and sustainability measures influence their purchase decisions (Vafadarnikjoo *et al.*, 2018). These players put pressure on organisations to take action towards becoming more sustainable and even they can gain competitive advantage by becoming greener. The benefits of remanufacturing mentioned in the literature are minimising landfill and waste, reduction of energy usage, increase sustainability consciousness, reducing manufacturing costs (Qu *et al.*, 2018; Wang and Kuah, 2018).

The success of remanufactured products in the market is dependent on customer acceptance (Wang and Hazen, 2016; Y. Wang *et al*., 2018) which is mentioned as one of the main obstacles for remanufacturing industry (Vafadarnikjoo et al., 2018). This is also a reason why organizations do not challenge themselves in terms of sustainability because the profitability of remanufacturing activities is dependent on sufficient demand for these products (Wang et al., 2013) which is not high enough yet. Hence, understanding the potential customer and their perception has critical importance to have a place in the market and improve CLSC performance (Xu *et al.*, 2017; Qu *et al.*, 2018; Y. Wang *et al.*, 2018). One of the ways to improve customer acceptance level suggested is that highlighting and promoting potential benefits of purchasing remanufactured products to convince customers to consider them as an option (van Weelden *et al.*, 2016). The research focusing on marketing, and customer acceptance of remanufactured products is limited (Bittar, 2018; Matsumoto *et al.*, 2018a, 2018b; McKie *et al.*, 2018; Wang and Kuah, 2018).

Accordingly, the overall purpose of this literature review is drawing an overall picture of customers' perception of remanufactured products and influencing factors by reviewing the journal articles. The outcome will be helpful to form future researches with the aim of establishing better remanufacturing strategy to reach more customers. This paper will try to answer the following review questions with the findings from the literature.

Review question:

- What are the factors influence potential customers' purchase intention towards remanufactured products?

Sub-questions to be able to construct the subject on a better ground are:

- RQ1-What characteristics of products were considered as influencing factors?
- RQ2-What makes people avoid purchasing remanufactured products?

- RQ3-What encourages people to purchase remanufactured products instead of brand new?

The paper is organized as follows: methodology, descriptive analysis, findings, conclusion and a reference list.

Methodology

In order to increase the validity of results and not to miss any related article while reviewing the literature, the systematic literature review is chosen as an appropriate method to apply. The methodology used in this paper was influenced by the works of Denyer and Tranfield (2009), Durac*h et al*, (2017), and (Larsen *et al.*, 2018). Five steps of the systematic literature review were formed which is called 5S, see figure 1.

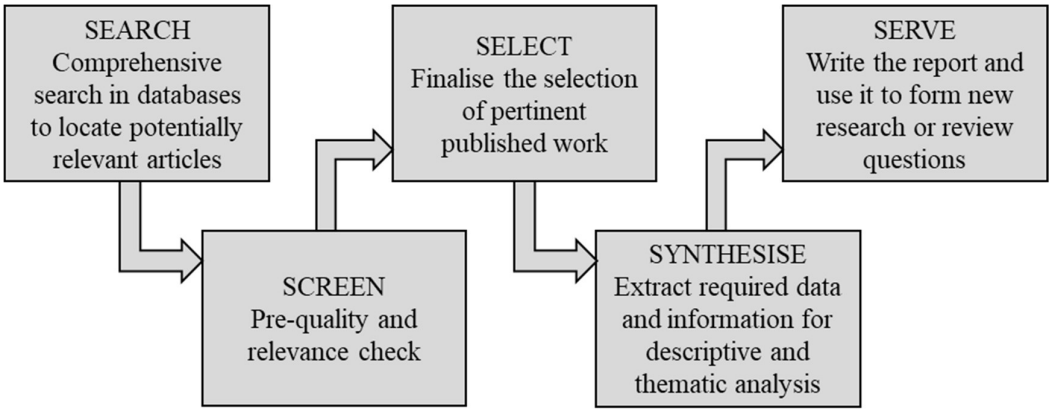

Figure 1: 5S's of systematic literature review process (adapted from Denyer and Tranfield, 2009; Durach et al., 2017; Larsen et al., 2018)

Set of keywords defined for each customer and remanufacturing focused. As mentioned before, terms remanufacturing and refurbishing are used interchangeably in the literature. Hence, these were selected as keywords for remanufacturing focus and customer and purchase intention for customer focus. Articles located in 3 different databases which are Scopus, ProQuest, and Web of Science. Initial research located 1720 articles and after duplicates removed there were 725 articles left for quality check by considering the journal ranking which left 292 articles for titles and abstracts screening, see figure 2.

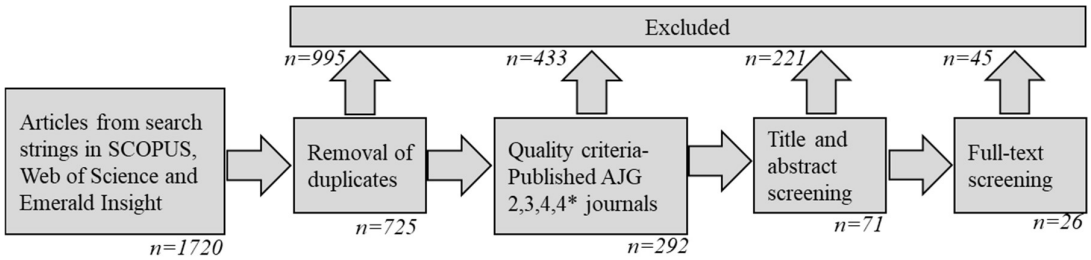

Figure 2: Selection of articles

Duplicates were eliminated by using a referencing software (Mendeley). This review includes the articles published in 2, 3, 4, and 4* ranked journals by Academic Journal Guide (AJG). A data extraction sheet was created to gather data for all included articles which include information of title, author(s), year published, journal, AJG ranking, data

sources, researched product or industry and location. This information was used for descriptive analysis. For coding, a qualitative data analysis software which is NVivo 12 Pro was used.

71 articles were included in the full-text review and 26 final articles selected for the final review. This review has three inclusion criteria, see table below: first, the article has to be written in English due to language barriers. Second, the article has to be published in a 2, 3, 4, or 4* journal according to AJG to make sure the publication quality. The last and most importantly, remanufacturing and customers have to be the main constructs of the articles. The articles do not meet these criteria were excluded. The paper

Table 1: Inclusion and exclusion criteria

INCLUSION CRITERIA	EXCLUSION CRITERIA
Remanufacturing and customers' perception are the main focuses of the article	The research focuses on other forms of end of life treatments such as recycling, reuse or second-hand market
The article is published in a 2, 3, 4 or 4* AJG ranked journal	The article focuses on the operational side of remanufacturing
The article is written in English	

Descriptive Analysis

This section will try to answer RQ4 which is focusing on research methodologies applied for the selected 26 articles. Information about the following point will be extracted: data source, data analysis method, researched product(s), and year of publication, journal ranking.

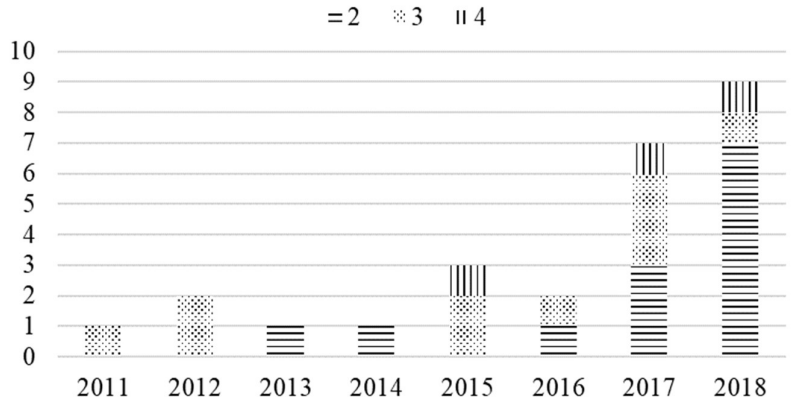

Figure 3: Descriptive analysis of 26 papers according to the year of publication and AJG journal ranking

The most common method of collecting data is questionnaire which is used by 18 out of 26 articles (69%), eBay transactions by 4, 2 experiments and lastly 1 review article and interview. Structural equation modelling and regression (ordinary/ partial least square, hierarchical) were the data analysis method used by 22 articles. Only one study considered three different product categories (technology, household and personal care) to compare the results. Three studies do not focus on any specific product or industry. Seven articles were about the automotive industry mostly about spare parts and more than half of the articles were about electronics such as phone, laptop, etc. Figure 3 demonstrates that researches published in 2, 3 or 4 AJG ranked journal were increased from maximum 3 to 7 and 9 in 2017 and 2018. Even there is a recent increase, still, there

is not a lot of examples of publications in top journals within the field. Furthermore, 35% of the papers were published in the Journal of Cleaner Production, and 12% in Business Strategy and the Environment, International Journal of Production Economics, and Production and Operations Management.

Findings

The following model was created to illustrate influencing factors of customers' perception or purchase intention towards remanufactured products by affecting perceived value or benefit and perceived risk of customer through different variables about product, personal and other attributes (van Weelden *et al.*, 2016; Wang and Hazen, 2016; Matsumoto *et al.*, 2018a; Y. Wang *et al.*, 2018), see figure below. This study will handle attributes separately to be able to purely focus on a single item. But, this does not mean that the study assumes the items do not have an impact on each other or together the impact is stronger or weaker.

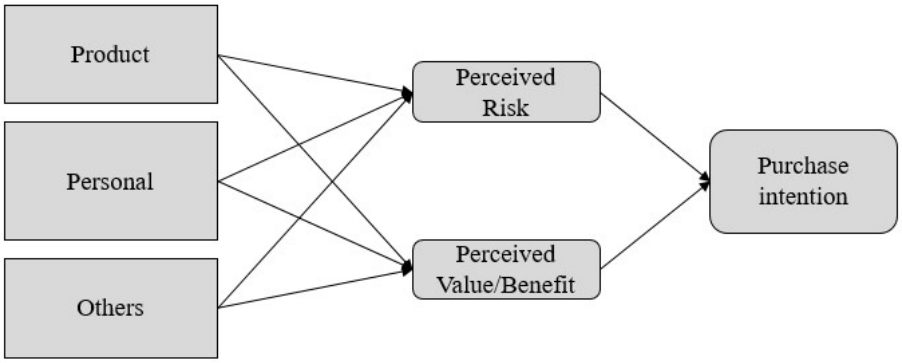

Figure 4: Conceptual model

Influencing factors extracted from the literature will be summarised by starting with availability.

Availability

Some authors claim that availability is one of the main obstacles to reach potential customers, especially, because of not being included in their purchase channels(Abbey, Meloy, Blackburn, *et al*., 2015; van Weelden*, et al*., 2016). Some studies show that some customers do not know where to access remanufactured products (Wang *et al.*, 2013; van Weelden *et al.*, 2016; Qu *et al.*, 2018). Wang *et al.* (2013) suggested to government and remanufacturers take initiative to form a sales network to increase accessibility. Additionally, country and region might affect this (Matsumoto *et al.*, 2017).

Brand Equity

High brand reputation means that customers trust the brand in terms of quality and performance. Original equipment manufacturers' brand reputation is a factor that can help to reduce the perceived risk of remanufactured products (Matsumoto *et al.*, 2018b; Vafadarnikjoo *et al.*, 2018). Furthermore, involved organisations' reputation also plays an important role to reduce perceived risk (Pang *et al.*, 2015; Vafadarnikjoo *et al.*, 2018).

Negative Associations

Even the definition of the term suggests that the condition is like new, some customers consider them as undesirable, second graded (Abbey, Meloy, Blackburn, *et al.*, 2015;

Khor and Hazen, 2017). These negative associations found stronger for personal care products than technology and household products (Abbey, Meloy, Guide, *et al.*, 2015). Furthermore, this disgust and repulsion directly affect the purchase intention towards and interest in remanufactured products (Abbey, Meloy, Blackburn, *et al.*, 2015).

Only New

Some consumers associate remanufactured products with negative terms such as dirty, garbage, trash, disgusting, etc. (Abbey, Meloy, Blackburn, *et al*., 2015) and consider as undesirable (Khor and Hazen, 2017). It is expected that this customer segment which is 20-40% would never consider purchasing remanufactured products. Therefore, there is a potential of 60-80% of the customers would consider purchasing remanufactured products. On the other hand, unwanted innovative features might be a motivating factor to look for remanufactured products (van Weelden *et al.*, 2016).

Price – Discount

Provided price advantage for remanufactured products reduces perceived risk and increases perceived value (Wang and Hazen, 2016). Therefore, one of the main drivers of demand for remanufactured products is lower price (Michaud and Llerena, 2011; Wang *et al.*, 2013; Jiménez-Parra *et al.*, 2014; Abbey, Meloy, Blackburn, *et al.*, 2015; van Weelden *et al.*, 2016; Xu *et al.*, 2017; McKie *et al.*, 2018; Vafadarnikjoo *et al.*, 2018). Lower price also provides an opportunity for OEMs to access new customers who couldn't afford the brand new product (X*u et al.*, 2017) even further, price is one of the most important factors that have a positive impact on convincing customer to switch from purchasing brand new products to remanufactured ones (Hazen, Mollenkopf, *et al.*, 2017). Impact of discounting might be different in different regions (Matsumoto *et al.*, 2017).

There is not a consensus about a standard ratio of discount (Bittar, 2018). This ratio is usually between 20 and 40% (Wang and Kuah, 2018). As a demand driver, discounting up to 60 is suggested due to quality concerns of products that over discounted (van Weelden *et al.*, 2016; Bittar, 2018), it could even lead to distrust of the overall brand and damage brand reputation (Abbey, Meloy, Blackburn, *et al.*, 2015). Additionally, customers are willing to pay more for products remanufactured by OEMs or authorised organisations than third-party firms (Subramanian and Subramanyam, 2012). Surprisingly, Mugge, Jockin and Bocken, (2017) found that financial benefit don't have a direct impact on purchase intention which is widely seen in the literature and practice. The reason behind this might be that participants could have seen the lower price as an already provided benefit.

Product – Technology, Warranty

Consumers interested in remanufactured products prioritise functionality over newness or appearance, and also performance is another important point to convince customers to purchase remanufactured (van Weelden *et al.*, 2016). Available return option and length of warranty increases the attractiveness level of remanufactured product (Pang *et al.*, 2015) by providing after sales services. Technology not mentioned much as an influencing factor. It might be because most of the researches focus on a specific product instead of a variety of choices where technology could be considered as a factor.

Product Usage and Treatment History

Knowledge about the product and treatment during remanufactured process is an important issue highlighted as information gap (Wang *et al.*, 2013; van Weelden *et al.*,

2016; Bittar, 2018) such as how remanufacturing been conducted, product usage history (S. Wang *et al.*, 2018; Wang and Kuah, 2018; Y. Wang *et al.*, 2018). These negatively impact remanufactured products' attractiveness (S. Wang *et al.*, 2018) by increasing ambiguity level (S. Wang *et al.*, 2018) and risk perception (Wang *et al.*, 2013). Therefore, reducing ambiguity level would be beneficial to attract more costumer (Xu *et al.*, 2017; Vafadarnikjoo *et al.*, 2018) by making the steps of remanufacturing more transparent (S. Wang *et al.*, 2018). On the other hand, reducing the information gap might have a negative impact on purchase behaviour (Wang *et al.*, 2013). Additionally, some customers have the intention to purchase remanufactured products they do not, due to lack of information which is called as intention-action gap (S. Wang *et al.*, 2018). To handle this issue, (Wang *et al.*, 2013) suggest governments and remanufacturers to take action to improve the image of remanufactured products by setting some standards.

Quality

Quality perception of remanufactured products is one of the factors that affect the purchase intention most (Abbey, Meloy, Blackburn, *et al.*, 2015; Abbey, Meloy, Guide, *et al.*, 2015; Wang and Hazen, 2016; Hazen, Boone, *et al.*, 2017; Vafadarnikjoo *et al.*, 2018). Customers do not a chance to test the product quality before making the purchase decision, therefore they require some signals to trust the like new condition as the definition of remanufacturing promises (Michaud and Llerena, 2011). Warranty, certification, and brand image could be used to increase perceived quality and reduce associated risk (Matsumoto *et al.*, 2018a). It is safe to say that if a remanufactured product is certified by a trustworthy organisation this will be seen as a symbol of quality (Matsumoto *et al.*, 2018a). Furthermore, as mention in the previous sub-section, sharing information about product usage history and remanufacturing processes could be used to increase perceived quality instead of leaving these uncertain and ambiguous. Additionally, country of origin is a factor that affects the perceived quality, such as Matsumot*o et al.*, (2018a) found that customers willing to purchase more the remanufactured products from developed countries than developing.

Risk

There are six types of risk associated with remanufacturing; performance (malfunctioning) , time (effort and time spend to repair in case of any problem), physical (safety risk), financial (repair or return cost and required new purchases), social (being laughed because of purchasing remanufactured products) and resource (dishonest parties) (Wang *et al.*, 2013; van Weelden *et al.*, 2016). All these have a negative relationship with customers' purchase intention (Matsumoto *et al.*, 2018a).

Providing information about products' usage and treatment history (Hazen *et al.*, 2012; Wang and Hazen, 2016; Abbey *et al.*, 2017), quality certification (Michaud and Llerena, 2011; Matsumoto *et al.*, 2018a), and warranty (Pang *et al.*, 2015; van Weelden *et al.*, 2016) would be beneficial to reduce associated risks.

Subjective Norm

Most scholars expect that remanufactured products would attract more environmentally friendly customers than others (Wang *et al.*, 2013). Surprisingly, there are studies claiming that environmental friendliness does not always reflect on the action of individuals (Khor and Hazen, 2017; Bittar, 2018; Qu *et al.*, 2018; Wang and Kuah, 2018). One of the main reasons why this gap exists is lack of information available about product, processes and environmental benefits (Wang and Kuah, 2018) but the challenge

to build the link between intention and action is greater than informing (Abbey, Meloy, Blackburn, *et al.*, 2015). Furthermore, approval or encouragement of purchasing remanufactured product by important people to customers (family, friend) would increase the chance of purchase happening (Jiménez-Parra *et al.*, 2014; Qu *et al.*, 2018; S. Wang *et al.*, 2018) also culture and country might make difference (Matsumoto *et al.*, 2017).

Being familiar with the concept of remanufacturing and previous purchase of remanufactured products are found to be an important factor to purchase them instead of new ones by reduced risk due to familiarity (Hazen *et al.*, 2012; van Weelden *et al.*, 2016; S. Wang *et al.*, 2018). Also, ambiguity tolerance limit of individuals positively relates with purchase intention of remanufactured products (Hazen *et al.*, 2012; S. Wang *et al.*, 2018). A study found that remanufactured products are more attractive to younger people (Abbey, Meloy, Guide, *et al.*, 2015).

Being sustainability conscious consumer started to become a status symbol (Wang and Kuah, 2018). Surprisingly, when people make green purchases they tend to display and when there is not a viable way of displaying the action or product they tend to prefer non-green option (Abbey, Meloy, Blackburn, *et al.*, 2015; Wang and Kuah, 2018).

Sustainability

Being environmentally friendly product is considered as a factor that influences customers willingness to purchase remanufactured products (Michaud and Llerena, 2011; Jiménez-Parra *et al.*, 2014; Hazen, Mollenkopf, *et al.*, 2017). On the other hand, there are researches claim that environmental benefits of remanufactured products do not play a major role to convince more customers (Abbey, Meloy, Guide, *et al.*, 2015; van Weelden *et al.*, 2016; Vafadarnikjoo *et al.*, 2018). The reason behind this behaviour would be that customers do not know enough about the environmental benefits of remanufactured products (Michaud and Llerena, 2011; Khor and Hazen, 2017; Mugge *et al.*, 2017). Furthermore, even customers receive information about the benefits, they are not willing to pay extra for remanufactured products just because of their green characteristics (Michaud and Llerena, 2011).

True Understanding of Remanufacturing Concept

Studies reveal that, surprisingly, consumers do not see remanufactured products as green (Abbey, Meloy, Blackburn, *et al.*, 2015; Khor and Hazen, 2017) even some see them as second hand, unusable (S. Wang *et al.*, 2018). Also, customers do not trust remanufactured products in terms of quality and performance (Abbey, Meloy, Blackburn, *et al.*, 2015; van Weelden *et al.*, 2016; Wang and Kuah, 2018) even the definition of the term says that their condition is like new. This misconception of remanufacturing is one of the main barriers to overcome (van Weelden *et al.*, 2016; Matsumoto *et al.*, 2018b). Because, awareness of remanufacturing have a positive impact on purchase intention (Mugge *et al.*, 2017) and if customers know more about the similarities between remanufactured and new products their chance of purchase increases (Jiménez-Parra *et al.*, 2014). Governments and enterprises should take action to overcome this issue and increase awareness (Qu *et al.*, 2018), also reducing ambiguity in remanufacturing activities is another recommended step to reduce perceived risk (Wang and Kuah, 2018).

Conclusion

Attributes that potentially influence customer's purchase intention are extracted from the academic articles and explained separately in the findings section which tries to answer the review questions.

RQ1: Selected 26 article mainly focus on a single product. Quality, price/discount, reputation, environmental benefits, warranty and being able to display were mentioned. If researches look for more than one product or product family the outcome would be different due to the availability of options. Also, this will make the studies closer to reality, especially in these days it is possible to find quite a few replacement products for the same purposes.

RQ2: Risks associated with remanufacturing products are the main reason why customers avoid purchasing or even do not consider as an option. The other potential reasons are the thrill of newness, misconception of remanufacturing, unavailability, social pressure and unawareness of ways to access remanufactured products.

RQ3: Being able to have access to a product with a lower price seems to be the main driver of demand for remanufactured products. In addition to price, approval of close individuals, culture, familiarity, and ambiguity tolerance are important. Surprisingly, being sustainability conscious was not found as a one of the main factors to look for remanufactured products. The reason might be the misconception or not seeing them as green products. One of the suggested solutions to this issue was taking actions to increase awareness. Also, previous experience of individuals is important.

The main contribution of the paper is providing a comprehensive overview to guide researchers for further studies in the field. A conceptual model is delivered with the aim of demonstrating the overall picture. This systematic literature review will be functioning as the ground for future empirical work. Future work will be testing the potential influence of different attributes by hypothesises to develop a better understanding of customers' perception to promote greener behaviour.

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Mitigation of intertemporal tensions in environmentally-sustainable manufacturing through Industry 4.0

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Abstract

Manufacturing organizations face intertemporal choice problem, i.e., falling victim to pursuing short-term financial objectives or pursuing long-term environmental protection and social equity objective. Despite of the need to balance the present with the future, most sustainability research is centred on the tension between business and society, irrespective of time. We argue in this research that principles of Industry 4.0 could contribute to mitigating this intertemporal tension in sustainable manufacturing, moving towards a more sustainable society as well as world-class sustainable manufacturing.

Keywords: Sustainable Manufacturing, Industry 4.0, Intertemporal Tensions.

Introduction

Much of the literature on corporate sustainability is centred around the tension between organizations and society, regardless of time (Smith and Lewis, 2011; Slawinski and Bansal, 2015). However, it is unclear how manufacturing organizations balance the short term and the long term sustainability objectives without restricting manufacturing organizations growth and freedom. Sarkis and Zhu (2018) posit that advances in manufacturing technology in the pursuit of manufacturing sustainability assumes achievement of organizational growth besides bringing about better cleaner production and rationalization of the use of resources that has a positive impact on environment and social welfare. In this realm, an emphasis is placed on the offerings of Industry 4.0 technologies, also known as smart manufacturing (de Sousa Jabbour, Jabbour, Foropon, *et al.*, 2018). Industry 4.0 is based on the establishment of smart factories, smart products and smart services embedded in an internet of things and of services (Lasi et al., 2014, Stock and Seliger, 2016). It facilitates providing real time information on production, machines, and flow of components; integrating this information to help managers to make cost-effective decisions, monitor performance, and track parts and products (de Sousa Jabbour et al., 2018). It is argued by Gouvea et al. (2017) that technological developments, such as those brought by Industry 4.0, is related to the sustainability of countries, and that technical advancements of manufacturers can

significantly enhance progress towards improvements in environmental quality (Song and Wang, 2016). For instance, de Sousa Jabbour et al. (2018) explained that using real-time data from manufacturing systems and suppliers can achieve high levels of efficient and economical use of resources such as materials, water, energy and products; as this leads to more sustainable manufacturing decision-making. Also, connecting machines, tools, devices, components, products, customers and logistics by means of internet, sensors, and RFID technologies would enable reconfiguration of these production system parts (Wang et al., 2016) based on customers' requirements, production parameters, and environmental performance (de Sousa Jabbour et al., 2018). In addition to these advantages, Industry 4.0 offers different sustainable approaches to cope with the social challenges of sustainability. Stock and Seliger (2016) asserted that Industry 4.0 adoption, first, increases the training efficiency of workers by combining new ICT technologies. Second, it increases intrinsic motivation and fosters creativity by establishing new cyber-physical based approaches of work organization and design, and, third, it increases extrinsic motivation by implementing individual incentive systems for the workers. Furthermore, the principles of Industry 4.0 enable instant data collection on customer requirements, usage and consumption patterns, thus allowing enhancement of service aspects of products, which will, in turn, improve customer satisfaction and well-being (de Sousa Jabbour et al., 2018). Based on this, it is argued in this paper that practices of Industry 4.0 support diverse temporal perspectives which encourage manufacturing organizations to juxtapose the short and long-term dimensions of sustainable manufacturing. Therefore, the following research question has been driving this research: RQ. How does Industry 4.0 principles and practices impact intertemporal tensions in sustainable manufacturing?

This paper is of a theoretical nature that is based on literature reviews of tensions of corporate sustainability, sustainable manufacturing, and Industry 4.0 topics. First, a literature review was conducted without focusing on one particular example or industry that was later followed by a more focused systematic review. Google Scholar was used to locate previous literature reviews conducted within the domain of Industry 4.0, tensions of sustainability, and sustainable manufacturing. Second, possible dimensions were inductively identified for analyzing relationships between the three main keywords used in this literature review process. This resulted in the identification of five different Industry 4.0 mechanisms to assist with mitigation of intertemporal tensions. However, this paper is further organized as follows. The next section presents the literature review conceptualizing intertemporal tensions in corporate sustainability. Next, principles of Industry 4.0 are characterized. This is followed by an attempt to link offerings of Industry 4.0 with intertemporal tensions of sustainable manufacturing. Finally, Industry 4.0 mechanisms for mitigating intertemporal tensions are explained and conclusions presented.

Intertemporal tensions in corporate sustainability

According to der Byl and Slawinski (2015), intertemporal tensions in organizations is understood through prioritizing short term economic dimension of sustainability over the two other long term dimensions. According to authors, this has been detrimental to our understanding of corporate sustainability. This is due to the fact that instrumental logic neglects intertemporal tensions where social and environmental goals cannot be aligned with profit maximization targets (Smith and Lewis, 2011). Slawinski and Bansal (2015) uniquely defined corporate sustainability as "the ability of firms to respond to

their short-term financial needs without compromising their (or others') ability to meet future needs". Arising from this, Marginson and Mcaulay (2008) revealed that short-termism cannot by understood through organizational economic causes only; short-termism must be approached through a lens that includes individual and organizational level to advance organizational ability to mitigate its detrimental consequences for the long-term performance. Similarly, Hahn *et al.* (2015) make the case that short-termism, in corporate sustainability context, is caused by a mismatch between information available for managers to make sustainability decisions and information needed for those decisions. In other words, lack of complete information that lowers uncertainty about the future force managers to focus on sustainability aspects that are relevant in the short term. This would firmly suggest that mitigating intertemporal choice problem is possible through cutting-edge technologies that facilitate real time information on all aspect of the business (Marginson and Mcaulay, 2008; Hahn *et al.*, 2015). However, in response to this need, Similarly, Slawinski and Bansal (2015) suggest three mechanisms for temporal ambidexterity. The first mechanism is the collection of broad range of qualitative and quantitative data. The combination of such data provides information that is useful for decision-making processes and widens dialogue with organizational members on possibilities to juxtapose short-term objectives with long-term targets. The second mechanism is stakeholder engagement; starting an open dialogue with stakeholders allows organizations to intake different perspectives on sustainable issues and helps them learn about how best to attend these issues. The third mechanism occurs when organizations collaborate with each other. It is through this collaboration that organizations approach short and long-term business issues more holistically, therefore, providing better quality solutions for environment and society.

Principles of Industry 4.0

Stock and Seliger (2016) explain that the concept of Industry 4.0 is centred around three main dimensions of the manufacturing paradigm. First, the horizontal integration between organizations and organization-internal intelligent cross-linking and digitalization of value creation modules. This takes place throughout the entire value chain of a product life cycle and other related product life cycles. Second, smart digitalization and cross-linking of all phases of product life cycle from raw materials acquisitions to product end of life (i.e. end-to-end engineering). Third, vertical integration of cross-linking and digitalization of different hierarchical levels of value creation modules; from manufacturing cells, production lines, factories, and other associated value creation functions such as marketing and sales. According to de Sousa Jabbour, Jabbour, Foropon, *et al.* (2018), Industry 4.0 has four fundamental components through which it can be understood. These technological components are explained below.

The internet of things technology refers to a system where the physical devices (things) are equipped with embedded electronics such as software, sensors, RFID, tags, and controllers and connected to the internet to collect and exchange data (Burritt and Christ, 2016). In this sense, the internet of things constitutes an information technology infrastructure providing real-time connection of people, machines, devices, and information technology systems to solve complex business problems (Kiel *et al.*, 2017). As a result, large quantity of data, also known as big data (Zhong *et al.*, 2017), is generated and exchanged along the entire manufacturing value chains which can be

subsequently analysed to support and improve decision-making processes of organizations.

Cyber-physical production systems are defined by Deloitte (2015) as physical systems monitored and controlled by computer-based algorithms using virtual networks. They are operating in a self-organized (non-human) manner through means of artificial intelligence to continuously interchange data in real-time. Sensors, data processing units, and actuators are main components of cyber-physical production systems enabling real-time data transfer (de Sousa Jabbour, Jabbour, Filho, *et al.*, 2018).

Cloud manufacturing is an advanced manufacturing model using cloud computing technologies for enabling virtual on-demand network access to a shared pool of configurable manufacturing resources with minimal interaction with resources provider (Xu, 2012; Liu and Xu, 2016). In other words, it enables transformation of manufacturing resources into digitalised services that can be shared seamlessly through the support of virtualization and internet of things technologies (Zhong *et al.*, 2017).

Additive manufacturing is considered as an essential ingredient that is expected to increasingly be deployed in the Industry 4.0 movement (Stock and Seliger, 2016). It is a technology through which manufacturing of different components of products is possible without the need for a specialised manufacturing tools (de Sousa Jabbour, Jabbour, Filho, *et al.*, 2018). The virtue of additive manufacturing lies in the fact that it is able to produce physical parts based on digital information "piece-by-piece, line-by-line, surface-by-surface, or layer-by-layer" (Thompson *et al.*, 2016), thus, allowing the determination of components' materials properties (Dilberoglu *et al.*, 2017).

Linking Industry 4.0 and intertemporal tensions of sustainable manufacturing

From an environmental perspective, smart digitalization and cross-linking of the entire product life cycle (i.e. from raw materials acquisitions to product end of life) provide broad range of data with an immense opportunity for manufacturing organizations to understand patterns of usage and consumption (i.e. qualitative and quantitative information), which in turn can help organizations plan for the short-term (e.g. prioritising raw materials acquisitions processes and maintenance schedules) and long-term (e.g. improving product end-of-life reuse, remanufacturing, recycling, recovery and disposal). Also, cleaner production of products without generating waste or consuming unnecessary resources inherent in Industry 4.0 (de Sousa Jabbour, Jabbour, Foropon, *et al.*, 2018) create cost saving opportunities (i.e. short-term), enhance possibility of protecting environment with reduced depletion of resources (i.e. long-term), and improve intergenerational equity due to protecting interests of future generations (i.e. long-term) (Hahn *et al.*, 2018). Additionally, by analysing real-time data on energy consumption behaviour at production lines and machine level, energy data can be integrated in production management practices to improve energy efficiency of the factory (Shrouf, Ordieres and Miragliotta, 2014). This has a short-term objective of reducing energy consumption costs and contributes to long term reduced generation of GHG emissions. Manufacturing organizations, this way, can mitigate intertemporal tensions of corporate sustainability by creating the possibility to juxtapose short-term and long-term sustainability aspects. Furthermore, Industry 4.0 technologies seem to help juxtaposing the short and long-term issues of corporate sustainability by means of integrating value chains through real-time data analysis and sharing (de Sousa Jabbour,

Jabbour, Filho, *et al.*, 2018), thus, providing optimised solutions (Stock and Seliger, 2016). This virtue of Industry 4.0 is also matching Hahn's *et al.* (2015) acceptance strategy of dealing with temporal tensions, explained earlier, of adopting practices that are beneficial for short-term financial outcomes while also not detrimental to environmental and social issues. In this context, it is evident that Industry 4.0 offerings are beneficial in terms of short-term financial winnings and are fraught with practices that benefit environmental and social outcomes in the long run (Burritt and Christ, 2016; de Sousa Jabbour, Jabbour, Filho, *et al.*, 2018).

In fact, engagement of different stakeholders in Industry 4.0 such as customers, employees, suppliers, distributors, manufacturing equipment, and other organizations along value chain of products can play an essential role in achieving temporal ambidexterity. According to Slawinski and Bansal (2015), stakeholder engagement contributes to temporal ambidexterity by means of exposing an organization to plethora of information on diverse sustainability perspectives. Many of these stakeholders have strong ties with community representatives and other activists' groups who make their views listened to on different social and environmental impacts of businesses (Rivera, Muñoz and Moneva, 2017). This enables organizations to see broader range of timeframes of sustainability issues that help formulate better responses (Marginson and Mcaulay, 2008; Slawinski and Bansal, 2015). Another aspect that has been stressed in Industry 4.0 is the intelligent automation and cross-linking of organizational levels (Herrmann *et al.*, 2014; Schuh *et al.*, 2014; Stock and Seliger, 2016). Thus, the manufacturing jobs will entail more knowledge work and hard-to-plan tasks that require decentralised decision making processes (KIEL *et al.*, 2017). This is particularly important, since the establishment of Industry 4.0 technologies will bring about agility and connectivity to daily decision-making (de Sousa Jabbour, Jabbour, Foropon, *et al.*, 2018). This manufacturing organization's structural change would redefine traditional role of lower level employees to be responsible for achieving short-term operational aspects of the work and are not expected to deal with long-term strategic issues. Thus, the achievement of long-term objectives of sustainability is the responsibility of top management. This traditional notion of role separation is in line with Hahn's *et al.* (2015) "spatial separation strategy" of dealing with temporal tensions. However, we argue that cross-linking of organizational levels offered by Industry 4.0 technologies allow "spatial integration strategy". In this context, empowered lower level employees will be focused on monitoring and sense-making of the automated equipment (Schuh *et al.*, 2014; KIEL *et al.*, 2017). Different organizational levels, including top management, take part in the sense-making process through interpreting shared information to understand complex situations, and to assess the short-term and long-term consequences. This cooperative sense-making produce new knowledge on how to rapidly attend to short and long-term issues of corporate sustainability (Hofmann and Rüsch, 2017; Zhong *et al.*, 2017). In addition, through increased digitised connectivity lower level employees, sustainability managers, accountants, and other senior managers would have access to real-time environmental management data where they could work together, in collaborative manner, on environmentally sound eco-efficient action for the long term (Burritt and Christ, 2016). Such offerings of Industry 4.0 broadened the solution space of issues of sustainable manufacturing, such that several simultaneous short-term and long-term considerations are achievable, thus juxtaposing present and future. Contributions of Industry 4.0 to mitigation of intertemporal tensions in corporate sustainability are depicted in Table 1.

Table 1 – Industry 4.0 mitigation mechanisms

Industry 4.0 mitigation mechanisms	**Short-term economic benefits through:**	**Long-term environmental and social benefits through:**
Cross-linking of entire product life cycle	• Prioritising raw materials acquisitions processes and Improving maintenance schedules	• Improved product end-of-life reuse, remanufacturing, recycling, recovery and disposal
Cleaner production	• Reduced waste and consumption of unnecessary resources	• Reduced depletion of resources.
Real-time data sharing and analysis	• Enhanced energy efficiency of the factory • Track product deliveries and improved logistics routes	• Reduced generation of GHG emissions
Stakeholder engagement	• Rapid modifications to production and enhanced customer satisfaction	• Enhanced well-being of customers and society at large
Cross-linking of organizational levels "Spatial integration"	• Sense-making of the automated equipment by all organizational members.	• Reduced emission outputs • Formulation of environmentally sound eco-efficient action

Conclusions

This work shed the light on the unique potential of Industry 4.0 technologies to unlock juxtaposition of the short and long-term dimensions of sustainable manufacturing without restricting manufacturing organizations growth potential. To date, studies that explore the contributions of Industry 4.0 to sustainable manufacturing have been very limited. This paper is the first of its kind to analyze the role of Industry 4.0 in mitigating intertemporal tensions by enabling five different mechanisms of cross-linking of entire product life cycle, cleaner production, real-time data sharing and analysis, stakeholder engagement, and cross-linking of organizational level "spatial integration".

Although this study points to Industry 4.0 as a significant savior for manufacturing sustainability (Sarkis and Zhu, 2018), it has some limitations which may pave the way for further research in the future. This paper is of a theoretical nature that is based on literature reviews of tensions of corporate sustainability, sustainable manufacturing, and Industry 4.0 topics. Therefore, the set of identified mechanisms might not be fully comprehensive. A question for future studies would be, therefore, under which conditions each one of these mechanisms would be more effective in tackling intertemporal issues of sustainable manufacturing. For this, it is strongly recommended that in-depth case studies be conducted using different methodological tools to further explore these mechanisms and their underlying aspects. Further, it would be relevant to include other domains in the analysis of the role of Industry 4.0 in mitigating intertemporal tensions of sustainable manufacturing. For example, exploring the role of green human resources management practices (Renwick, Redman and Maguire, 2013) in efficient application of different mitigation mechanisms of Industry 4.0. Another topical area is the investigation of impacts of information linkages and flow in Industry 4.0 on management of environmentally focused supply chains, and how this relates to intertemporal mitigation in manufacturing context. Overall, it is

evident in this paper that there is optimism that Industry 4.0-associated technologies hold numerous social and environmental sustainability benefits; beside those of financial benefits. Our suggested mitigation mechanisms thus help to provide substantive contributions to embracing intertemporal tensions of sustainable manufacturing.

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A classification of deception in operations and supply chain management: A case study of deception in Australian souvenir markets

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Abstract

Sustainability concepts inform business considerations of production and procurement in order to satisfy consumer demands for ethical products. Drawing on the Deception Impact Model, the aim is to understand the severity of deception, implementation of socially sustainable practices, and impact on consumers by examining a case in the Indigenous art Australian souvenir industry. It found where a firm decouples from socially sustainable practices the result, a form of deception, negatively impacts ethically motivated consumers. The paper highlights where Indigenous people should be involved in the development chain to avoid infringing on human rights as it relates to commodification of culture.

Keywords: Social Sustainability, Ethical Practice, Deception, Indigenous Art

Introduction

The growing consumer desire to make ethical purchases necessitates firms to become more transparent in their production and procurement processes. Sustainability concepts, which include social, environmental, and economic dimensions, are ways in which business can consider the production and procurement in order to satisfy

consumer demands for ethical products. Likewise, the sustainability dimensions are a lens in which to examine operational processes to understand where practices decouple from what is legally and socially accepted in the provision of goods and services.

Sustainability issues transform the competitive environment for business (Longoni and Cagliano, 2015). There are various reasons for the private sector to demonstrate sustainability practices in their operations and behaviour. For example, the recent shift within the sustainable development paradigm has seen the private sector take a more prominent role alongside civil society and governments in addressing issues facing inclusive global growth and development (Scheyvens et al., 2016). Beyond contributing to global aspirations for sustainable development, economies can be achieved through environmentally sustainable operational practices, such as waste reduction and energy conservation. These savings can be amplified across a supply chain through coordination with upstream and downstream partners (Gupta and Benson, 2011) and assist in achieving a positive long-term performance of individual companies and their supply chain (Ahi and Searcy, 2015).

When considering sustainability within a supply chain context financial returns are not the only benefits for a network of firms working together to compete in the industry. Supply chain partners also have an interest in understanding each other's processes in order to ensure they are satisfying the needs of stakeholders in both legal and social aspects. The reason is to uphold legal obligations and avoid broader scrutiny by society.

Despite the benefits of practising sustainability in business processes, there are many instances of firms decoupling from strategic sustainability goals during implementation at the operational level. This paper uses the case of the Australian souvenir industry to illustrate where a firm decouples from socially sustainable practices in the production and procurement of low-cost souvenirs featuring stylised designs representative of the culture of Indigenous people. The result of the decoupling, a form of deception, negatively impacts consumers who are motivated to make ethical purchases. In addition to upholding the rights of Aboriginal and Torres Strait Islander people to protect and commodify their culture as a fundamental concept of Indigenous human rights.

This case has been chosen to illustrate deceptive practices as it has been recently highlighted within a Federal Government Inquiry (the Inquiry) and subsequent report (the Report) and legal proceedings brought before the Australian courts prosecuting a well-known souvenir distributor (the Distributor) mislabeling products to deceive consumers who are concerned with making ethical souvenir purchases. Further, this case highlights the role of social sustainability in business to protect human rights as it relates to the cultural dimension. Reasons for this will be outlined.

To understand deception in this context and understand where operational processes decouple from sustainability objectives happen, the Deception Impact Model (DIM) by (Hammadi et al., 2018) is utilised. The DIM connects three dimensions to provide an understanding and positioning of a firm's practices and impacts regarding severity of deception, implementation of sustainability practices and, impact on customers and other stakeholders.

There are differing attitudes and values towards the commodification of culture to produce souvenir product influencing what is classified as 'authentic' or 'fake' product. It is not the aim of this paper to classify or debate authenticity concepts, rather demonstrate the implementation (or lack) of social sustainability concepts in the production and sale of souvenir products featuring designs representative of Indigenous culture, and their subsequent impacts on operations management, supply chains, consumers and stakeholders. The term *inauthentic* will be used in reference to objects or products that do not engage Indigenous people in the design for the purpose of providing clarity and consistency.

The aim of this paper is to highlight where operations management and supply chain concepts can add value to society - particularly with respect to developing Indigenous Australian enterprises which are a valuable mode of sustainable development in remote regions. The paper provides a background to unsustainable practices, then discusses the concept of culture within a human rights framework and how it relates to the social sustainability in the Australian souvenir industry. The legal proceedings brought before the Distributor are examined using the DIM framework to understand the severity of the Distributor's deception. The Distributor's development chain is then examined to understand the degree to which the firms are implementing socially sustainable practices from an operations management and supply chain perspective. Finally, the impact of consumers and other stakeholders is considered to position the Distributor in relation to the implementation of social sustainability practices.

Background

Historical factors also demonstrate a lack of internal culture towards social sustainability among distributors and retailers with the issue of deception relating to inauthentic products within the Australian souvenir supply chain having been addressed in 2003 prior to the Distributor case in 2018. The Australian Competition and Consumer Commission brought action against Australian Icon Products Pty Ltd (AIP) for engaging "in conduct likely to mislead or deceive consumers" due to making claims that souvenirs were hand-painted by Indigenous Australians (NSW Government, 2007). Under Australian consumer law, "consumers are entitled to receive goods that match their description". The ACCC alleged Australian Aboriginal Art Pty Ltd (AAA) mislabelled products claiming they were 'Australian Aboriginal Art', 'Aboriginal Art' and/or 'Authentic, made by Aboriginal artists or artists of Aboriginal descent' despite not employing Indigenous people in the production process (NSW Government, 2007). The 2003 and 2004 cases demonstrate broader public awareness of deceptive practices by souvenir wholesalers in the form of mislabelling products. Despite this awareness, the production and sale of goods to retailers with misleading labels continued.

Recently in Australia, the Arts Law Centre of Australia revealed the widespread use of deception in the souvenir industry through an advocacy campaign. The campaign, known as *Fake Art Harms Culture,* highlighted the pervasiveness of merchandise available at tourism retailers, which presented as Indigenous cultural souvenirs appeared

ambiguous in provenance (Indigenous Art Code, 2019). One of the aims of the *Fake Art Harms Culture* campaign was to draw awareness to products whereby culture is commodified, often with inappropriate designs and materials, to create a product for a specific market. The advocacy campaign led to the Federal Australian Government undertaking an official *Inquiry into the growing presence of inauthentic Aboriginal and Torres Strait Islander 'style' art and craft products and merchandise for sale across Australia* (Inquiry) and a final report (Report) into the findings was published in 2018 (Australian Government, 2018).

Additionally, in 2018, the Australian Competition and Consumer Commission (ACCC) launched legal proceedings against a souvenir distributor finding the firm in breach of labelling laws (Australian Competition and Consumer Commission, 2018). The ACCC case demonstrates a legal mechanism (i.e. consumer law) in which incorrectly labelled souvenirs representing Indigenous culture assist in protecting consumers from making unethical purchases.

Despite consumer law providing protections for consumers in this context, Australian law does not extend to the "underlying idea or information that is put into a work" or a "style or method of art" such as dot painting techniques synonymous with Indigenous culture. Therefore, there are limited legal mechanisms in place to prevent a product being produced that references an Indigenous story or artistic style associated with a culture or specific nation (Artists in the Black, 2019). The commodification of Indigenous cultures to produce and sell souvenirs, without having an overt connection to an Indigenous person is not legally prohibited, and are termed 'inauthentic' for the purposes of clarity. Thus, as evidenced by the 2018 Distributor case, producers, wholesaler, and retailers of souvenirs continue to engage in deception.

Social sustainability: Culture as an aspect of human rights

While social sustainability is becoming an increasing concern of business (Mani and Gunasekaran, 2018), there is ambiguity regarding the social sustainability dimension and what it encapsulates (Ajmal et al., 2018). Cultural and ethical issues have been overlooked compared to factors related to legislative compliance, and the hierarchy of factors enabling social sustainability has not been clearly established (Mani et al., 2014).

A dimension of social sustainability is the rights of Indigenous people. The *United Nations Declaration on the Rights of Indigenous Peoples* protects Indigenous people's "right to maintain, control, protect and develop their cultural heritage" and "to maintain, control, protect and develop their intellectual property over such cultural heritage"; the "right to the dignity and diversity of their cultures"; further advance their economic and social conditions including employment (Australian Human Rights Commission, 2012).

Supply chain management research has been limited in considering the interrelationships between sustainability issues (Gimenez et al., 2012). The three sustainability pillars are ubiquitous in our understanding of sustainability, however, their distinction as separate dimensions is conceptually fuzzy (Kuhlman and Farrington, 2010). There has been a stronger focus on addressing economic and environmental

dimensions of sustainability in business, while the social aspect has not been well developed (Ajmal et al., 2018). As a concept of social sustainability, upholding the rights of Indigenous people demonstrates the convergence of positive social and economic development outcomes.

The *Declaration* highlights the role of culture, cultural heritage, and intellectual property as fundamental to the rights of Indigenous people. A successful example of Indigenous Australians engaging in enterprise and using culture as a means of advancing economic and social conditions is Indigenous art centres. Art centres have become important institutions in remote Australia as they provide people with access to the mainstream art market where only a limited opportunity for economic inclusion exists, and in some instances, represent the only non-welfare form of income available to Indigenous people (Seet et al., 2018). Art centres are also linked to the overall wellbeing of Indigenous people and broader communities by generating positive psychological and emotional impacts (Allain, 2011).

Despite the success of art centres in facilitating cultural production for the art market, commercialisation of culture can lead to conflicting priorities between producers and consumers within the souvenir industry. Indigenous artisans producing handcrafted goods according to cultural protocols (e.g. use of a specific material or production technique) for tourist markets may not be able to price a product to fit the requirements of consumers seeking a low-cost travel memento (Guttentag, 2009). Thus, non-Indigenous firms with capabilities to produce low-cost products, and without legal obligations to follow cultural protocols, are free to appropriate elements or styles of Indigenous culture to meet consumer demands (Guttentag, 2009). In this instance, the non-Indigenous producers are able to exploit the legal environment and take away opportunities for Indigenous people to advance their economic and social conditions through the commodification of culture and intellectual property. The example of non-Indigenous firms participating in the market under these conditions illustrates how firms can engage in socially unsustainable practices in the production of inauthentic goods within the souvenir industry.

Severity of the Distributor's deception

The relationship between social sustainability and the production of authentic souvenirs has been established as an aspect of human rights. Examining levels of deception is one of the three interrelated factors proposed by DIM to determine the degree to which a business is delivering on sustainability objectives from a supply chain perspective. In the case of the Distributor who was prosecuted by the ACCC, the DIM framework provides a basis for understanding the severity of deception. In a supply chain context, deception can occur between buyer-supplier or organisation-consumer. Deception is the gap between actual claims, practices and outcomes of those practices.

The development of nomenclature for deception relating to sustainability within supply chain literature demonstrates its prevalent in contemporary business. Green-washing and blue-washing (Dadush, 2018) describes the practice of misleading

consumers by misrepresenting the degree to which a product or service is environmentally (green) or socially (blue) sustainable.

The Australian Federal Court found the Distributor in breach of Australian Consumer Law over misrepresenting souvenirs featuring Indigenous style designs as being hand painted by Indigenous people (Australian Competition and Consumer Commission, 2018). The products at the centre of the case were represented to be 'associated with Australian Aboriginal Art' and using words in the labels including 'Aboriginal Art, 'genuine', and 'Australia' (Australian Competition and Consumer Commission, 2018). Several products were featured in the case including loose boomerangs, boxed boomerangs, bullroarers, didgeridoos and message stones. Some of the products featured designs licenced by an Indigenous artist. However, the products examined in this case that were in breach of labelling laws were manufactured in Indonesia with designs the firm procured from Internet sources (Federal Court of Australia, 2018).

Blue-washing is applicable to this case as the Distributor made claims on particular products to infer a connection to Indigenous people and local products that do not exist in that form. The deception not only impacts consumers but also the buyers (retailers). When using the DIM model (Figure 1) to investigate the deception, consider the inauthentic supply chain in the Donald Trump quadrant as the supplier deceives with low sustainable impact yet are liked for the low price. The change to the authentic responsible supply chain can risk failure as consumers may not like the increased price despite having an authentic product and thus have made an ethical purchase. However, it is most likely that it shifts to influencer with an outcome being the partial loss of consumers, triggering a new concept/idea being marketed for its sustainability, with a final shift towards maturity. Note though, Robin Hood is a possibility if both supply chains collaborate and find a solution to be authentic and to keep the price in an acceptable price range.

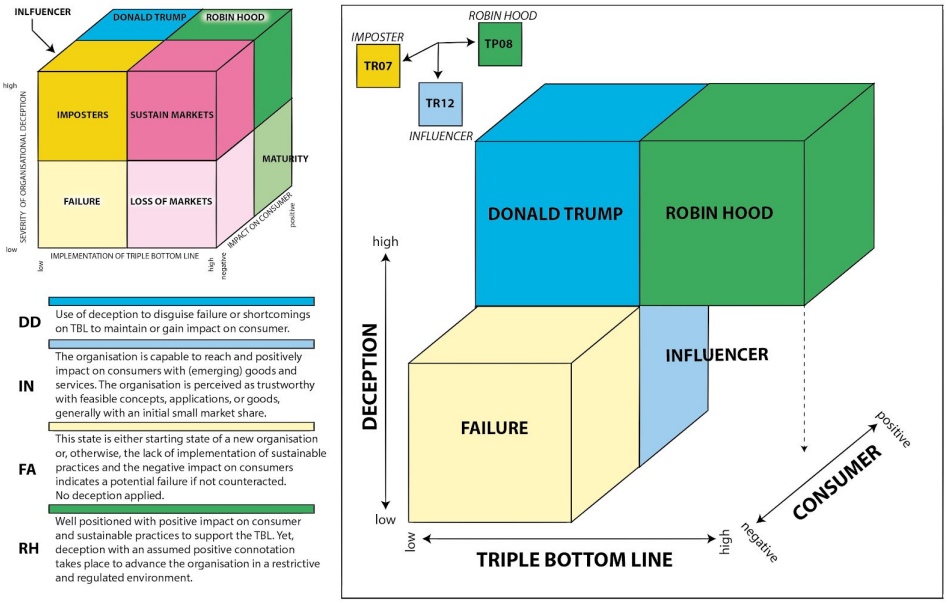

Figure 1: Deception Impact Model (DIM). See also Hammadi et al. (2018)

Implementation of sustainability practices

The sustainability orientation of an organisation is significant and is based on sustainability practices to achieve sustainability goals. The DIM proposes a firm's sustainability orientation on a spectrum between compliance with standards or legal obligations through to internal firm culture. The spectrum has been developed through Goldsmith and Samson's (2005) four categories of sustainability practices: compliance, conformance, performance, and transformation. Compliance and conformance are on one end of the spectrum, considered a reactive approach to sustainability implementation, and are demonstrated by firms who will only do what is necessary within a particular industry (Goldsmith and Samson, 2005). The DIM proposes the impact of this reactive orientation as an indicator of low implementation of sustainability.

To operationalise this impact in the context of the Australian souvenir market, the Distributor's development chain was examined. A strategic business activity is new product development (Hilletofth and Ericsson, 2010), with the intersection of product development with the supply chain known as the development chain (Primus, 2017). Attributes of products and the supply chain process can be aligned by firms to increase competitiveness (Morita et al., 2018) and thus, influence operations processes.

Two key elements of the development chain are 'planning and design' and 'sourcing' activities, with product architecture (planning and design phase) connected to the attributes of products. Within souvenir purchasing Revilla and Dodd (2003) found "appearance/utility, traditional characteristics and certification, rarity, local production and low cost" as factors impacting purchases. The Distributor sourced Indigenous symbols from the internet to be incorporated into souvenir products to give the products a particular appearance that would be attractive to customers (e.g. traditional characteristics). Labelling and packaging also inferred local production.

Design sourcing is the primary activity in which the Distributor decouples from human rights within the social sustainability dimension. This represents a key stage during the development chain where a firm can go beyond legal requirements, and ethically source a cultural element which will return positive benefits to Indigenous people, while satisfying product architecture requirements, thus supporting the human rights of Indigenous people to protect, maintain, and control their cultural heritage.

Make or buy decisions is another dimension of the planning and design phase, and supplier selection falls under sourcing activities. A factor influencing souvenir purchases is price. Research has found that price-orientated operations strategy models are less likely to compliment social and environmental sustainability aims (Longoni and Cagliano, 2015). The products considered in this case are at the lower end of the market and there is evidence that the Distributor outsourced production of souvenirs to Indonesia (Federal Court of Australia, 2018). Offshoring production of Indigenous style souvenirs may not result in decoupling from social sustainability as a discrete activity. However, combined with a decision to not include Indigenous people in the design of

the product combined with mislabeling statements on the product's packaging demonstrates a low commitment to social sustainability.

Consumers and other stakeholders

Within souvenir purchasing there are a variety of customer motivations "including workmanship, sensuous appreciation, cultural linkage and ease of handling" (Hu and Hong, 2007, p. 123). As consumers become more aware of products and manufacturing processes, firms are driven to address sustainability concerns (Mani et al., 2014). Despite customer trends, retailers need to consider balancing the demands of customers who are interested in sustainability, while also guarding against potential loss of market share and sales resulting from sustainable practices (Wilson, 2015).

Within the DIM, organisations able to accomplish positive impacts on consumers, despite relying on deception, are considered to be at the high end a deception severity spectrum. Retailers who knowingly procure products such as those discussed in the Distributors development chain, that disregard the cultural aspect of human rights, and are also priced at the lower end of the market, can satisfy price conscious consumers who are not motivated by ethical purchases. Due to the nature of competitive environments, buyers and suppliers on the supply chain may be motivated to align competitive priorities and have a low commitment to social sustainability. A challenge for business in the operationalisation of sustainable practices is reconciling traditional operations management models that focus on price, markets, and capability, to fit sustainability aims (Longoni and Cagliano, 2015). An internal 'reactive' culture towards social sustainability, which relies on maintaining minimum compliance with regulatory requirements, demonstrates the low commitment of those Australian souvenir supply chains to address human rights issues.

Conversely, authenticity is also a dimension motivating souvenir purchasing. Authenticity is considered a social construct, and consumer perceptions of authenticity is shaped by the "social and cultural conditions under which the product was produced" (Littrell et al., 1993, p. 200). It is not the aim to classify which product attributes constitute an authentic Indigenous souvenir product. However, this concept is important when souvenir producers mislabel products and engage in blue-washing as consumers seeking authenticity are at a disadvantage when making an ethical purchasing decision. This is also relevant in a buyer-supplier context as retailers may also be deceived if they are seeking to supply ethical products.

Conclusion ideas

Applying the DIM, this paper contributes to the understanding of product development and supply chain decisions within the Australian souvenir industry with regards to Indigenous art. When examining the Distributors development chain it was revealed that a critical stage in which a firm decoupled from social sustainability practices occurred in the procurement decision supporting a product's architecture. The paper highlights where Indigenous people should be involved in the development chain for

other non-Indigenous firms selling like-for-like products so as to avoid infringing on human rights as it relates to commodification of culture.

For Indigenous organisations and individual artists, seeking to enter the souvenir industry as a means of economic participation and inclusion, the paper provides an understanding of why specific techniques (such as offshoring) are used to satisfy customer purchase requirements, conversely impacting social sustainability. Additionally, for existing firms within the souvenir industry seeking to satisfy the market for ethical products, the research highlights where deception and decoupling from social sustainability relating to human rights and the cultural paradigm can occur from a production perspective.

Here, we addressed the gap in supply chain and operations management knowledge Indigenous producers face when participating in souvenir markets as established in the Report. Finally, the research contributes to the understanding of cultural paradigms within commodification contexts, as they relate to social sustainability as a concept.

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Can lean management practices in the operations of the universities lead to sustainability?

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Abstract

Sustainability in the educational curriculum of the higher education providers like universities has received considerable attention due to its importance in practice in most of the industry sectors. However, when it comes to having a sustainable operation in universities, limited evidence is found in both theory and practice. The few research papers that addressed the issue, did not quite address the underlying barriers by proposing effective solutions. This research aims to propose solutions to this problem by examining if lean practices would be able to facilitate environmental sustainability in the universities' operation in the UK.

Key Words: Sustainable University, Lean Management, Barriers to Sustainability

Introduction

Sustainability has been a buzzword in practice for the last couple of decades. It has also been a matter of academic interest to most of the universities in modern times. There has been a considerable shift in sustainable development in the last two three decades due to the increasing importance of policies to promote sustainability (Jorge et al., 2015). Yet, the universities often struggle to manage their sustainability targets in their own operations especially in the case of environemnatl sustaibaility. This has been documented in several studies from different parts of the world including studies in Portugal (Aleixo et al., 2018), in the UK (Robinson et al., 2018), in Poland (Kogcielniak, 2013), in Lithuania (Dagiliute and Liobikiene, 2015). The present study focues on the UK higher education providers and to the issues on the environmental sustainability of the triple bottom line framework. The rational for this is the doeumented concerns regarding the performance of many of the university's environmental sustainability issues based on People and Planet League table. Following the Data Energy Certificate release in 2017, a study was followed to identify the potential savings opportunities in the UK higher education sector. A potential £15.6 million savings opportunity was identified (Hawkins, 2017). In a report published in the Guardian (2016), only 25% of the UK based university campuses are on course to meet the carbon reduction targets by 2020 (Lightfoot, 2016). The author further mentioned-"*UK universities are helping lead the world on environmental research – but when it comes to their own back yard they appear to be falling behind.*"

This leads to the question of why the higher education sector falls behind their environmental performance. This has been mentioned in the literature including Disterheft et al. (2012), Netaji and Netaji (2013), Kogcielniak, (2014), Berchin et al. (2017), and Akins et al. (2019) where the authors highlighted the presence of certain challenges/barriers to sustainable approaches in the form some case studies. These studies highlighted the importance of cultural change, but these studies did not highlight the type of change required and the stages involved in operational improvements to achieve those changes. Some authors tried some assessment tools to offer some practical insight regarding assessment and reporting of sustainability performances, but these have limitations in terms of addressing some of the basic barriers including awareness (Lauder et al., 2015). Moreover, there has been limited evidence on how to address those challenges against achieving those sustainability targets in the university set up by improving the universities' operations. Adoption of some of the continuous improvement techniques from operations management such as lean management has been found to be improving the sustainable operations in practice in many sectors including manufacturing (Piercy and Rich, 2015). Yet, limited evidence is available when it comes to operations in universities. On this backdrop, "this research aims *at exploring and examination" if lean management principles can be implemented in universities operations to facilitate the sustainability targets to be achieved by addressing the barriers. This research will focus on the operations of the universities in Scotland in the first phase with an extension to the UK wide research in the subsequent phase. The objectives are*

Objective 1. To examine the barriers to achieving sustainability goals in universities operations in the UK.

Objective 2. To examine if the lean management principles can be applied to address those barriers and improve performance.

Literature review/Research backdrop

There is a growing body of literature on sustainability in the universities and other higher education institutions. This section presents an appraisal of extant literature considered relevant to this study, highlighting key themes and theoretical propositions for this research. A conceptual framework is also presented.

Sustainability Tools

A literature review shows some of the themes in the research involving sustainability issues such as tools used for sustainability measures (Li et al., 2018; Marrone et al., 2018; Algamdi et al., 2017; Berzosa 2017; Jorge et al., 2015; Lozano, 2011; Lozano, 2006), application of environmental management system (EMS) (Disterheft et al., 2012; Clarke and Kouri, 2009). Research in presenting the tools used for sustainability performance reporting has been considerably popular in the last 10-15 years. Lauder et al. (2015) presented a review of the Green Metric of the university ranking that is used for sustainability reporting in the university. In early research, Lozano (2006) presented a comparative study among the different tools used to assess and report the sustainability efforts by the universities along with some proposed modification in some of the tools such as Global Reporting Initiative (GRI), and Graphical Assessment of Sustainability in Universities (GASU). The author further extended the study to incorporate the GASU to compare the performance of the 12 universities' sustainability performance (Lozano, 2011). Townsend and Barrett (2015) used Environmentally Extended Input Output Analysis (EEIOA) in their empirical study based on the University of Leeds. The authors found this tool to be allowing the performance

comparioson between the universities. Jorge et al. (2015) proposed a multi-item quantitative tool which can be used for cross-university comparison. Alghamdi et al. (2017) examined 12 tools in sustainability in universities. Berzosa et al. (2017) conducted a comparative study with the application and application of multiple tools of sustainability applied for universities. Li et al. (2018) used the Analytical Hierarchy Process approach to propose prioritisation of the sustainability indicators in an Australian University. Marone et al. (2018) analysed and investigated the strengths and weaknesses of one of the popularly used index, the green metric index. Leon (2018) used Neighbourhood Evaluation for Sustainable Territories (NEST) tools for the environmental assessments of the University of the Basque County. Alshuwaikhat et al. (2018) proposed a model using the application of Geographical Information (GIS) tools to evaluate the sustainability related performance at the King Fahd University of Petroleum and Mineral. Alba-Hidalgo et al. (2018) proposed the definition/scope of environmental sustainability in the context of universities. The authors highlighted some of the characteristics of the tools that are used for this purpose such as STARS, SAQ (ULSF), AISHE, GASU, Green Report card, CSAF, AUA, STAUNCH, UI Green Metrics, CRUE, and USAT (MESA).

Alongside the sustainability performance reporting, the research on the application of Environmental Management System (EMS) has also been the topic of discussion in the literature. Clarke and Kouri (2009) discussed different campus EMS frameworks, their characteristics, and the drivers of implementation. Disterheft et al. (2012) conducted an empirical study on EMS development and implementation in universities across Europe. Velazquez et al. (2013) conducted a study on Sustainability Management System (SMS) implementation at the University of Sonora in Mexico to reduce the waste of water. Lo-Iacono-Ferreira et al. (2016) emphasized the importance of having an EMS for Ecological Footprint Assessment using Life Cycle Assessment. In a recent work by Omrecen et al. (2018), the authors presented a case study based on the implementation of climate strategy at the University of Gothenburg by the effective use of EMS. However, a limited insight was offered in these studies on the perceptions of the staffs and students. A study by Sammalisto et al. (2015) addressed this issue in a case study of a Swedish university. The authors addressed the perceptions of the staff members of the university on ISO14001 implementation. Other tools found such as Sustainability Management System.

Perception of Sustainability

Sammalisto et al. (2013) addressed the perceptions of the staff members by proposing a conceptual model. The author concluded with some insightful findings including variety in staff perceptions, and the importance of top management's encouragement. The importance of top management support was also highlighted in the studies of Wright (2010), Wright and Horst (2013). Nejati and Nejati (2013) proposed a scale for capturing the student perception on sustainability in the universities. Sylvestre et al. (2014) conducted an empirical study to address the perceptions of the professors of Dalhousie University by the implementation of Q-method.

Barriers to Sustainability

Despite a considerable amount of research in sustainability reporting and the tools used for sustainability in the universities, the efforts to achieve sustainability in the universities often fall short. This is mainly due to the existence of some of the barriers. This has been highlighted in few studies including Wright (2009), Wright and Horst (2013), Kogcielniak (2014), Robinson et al. (2015), Disterheft et al. (2015), Dagiliute

and Liobikiene (2015), Leal Filho et al. (2017), Alexio et al. (2018), and Akins et al. (2019). The issues identified as barriers includes financial predicament (Wright, 2009; Wright and Horst, 2013; Aleixo et al., 2018), lack of awareness/weak acknowledgement (Wright, 2009; Dagiliute and Liobikiene, 2015; Leal Filho et al., 2017; Alba-Hidalgo et al., 2018; Akins et al, 2019), resistance to change (Wright, 2009), lack of leadership/management support (Wright and Horst, 2013; Kogcielniak, 2014; Leal Filho et al, 2017), type of approach adopted by policy makers/lack of support from policy makers (including Government) (Kogcielniak, 2014; Dagiliute and Liobikiene, 2015; Robinson et al., 2015; Leal Filho et al., 2017; Aleixo et al., 2018). In addition, authors including Vieira et al. (2018) discussed barriers to the EMS implemementation in the university set up. Vieira et al. (2018) conducted the study in the Brazilian higher education sector.

One of the key internal issues has been identified as the barrier was the lack of top management support in some of the above studies in the last paragraph. A top-down approach to entail the goals and objectives of the sutainability has been recommended as a proposed requirement in the studies including Wright and Horst (2009), and Kogcielniak (2014). However, some counterintuitive evidence has also been documented such as Dagiliute and Liobikiene (2015) the existence of a top-down approach in their study in the Lituanian universities. The authors extended this as a possibly due to external barriers including government support and frequent policy changes. This has been highlighted in some other studies such as well to be having a significant impact on the clarity on the sustainability goals at the workplace among the higher education providers (Kogcielniak, 2014; Robinson et al., 2015; Leal Filho et al., 2017; Aleixo et al., 2018). In fact in the study by Robinson et al. (2015), the authors identified a need for setting a realistic and achievable carbon reduction target to be set in place.

There are certain limitations are in existence in the above studies such as

- Many of the studies were conducted in specific geographic locations such as Canadian universities (Wright, 2009), Portugese universities (Aleixo et al., 2018), Polish univeristies (Kogcielniak, 2014), Lithuanian universities (Dagiliute and Liobikiene, 2015), Brazilian universities (Vieira et al., 2018). Li et al. (2018) highlighted the geographical differences may have implications on the results to be changing form case to case.
- A need for a more exploratory investigation with a different group of stakeholders (Wright and horst, 2013; Disterheft et al., 2015; Leal Filho et al., 2017);
- A need for identifying solutions/ways to overcome the barriers (Filho et al., 2018).

Earlier, this research highlighted the importance of the problems of poor environmental performance and related flak being drawn towards the universities in the UK. This has motivated the present research to aim at conducting an exploratory study and identifying if any proposed solution can be offered to address some of the barriers.

Problems of environmental sustainability can be improved by imporoving the practices of operations within the organisation. Some well known continuous improvement practices such as Lean operational practices have been identified as one of the key facilitators towards environmental sustainability in manufacturing sctor in some early researches by Florida, (1996), and Corbett and Klassen (2005): “lean is green”. In fact, this mantra was the theme of a literature review of Garza-Reyes (2015). Authors including Hughes et al. (2012) highlighted the importance of lean practice with the focus on “doing more with less being used/spent”. Simpson and Power (2005) found the similarity between the practices that support lean manufacturing and environmental performance. This type of overlap between lean and sustainable practices has been

identified in the study of Cabral et al. (2012) where the author found the environmental waste reduction from lean tool implementation. According to Piercy and Rich (2015), one of the key limitations of the majority of these previous research topics was the focus on the relationship between lean practice and environmental sutainability only. In their research, the authors showed far stretching benefits that could be derived from lean practice towards sustainability in the UK based manufacturing sector. In recent research by Halldosson et al. (2018) reiteretaed the potential for integrating the principles of lean mangagement and sustainability initiatives. The authors further supported the findings of Piercy and Rich (2015) on the need for exploring the potential benefits of lean practices beyond environmental sustainability to other forms of sustainability that can be derived from the triple bottom line.

Despite its proven success in many other sctors including manufacturing, the application of lean management practice in higher education's own operation has been quite limited. Thomas et al. (2015) argued that higher education institutions (HEI) in the UK are quite slower to adopt the lean practice and derive the necessary benefits. Balzer et al. (2014) highlighted some of the factors as a facilitator including institutional readiness, leadership, awareness, understanding, support, and a favourable culture or the associated changes towards it. Similar was the finidng by Anthony et al. (2012) where the authors highlighted some additional critical success factors of successful implementation of lean six-sigma such as support from top management, effective communication, strategic and visionary leadership, and a favourable culture. This research has identified some of the similar key facilitators/success factors in the case of achieving sustainability by the universities. In fact, Balzer et al. (2014) highlighted based on some previous research by Balzer (2010), the amount of paper cost reduction upro 92% in facilities and management work orders in University of Central Okahoma. Based on these observations and the growing concern in terms of league table performance and the follow up implications, our research focuses on the aim highlighted in the introduction section.

Design/Methodology/Approach

The objectives of this research aimed to understand the barriers of sustainability in the operations of the higher education sector in the UK. This was followed with the exploration and examination of some of the solutions using the concepts of continuous improvement such as lean management techniques. According to Creswell (1998), when the phenomenon of interest is its early stage with a lack of understanding around the theories, qualitative exploration is more appropriate. On the contrary, the well defined phenomenon may render a need for the quantitative investigation. The research methods adopted in similar research are quite diverse including qualitative methods such as in-depth interviews (Wright, 2009; Wright and Horst, 2013), semi-structured interviews (Disterheft et al. 2015; Aleixo et al., 2018), and qualitative case study (Akins et al., 2019). In the study of Leal Filho et al. (2017) used survey methods to gather qualitative and quantitative data in respective phases to conduct a mixed method research study. Scondaruy data based research was also found in some literature including Robinson et al. (2015). To select an effective methodology foir this study, a set of literature on methodological discussion in operations management and related fields such as supply chain management were referred including merediuth et al. (1989), Craighead et al. (2007), Boyer and Swink (2008), and Golicic and Davies (2012). The framework poroposed by Meredith et al. (1989) (Please see fig 1.) was found to be the appropriate starting point for this reasacrh as it allowed the current research to cater the three elemenst of research paradigm: Ontology, Epistemology, and Methodology

(Denzina and Lincon, 1994, Frankel et al., 2005). The vertical dimension of the framework represents the epistemological elements where as the other dimension explains how the reality exists (Meredith et al., 1989).
Although, the concepts of sustainability are not new, given the present research context, the concepts are relatively in its earlyy days (Jorge et al, 2015). The objectives of this research require an understanding of the way people perceive, behave and react to the changes that are brought about by the incorporation of the priniciples/strategies required to achieve sustainable goals. Thus, this research adopted qualitative methods. The intension of the researcher of the present research is to interpret people's perception. Considering these elements, this research adopted semi-structured interviews with the university academics/non-academic staff members and the policy makers including the top management. In phase 1 of this study, the interviews will be condcueted with the above mentioned participants from Scottish Universities. Then a preliminary analysis will be conducted. This is expected to be followed by the UK wide sampling.

Natural ⟷ Artificial

Rational ↕ Existential

	DIRECT OBSERVATION	PEOPLE'S PERCEPTIONS	ARTIFICIAL RECONSTRUCTION
AXIOMATIC			• THEOREMS/LOGIC/REASONING • NORMATIVE MODELLING • DESCRIPTIVE MODELLING
LOGICAL POSITIVIST	• FIELD STUDIES • FIELD EXPERIMENTS	• STRUCTURED INTERVIEW • SURVEY RESEARCH	• PHYSICAL MODELLING • LABORATORY EXPERIMENTS • SIMULATION
INTERPRETIVE	• ACTION RESEARCH • CASE STUDIES	• HISTORICAL ANALYSIS • DELPHI METHODS • INTENSIVE INTERVIEWS • EXPERT PANNEL	• CONCEPTUAL MODELLING • HERMENEUTICS
CRITICAL THEORY		• INTROSPECTIVE REFLECTION	

Figure 1 – Framework for research method (Source: Meredith et al. (1989))

Relevance/Contribution
The literature review section of this research highlighted how the research about sustainability and lean management in the operation of the higher education sector is in

their early stage. Similar is the case in practice as well as highlighted in the form of docuemnetd problems with certain league table performance in the UK higher education sector. On this backdrop, the present research is expected to contribute to the theoretical knowledge especially identifying the barriers of achieving environmental sustainability and proposing some conceptual solutions with the help of lean management principles. Recent trends including plastic free society, requirements of less energy consumption in public sector premises, and less consumption of paper are some of the modern day challenges modern day universities face including the Scottish universities. Moreover, wider issues including challenges including a change in geopolitical changes, tighter budget, societal changes including poverty, and increasing tuition fee are also posing challenges in terms of the sustainable performance of the universities in the UK. However, often the universities do struggle to set out an optimal policy with respect to sustainability performance. Hence, the present research is expected to contribute to the generation of ideas to have an effective policy by having a more efficient operation in the universities for Scotland with a further expectation to generate future research ideas for UK wide.

Discussions and Conclusions

This research is expecting to find a similar set of barriers including lack of awareness, financial constraints, lack of stakeholder engagement, and resistance to changes. It is expected to be found that the lean management principles to be having a positive impact on achieving the sustainability targets of the university by addressing the barriers. There are some counter-intuitive resulst were shown in an earlier study by Rothenberg et al. (2001) in manufacturing set up where the authors found some negative relation between the lean practices and sustainability in certain particular cases. However, this research ahs shown a great deal of litetaure has found a positive relation between the implementation of lean practices and achieving sustainability in manufacturing. In fact, the authors including Anthony et al. (2012) even argued that the non-applicability of lean practices in a non-manufacturing sector like higher education is a misconception. Thus, this research is expecting to generate new ideas as a solution to overcome some of the barriers toward achieving environmental sustainability in the higher education sector in the UK.

A possible limitation would be some of the barriers of sustainability would be quite external in nature and proposing a solution would either require a longitudinal study over time. Another possible limitation that would emerge would be the applicability within the specific geographical situation. This problem has been highlighted in some of the research papers cited in the literature review. This study is expected to set the basic foundation solution approaches/concepts which could be extended in future research to offer more genaralisable solutions. In addition, future research could also take into consideration the other dimensions triple bottom line i.e. social and economical sustainability.

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Practice-based supply chain sustainability: proposing a set of practices

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Abstract

This paper aims to propose a set of practices that can be used across firms to perform sustainability practices and enhance sustainability performance for the SC members. For this end, after a bibliometric review, the extracted papers were analyzed to derive a classification of practices for supply chain sustainability based on the framework of Campos (2015, p.21) on integrated sustainable supply chain practices. Findings demonstrate a total of 55 practices that represent what companies can do to perform better sustainability. The contribution involves the development of this set of practices in order to support scholars and practitioners in advancing on sustainability.

Keywords: Supply chain sustainability, Sustainability practice, Practice-based view.

Introduction

There are several challenges for the supply chain sustainability (SCS) theory regarding the effective definition of how it is possible to manage sustainability through firms and spread it throughout the supply chain (SC). One possibility is by using the practice-based view (PBV) approach and going beyond the focus on performance and resources (Carter et al., 2017; Silva et al., 2018). This is still an underexplored theoretical lens, which demonstrate a interesting contribution from this paper. More than advance by proposing a new framework, this paper focus on demonstrate that the current knowledge and comprehension may be reorganized to reach supply chain sustainability.

This paper aims to propose a set of practices that can be used across firms to perform sustainability practices and enhance sustainability performance for the SC members, including the economic, environmental, social and governance dimensions of

sustainability of sustainability. In practice, all these dimensions need to be considered for sustainability assessment via, e.g., the ISO 26000 or the Global Reporting Initiative. In academia, research is still focused on performance as the main target; however, to have a comprehension on what and how to do things in SCs, it is necessary to combine sustainability performance and practices due to contextual factors that influence SCS such as local culture or working conditions (Fritz and Silva, 2018).

Bringing Practice Based View to debate Supply Chain Sustainability

The current proposal focus on to debate about the topic several strategic management approaches may emerge, and here the debate around practice based view that is timely and contributively for the purpose. In this context, Bromiley and Rau (2014) pointed out that in contrast with the resource-based view (RBV) which emphasize that firms cannot imitate each other, PBV could be used to focus on firms interactions. Corroborating that argument, for Carter et al. (2017), 'PBV focuses on differences in performance among firms across the entire range of performance ... [and] the explanatory variables in the PBV are practices that are imitable and amenable to transfer across firms, as opposed to ... RBV'.

According to Bromiley and Rau (2014), 'focusing on practices will help us to create specific, actionable advice for managers and other practitioners while continuing to advance our ability to explain firm behavior and the influence of firm behavior on performance.'. As indicated by Bromiley and Rau (2016) 'performance is not only a more tangible construct than competitive advantage, it has the advantage of being more readily measurable.' Related to supply chain strategy the debate should consider the organisational level of analysis as well. Hence, more than consider only the firm resources, capacities or practices, it is necessary to observe interactions.

This recent approach need to have more discussion once there is a critical perspective beyond the debate. For Jarzabkowski et al. (2016), PBV is not presenting the total debate about practice that is necessary. According to the authors instead of to analyse only *what* to do, the practice related to strategy (i.e. strategy as a practice) should also analyse *how* and *who* is involved in all the process. Therefore, as argued by Carter et al. (2017), PBV is a new and unexplored theory, which stimulate the use, refine and advance of the approach, mostly the debate of supply chain practice view. PBV has been applied by Silva et al. (2018) to understand sustainability practices facing natural disaster in Brazil. The research demonstrate that the use of PBV in SC studies is timely and possible to advance towards sustainability.

In order to better map and analyze SCS practices, Campos (2015) developed a holistic framework consisted of seven clusters of initiatives: Supplier Relationship, Governance, Procurement, Production, Distribution, Waste and Customer Relationship (Figure 1). According to this model Customer Relationship practices can be divided into Demands and Engagement. The first subgroup includes one-way initiatives from companies to study and forecast customer demands and offer more sustainable

products/services/processes that fits to their demands. The second subgroup, which includes double-way initiatives, intends to engage customers in actions where they can change their daily purchasing and usage habits towards a more sustainable behavior.

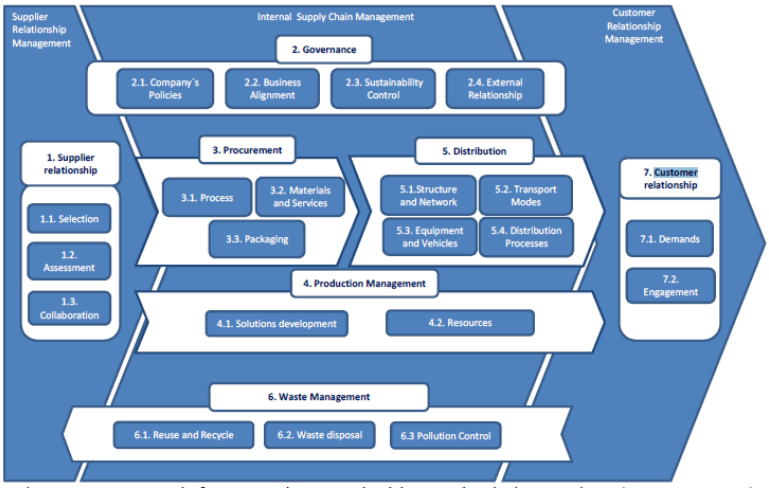

Figure 1: Framework for managing supply chain sustainability practices
Source: Campos (2015)

This framework can support scholars to understand how to perform sustainability in both internally and externally way by considering its supply chains. For the current paper, we use the seven categories presented by Campos (2015) and advance identifying in the literature which practices can be used to introduce sustainability. It is important to highlight that these practices need to be shared among the supply chain members in order to have a more consistent practice from the sector. Also it is important to highlight that there are several contingency factors that influence the practice (cf. Silva et al., 2018), which sometimes is forgotten from the studies on supply chain sustainability.

Research Method

To develop theory on sustainability management in SCs, a multi-disciplinary approach is necessary, such as using a social science theory, the branch the PBV belongs to. To develop a set of practices for a PBV to SCS management, two steps were followed. First, a bibliometric analysis with the R program (an open and free software) was used, which is an appropriate method to analyse a large body of literature. This bibliometric analysis was undertaken based on 11 databases chosen for their clear links with management and operations. For instance, ABI/INFORM Collection, ProQuest, Business Source Ultimate (EBSCOHost), Sage Journals, Taylor & Francis e-Journals, and Wiley Online Library Journals, were analysed. No timespan was defined since there is no consensus in literature on when research in this field started. To extract the papers from these databases, the following keywords were used: "sustainable" AND "supply chain practices", and "sustainably AND supply chain practices" and searched in the

whole article. This led to a total of 71 research papers. Out of these 71 papers, 48 were retained after reading and examining the summary and conclusions of each paper.

Second, the extracted papers were analyzed to derive a classification of practices for SCS that is presented in the finding section based on the framework of Campos (2015, p.21) on integrated sustainable supply chain practices. This framework is meant to support companies in developing their SCS strategies and was chosen for its comprehensiveness on categories of practices: supplier relationship management, internal supply chain management, and customer relationship management. However, there is no clear recommendations on which are these practices that can support the integration of sustainability in SC. Through this proposal a focus was set on finding out which are these practices.

Findings

Data was collected from 2009 and 2018. Developing the analysis was found that the largest years in the publication of papers in the field is the year of 2018 with a total of 204 papers, and the lowest is in 2011 with only 33 papers. The last three years represent more than half of the total papers published in the last 10 years, accounting for 52.5% of the total published in 10 years. This confirms that the concerns of researchers and practitioners are directed towards sustainability methodology and sustainable supply chain practices. The most published periodicals on the sustainability practices of supply chains were: (1) Journal of Cleaner Production - 75; (2) Supply Chain Management - 54; (3) Sustainability - 27; (4) Resources Conservation And Recycling - 23; and (5) Business Strategy And The Environment - 23.

The framework of Campos (2015), is formed by three dimensions, namely: 1) supplier relationship management, 2) internal supply chain management, and 3) customer relationship management. These dimensions are composed by seven categories (e.g., procurement, customer relationship) and twenty sub-categories (e.g., supplier selection, customer engagement). When selecting the practices, groups of practices were found for each sub-category of this framework (Table 1). For instance, supplier collaboration has six practices (e.g. cooperation with supplier for sustainability), solutions development has seven practices (e.g. design of products for easy disassembly), and customer relationship has ten practices (e.g. collection of feedback).

Factors	Items	LITERATURE
Sustainable Supplier Management Practices	Supplier Evaluation	(Hasan, 2013), (Emamisaleh, et al., 2018), (Luthra et al., 2014), (Das, 2017), (Yang et al., 2010), (Hsu, et al., 2016), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Supplier Development	(Hasan, 2013), (Emamisaleh, et al., 2018), (Yang et al., 2010), (Das, 2017), (Rao and Holt, 2005).
	Information Sharing with Suppliers	(Hasan, 2013), (Emamisaleh, et al., 2018), (Das, 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).

Sustainable Operations Management Practices	Quality Management	(Hasan, 2013), (Emamisaleh, et al., 2018), (Das, 2017), (Yang et al., 2010), (Luthra et al., 2014), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Yusuf, et al., 2013), (Yang, et al., 2011), (Rao and Holt, 2005).
	Corporate Environmental Management	(Hasan, 2013), (Emamisaleh, et al., 2018), (Liang and Liu, 2017), (Ansari and Qureshi, 2015), (Hsu, et al., 2016), (Vijayvargy, et al., 2017), (Ameer and Othman, 2012), (Rao and Holt, 2005), Vachon and Klassen (2006).
	Corporate Social Responsibility	(Emamisaleh, et al., 2018), (Ansari and Qureshi, 2015), (Ağan, et al., 2016), (Das, 2017), (Ameer and Othman, 2012), (Rao and Holt, 2005).
Sustainable Customer gement Practices	Customer Management	(Emamisaleh, et al., 2018), (Pekovic et al., 2016), (Zhu et al., 2007).
	Information Sharing with Customers	(Emamisaleh, et al., 2018), (Pekovic et al., 2016), (Vijayvargy, et al., 2017), (Rao and Holt, 2005).
Sustainable product design	Pay attention to reduced consumption of material/energy When designing products	(Hasan, 2013), (Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Das, 2017), (Kara and Li, 2011), (Asian Productivity Organization, 2004), (Pajunen et al., 2012), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Yusuf, et al., 2013).
	Pay attention to reuse, recycle, and/or recovery of material When designing products	(Hasan, 2013), (Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Lee et al., 2001), (Sarkis, 1998), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Rao and Holt, 2005).
	We design our products to use environmentally friendly materials	(Hasan, 2013), (Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Zhu et al., 2007), (Hsu, et al., 2016), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Rao and Holt, 2005).
	Designing products with standardized components to facilitate reuse	(Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Carter and Ellram,1998), (Álvarez-Gil et al., 2007), (Beamon, 1999), (Vijayvargy, et al., 2017).
	Designing products for easy disassembly	(Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Duflou et al., 2012), (Lin et al., 2001), (Hsu, et al., 2016), (Vijayvargy, et al., 2017), (Ameer and Othman, 2012).
	Using cycle analysis to evaluate the environmental impacts of products	(Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Manzini and Vezzoli, 2003), (Mont and Lindhqvist, 2003), (Hirschl et al., 2003), (Vijayvargy, et al., 2017), (Ameer and Othman, 2012).
	Having formal guidelines for environmental product design	(Hasan, 2013), (Paulraj, et al., 2017), (Abdul Rashid, et al., 2017), (Manzini and Vezzoli, 2003), (Manzini and Vezzoli, 2003), (Mont and Lindhqvist, 2003), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
) Sustainable process design	The design of our processes is heavily dependent on	(Paulraj, et al., 2017), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Vachon and Klassen, 2006).

	sustainability goals	
	We evaluate our existing processes to reduce their impact on the environment	(Paulraj, et al., 2017), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Vachon and Klassen, 2006).
	We have formal design for environment guidelines for process design	(Paulraj, et al., 2017), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Vachon and Klassen, 2006).
	We constantly reengineer our processes to reduce their environmental impact	(Paulraj, et al., 2017), Rao, (2007), (Vijayvargy, et al., 2017), (Vachon and Klassen, 2006).
	We improve the environmental-friendliness of our production	(Paulraj, et al., 2017), (Rao, 2007), (Vijayvargy, et al., 2017), (Vachon and Klassen, 2006).
) Supply-side sustainability collaboration	We cooperate with our suppliers to achieve sustainability objectives	(Hasan, 2013), (Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005).
	We provide our suppliers with sustainability requirements for their processes	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	We collaborate with our suppliers to provide products and/or services that support our sustainability goals	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005).
	We develop a mutual understanding of responsibilities regarding sustainability performance with our suppliers	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005).
	We conduct joint planning to anticipate and resolve	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005), (Vachon and Klassen, 2006).

	sustainability-related problems with our suppliers	
	We periodically provide suppliers with feedback about their sustainability performance	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
) Demand-side sustainability collaboration	We cooperate with our customers to achieve sustainability objectives	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Azevedo, et al., 2011).
	We cooperate with our customers to improve their sustainability initiatives	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Azevedo, et al., 2011).
	We collaborate with our customers to provide products and/or services that support our sustainability goals	(Hasan, 2013), (Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005).
	We develop a mutual understanding of responsibilities regarding sustainability performance with our customers	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008).
	We conduct joint planning to anticipate and resolve sustainability-related problems with our customers	(Paulraj, et al., 2017), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
Incorporating Reverse Logistic Practices	Reducing solid waste	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Rao, 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Despeisse, et al., 2012),
	Waste elimination strategies	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Rao, 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Despeisse,

		et al., 2012), (Fairfield, et al., 2011).
	Reducing toxic gas emissions into the environment	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Despeisse, et al., 2012).
	Reuse/Recycle the product at the end of life	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Rao, 2007), (Vijayvargy, et al., 2017), (Rao and Holt,2005), (Despeisse, et al., 2012).
	Use of biodegradable raw material	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Rao, 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Despeisse, et al., 2012), (Fairfield, et al., 2011).
	Reducing the use of harmful raw materials	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Carter and Ellram,1998), (Rao, 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Despeisse, et al., 2012), (Fairfield, et al., 2011).
Top Management Commitment	Sharing the information	(Ansari and Qureshi, 2015), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Training education of purchasing employees and suppliers	(Hasan, 2013), (Ansari and Qureshi, 2015), (Ağan, et al., 2016), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Rao and Holt, 2005), (Vachon and Klassen, 2006), (Liang and Liu, 2017).
	Evaluating supplier certification	(Ansari and Qureshi, 2015), (Hsu, et al., 2016), (Walton et al.,1998), (Zhu et al., 2008), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Adopting new manufacturing technologies	(Ansari and Qureshi, 2015), (Zhu et al., 2008), (Azevedo, et al., 2011), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Rao and Holt, 2005), (Despeisse, et al., 2012).
	Innovation	(Ansari and Qureshi, 2015), (Hsu, et al., 2016), (Zhu et al., 2008), (Azevedo, et al., 2011), (Ameer and Othman, 2012), (Yusuf, et al., 2013).
	Trust among the members of supply chain	(Ansari and Qureshi, 2015), (Vachon and Klassen, 2006).
	Customer satisfaction	(Ansari and Qureshi, 2015), (Zhu et al., 2007), (Rao and Holt, 2005).
Green Purchasing	Suppliers ISO 14000 certification	(Hasan, 2013), (Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Ağan, et al., 2016), (Das, 2017), (Yang, et al., 2010), (Zhu et al., 2007), (Hsu, et al., 2016), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Providing information to supplier about environmental issues	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Ağan, et al., 2016), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Supplier-buyer cooperation for environment-friendly raw material	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Ağan, et al., 2016), (Zhu et al., 2007), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Vachon and Klassen, 2006).
	Eco-friendly packaging	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Das, 2017), (Zhu et al., 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Rao and Holt, 2005).
	Reducing carbon	(Ansari and Qureshi, 2015), (Eltayeb, et al., 2011), (Luthra, et al., 2014), (Yusuf, et al., 2013).

	footprints	
Sustainable Manufacturing process	Material recovery (e.g. use wastes as internal resources such as metal swarf and chips)	(Hasan, 2013), (Thiede et al. 2012), (Pajunen et al., 2012), (Abdul Rashid, et al., 2017), (Yang, et al., 2010), (Luthra et al., 2017), (Luthra, et al., 2014), (Hsu, et al., 2016), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Rao and Holt, 2005), (Despeisse, et al., 2012), (Fairfield, et al., 2011), (Liang and Liu, 2017).
	Waste recovery (e.g. use coolants and transport solid wastes from the factory for use as resources in other manufacturing processes)	(Hasan, 2013), (Ansari and Qureshi, 2015), (Jawahir and Dillon, 2007), (Kara and Li, 2011), (Duflou et al. 2012), (Abdul Rashid, et al., 2017), (Luthra et al., 2017), (Luthra, et al., 2014), (Hsu, et al., 2016), (Rao, 2007), (Walton et al.,1998), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Rao and Holt, 2005), (Vachon and Klassen, 2006), (Despeisse, et al., 2012), (Fairfield, et al., 2011), (Liang and Liu, 2017).
	Energy savings	(Fang et al. (2011), (Despeisse et al. 2012), (Jayal et al., 2010), (Abdul Rashid, et al., 2017), (Hsu, et al., 2016), (Rao, 2007), (Vijayvargy, et al., 2017), (Zhu et al., 2008), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Jeswit and Kara, 2008), (Rao and Holt, 2005), (Despeisse, et al., 2012), (Fairfield, et al., 2011), (Liang and Liu, 2017).
	Reduce CO2 emissions	(Ball, et al.,2009), (Abdul Rashid, et al., 2017), (Rao, 2007), (Walton, et al.,1998), (Vijayvargy, et al., 2017), (Ameer and Othman, 2012), (Yusuf, et al., 2013), (Jeswit and Kara, 2008), (Rao and Holt, 2005), (Fairfield, et al., 2011), (Liang and Liu, 2017).
	Improve manufacturing and machine efficiency	(Granados, et al., 2009), (Newman, et al. 2012), (Pusavec, et al., 2010), (Bi and Wang, 2012), (Jawahir and Dillon, 2007), (Kara and Li, 2011), (Duflou et al., 2012), (Millar and Russel, 2011), (Fairfield et al., 2011), (Abdul Rashid, et al., 2017), (Hsu, et al., 2016), (Rao, 2007), (Vijayvargy, et al., 2017), (Rao and Holt, 2005), (Despeisse, et al., 2012).
	Adopt lean production systems	(Miller et al., 2010), (Baines et al., 2007), (Abdul Rashid, et al., 2017), (Das, 2017), (Rao, 2007), (Yang, et al., 2011).

By considering this set of practice, the purpose is to develop an empirical research in order to understand how this happen in the market. We purpose to advance in the comprehension of practice of sustainability, since so far there is no clear theoretical debate around the topic. In addition, we purpose to understand elements that go beyond the Triple Bottom Line perspective. This idea is aligned with some recent research on, e.g., determining how sustainability is managed in different contexts since it highlights that practices such as routines or culture are to be considered to enhance SCS (e.g., Fritz and Silva, 2018). This first step is important to demonstrate how we can develop research and advance in the comprehension of sustainability in supply chains.

Conclusions

This paper demonstrate via a bibliometric review, how is possible to group a set of practice that facilitate a better performance in a supply chain. By using an under-explored debate regarding practices toward sustainability in supply chains following the practice-based view approach, this paper advances theory in the field of sustainability management in supply chain. The use of PBV is still incipient in the literature which ratify our contribution. Furthermore, this paper provides a first set of sustainability practices that firms can use to implement their sustainability goals within their supply chains. It is necessary to understand that several other practices can be found; however for our proposal, there are some criteria that could be used and influence companies.

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Arc of engagement: Exploring the effect of stakeholder relations for environmental practices

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Abstract
Survey data from multiple respondents in 295 plants in 15 countries are used to explore how the configuration of stakeholder relations can influence the effects of both internal and external environmental practices, in terms of their contributions to environmental as well as manufacturing performance. We find that the implementation of environmental practices can be beneficial for both environmental and manufacturing performance, when the manufacturers have developed close relations with all three main groups of stakeholders: suppliers, employees, and customers. Otherwise, implementation of environmental practices can only improve environmental performance, but cannot improve manufacturing performance.

Keywords: environmental practices, manufacturing performance, stakeholder relations

Introduction
Customers, suppliers, and the general public are increasingly demanding businesses in general, and manufacturing plants in particular, to minimize any negative impact of their products and operations processes on the natural environment. Moreover, as manufacturers move toward environmental sustainability, it is an imperative to improve environmental practices across their supply chains (SCs) (Vachon & Klassen, 2008). While it is relatively easy for manufacturers to implement certain environmental practices, including pollution prevention and pollution control, and to achieve some quick benefits, such as water/energy saving (Klassen & Whybark, 1999), the real challenge is to effectively implement environmental practices across SCs to go beyond low-hanging fruits and reap substantial benefits from environment investments. In other words, how can environmental practices contribute to environmental as well as manufacturing performance in terms of cost, quality, delivery, and flexibility?

To identify contingencies that can make environmental practices more effective, researchers on sustainable supply chain management (SSCM) have explored various factors related to industrial context, market environment, product specifications, manufacturing processes, and firm specifications. However, researchers have yet to clarify how stakeholders can impact on the performance implications of environmental practices, although multiple groups of stakeholders including customers, employees, regulatory agencies, and NGOs have been identified as important drivers of implementing environmental practices. We see this as a

major gap, considering that effective implementation of environmental practices entails active participation of multiple groups of stakeholders. In this study, we conjecture that the focal manufacturers' relationship quality with three main groups of stakeholders – namely suppliers, customers, and employees – can influence the effectiveness of environmental practices implemented at the focal manufacturers' SCs.

A survey methodology was used to examine the complex relationships among bundles of environmental practices (internal and external) and stakeholder relations to improve environmental and manufacturing performance. The fourth round of data collection for the High Performance Manufacturing (HPM) project serves as the empirical setting for our study. Structural equation modeling (SEM) approach was used to test our hypotheses. For what concerns stakeholder relations, cluster analysis was used to identify configurations of three dimensions of stakeholder relations, i.e., supplier relations, employee relations, and customer relations, following a configuration approach (Meyer et al., 1993). Then, we used multi-group analysis to examine possible significant differences in the performance implications of internal as well as external environmental practices among different configurations of stakeholder relations.

Theoretical Foundations and Hypotheses Development

Environmental practices and manufacturing performance

Industrial activities of the past half century have created serious environmental problems, including global warming, ozone depletion, loss of biodiversity, resource depletion, and pollutions (Shrivastava, 1995). Against this backdrop, environmental management has emerged as a core issue of manufacturing strategy, as manufacturing plants have to reduce their impact on the natural environment. In the early 1990s, practitioners and academics alike were generally critical about the strategic value of environmental management, and the shared concern was that allocating resources to reduce environmental impact can harm the core competitiveness of manufacturers. As Friedman put it: "there is one and only one social responsibility of business – to use its resources and engage in activities designed to increase its profits as long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud" (Friedman, 2007). One common argument used by environmental skeptics such as Milton Friedman was traditional economic trade-off, in which any environmental improvement made by a manufacturing firm transfers costs previously incurred by society back to the firm. As a result, manufacturing performance, traditionally defined in terms of cost, quality, speed, and flexibility, worsens (Klassen & Whybark, 1999).

Growing empirical evidence (Orlitzky et al., 2003; Margolis et al., 2007; Horváthová, 2010; Golicic & Smith, 2013) and theoretical development (Hart, 1995) show that improved environmental performance does not necessarily come at the cost of worsened manufacturing and/or financial performance. Several scholars (Hart, 1995; Porter & Van der Linde, 1995; Shrivastava, 1995; Russo & Fouts, 1997) have developed converging arguments that can justify the strategic value of environmental management: proactive investments for improving environmental performance can enable the manufacturers to develop product, process, and managerial resources and capabilities that generate competitive advantage. For example, pollution prevention can drive manufacturers to critically evaluate and improve the product and/or process design, so as to achieve a higher level of resource productivity (Porter, 2008). Essentially, all forms of pollution and wastes represent resources that are misplaced. As such, pollution prevention calls for continuous improvement, through which the managers and engineers within the manufacturer can develop in-depth knowledge about the products and processes. Arguably, these in-depth understanding, knowledge, and capabilities are rare, difficult to imitate, and have few substitutes. More importantly, the development of such capabilities is largely path dependent, and they are not readily available in the market. Likewise,

several other internal environmental practices, including design for disassembly, manufacturing for the environment, and total quality environmental management (Shrivastava, 1995), are found to contribute positively toward manufacturing performance, which forms the baseline the first hypothesis of this study.

As operations management (OM) has moved beyond the four walls of the manufacturers, environmental management has already been extended to include upstream as well as downstream SC activities, in order to mitigate the environmental impact of these activities (Golicic & Smith, 2013; Lund-Thomsen & Lindgreen, 2014). These practices are here referred as external environmental practices. Typical environmental practices in this category include green purchasing (Green et al., 1998), supplier assessment and development for sustainability (Gimenez & Tachizawa, 2012), and green logistics (Lai & Wong, 2012). Implementation of external environmental practices can also affect a plant's manufacturing performance. Although past research has not always provided consistent empirical evidence of the effect of external environmental practices, a prominent argument is that the joint effort of a manufacturer and its suppliers and customers can enable knowledge sharing and the development of relation-specific and capabilities that are socially complex and not easily tradable, and therefore can result in competitive advantage (Pagell et al., 2007; Paulraj, 2011). For example, environmental collaboration between a manufacturer and its suppliers and customers, such as joint decisions about ways to reduce environmental impact of products and/or processes, promotes exchange of technical information and mutual learning, which can lead to innovative solutions for environmental management and in turn improvements in both environmental and operational performance (Vachon & Klassen, 2008). In line with this reasoning, we also hypothesize a positive relationship between external environmental practices and a manufacturer's performance.

Hypothesis 1: *Implementation of environmental practices positively relates to manufacturing performance.*

> ***Hypothesis 1a****: Implementation of internal environmental practices positively relates to manufacturing performance.*
>
> ***Hypothesis 1b****: Implementation of external environmental practices positively relates to manufacturing performance.*

Many (environmental) sustainability programs started as isolated efforts by a manufacturer. However, over the years, more and more companies have recognized the need to extend such programs beyond the firms' boundary, thus engaging in (environmental) sustainability practices with their supply chain partners (Kytle & Ruggie, 2005). It can be expected that, in this process, knowledge and capabilities developed in sustainability management at plant level could act as an enabler for the implementation of external practices (Graham, 2018). In line with this, some recent research suggest that bundles of (environmental) sustainability practices may be related to each other, with some studies also highlighting significant implications for performance (Zhu et al., 2012; Green et al., 2012; Gualandris & Kalchschmidt, 2016; Graham, 2018). We therefore hypothesize:

Hypothesis 2*: Implementation of internal environmental practices positively relates to implementation of external environmental practices.*

Stakeholder relations and environmental management

Various groups of stakeholders, including customers, local community, and NGOs, have been the driving force for manufacturers' implementation of internal as well as external environmental practices (Kassinis & Vafeas, 2006). While prior studies have thoroughly investigated the "driving" effect of stakeholder pressures on the manufacturers' environmental management, rather limited attentions have been paid to explore how and to what extent these

stakeholders enable the effective implementation of internal and/or external environmental practices. We see this as an important omission, considering that several seminal papers on the strategic value of environmental management (Hart, 1995; Porter & Van der Linde, 1995; Shrivastava, 1995; Russo & Fouts, 1997) consistently highlight stakeholder engagement as a key to the effective implementation of environmental practices. For example, several studies on SSCM (Sancha et al., 2016; Gualandris & Kalchschmidt, 2016) show that good buyer-supplier relations can significantly enable the effective implementation of supplier sustainability practices. This study aims to advance this stream of studies by exploring the performance implications of internal as well as external environmental practices while explicitly taking into account the contingency role of the manufacturer's relation quality with three main groups of stakeholders: suppliers, customers, and employees.

We adopted a configuration approach (Meyer et al., 1993) when investigating the impact of stakeholder relations on the effectiveness of environmental practices. Configuration approach is deemed appropriate for handling complex relationships, such as the relationships between patterns or "arcs" of SC integration and manufacturing performance (Frohlich & Westbrook, 2001; Flynn et al., 2010). Instead of analyzing the impact of specific contingencies separately, a configuration approach explores configurations of various elements and their interactions (Drazin et al., 1985). Therefore, a configuration approach allows us to not treat stakeholders as separated entities one from the others. Many advanced projects for improving environmental performance entail engaging suppliers, customers, as well as employees. Cooperation and interactions among different groups of stakeholders can facilitate knowledge sharing and creation, which can foster the effective implementation of environmental practices. However, the quality of relations a company has with its employees, suppliers, and customers can differ across organizations. For this reason, we acknowledged the existence of different configurations of stakeholder relations, and posit that in different configurations of stakeholder relations, environmental practices will have different performance implications.

Hypothesis 3*: In different configurations of stakeholder relations, environmental practices will have different performance implications.*

Methods

Data from the HPM survey was used to explore the research question (see for example Schroeder & Flynn, 2001). The HPM is an international network of researchers that have collaborated for many years with each other and with manufacturing plants all over the world to develop a common survey. The primary aim of the survey is to explore the relationship between OM and SCM and the success (i.e., high performance) of manufacturing plants. However, the dataset can be used to examine many other research questions in the OM field. This study uses data from the fourth round of HPM, which includes plants located in 15 countries (Brazil, China, Finland, Germany, Israel, Italy, Japan, Korea, Spain, Sweden, Switzerland, Taiwan, UK, US, and Vietnam) and operating in 3 industries (machinery, electronics, and automotive).

Data collection was performed in a similar way across countries, thanks to the use of shared guidelines. In all countries, a team of researchers was in charge of selecting the plants, contacting them, administrating the questionnaires, and providing assistance to the respondents to ensure that the information gathered was correct and complete. Selection was on a random basis, from a master list of manufacturing plants in the country. All plants received a set of 13 different questionnaires (translated as needed). Each questionnaire (except the accounting one, not used in our study) was administered to two respondents within the plant, selected by the CEOs considering who were the best informed about the topic of each questionnaire. This choice was made to minimize the risk of common method bias, which is higher in case of a single compared to multiple respondents. The final sample includes 331 plants, with a response

rate of approximately 65% in each country (Danese et al., 2018). However, we deleted thirty-six plants due to missing data.

Results

Baseline Model: Environmental Practices and Manufacturing Performance

We checked that the fit indices of our baseline model were indicative of a well-fitting model. The results of path analysis for our baseline model are reported in Tables 1. The results of direct paths from internal environmental practices show a strong and positive relationship with environmental performance, a strong but negative relationship with cost, and no significant relationship with both quality and responsiveness (Table 1). For what concern external environmental practices, we found strong positive relationships with both environmental performance and cost, weak positive relationship with quality, and no significant relationship with responsiveness. We also tested the total effects, which show strong positive relationships with environmental performance and quality, a positive but weak relationship with cost, and no significant relationship with responsiveness. Overall, these results provide partial support for hypothesis 1.

Table 1 also shows a strong positive relationship between internal environmental practices and external environmental practices, which provides support for hypothesis 2.

Table 1

SEM path analysis for the overall sample: Results for hypotheses 1, 1a, 1b, and 2.

SEM path analysis - overall sample	
Model paths	
Direct paths from internal environmental practices	
Env Int → Env Perf	**.209***
Env Int → Cost Perf	**-.246***
Env Int → Qual Perf	.013
Env Int → Resp Perf	-.001
Env Int → Env Ext	**.696****
Direct paths from external environmental practices	
Env Ext→ Env	**.400****
Env Ext→ Cost	**.525****
Env Ext→ Qual	**.216**$^{+}$
Env Ext→ Resp	.124
Total effects of environmental practices on performance	
Env Perf	**.488****
Cost Perf	**.119**$^{+}$
Qual Perf	**.163***
Resp Perf	.085

Note: The ‘‘bold’’ entries indicate path coefficients that are statistically distinct across sub-groups.

** $p < 0.01$

* $p < 0.05$

$^{+}$ $p < 0.1$

Cluster Analysis Results: configurations of stakeholder relations

Hypothesis 3 posits that configurations of stakeholder relations can be developed based on the quality of the relations of firms with their employees, suppliers, and customers and calls for a differential effect on the pattern of linkages in Table 1 according to the configurations of stakeholder relations. Hair et al.’s (2010) two-step cluster analysis procedure was used to classify plants into configurations of stakeholder relations. That is, we first applied a

hierarchical clustering procedure to determine the number of clusters, and then a non-hierarchical procedure to produce the final clusters.

Figure 1 shows results of the analysis of the agglomeration coefficient, which was used to determine the number of the clusters. Four clusters were judged as sufficient, as the percentage of change in the agglomeration coefficient was the highest when the number of groups changed from four to three (Flynn et al., 2010). A four-cluster solution was also preferred over a five cluster solution due to a better interpretability of the data (Hair et al., 2010), having the five cluster solution a cluster of only 29 plants. In the second step, the K-means algorithm was used to assign observations to the four clusters. We then used ANOVA and a Scheffé post-hoc test of mean differences to examine the quality (or strength) of relations with employees, suppliers, and customers across the four clusters. The final clusters and their centroids are reported in Table 2.

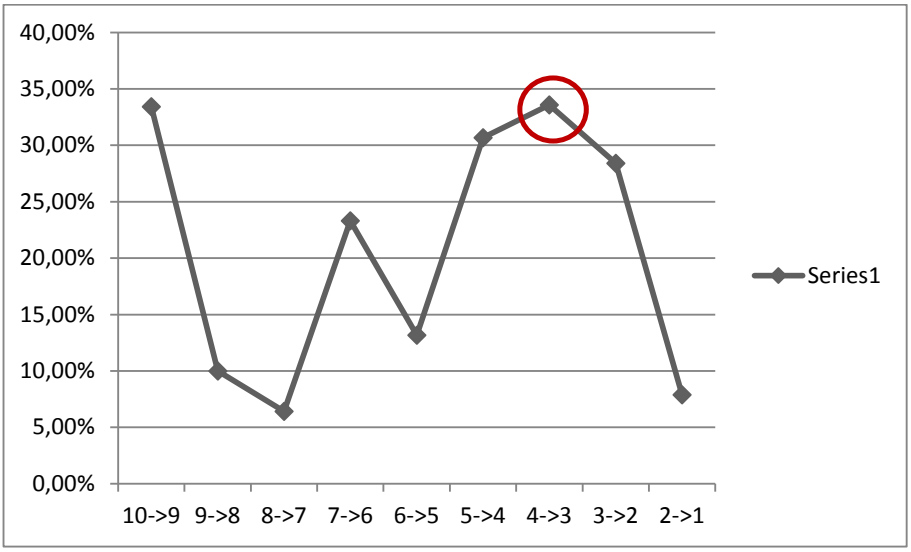

Figure 1. Percent change in the agglomeration coefficient

Table 2
Cluster Centroids

	Mean			
Cluster	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**
Name	**Comprehensive orientation**	**Upstream orientation**	**External orientation**	**Downstream orientation**
Supplier relations	Higher[1] 4.51	Medium-higher 4.25	Medium-lower 4.03	Lower 3.42
Employee relations	Higher 4.32	Medium 4.00	Lower 3.05	Medium 4.13
Customer relations	Higher 4.51	Lower 3.70	Medium 3.94	Medium 4.04
Number	99	86	64	47

Note: [1]Higher, Medium-Higher, Medium, Medium-Lower, and Lower based on Scheffe post Hoc tests of mean differences.

In interpreting the results of Table 2, we first examined the balance of the relations with each stakeholder. Cluster 1 developed good relations with employees, suppliers, as well as customers. We labelled it "comprehensive orientation". Instead, the other three clusters have unbalanced patterns, with relation with one stakeholder scoring lower than the other clusters, and the relations with the other two stakeholders scoring medium (medium-lower, medium, or medium-higher). For this reason, we referred to a "selective orientation". In order to better categorize clusters with a selective orientation, we also analyzed the quality (or strength) of relation with each stakeholder. We labelled cluster 3 as "external orientation", as it scored medium in relations with suppliers and customers, but has a lower score in the internal relations. Clusters 2 and 4 have symmetrical patterns. Cluster 2 has a lower score in the customer dimension and was therefore labelled as "upstream orientation", while cluster 4 has a low score in the supplier dimension and was therefore labelled as "downstream orientation".

Multi-group Analysis: Moderating Role of Stakeholder Relations

The aim of Hypothesis 3 was to see whether the configurations of stakeholder relations can moderate the relationships among environmental practices and manufacturing performance. We ran an iterative process assessing the presence of significant differences in χ^2 values ($\Delta\chi^2$) between pairs of nested models. As for the path analysis in the overall dataset, we verified both the direct and the total effects. The results of our multi-group analysis are reported in Table 3.

Table 3

SEM path analysis for the four clusters: Results for hypothesis 3.

Four-group path analysis				
Model paths	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Direct paths from internal environmental practices				
Env Int → Env Perf	**.238****	**.238****	**.238****	**.238****
Env Int → Cost Perf	**-.254****	**-.254****	**-.254****	**-.254****
Env Int → Qual Perf	.021	.021	.021	.021
Env Int → Resp Perf	.011	.011	.011	.011
Env Int → Env Ext	**.902****	**.630****	**.630****	**.440****
Direct paths from external environmental practices				
Env Ext→ Env Perf	**.285****	**.285****	**.614****	**.285****
Env Ext→ Cost Perf	**.503***	**.503***	**.503***	**.503***
Env Ext→ Qual Perf	.163	.163	.163	.163
Env Ext→ Resp Perf	.068	.068	.068	.068
Total effects of environmental practices on performance				
Env Perf	**.501****	**.439****	**.555****	**.391****
Cost Perf	**.198***	.064	.064	-.033
Qual Perf	**.167***	**.124**$^{+}$	**.124**$^{+}$	.093
Resp Perf	.072	.054	.054	.041

Note: The ''bold'' entries indicate path coefficients that are statistically distinct across sub-groups.

** $p < 0.01$

* $p < 0.05$

$^{+}$ $p < 0.1$

Firstly, the results of direct paths from internal environmental practices show a strong positive relationship with environmental performance, a strong but negative relationship with cost, as well as no significant relationship with both quality and responsiveness across the four clusters. For what concern external environmental practices, we found strong positive

relationships with environmental performance and cost, while relationships with quality and responsiveness were not significant. In addition, the impact of external environmental practices on environmental performance in cluster 3 was significantly higher than in the other three clusters.

Secondly, the analysis of the relationship between internal and external environmental practices showed a strong positive relationship in all the clusters. However, internal environmental practices has a higher impact on external environmental practices in cluster 1 than in the other three clusters, there was a similar impact in cluster 2 and 3, and a lower impact in cluster 4.

Finally, the test of the total effects revealed additional differences in the performance levels across the four clusters. While environmental performance was positively affected in all the clusters, cost and quality were positively affected only in cluster 1. The effect on quality was positive but week in clusters 2 and 3. Cost was negatively affected in cluster 4, although the impact was not statistically significant.

Overall, the multi-group analysis results suggest that differences in configurations of stakeholder relations can result in different performance, providing support for hypothesis 3. In addition, they suggest that such differences can be due to (1) a different impact of the internal environmental practices on external environmental practices and (2) a different impact of external practices on performance.

Conclusions

This study contributes to SSCM literature by providing a better understanding of the complex relationships between specific bundles of environmental practices and their interaction with stakeholder relations to improve manufacturing performance. Our results have also important implications for practitioners. Firstly, managers should acknowledge the importance of both internal and external environmental practices. While the implementation of external practices is particularly important to overcome trade-offs between environmental and operational performance, internal practices not only contribute to environmental performance, but are also an important enabler for external environmental practices. Therefore, manufacturers should investment in both internal and external environmental practices to make the most out of their environmental programs.

Secondly, managers should carefully assess their general relations with employees, suppliers, and customers, as they affect the effectiveness of their environmental programs. Only when good relations with all of these stakeholders are present, manufacturers can expect to achieve the full benefits of their environmental programs. A selective orientation, excluding one of these groups, it is likely to result on environmental improvements only, thus precluding improvements on operational performance. However, good relations with multiple stakeholders can require significant resources to be developed or even maintained. Our results can also guide manufacturers that do not have good relations in place, on which group(s) of stakeholders target their limited resources. Indeed, we found that a downstream orientation (cluster 4) can be more detrimental than other selective orientations for operational performance. This suggests to not exclude suppliers, as it is likely they have important as well as unique knowledge and capabilities that can booster effectiveness of environmental programs.

It is important to note some limitations of our study, which suggest an interesting agenda for future research in this area. First, for what concern the research setting, manufacturing plants in our sample operate in machinery, electronic, and transportation components industries, and this can limit the generalizability of our findings. It might be that other sectors may show different results. Therefore, future research should replicate and extend our model to samples drawn from other industries.

Second, our study examined environmental practice effectiveness considering manufacturing performance of focal manufacturers. However, it could be interesting to also include the performance of suppliers as well as customers in order to provide a better understanding of possible trade-offs in performance at a SC level.

Third, we analyzed the role of stakeholder relations by including three groups of stakeholder, i.e. employees, suppliers, and customers. Although these may arguably be the stakeholders with a more direct impact on effectiveness of environmental practices, literature suggested other groups, including regulatory agencies and NGOs, as important drivers of environmental programs. Therefore, we call for future research that analyzes the role of various groups of stakeholders for environmental program effectiveness.

Finally, our study focused on environmental sustainability and impacts of environmental practices on two dimensions of the so-called triple-bottom-line (Elkington, 1998). As manufactures are nowadays required to also improve their social performance, an interesting venue for future research is to also include the social dimension in the investigation of the effectiveness of sustainability programs.

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Factors and Motives in Practitioners' Decision Making in Industrial Sourcing: Local Versus Global Perspectives

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Abstract

Global sourcing has dominated in industrial sourcing understating operational impacts as key objective. Low unit price has been pivotal: This paper investigates buyers' and influencers' decision-making on local versus global industrial sourcing, from a qualitative perspective, by contrasting between intentional and actual drivers related to operational fundamentals. Our study indicates that the prioritization in sourcing are: 1) unit costs; 2) quality and lead time; 3) flexibility of sourcing; 4) transportation/logistics, dependability, inventory level. Simpler drivers (unit costs) are favoured over "complex" drivers such as flexibility. This paper calls for closer reviews of sourcing decisions to streamline sourcing and operations better.

Keywords: Local Sourcing, Global Sourcing, Operations Management

Introduction

The choice between local and global sourcing has presented an ongoing challenge for decision makers over the last three decades (Bailey and De Propris, 2014; Bals et al., 2016; Johansson and Olhager, 2017; Monczka et al., 2016). The location of sourcing influences the geographical dispersion of business activities, and thus creates consequences throughout the company. Managerial issues relating to the geographical dispersion of sourcing and product development activities have been extensively studied (Echtelt et al., 2007; Gray et al., 2017), and this has improved our understanding of the drivers influencing the location of sourcing (McIvor, 2013), the involvement of suppliers (Dain and Merminod, 2014), cross-border collaboration and knowledge sharing (Revilla and Knoppen, 2015). However, decisions on the location of sourcing are mostly disconnected from operations (Dekkers, 2011), mainly due to a lack of understanding from sourcing management about the practical consequences of their decisions on operations (Brown, 2013). Indeed, Ketokivi et al. (2017) point out that senior managers

often have a perfunctory understanding of operations, and this results in decision making that does not reflect the short- and long-term opportunities and consequences.

Accordingly, by exploring the drivers influencing the decision on local versus global sourcing and analyse these drivers in the light of the impact on operations the purpose of this paper is to provide analytical means for qualifying and improving decision making in the relationship between sourcing and operations management. To do so, this paper draws on Argyris' and Schön's (1974) classical work highlighting a gap between "espoused theory" (a practitioner' intentional action) and "theory in use" (a practitioner's actual action). This understanding is used to distinguish between intentional drivers and actual drivers, and to guide the research as a research question we ask "*to which extent are the local versus global decision-making based on intentional- or actual drivers*".

The empirical setting for this qualitative study is a global company with business activities around the globe. We focus on the sourcing of strategic materials for manufacturing plants located in Denmark.

Theoretical background

Definition of terms

Weele (2014) focuses on activities related to sourcing, and thus regards sourcing as a process of identifying, selecting and managing an optimal source of supply around the globe. Drawing on Weele's viewpoint and Webster and Wind's (1972) "Buy Grid" model, sourcing is understood here as a phased process involving activities related to the creation of specifications, supplier selection, negotiation and contracting, ordering, expediting and follow-up. The first three phases involve strategic sourcing, and thus mainly entail collaboration with product development, while the last three phases deal with operational sourcing in collaboration with operations (manufacturing). Thus, this paper defines *operational sourcing* as the ordering of materials, ongoing follow-up on these orders and activities related to the final evaluation of the sourced materials.

The globalisation of business activities has turned global sourcing commonplace (Kotabe and Murray, 2004). Weele (2014) regards global sourcing as the accomplishment of sourcing activities in globalised settings, often as sourcing from low-cost countries. Wagner and Bode (2006) describe global sourcing as an extension of the sourcing network in geographical terms. Local sourcing is understood by Wagner and Bode (2006) to be the activity of sourcing from geographic and socio-economic vicinity (Contractor et al., 2010). Accordingly, this paper understands *local sourcing* to take place within the domestic setting, while *global sourcing* refers distance and complexity.

Kraljic (1983) and Bensaous (1999) focus on the existing products being produced, meaning that these two well-known approaches to categorising the sourced materials draw on an operational perspective. According to Kraljic (1983), strategic materials are characterised as having high financial impact and high supply risk, while Bensaou (1999) defines strategic materials as requiring high levels of investment in the relationship by both the buyer and supplier. Since its publication, Kraljic's approach has been widely adopted by practitioners in various business areas (Rezaei et al., 2015) and in academia. For instance, Gelderman and Weele (2003) call into question the sensitivity to measurement drivers, while Gelderman and Semeijn (2006) emphasise that in the case of strategic material, companies often have to accept the dominance of a supplier. Pagell et al. (2010) and Hesping and Schiele (2016) have further developed Kraljic's model, and emphasise that not only the profit impact but also the long-term strategic importance of materials should be considered relevant when identifying portfolio groups.

Based on the above, *strategic materials* are defined here as having high strategic importance, including high profit impact, high supply risk, and deviations will have high impact on the operational performance.

Identification of drivers

Sourcing decisions must be analysed from its impact of general business functions such as sales and marketing (Ketokivi et al., 2017), logistics (Wagner and Bode, 2006), quality (Stanczyk et al., 2017), and warehousing and levels of inventory (Slack et al., 2016).

A study of 373 manufacturing companies (Johansson and Olhager, 2017) illustrates that although low labour cost is the determining driver in the globalisation of sourcing, the consequences of this decision are often disappointing in terms of quality, lead time and flexibility of performance, thus prompting a reconsideration of the chosen sourcing location. Stanczyk et al. (2017) present a comprehensive literature review of drivers influencing the globalisation of companies' sourcing activities; the drivers are divide into those relating to operational performance and financial performance, respectively. The former includes drivers such as lead time, inventories, quality and complexity, while the latter consists of costs related to materials, transportation, inventories and overhead.

According to the sourcing process model presented above, the selection of suppliers (i.e. the sourcing location) is one of the first decisions to be taken (Webster and Wind, 1972; Weele, 2014), meaning that the decision on sourcing location is decoupled from operational issues (Dekkers, 2011). Accordingly, the review of influencing drivers in this study focuses only on the performance-related consequences of sourcing location decisions; in other words, the aim of this review is to reveal the drivers of location decisions taken by practitioners in operational areas.

Slack et al. (2016) suggest that performance-related consequences include quality, time of delivery, lead time, dependability, flexibility (to cope with fluctuations in demand) and costs. Bozarth and Handfield (2016) agree, but omit dependability. Schönsleben (2004) identifies quality, costs, delivery and flexibility, while Chae (2009) emphasises inventory days of raw material supply and the dependability of upstream actors. Leonczuk's (2016) finds that quality, dependability of delivery, lead time, flexibility, inventory levels and costs are key performance drivers.

Drawing on the above, it seems that researchers agree upon the following performance-related consequences: costs, quality, dependability (supplier reliability), lead time, inventory levels and flexibility. In the following, these performance-related consequences are used to structure a review of articles examining the drivers influencing the choice between local and global sourcing.

Costs are considered to be an influencing driver by Fagan (1991), Bozarth et al. (1998), and several others; Table 1 gives a comprehensive listing. These costs involve both unit costs and indirect costs, for instance transportation/logistics costs (Fagan, 1991). Trent and Monczka (2003) find that direct costs (unit costs) are the most important influencing driver. According to Kotabe and Murray (2004), although opportunities for reductions in unit costs were previously a crucial influencing driver, unit cost currently ranks alongside quality and dependability drivers. Zhai et al. (2016) echo this viewpoint, and mention unit costs alongside quality as the primary drivers. Joubioux and Vanpoucke (2016), Stentoft et al. (2016) and several others (see Table 1) consider quality to be an influencing driver. Except for Kotabe and Murray (2004) and Wagner and Bode (2006), these authors also find that lead time is a driver influencing decision making. Trent and Monczka (2003), Bailey and De Propris (2014) and others (see Table 1) suggest that dependability influences this decision. Inventory level, including the volume of the sourced material, is considered to be an influencing driver by Kotabe and Murray (2004), Ashby (2016) and

Fratocchi et al. (2016). Finally, according to Bailey and De Propris (2014), Fratocchi et al. (2016), and several others (see Table 1) flexibility is a determinant of the choice between local and global sourcing.

In summary, based on the above review of 16 articles, the seven drivers are as follows: unit costs (identified in 14 articles); transportation/logistics costs and quality (identified in 13 articles); lead time (identified in 12 articles); flexibility of sourcing (identified in 10 articles); dependability (supply reliability; identified in nine articles); and finally inventory level (identified in seven articles).

Table 1. Drivers influencing the decision between local and global sourcing methods

	Costs	Transportation	Quality	Lead-time	Flexibility	Dependability	Inventory
Ashby (2016)	•	•	•	•	•	•	•
Bailey and De Propris (2014)	•	•	•	•	•	•	
Bals et al. (2016)	•	•	•	•	•		
Bozarth et al. (1998)	•	•	•	•	•		•
Fagan (1991)	•		•	•		•	•
Fratocchi et al. (2016)	•	•	•	•	•		•
Johansson and Olhager (2017)	•	•	•	•	•		
Joubioux and Vanpoucke (2016)	•	•	•		•	•	
Kotabe and Murray (2004)	•	•	•			•	•
Petersen et al. (2000)	•	•					
Stentoft et al. (2016)	•	•	•	•	•	•	
Trent and Monczka (2003)	•		•	•		•	•
Wagner and Bode (2006)		•		•		•	
Weele (2014)	•	•	•	•	•	•	•
Zhai et al. (2016)	•	•	•	•	•		

Methodology

This research is exploratory, and a qualitative research approach is applied here (Creswell, 2014). Boer et al. (2015) suggest that a review in an explorative study should be short, rather than comprehensive as for theoretical tests. Narrative literature review in this paper is to gain an overview of the influencing drivers (Hammersley, 2001). A literature review reveals seven identified drivers. These seven drivers feed into and structure the empirical analysis. Thus, although the research commences with a literature review, the line of inquiry is not a purely deductive approach; as Bertilsson (2004) states, "Deduction does not really 'see' anything at all as it serves a control office".

The empirical context for this paper is a large global company producing complex products with both mechanical components and hardware with embedded software. The company has operated with both local and global sourcing methods for 10 - 15 years. While the company has several facilities globally, the focus in this research is on sourcing strategic materials for its manufacturing plants located in Denmark. Thus, the distinction between local and global sourcing is based on the geographical location of suppliers in relation to the Danish facilities. The study of this company constitutes a case-based research approach (Woodside and Wilson, 2003; Yin, 2009).

Product variants are often made on engineer-to-order basis. There is also a certain degree of customisation or configurability of each system with respect to a range of customer or local requirements. Most parts are manufactured by suppliers, but critical

parts are assembled within the company. The planning horizon for assembly and shipping systems to customers is typically very long – measured in years.

The data collection carried out here involves observations and semi-structured interviews with practitioners in a range of different organisational functions. Seven semi-structured interviews were conducted. A gatekeeper (Bryman and Bell, 2007) supported the identification of each of the practitioners interviewed. Informants were identified with a range of different organisational functions, who were either involved in or directly influenced by the local or global decision making, for example operational procurement, engineers involved in engineering changes to existing products, quality, planning, warehousing and production. Extensive action research was also used to underpin the results, consisting of a presence in the company for approximately one year, shadowing meetings, decision-making and daily data processing.

Our analysis draws on the above interviews and observations, which were coded into a matrix with the identified drivers as one dimension, and the informants and observations making up the other dimension. Focal point of this analysis is the influencing role of the drivers, rather than the different functional areas. Through our approach, a pattern gradually emerges from the collected data, enabling an understanding of the current approach to the decision on local versus global sourcing followed by clarification of the practitioners' suggestions for an ideal approach to determine the location of sourcing.

Empirical findings and analysis

With the aim of providing analytical means for qualifying and improving decision making in the relationship between sourcing and operations management the analysis in this section explores the drivers influencing the decision on local versus global sourcing. To guide the analysis we focus on "*to which extent are the local versus global decision-making based on intentional- or actual drivers*".

Although the seven influencing drivers are presented and analysed separately below, the majority of practitioners emphasised that the decision between local and global sourcing location should not be based on a single driver. Instead, proper decision-making should take into consideration several of these seven drivers. Intentional driver for the local/global decision-making is to apply a trade-off approach among all drivers.

The majority of practitioners ranked *unit costs* (direct material costs) as a pivotal driver affecting the decision between local and global sourcing. Few practitioners ranked it in second place, who considered *dependability* as the most crucial driver. Even though placing unit costs as their first priority driver, the practitioners acknowledged that the total cost of sourcing strategic materials would be more appropriate, emphasising that although global sourcing has lower unit costs, the total cost of global sourcing will in some situations be higher than for local sourcing.

Although the practitioners noted the benefits of applying a total cost analysis in this decision, the weighting of *transportation/logistics costs* was surprisingly low. All practitioners stated that this driver had only a minor influence on the decision-making process; issues being highlighted by the practitioners are costs consideration based on INCOTERMS agreements (Weele, 2014). The viewpoint in the company is that since the supplier is responsible for carrying all risk and *transportation/logistics costs*, the *unit cost* is the pivotal driver. Thus, costs related to increasing the safety stock (*inventory level*) due to longer lead times and potential quality issues are neglected. This indicates that the actual driver for the decision-making is unit costs.

All practitioners highlighted that *dependability* was not a matter that greatly influenced the decision-making process. The only *dependability* issues that influenced decision-making were audits of the suppliers' financial positions; *dependability* in terms of timely

deliveries and the right quality had no influence. Practitioners pointed out that *dependability* influenced the selection process of suppliers, but did not have any influence on whether local or global sourcing was selected. The practitioners acknowledged that *dependability* in regard to on-time deliveries and quality should have a higher degree of influence on the selection process of suppliers, as it could be a means of reducing the risks of sourcing. It seems the actual influence of the *dependability* driver is minimal.

Responses regarding the influence of *lead time* are diverse. Practitioners who were involved in engineering change management, quality and planning stated that *lead time* was among the most important influencing drivers. Their argument was that sourcing with a short *lead time* (from suppliers) was more capable of handling fluctuations in production plans than sourcing operating with long *lead times*. Practitioners working in production and operational procurement considered *lead time* to have a degree of influence on decision making, and ranked *lead time* as having a medium degree of importance. As long as a supplier's *dependability* in terms of timeliness and quality was acceptable, *lead time* considerations should only have a minor influence on the decision-making process.

All practitioners agreed that *quality* influenced the selection of local or global sourcing location. In the past, *quality* issues had been frequently encountered when receiving materials from global sourcing locations; however, practitioners stated that the level of *quality* from foreign locations ranked alongside domestic sourcing locations at the time of response. Indeed, *quality* was not regarded as a main influencing driver when distinguishing between local and global sourcing locations. Rather, *quality* was considered to be a generic driver in the choice of suppliers, and some practitioners ranked the influencing role of *quality* as lower than *unit costs*, while others suggested that *quality* was less important than both *unit costs* and *lead time*. Nevertheless, all practitioners felt that *quality* should be the pivotal driver in all sourcing decisions, as it could ensure the lowest total cost in the long term; as stated above, differences in *quality* performance are not generally caused by the location of sourcing, meaning that *quality* should remain a generic selection intentional driver.

All practitioners responded that *inventory level* did not influence the selection process of suppliers in any way. Practitioners pointed out that issues related to *inventory level* were handled by operations totally decoupled from the sourcing location. Practitioners apparently faced the consequences of this neglect, and they emphasised that *inventory level* considerations should be taken into account in the choice of local and global sourcing location. Practitioners from warehousing and procurement suggested that either local sourcing locations should be used or that global sourcing locations (suppliers) should establish local warehouses.

In regard to the last driver, the majority of practitioners considered *flexibility of sourcing* to be a driver of some importance. All practitioners underlined two aspects of flexibility: the availability of technology and the availability of free capacity. Both aspects were rated as being highly important when selecting local or global sourcing methods. In terms of the availability of technology, the practitioners did not identify any issues associated with local sourcing; however, in terms of the availability of free capacity, they emphasised that it was often necessary to use or supplement local sourcing with global sourcing, via a dual-sourcing scheme. Compared with the present situation, the practitioners did not see any need to change the priority of the *flexibility of sourcing* driver, highlighting that the total costs should be the pivotal influencing driver in the choice between local and global sourcing.

In summary, a huge gap between intentional and actual drivers for the local/global decision-making is revealed. The practitioners highlight the importance of using a trade-off approach in an attempt to reduce the total cost, but at the end of the day, the actual

driver having pivotal influence on the location decision is unit cost. Following unit cost, quality and lead time have also high priority, while flexibility of sourcing (capacity-wise) has a certain level of influence. Transportation/logistics costs, dependability and inventory level have only a minor influence. To close the gap between intentional and actual driver, the analysis indicates that practitioners should pay more attention to flexibility, dependability, inventory level and transportation/logistics costs.

Discussion

The consequences of an excessively one-sided focus on unit costs have been examined by researchers. For instance, due to issues relating to quality, lead time and flexibility performances, local versus global sourcing decision making based on reducing unit costs are often reversed (Johansson and Olhager, 2017), meaning that production is backshored (Ashby, 2016). Practitioners in the operations department were "held hostage" by the sourcing decisions, as they had to find a way to cope with inadequate quality, long lead times, a lack of flexibility, high transportation/logistics costs, low dependability and high inventory levels. According to the practitioners in the operations it was often necessary to carry out rescheduling of the productions and produced rush-orders/deliveries, which were resource demanding and costly for the company. Accordingly, it seems that the drawbacks of decisions made in the early phases of the sourcing process model (Webster and Wind, 1972; Weele, 2014) are difficult to overcome.

In contrast to the prevailing theoretical viewpoint regarding decisions on local versus global sourcing, which suggests a trade-off in terms of costs (Monczka et al., 2016), the findings in this paper illustrate that the practical realities of sourcing decisions favour unit costs at the expense of considering the total costs. The question thus arises as to why practitioners favour a total costs approach while at the same time acknowledging that since the suppliers carry both the risk and costs of delivering the materials, transportation/logistics costs should not have any influence. Likewise, although the influence of dependability is regarded as being small, a low degree of dependability makes it necessary to increase the level of safety stock, handle rush deliveries and increase the awareness of inventory management. Hence, we echo Stentoft et al.'s (2016) viewpoint that it is important for practitioners to have knowledge about the rationales of both local and global sourcing to carry out a balanced decision-making process. Our findings suggest that practitioners need to use a simple overall benchmark, unit cost, in the verbal expression of decision-making, but can analyse and verbalise complexity in depth when necessary due to their professional background and experience.

Researchers suggest using a total cost approach in the local-global sourcing decision-making (Bailey and De Propris, 2014; Johansson and Olhager, 2017; Kotabe and Murray, 2004; Zhai et al. 2016). Practitioners have accepted this viewpoint, but the practical realities revealed in this study illustrate that the decision makers struggle in applying such a method. Basically, it can be argued that the empirical findings in this study challenge the distinction between local vs. global sourcing. For instance, these practitioners suggest that quality, logistics and transportation costs, dependability and inventory level should be seen as generic drivers for selecting suppliers, and that these drivers are therefore not directly linked to the local and global sourcing decision. This implies that unit costs, lead time, and to a certain extent flexibility requirements due to fluctuations are the determining drivers in the location of sourcing; trade-off exists between a reduction in unit cost and coping with the consequences of increased lead time.

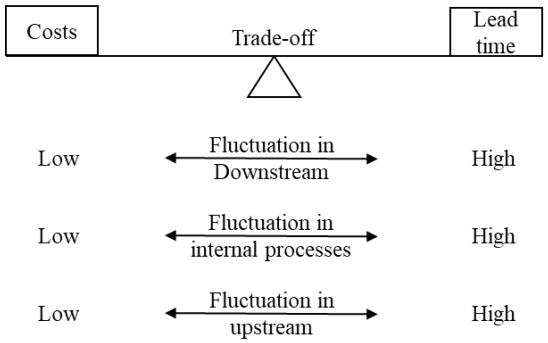

Figure 1. Local/global sourcing decision-making

Figure 1 illustrates a framework for qualifying and improving the relationship between sourcing and operations management in terms of local/global sourcing decision-making. As it appears from the analysis, the practitioners have acknowledge that it is crucial to prioritise short lead time if they should be capable of coping with high fluctuation. In contrast if the fluctuation is low, it is just a matter of drawing up a good plan. Having a laser like focus on fluctuation as the determinant for handling operations issues is well-evidenced (Christopher, 2016; Slack et al. 2016;). These researcher suggest addressing the level of fluctuations in downstream activities, in the internal value creating activities and final in the upstream activities. Acceptance of the viewpoint depicted in figure 1 reduces the distinction between local versus global sourcing, making it a matter of simply balancing unit costs and lead time issues.

This study has certain limitations. Findings are based on one company study with data collected from an inside-out perspective, and our empirical understanding does not draw on the network of the enterprise. The company examined here is sourcing high-end industrial products in low quantities, with a high level of engineer-to-order, but is making sourcing decisions partly with a “grocery shopping” philosophy, based on individual attitudes, perceptions and behavioural traits. Finally, we address the local versus global sourcing issues from an operational perspective, and thus deliberately neglect the decision-making processes in relation to product development. Future research should therefore extend the number of companies examined, and should also include both local and global suppliers, meaning that both an inside-out and outside-in perspective should be used. A comparison of the differences between the working practices of different companies and carrying out more interviews in each organisational department may pave the way for further learning points and increase the reliability of the research.

As a reflection upon the practical realities of sourcing decisions recalls Argyris’ and Schön’s (1974) classical work presented in the introduction of this paper. The practitioners are aware of the benefits of applying a total costs approach, and in general, the level of education in the company is very high. In other words, the espoused theory suggests that a total costs approach should be used, while the theory in use demonstrates that the practitioners limit themselves to a direct unit costs approach. Hence, by addressing the gap between the espoused theory and the theory in use, future research could study the extent to which social and/or technical drivers allow the practitioners to ignore decision-making based on total cost considerations.

Conclusions

This study focuses on operations, with the dual aims of improving the current understanding of the drivers influencing the motives of individual decision makers, and thereby influencing decisions on local and global sourcing.

A literature review identifies seven drivers, which shows that the drivers of unit costs, transportation/logistics costs, lead time, quality, dependability, inventory level and flexibility influence the location of sourcing. Although unit costs are mentioned most often in existing articles, a review does not provide us with the knowledge necessary to rank the influence of the drivers identified here. These seven drivers are studied empirically. The practitioners interviewed in this study had various functional affiliations. Our empirical study indicates that the prioritisation of these drivers is as follows: 1) unit costs; 2) quality and lead time; 3) flexibility of sourcing; and 4) transportation/logistics costs, dependability and inventory level. Although unit costs constitute the most important driver, practitioners are aware that a total cost approach may be more appropriate; however, this is largely left at an intentional level. Global sourcing enables a reduction in unit costs, but the total costs of global sourcing often surpass those of local sourcing. A better approach to local and global decision making would pay more attention to quality, lead time, dependability, inventory level and transportation/logistics costs.

Finally, this study aims to understand the drivers driving practitioners. “Simple” drivers such as unit costs are favoured over “complex” drivers such as flexibility. We call for careful reviews of sourcing decisions in order to ensure the overall optimisation of costs, and for continuous lessons learned activities.

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Can we have it all? Sustainability trade-offs and the insurance effect in supply chains

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Abstract

As the sustainability debate gained momentum, the idea that firms should simultaneously pursue social, economic, and environmental goals (Elkington, 1997) was progressively incorporated. In face of difficulties or even the impossibility to equally serve all stakeholders at the same time (Jensen, 2010), further investigation on sustainability trade-offs (i.e. prioritizing one dimension in sacrifice of others) and on the insurance effect (i.e. the meeting of one sustainability goal possibly attenuating effects of poor performance in others) is urgent. Through the analysis of 20 variation vignette-based scenarios, the present study investigates these issues within a typical supply chain of the food industry.

Keywords: Sustainable supply chain management, sustainability trade-offs, insurance effect

Introduction

As the sustainability debate became mainstream (Lyon *et al.*, 2018), the idea that firms hold responsibilities to society gained momentum. Tensions between profit-orientation perspectives (Friedman, 1970) and those of the stakeholder theory (Freeman, 1984), for example, seem to have influenced the expectations of consumers, pushing companies to stretch their focus beyond financial performance. Assorted and complex issues such as climate change (e.g. Procter and Gamble, 2015), preservation of wildlife (e.g. Kingfisher, 2018), the promotion of child education (e.g. Henkel, 2018), and social equality (e.g.Tata, 2016), among others, were progressively incorporated into corporate strategy. The meeting of these demands led organizations to (re)shape business models, in a way that their images among stakeholders could be enhanced, or at least preserved as they operated in a responsible manner. Just like a short blanket, however, the pursuit of one goal may lead to the sacrifice of others, even if an alignment is argued to be possible (Porter and Van der Linde, 1995).

Along with the perception that the objectives of companies should be reconsidered not to privilege the interests of specific groups (e.g. investors, customers) over others (e.g. local communities), real sustainability in business has been often pointed as unlikely (Wells, 2013), utopian (Lyon *et al.*, 2018), or even impossible (Garrido, 2009). Despite noble, the idea that the needs of disparate parties could be concurrently fulfilled would be non-realistic. In analyzing the relationship between corporate productivity, social welfare and the accountability of managers within the corporate objective function, Jensen

(2010), for instance, claims that the maximization of more than one dimension would be logically impossible. Accordingly, the stakeholder theory would not allow purposeful decision making, once, at the same time its proponents claim that "managers should attempt to balance the interests of all corporate stakeholders", they "refuse to specify how to make the necessary trade-offs among these competing interests" (pp. 32). With responsibilities extending beyond organizational borders (Bowen *et al.*, 2001) and companies jointly responding for the negative social or environmental conducts of their partners (Fracarolli Nunes, 2019), the interaction between sustainability dimensions within supply chain contexts becomes particularly critic.

While the skepticism over corporate sustainability is not a novelty, the interaction between its dimensions indeed calls for further investigation. It is not clear, for example, the extent to which sustainability trade-offs (i.e. prioritizing one dimension in sacrifice of the others) are accepted by stakeholders. Likewise, the insurance effect (i.e. the meeting of one sustainability goal possibly attenuating the effects of poor performance in others) remains cloudy. In search to offer empirical evidence on that direction, the present study investigates the impact of these matters on distinct players of a typical multi-tier supply chain of the food and beverage industry (i.e. pesticide producer, farmers, companies from the food and beverage industry, and retail chains). Through the application of 20 variation scenario-based experiments, the impact of both sustainability trade-offs and the insurance effect on the perception of consumers is measured. More specifically, we analyze the power of social and economic performance to justify, excuse, or, attenuate severe environmental damage in terms of corporate credibility – trustworthiness and on the corporate credibility – expertise within supply chains. The objectives of the study are then framed into the following research questions: (1) Do stakeholders accept poor environmental performance if they are necessary for social and economic ones in supply chains (sustainability trade-offs)?; and (2) Does the meeting of social and economic goals grant supply chain partners with an insurance effect for poor environmental performance?

Along with adding to the understanding of sustainability issues in general, the investigation stretches the sustainable supply chain management debate to dimensions which, despite relevant to business practice, are often neglected in the field. Also, the joint analysis of the effects of sustainability trade-offs and the insurance effect on the corporate credibility of different tiers contributes to the research over the dynamics of intangible resources within supply chain contexts.

Method

Experimental study design

In search to test for the impact of the trade-off and the insurance effects on corporate credibility, we conducted a vignette-based experiment situated on a multi-tier food and beverage industry supply chain. Scenarios portrayed four different supply chain tiers (i.e. pesticide producer, farmers, companies from the food and beverage industry, and retail chains), within five distinct conditions – the first one featuring a neutral situation, and the other four referring to the social trade-off, the economic trade-off, the social insurance, and the economic insurance effects. Participants were randomly asked to focus on one supply chain player, and assigned with a variation scenario, generating 20 possible combinations. The base vignette featured the description of the fictitious US-headquartered Martin-Losano, profiled as one of the largest agricultural biotechnology companies in the world, present in 69 countries with over 20,000 employees, with annual sales yielding above USD 14 billion, and supplying farmers with products such as seeds, crop protection products, and data analysis. It was also stated to be a leading player in

technology and innovation development, having intensively contributed to enhance productivity in food production.

Next, accusations for unsustainable practices were introduced, linking the company's products to water contamination with heavy metals and pernicious chemicals in decades of litigation processes. Culminating in an international citizen court case represented by environmentalists, activists, academics, and jurists, the company was vindicated to have acted in violation of human rights, crime against mankind, and ecocide. Farmers, four large companies from the food and beverage industry, and three retail chains were also pointed as accomplices in the scandal, widely reported by the media.

Manipulations were then described in the text, giving rise to the five possible scenarios. In the first one, the chief executive officers from the accused companies and farmers' representatives came forward to publicly admit the damage caused by the use of the products, configuring thus a base scenario with no variation. The second and third manipulations referred to the social and the economic insurance effects, respectively. While admitting to the environmental harm caused, they claimed that the company was also responsible for significant social and economic development through the enhancement of farmers' productivity, reinforced by an extensive report. Examples of such would be a wider access to food, insuring minimum amounts of nourishment to less favoured populations, and the development of small farmers working in poor regions for the social contributions, and the proper remuneration of shareholders and employees, along with significant customer price reduction for the economic ones. Finally, the fourth and fifth manipulations concerned the social and the economic trade-off effects. In these scenarios, the same social and economic benefits were presented, but as having had the environmental harm pointed at the scandal as consciously triggered and, furthermore, as a necessary outcome that permitted the company to achieve such contributions.

Data collection, manipulation and realism checks

An initial pool of 698 participants from the US was recruited through a research-specialized crowdsourcing platform (Prolific Academic, www.prolific.ac). 51 respondents were removed from the experiment after failing attention gauge points, and 44 did not complete their participation, leaving a final sample of 603 respondents. Additional manipulation check points were provided after the main questionnaire, asking participants if the company was stated to have contributed to social or economic development, and if the mentioned environmental harm was caused in order to do so, and 83 responses were further removed from the sample as not having had correctly identified their respectively assigned variation scenario, thus configuring 520 valid responses, being 45.96% female, with average and median ages of 34.80 and 32 years old, and 78.46% Caucasian.

Scenarios were clearly classified by respondents as realistic ($M = 6.048$ against the mid-score 4, standard deviation = .043, $t = 47.216$, p-value = .000), believable ($M = 6.028$, standard deviation = .044, $t = 45.672$, p-value = .000), and likely ($M = 5.984$, standard deviation = .047, $t = 41.955$, p-value = .000). Furthermore, scenario check questions were inserted to test if respondents coherently captured the described vignette, regarding the company's global presence ($M = 6.571$, standard deviation = .042, $t = 60.135$, p-value = .000), its annual revenue ($M = 6.575$, standard deviation = .041, $t = 61.374$, p-value = .000), and if it has been accused of severe environmental and social damage ($M = 6.551$, standard deviation = .040, $t = 63.593$, p-value = .000), to which participants' means were significantly higher than the neutral point.

Measurement instruments validation

Corporate credibility was measured through the composition of expertise and trustworthiness (Newell and Goldsmith, 2001). Seven-point Likert scales were drawn from the literature, and Confirmatory Factor Analysis (CFA) validated the constructs, having both remained integrally with their original items scored above .80. Although χ^2 and the χ^2 per degrees of freedom ratio (χ^2/DF) did not yield in favorable values, incremental indexes (comparative fit index – CFI, normed fit index – NFI, and incremental fit index – IFI) above the recommended .95 threshold demonstrated good model fit for both constructs, along with strong reliability in Cronbach's alpha values higher than .90. Composite reliability also denotes the measurement models' internal consistency and average variance extracted indicates that the larger portion of the constructs' variance is being captured by the instruments, and not by measurement errors. Table 1 displays validation, unidimensionality, and reliability analyses, and the items for each operationalized construct.

Table 1: Corporate Credibility Scales Validation, Unidimensionality and Reliability Analyses

	Corporate Credibility (Expertise) [a]	Corporate Credibility (Trustworthiness) [b]
Number of items	4	4
Average	5.349	3.639
Standard deviation	1.239	1.549
Items' standardized factor loadings	.87, .91, .90 and .81	.91, .92, .95 and .80
χ^2 (p-value)	39.234 (.000)	12.869 (.002)
χ^2 / DF	19.617	6.434
CFI	.978	.995
NFI	.977	.994
IFI	.978	.995
Cronbach's alpha	.928	.940
Composite reliability	.927	.942
Average variance extracted	.762	.804

Results

Hypotheses were tested through a series of ANOVAs, analyzing the differences in corporate credibility – expertise and trustworthiness for the distinct supply chain tiers when a social / economic insurance or trade-off effect takes place following an unsustainability scandal (Table 2), and for such effects given each supply chain link (Table 3).

Table 2: ANOVA Results for Social and Economic Insurance and Trade-Off Effects

			Corporate Credibility (Expertise)	**Corporate Credibility (Trustworthiness**
			Mean(S.D.)	Mean(S.D.)
No manipulation	1- Pesticide Producer	N=29	5.112(1.552)	3.094(1.832)
	2- Farmers	N=30	5.391(1.153)	4.033(1.449)
	3- Food and Beverage Companies	N=28	5.651(0.933)	3.294(1.659)
	4- Retail Chain Companies	N=30	5.591(1.013)	3.316(1.488)
	Statistics	P-value	.308	.128
		F	1.213	1.932
		df (in; within)	3;113	3;113
Social Insurance Effect	1- Pesticide Producer	N=30	5.375(1.335)[1]	3.441(1.588)[1]
	2- Farmers	N=25	5.250(1.111)[2]	4.120(1.299)[2][4]
	3- Food and Beverage Companies	N=25	3.170(1.421)[1][2][3]	5.550(0.813)[1][2][3]
	4- Retail Chain Companies	N=29	5.353(1.094)[3]	3.137(1.291)[3][4]
	Statistics	P-value	0.000***	0.000***
		F	19.314	18.131
		df (in; within)	3;105	3;105
Economic Insurance Effect	1- Pesticide Producer	N=24	5.697(1.213)	3.000(1.331)[1]
	2- Farmers	N=27	5.074(0.992)	4.064(1.555)[1]
	3- Food and Beverage Companies	N=24	5.583(1.261)	3.760(1.411)
	4- Retail Chain Companies	N=11	5.704(.879)	3.431(1.383)
	Statistics	P-value	0.177	0.066*
		F	1.684	2.496
		df (in; within)	3;82	3;82
Social Trade-off Effect	1- Pesticide Producer	N=28	5.875(0.998)[1]	3.910(1.456)
	2- Farmers	N=27	5.416(0.917)	4.259(1.387)[1][2]
	3- Food and Beverage Companies	N=26	5.413(1.009)	3.105(1.010)[1]
	4- Retail Chain Companies	N=30	5.125(1.370)[1]	3.241(1.747)[2]
	Statistics	P-value	0.082*	0.010*
		F	2.296	3.957
		df (in; within)	3;107	3;107
Economic Trade-off Effect	1- Pesticide Producer	N=25	5.730(1.025)	3.570(1.548)
	2- Farmers	N=24	5.364(1.075)	4.177(1.506)
	3- Food and Beverage Companies	N=20	5.800(1.046)	3.162(1.638)
	4- Retail Chain Companies	N=28	5.535(0.835)	3.187(1.255)
	Statistics	P-value	0.443	0.068*
		F	0.904	2.450
		df (in; within)	3;93	3;93

Notes:
* p<0.10, ** p<0.05, ***p<0.01
The numbers in parentheses are sample standard deviations.
The numbers in brackets indicate the group means from which this group is significantly different at the 0.10 significance level, as indicated by Tukey and Games-Howell pairwise comparison tests.

Table 3: ANOVA Results for Supply Chain Tiers

			Corporate Credibility (Expertise)	**Corporate Credibility (Trustworthiness**
			Mean(S.D.)	Mean(S.D.)
Pesticide Producer	1- No manipulation	N=29	5.112(1.552)	3.094(1.832)
	2- Social Insurance Effect	N=30	5.375(1.335)	3.441(1.588)
	3- Economic Insurance Effect	N=24	5.697(1.213)	3.000(1.331)
	4- Social Trade-off Effect	N=28	5.875(0.998)	3.910(1.456)
	5- Economic Trade-off Effect	N=25	5.730(1.025)	3.570(1.548)
	Statistics	P-value	0.150	0.211
		F	1.718	1.482
		df (in; within)	4;131	4;131
Farmers	1- No manipulation	N=30	5.391(1.153)	4.033(1.449)
	2- Social Insurance Effect	N=25	5.250(1.111)	4.120(1.299)
	3- Economic Insurance Effect	N=27	5.074(0.992)	4.064(1.555)
	4- Social Trade-off Effect	N=27	5.416(0.917)	4.259(1.387)
	5- Economic Trade-off Effect	N=24	5.364(1.075)	4.177(1.506)
	Statistics	P-value	0.746	0.979
		F	0.486	0.108
		df (in; within)	4;128	4;128
Food and Beverage Companies	1- No manipulation	N=28	5.651(0.933)[1]	3.294(1.659)[1]
	2- Social Insurance Effect	N=25	3.170(1.421)[1][2][3][4]	5.550(0.813)[1][2][3][4]
	3- Economic Insurance Effect	N=24	5.583(1.261)[2]	3.760(1.411)[2]
	4- Social Trade-off Effect	N=26	5.413(1.009)[3]	3.105(1.010)[3]
	5- Economic Trade-off Effect	N=20	5.800(046)[4]	3.162(1.638)[4]
	Statistics	P-value	0.000***	0.000***
		F	22.776	14.481
		df (in; within)	4;118	4;118
Retail Chain Companies	1- No manipulation	N=30	5.591(1.013)	3.316(1.488)
	2- Social Insurance Effect	N=29	5.353(1.094)	3.137(1.291)
	3- Economic Insurance Effect	N=11	5.704(0.879)	3.431(1.383)
	4- Social Trade-off Effect	N=30	5.125(1.370)	3.241(1.747)
	5- Economic Trade-off Effect	N=28	5.535(0.835)	3.187(255)
	Statistics	P-value	0.389	0.978
		F	1.040	0.113
		df (in; within)	4;123	4;123

Notes:
* p<0.10, ** p<0.05, ***p<0.01
The numbers in parentheses are sample standard deviations.
The numbers in brackets indicate the group means from which this group is significantly different at the 0.10 significance level, as indicated by Tukey and Games-Howell pairwise comparison tests.

Results suggest that social insurance, economic insurance, and social trade-off effects have a significant impact in corporate credibility when it comes to perceived expertise and trustworthiness, yet with different repercussions for distinct tiers of the supply chain. The industry-level, for instance, was the one that benefited the less from the social insurance effect in terms of perceived expertise, but was also perceived as the most trustworthy link in comparison with the other players within the same situation. Farmers were also considered more trustworthy than the retail-level when the social insurance effect were drawn, and than the pesticide producer when the economic insurance effect was in place. On the other hand, the social trade-off effect seems to benefit the corporate credibility of the upper supply chain tiers – while the pesticide producer was granted with higher expertise scores than the retail-level companies, respondents seem to place higher trustworthiness in farmers than in the downstream supply chain players.

Discussion and Conclusion

As discussed throughout the text, with the popularization of the triple bottom line in business (Elkington, 1997), managers have struggled to simultaneously meet social, environmental, and economic performance. Within the perspectives of corporate social (Carroll, 1999) and environmental (DesJardins, 1998) responsibilities, industrial operations came to the center stage of public debate, being not only closely monitored by scientists, governments, and NGOs, but also openly debated in traditional and social media. Not restricted to single companies, these calls typically spread across whole supply chains, increasing the intricacy of the task. This "green revolution" in business was vigorous, to the point that "corporate sustainability – once viewed as utopian, irrelevant, or even subversive – has gone mainstream" (Lyon *et al.*, 2018).

In that direction, by exploring the dynamics of sustainability trade-offs and the insurance effect within supply chain contexts, our investigation adds to the literature on sustainable supply chain management. Beyond contributing to the further understanding of the consequences of sustainability fails and misconducts, our results offer empirical evidence that supply chain partners may jointly absorb the consequences of such issues, at least in the eyes of consumers.

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Supply Chain Sustainability Trajectories: contingency and evolution toward enhanced sustainability performance

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Abstract

The importance of supply chain sustainability has been recently receiving growing attention from practitioners, academics and policy-makers. Although there is a consensus that sustainability cannot be narrowly viewed as an issue within the organizational boundaries, most of the existing research tackle the issue by using an organizational perspective, instead of a more holistic and broad approach pertinent to the supply chain perspective. However, research on how supply chains learn, adapt and evolve on their sustainability trajectory is still scarce. This research aims to fill this gap and draws from the contingency theory and evolutionary theory to explore how the development of ordinary and dynamic capabilities affect the supply chain sustainability trajectory and supply chain sustainability performance. Methodologically, it employs a multi-method approach encompassing a large-scale survey, exemplary case studies and archival data. Contributions of this research extend existing supply chain sustainability theory and inform practitioners, academics and policy-makers on how supply chains actually learn and evolve on their sustainability trajectories.

Keywords: Supply chain sustainability trajectories, Contingency theory, Evolutionary theory

Introduction

Although supply chain (SC) sustainability has been receiving growing attention recently, details on how SC sustainability trajectories evolve overtime are still unclear. The literature converges to the fact that SCs do not become sustainable overnight, but go through a complex and dynamic learning process behind the evolution of their sustainability performance. This research aims to uncover key nuances of and empirically test how SCs learn and improve their sustainability practices. The construct of SC sustainability trajectories (Silvestre, 2015a) highlights that SCs go through learning loops to enhance the practice of sustainability. SC learning requires players within the SC who deliberately learn and incorporate sustainability knowledge into their daily business processes (López et al., 2004). The next section describes the concept of supply chain trajectories. The structural model relating SC trajectories to performance and research hypothesis ensue, followed by a section on research methods. The conclusion outlines key expected results and future practical, research and policy implications.

Supply Chain Sustainability Trajectories

This paper adopts a learning approach to SC sustainability (Spekman et al., 2002) to develop the theoretical framework. Through the lenses of the evolutionary theory, SCs are similar to organizations: they are initially immature, but they learn and accumulate knowledge and capabilities overtime (Nelson and Winter, 2002; Silvestre, 2015a). This SC dynamic evolution strongly connects to those type of capabilities SCs deliberately try to acquire or develop. SCs can focus their efforts on the acquisition/development of exploitation or exploration capabilities (Benner and Tushman, 2003). Yalcinkaya et al (2007: 66) defines exploration capabilities as the “ability to adopt new processes, products, and services that are unique from those used in the past” and exploitation capabilities as the “ability to improve continuously its existing resources and processes”. This evolutionary perspective relates to the elements of contingency theory, which suggests there is no single approach that can be applicable to all situations (Lawrence and Lorsch, 1967).

Contingency theory argues the environment within which a SC operates shapes its structures and processes (Flynn et al., 2010), and the way they behave and change. The four basic postulates of the structural contingency theory provides a powerful lens to analyze SCM trajectories. First, contingencies have an impact on the organizational structure, which has an impact on performance. Second, there must be some level of adjustment between the structural variable and each contingency level, where high levels of adjustment produce efficiency and low "fit" causes inefficiency. Third, there is no universal type of more efficient organization. Fourth, the impact of organizational structure on performance is empirically analysable (Donaldson, 2001). This contingent perspective highlights the notion of path dependence (Pierson, 2000), where decisions managers will make in the future depend on the decisions they have previously made

(Liebowitz and Margolis, 1995). Although very few studies combine path dependence with SC management, the literature argues that path dependence is a key construct to understand SC evolution toward sustainability (Holweg and Pil, 2008; Silvestre, 2015b). This dependence from the past can be positive as it represents the accumulation of critical knowledge, competences and experiences, but can also be negative by offering significant resistance to learning and implementing new sustainability practices. This harmful phenomenon is what the literature calls lock-in. In this context, this research aims to answer the following research question (RQ): How do ordinary and dynamic capabilities affect the SC sustainability trajectory and sustainability performance?

Through the lenses of the contingency and evolutionary theory, this empirical paper develops an innovative theoretical framework to analyze such issues and proposes a typology of SC sustainability trajectories and performance. This typology will be tested based on large-scale survey in four major supply chains in Brazil: automobile, oil and gas, agriculture and tourism. Survey instruments will be developed and employed to focal companies and 1st and 2nd tier suppliers/buyers. The survey will also serve to identify four case studies within each of those supply chains to be explored further.

Structural model and hypothesis

Very few studies combine path dependence with SC management, the literature argues that path dependence is a key construct to understand SC evolution toward sustainability (Holweg and Pil, 2008; Silvestre, 2015b). This dependence from the past can be positive as it represents the accumulation of critical knowledge, competences and experiences, but can also be negative by offering significant resistance to learning and implementing new sustainability practices. This harmful phenomenon is what the literature calls lock-in. Through the lenses of the contingency and evolutionary theory, this empirical paper develops an innovative theoretical framework to analyse such issues and proposes a typology of SC sustainability trajectories and performance. The theoretical approach led to the identification of two critical dimensions for the evolution of SC sustainability trajectories and performance (Figure 1). The construct of path dependence/lock-in is the dimension representing the contingent perspective of SCs. SCs can be classified as low or high path dependence/lock-in. Low path dependence/lock-in is associated with SCs that currently possess resources (e.g., knowledge, skills, workforce, and machinery) that are broad and flexible enough to change the course of action without an overwhelming resistance from the current state.

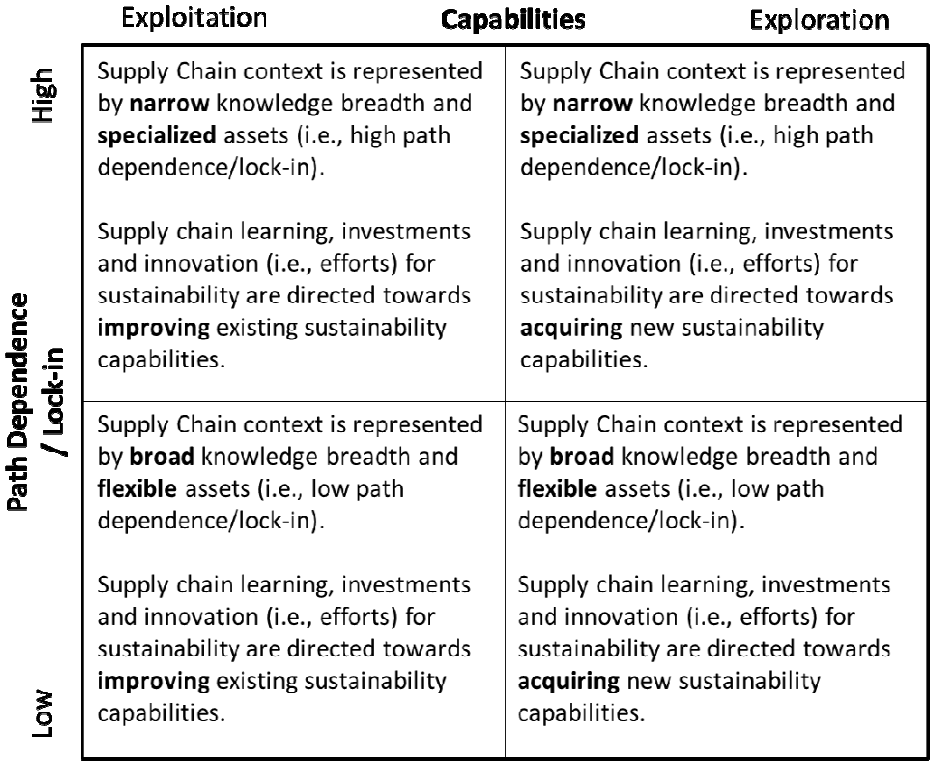
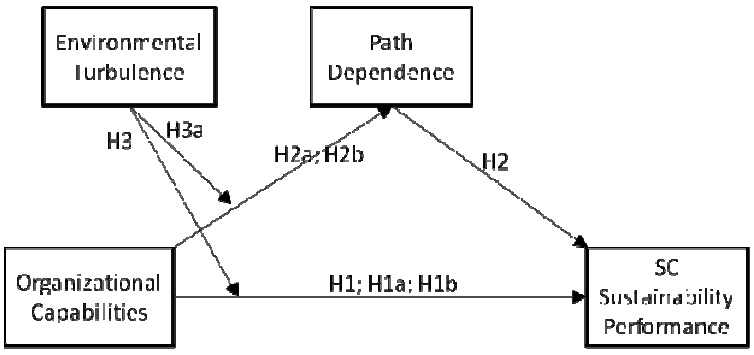


Figure 1: Current state and efforts for future supply chain sustainability positioning

On the contrary, high path dependence/lock-in is associated with SCs that currently possess resources that are too narrow and specialized that resistance to change can be overwhelmingly high. The construct of capabilities is the second key dimension, representing the evolutionary perspective of SCs. SCs can be either classified as investing in exploitation capabilities, i.e., predominantly making efforts (e.g., learning, investments and innovation) that are directed towards improving existing sustainability capabilities, or exploration capabilities, i.e. predominantly making efforts that are directed towards acquiring new sustainability capabilities. Figure 2 depicts the structural research model.



Variables:
-IV: Organizational Capabilities (ordinary; dynamic; ambidextrous)
-DV: Supply Chain Sustainability Performance
-Mod: Path Dependence (1 low, 2 high)
-Mod: Environmental Turbulence (1–low; 2–high)

Controls:
-company size
-company age
-company's position

Based on the extant literature, the model of Figure 2 offers the following hypothesis.

H1: Companies with higher level of organizational capabilities will have higher SC sustainability performance

- H1a: Companies that invest primarily in exploitation/ordinary capabilities will have lower SC sustainability performance than companies that invest primarily in exploration/dynamic capabilities
- H1b: Companies that invest in ambidextrous approaches will have higher SC sustainability performance than companies that invest primarily in exploitation/ordinary
- H1c: Companies that invest in ambidextrous approaches will have higher SC sustainability performance than companies that invest primarily in exploration/dynamic capabilities

H2: Path dependence mediates the relationship between organizational capabilities and SC sustainability performance

- H2a: The higher is the company's focus on exploitation/ordinary capabilities, the higher the path dependence will be
- H2b: The higher is the company's focus on exploration/dynamic capabilities, the lower the path dependence will be

H3: Environmental turbulence moderates the relationship between organizational capabilities and SC sustainability performance

- H3a: The higher is the environmental turbulence, the higher is the path dependence

Research methods

The research adopts a multi-method design for data collection and analysis, combining survey data with case study and archival data.

A random sample for the survey will be drawn from the 276 organizations affiliated to the Brazilian National Foundation for Quality, which were enrolled in the 2019 Brazilian National Innovation Award (BNA). The respondent's organisation is the unit of analysis. For monadic constructs, the sole best respondent will be the plant manager or a high-ranked and experienced manager in services operations. To reduce the risks of common-method and single respondent bias in polyadic constructs, multiple respondents will be assessed in the focal firm and in the paired firms in the supply chain (either suppliers or buyers). This rigorous design corresponds to SCM type 4 design in Flynn et al. (2018). Perceptual scales will be validated using Anderson and Gerbing (1988) two-step approach to structural equation modelling. Confirmatory factor analysis will be used to validate unidimensionality, validity and reliability of the scales. Multi group measurement invariance will be tested for companies exhibiting high and low levels of environmental turbulence. Conditional process analysis (Hayes, 2017) of the moderated mediation model will run on SPSS and structural equation modelling will use the M-Plus software (Muthén and Muthén, 2017).

The four case study research will focus on firms representing high and low path dependence segments among those improving existing sustainability capabilities (exploitation) and those acquiring new sustainability capabilities (exploration). GRI, OECD and São Paulo Stock Exchange (BOVESPA) reports on sustainability will be used to validate survey and case study research whenever feasible.

Conclusions

This research contributes a new perspective to the analysis of SC sustainability. It offers a novel and rigorous multi-method research triangulating survey data with case study research and archival data on sustainability. It explores sustainability performance mediators and moderators through the powerful lenses of operations management practices contingency research (Sousa and Voss, 2008). By employing an innovative theoretical framework, that combines elements from the evolutionary and contingency theory, this paper aims to contribute to the discussion on how SCs actually learn and evolve on their sustainability trajectories. This research extends the literature of SC sustainability management and opens up several new practical, research and policy avenues. Practitioners can learn how to evolve in their sustainability practices to enhance sustainability performance. Policy-makers can gain insights about the contextual variables that would be more conducive to the economic, social and environmental gains of sustainability trajectories. Researchers will benefit from a novel approach to multi-method research that could be applied in different sets.

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Enhancing the environmental performance of last mile logistics in e-commerce

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Abstract

This paper addresses the problem of sustainability in last mile logistics, trying to understand how consumers can be led toward the adoption of more eco-friendly delivery solutions. Building on the technology adoption literature and on extant studies on consumers' sensitivity to environmental issues, this paper tests the hypothesis according to which, if consumers are properly informed about the superior environmental performance of parcel lockers, they become more willing to consider their adoption as an alternative to the traditional home delivery. Empirical data collected through a survey among 290 consumers supports this hypothesis.

Keywords: Last mile logistics, E-commerce, Sustainability

Introduction

This paper aims at understanding the conditions under which consumers become willing to choose delivery options for the last mile logistics that are more sustainable from the environmental viewpoint. The remarkable increase of the e-commerce and the widespread adoption of omnichannel strategies by "brick and mortar" companies are resulting in a huge diffusion of the home delivery as the best-preferred delivery option by the consumers. Although home delivery can bring about positive effects in terms of service level to the client, it also results in a higher traffic congestion in urban areas, as well as in a relevant increase of CO_2 emissions due to the low level of efficiency peculiar to home delivery (Belvedere and Grando, 2017; Brown & Guiffrida, 2014; McKinnon et al., 2012; Edwards and McKinnon, 2010). In this setting the adoption of alternative delivery solutions, namely parcel lockers, could be beneficial from the environmental viewpoint since it would increase the efficiency of the delivery process. On the other hand, such a choice could negatively affect the logistic service perceived by the client. This paper tests the hypothesis according to which if consumers are properly informed about the superior environmental performance of an alternative delivery option (namely parcel lockers), they would be more willing to consider its adoption.

In the remainder of this paper a brief literature review on last mile logistics and on its environmental effects is proposed. Then, the empirical evidence stemming from a survey conducted among 290 consumers is presented and conclusions and managerial implications are drawn.

Literature Background

The rise of the e-commerce phenomenon and more recently the widespread adoption of the omnichannel strategy are leading to a new interest toward logistics and supply chain management solutions suitable for supporting companies in this new scenario.

Indeed, the successful implementation of omnichannel strategies relies very much on the ability of the company to manage the tradeoffs between several performance attributes, providing customers with a good logistic service at reasonable logistic costs (Lim et al., 2016). In the early stages of the e-commerce, nearly two decades ago, several e-tailers started offering a limited variety of items provided to customers with a high speed and most of them failed in their attempt to gain reasonable market shares due to the high delivery costs. Nowadays, these trade-offs are becoming even more challenging and complex to manage since e-tailers are offering a much wider product variety, coupled with fast and flexible deliveries at competitive prices, while delivery costs continue to be a critical success factor, driven by labor costs, product's value density, and average order size (Lim et al., 2018). Due to the relevance of the logistic process and namely of the last mile logistics for the success of any initiative of digital selling, several studies have tried to identify the main factors affecting the delivery costs, as well as the organizational solutions suitable for properly managing the trade-off between logistic service and transportation cost. According to Gevaers et al. (2014), the main drivers of the latter rely on the service level promised to the customer, the delivery security, the geographical features of the market in terms of people density, and the technological level of the fleet. Boyer et al. (2009) focused on the customer density and the delivery window as conditions that sharply affect the efficiency of the delivery in the context of e-commerce. Wollenburg et al. (2018) have highlighted the relevance of the nature of the product in the design of the last mile logistics. On top of these operational features that act as driving factors of the key design decisions of the delivery process, several proposals have been made concerning the distribution network design (Marchet et al., 2018; Melacini et al., 2018; Gavears et al., 2011; Boyer et al., 2005).

This discussion is leading scholars and managers to think about the kind of logistic service that can be offered under reasonable conditions of efficiency, still providing the client with good levels of speed, dependability and availability of the products for digital purchases. This is leading companies to offer such services as click and collect or technological solutions as parcel lockers (Melacini et al., 2018).

Another area of concern associated with the delivery process in the context of e-commerce and omnichannel strategies is the environmental sustainability of e-fulfilment. Indeed, several studies have tried to understand whether and to what extent the wide adoption of home delivery (as a result of the rise of e-commerce) can result in a higher production of CO_2 emissions. In this regard, while some researchers claim that the overall effect can be even positive, due to the fact that consumers will not visit traditional shops anymore (Brown and Guiffrida, 2014), thus reducing the use of cars or other vehicles, other contributions seem to demonstrate the opposite. As matter of fact, in an omnichannel environment, consumers frequently visit shops in order to see and choose the product, then they place the order on-line, asking for home delivery in most cases. This choice results in the fact that the delivery process takes place in a way which is highly inefficient, due to the use of smaller vehicles to support the last mile logistics and to their low level of saturation (McKinnon et al., 2012; Goodman, 2005; Sarkis et al., 2004). The widespread phenomenon of returns of goods sold online further worsen the environmental performance of e-commerce.

Edwards and McKinnon (2010) claim that comparative analyses between the two scenarios (pick-up at the traditional shop vs. home delivery) can result in a wide range of different (and conflicting) results due to the complexity of the shopping activity, which can be carried out in many different ways and through the adoption of several vehicles that support the flows of goods and people.

In order to cope with the increasing complexity (and the related lower efficiency) of home delivery, some new technologies are now emerging, which try to involve the customer into the fulfilment process. This is the case of parcel lockers, which can be adopted to combine a good enough service level to the client with an improved efficiency and eco-friendliness of the last mile logistics (Vakulenko et al.,2017).

Such new technological alternatives are leading to the development of new types of organization of the order fulfilment process (Ranieri et al., 2018), which aim at achieving three main objectives: providing the client with the best possible shopping experience in the context of e-commerce; improving the efficiency of the delivery process; improving the environmental performance of last mile logistics.

Research question and methodology

Building on the above mentioned literature review, the following research questions are proposed:

- What drives the willingness of the client to use parcel lockers instead of home delivery solutions?
- If a client is properly informed about the higher environmental sustainability of the parcel lockers, would he/she become more willing to use them?

To answer these research questions, a survey was conducted among consumers. To design the questionnaire, the second UTAUT model proposed by Venkatesh et al. (2012) was leveraged, which describes the drivers of acceptance and use of technology. According to this model, the factors that influence the willingness ("behavioral intention") to adopt a technology are: performance expectancy; effort expectancy; social influence; facilitating conditions; hedonic motivation; price value; habit. Although this model was considered a sound interpretative framework suitable for understanding the levers behind the customers' willingness to use a technology (namely parcel lockers to collect products bought through an e-commerce system), some modifications have been made in order to make it more consistent with the context of e-commerce and parel lockers as delivery option. In particular, as it can be seen in Figure 1, the "Habit" construct has been removed since the use of parcel lockers is still at its beginning, so it can be excluded that consumers have already developed any sort of repetitiveness in its use. Three new constructs have been added to the second UTAUT model. In particular, "Technology anxiety" has been included (as it has been already done in other extensions of the second UTAUT model) since the technology under analysis is new and is a self-serving one.

On top of these drivers, the questionnaire used for this research encompassed also two more constructs. One refers to the "Environmental knowledge" of the customer, the other concerns his/her "environmental sensitivity". The former construct is understood as the ability of individuals to recognize symbols, concepts and behavior patterns related to environmental protection (Laroche et al., 2001) and has been operationalized through questions aimed at understanding how the customer reacts to information concerning the higher level of sustainability of parcel lockers in the context of e-commerce. The latter has been operationalized through questions aimed at testing the environmental sensitivity of the respondents (Markle, 2013). We assume that

"Environmental knowledge" can have a positive direct effect on "Behavioral intention" (on top of all other drivers previously highlighted by Venkatesh et al., 2012). We also formulate the hypothesis that "Environmental sensitivity" can have a moderating role in the relationship between "Environmental knowledge" and "Behavioural intention".

Questions related to the second UTAUT model (and its extensions) required answers on a 1-7 Likert scale. Although all of them were based on extant studies, their wording has been adapted to make them consistent with an e-commerce context and to clearly highlight that the technology under analysis was the parcel locker. Totally, 290 usable questionnaires have been collected insofar.

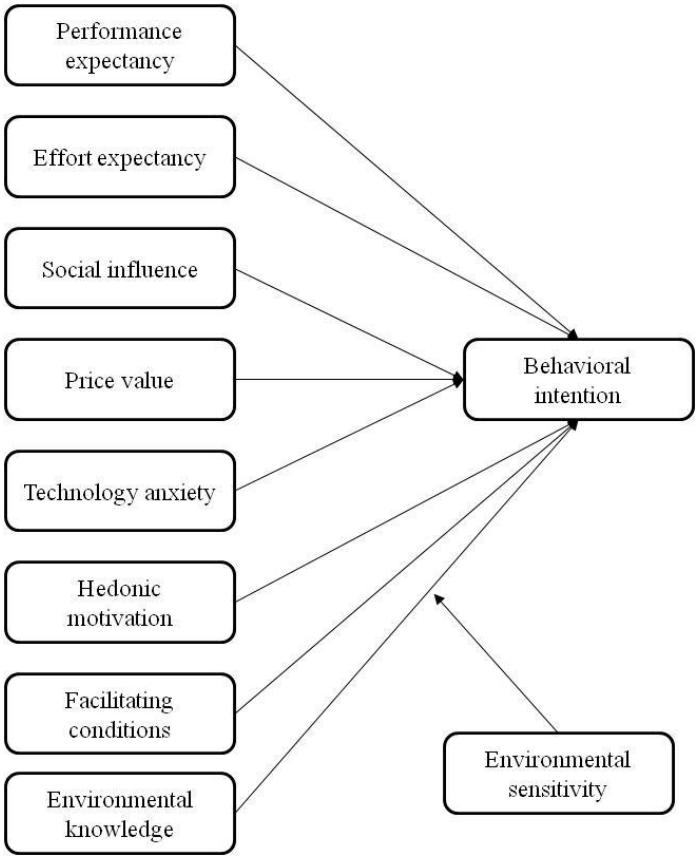

Figure 1 – Theoretical framework

Empirical evidence

A confirmatory factor analysis (CFA) was initially carried out to check that all the constructs encompassed in the model are properly described by the related questions. The results show that all constructs, but "Facilitating conditions", enjoy a Cronbach's Alpha higher that 0.6 and a Variance Explained above 0.5. Thus, "Facilitating conditions" was excluded from the subsequent analyses.

Then, a regression analysis was conducted in order to understand whether and to what extent the drivers of our model can explain the willingness of the client to use parcel lockers instead of traditional home delivery, and if "environmental sensitivity" is a moderating variable. Our evidence shows that the adjusted R-square on the overall model (including also the moderating variable) is 0.706, which witnesses the robustness of the model. Furthermore, it is also demonstrated that, among all predictors of

"Behavioral intention", only "technology anxiety" does not show a statistically significant regression coefficient. Furthermore, the driver with the highest regression coefficient is "Environmental knowledge". Finally, "Environmental sensitivity" is not confirmed as a moderating variable.

Conclusions and managerial implications

This paper addresses a topic of increasing relevance, i.e. the sustainability of the delivery process in the context of e-commerce. The empirical evidence reported in this study demonstrates that a customer properly informed on the higher level of environmental sustainability of alternative delivery options (namely parcel lockers) becomes much more willing to use them. This positive effect is not moderated by client's sensitivity to environmental issues, which means that even customers who are not strongly concerned about this topic can change their delivery preferences if properly informed on the related environmental performance.

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Identifying the Formula of Success for Bike-Sharing Operations: Evidence from Sweden and Greece

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Abstract

A new mobility ethos is needed to overcome the problems that have been accumulated by a transport paradigm prioritising automobiles over people. Bike-sharing, a measure promoting travel behaviour change, could be part of a refined mobility provision toolbox. Despite a rapid emergence during the last decade, as evidenced by 1963 operating local schemes globally, bike-sharing is attracting negative attention. Numerous schemes closed down as huge financial or operational failures stigmatising bike-sharing's brand. This paper identifies the formula of success for bike-sharing operations based on evidence from two survey-based studies in Sweden and Greece and from a state-of-the-art case study analysis.

Keywords: Bike-sharing, Shared Use Mobility, Sustainable Transport Operations

Introduction

A predominately car-oriented transportation has been the cornerstone of urban development for decades now; a cornerstone associated with adverse effects on social, economic and environmental sustainability. The problems of the reign of the conventional, fossil-fuelled, human-led privately-owned car include increased traffic congestion, climate change, local air and noise pollution, road injuries or casualties, obesity and decline in physical activity, chronic diseases and loss of social engagement (Nikitas et al., 2016; Thomopoulos and Nikitas, 2019). A new urban mobility ethos is needed for cities looking to effectively address these challenges, which among others will require from policy-makers and mobility suppliers to promote voluntary travel behaviour change via powerful shared transport initiatives. Bike-sharing, the greenest form of shared use mobility interventions, can be defined as a system that provides affordable short-term access to a fleet of locally customised bicycles on an "as-needed" basis (Nikitas, 2018).

Bike-sharing, typically framed as an ideal first- and last-mile travel solution for congested metropolitan environments (DeMaio, 2009) and less often tested for the context of smaller and medium cities (Caulfield et al., 2017) is now with the recent game-changing introduction of station-less, free-floating, GPS-equipped schemes more relevant than ever before. It has emerged rapidly across the globe, with 1963 operating schemes and approximately 14,850,000 self-service public bicycles and pedelecs in use (Meddin and DeMaio, 2019), as an easily implementable modal shift mechanism that is iconic for the host city's commitment to sustainable transport and logistics operations (Nikitas, 2018).

But at the same time bike-sharing, especially with the somewhat reckless and under-designed implementation of numerous dockless systems, is attracting negative attention with tens of schemes closing as huge financial or operational failures putting major public bicycle companies in jeopardy. The withdrawal of Mobike from Manchester and Ofo from London in the UK, who represent the two global bike-sharing colossuses that have invested in Europe, and the closure of Bluegogo, China's third-biggest bike-sharing company with 20m users and £226m in deposits at its zenith, underline the need to revisit what makes bike-sharing services efficient in an operational level and how local schemes can transform to valuable smart city ingredients and flourish long-term.

This paper aims to identify and re-write the formula of success for bike-sharing operations by developing policy and business lessons that will help policy-makers and transport providers in establishing and managing successful micromobility schemes. This paper supports that the concept of bike-sharing is not a failing one that will be dismissed in the near future but a resourceful one that is simply "tested" because of bad operational thinking and decision-making.

Hereafter, the paper provides a description of the chosen methodology, a concise analysis of the key results, a discussion that will identify lessons learnt and suitable policy and industrial recommendations and a conclusion section that will epitomise the genuine contribution of this work to academia, policy and practice.

Methodology

This work adopts a dual methodological approach for providing validated and triangulated findings that could be widely representative and generalisable. It is a systematic effort designed to collect and analyse results that will allow the author to understand how bike-sharing can re-establish its reputation as a pragmatic long-term transport alternative and how local systems can develop better operations strategies that fit the needs of the cities hosting them.

On the one hand, it is based on quantitative evidence from two survey-based studies held in Gothenburg, Sweden (mid-sized city ~520,000 residents) and in Drama, Greece (small city ~ 60,000 residents) looking at acceptability and usage determinants. The two surveys captured road user attitudes for Gothenburg's 1000-bike station-based scheme Styr&Ställ that was established in 2010 and for a hypothetical small-scale forthcoming city-centre scheme in Drama. The combined sample refers to 1175 respondents that could be users, future users or non-users of the local scheme(s); 535 respondents in Sweden and 640 respondents in Greece.

On the other hand, this paper will present the key findings of a state-of-the-art analysis of the latest developments in bike-sharing operations using exemplary bike-sharing case studies from across the world. Some of these case studies refer to successful implementation and service delivery stories and others to systems that failed to establish commercially viable operations capable of adding value to the image of the city hosts.

This versatile mixed method approach ultimately creates a synthesis of well-supported arguments that may allow the delivery of some important lessons, valuable to transport academics, urban policy-makers and mobility providers that could be applicable to a wider context at least for similar urban environments and schemes with the ones discussed in this paper.

Results and analysis

Survey results

This part of the research work provides evidence that if bike-sharing is introduced, operated and promoted adequately could be acceptable in small and medium sized cities (including those that have yet to establish a pro-cycling culture) even from people not intending to ever use them. Acceptability could be therefore regarded as equally, if not more, important than strict usage-related criteria for success because it means that people would be willing to see more investment going towards bike-sharing because of its ability to add to their city's smart and eco-friendly image. These are valuable lessons proving that bike-sharing is not a fundamentally flawed concept that somehow emerged because of a rush to push forward relatively inexpensive sustainability-centric mechanisms; it is a sound shared use mobility initiative that in some case suffers from bad operational management and is doomed from unrealistic profit expectations.

Gothenburg study

Gothenburg's dock-based Styr&Ställ is highly supported by more than 90% of the city's residents despite usage rates reflecting some level of participation to the scheme by only a quarter of the study's sample (Nikitas et al., 2016; Nikitas and Sochor, 2018).

More specifically, the vast majority of the respondents believed that Styr&Ställ is an affordable travel mode with the capacity to promote healthy living, improve road traffic conditions, make cycling more popular, complement the city's other public transport services and help the city becoming more liveable. Also 85.3% of them recognised bike-sharing's potential for making people's travel behaviour increasingly less car dependent. Most importantly though, the survey participants acknowledged the significance of bike-sharing for their city; 92.4% agreed or strongly agreed that the scheme is good for Gothenburg and 93.5% disagreed or strongly disagreed with the notion that Styr & Ställ is a sub-standard transport initiative. Even the respondents that have never used it before or self-reported no (or little) intention to bike-share in the future were positive towards the scheme. Many respondents were also supportive of the scheme's further expansion through more bike-sharing investments and considered that the scheme is a viable public service for the city; 86.5% and 96.1% agreed or strongly agreed with these notions respectively. Also, only 6.5% of the people that had actually used the scheme considered that there is something fundamentally flawed with it. It is almost a unanimous decision for Gothenburg respondents that the local scheme is a good addition to their city's transport provision that needs to continue its operations and even expand.

Despite these high acceptability rates, it was found that the majority of the respondents rarely used the scheme even as a secondary travel option; 76.8% of the respondents stated that they never use the scheme while only 2.8% use it as their main mode choice. Nonetheless, longitudinal data collected for the first four full operating years of Styr&Ställ (based on respondents' self-reporting capacity) indicate a small but distinct annual increase in the number of participants that used the scheme especially for those using it as a main or a secondary travel alternative to their typical modal choice. This underuse indicates that there is, in theory, a massive untapped potential for utilising, in real usage terms, the scheme's wide acceptance.

The reasons for which the respondents of Gothenburg did not use the bike-sharing scheme that often have also been captured (each respondent was limited to give only two reasons when filling in the survey). Only 14.9% of the respondents answered that limited road safety could act as an obstacle for them in using bike-sharing, while 30.9% felt that lack of good bike-sharing related infrastructure was an issue. Another 16.9% of

the respondents thought that cycling was not ideal for the city and 11.5% that bike-sharing was not convenient for all purposes. Nevertheless, the most popular answer by far (i.e. 41.1%) was that people had their own bike so they did not need to bike-share. Figure 1 presents the full set of these results.

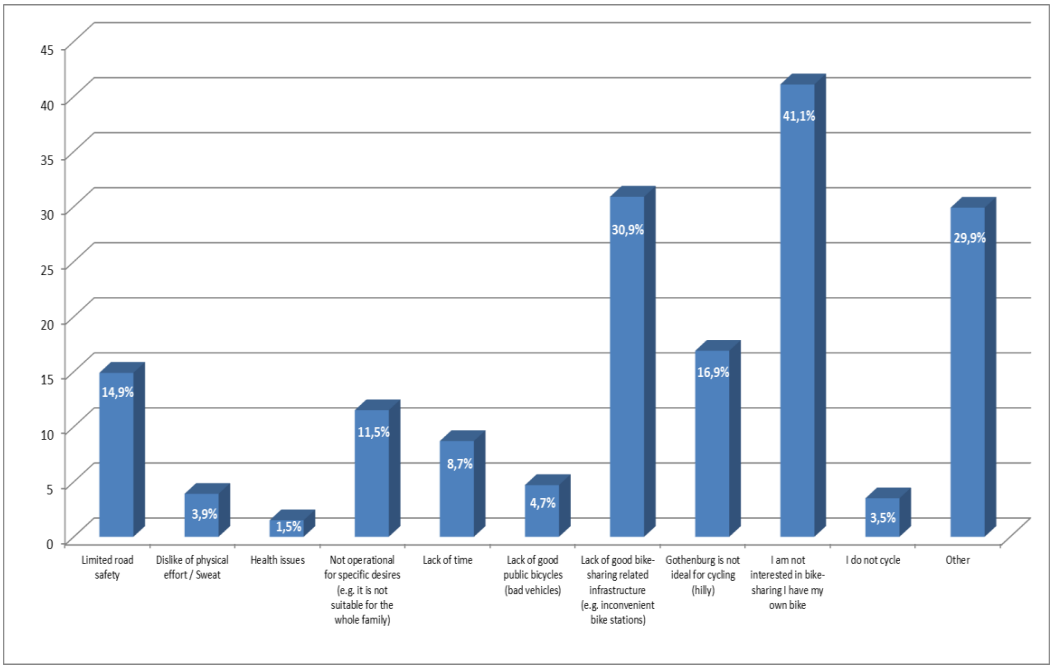

Figure 1 – Reasons for not using bike-sharing more regularly or at all (Sweden)

Drama study

The second survey results were in some regards very similar to the Gothenburg's key findings. Close to 90% of Drama's respondents thought that bike-sharing could be a good scheme for their city despite significantly lower usage intention rates (that could have been exaggerated due to unintended optimism bias).

Overall, Drama's respondents recognised that bike-sharing could be beneficial for their city. The vast majority of them considered that bike-sharing is a sustainable modal option that could improve road traffic conditions, compliment other means of public transport, offer an inexpensive transport option for the society, promote wellbeing, make cycling a more popular travel choice and reduce people's reliance on automobiles. However, perhaps the strongest finding, directly referring to the public acceptance of an eventual scheme, was people's disagreement to the notion that "public bicycles constitute an investment that they would not like to see being materialised". In absolute numbers, 86.5% of the respondents disagreed or strongly disagreed with this notion; only 5.1% agreed or strongly agreed and 8.4% were neutral respectively. The respondents self-reported relatively high levels of potential usage with expected usage in a somewhat frequent basis being 46.9% and "rarely or never" being 31.5%. Still these rates were considerably smaller than the reported acceptance rates.

The main reasons according to the respondents of Drama for being reluctant to cycle and potentially to use public bicycles are principally associated with the lack of cycling-oriented or bike-friendly urban infrastructure and the feeling that currently there is only

limited road safety for cyclists. Almost one in every two respondents made the case for each of these two specific answers making clear that physical and cognitive barriers associated with the way a cyclist is hosted in one's respective urban environment constitute the key in giving up the ideas of cycling and bike-sharing. It is true that only recently the construction of bike lanes, bike roads and bicycle racks has been initiated in the city of Drama; thus these specific attitudes are well justified (Nikitas, 2018). Dislike of physical effort was chosen by 12.5% of the respondents, lack of time by 13.8% and cycling and bike-sharing not being suitable for the city for 21.9%. Figure 2 presents the full set of these results.

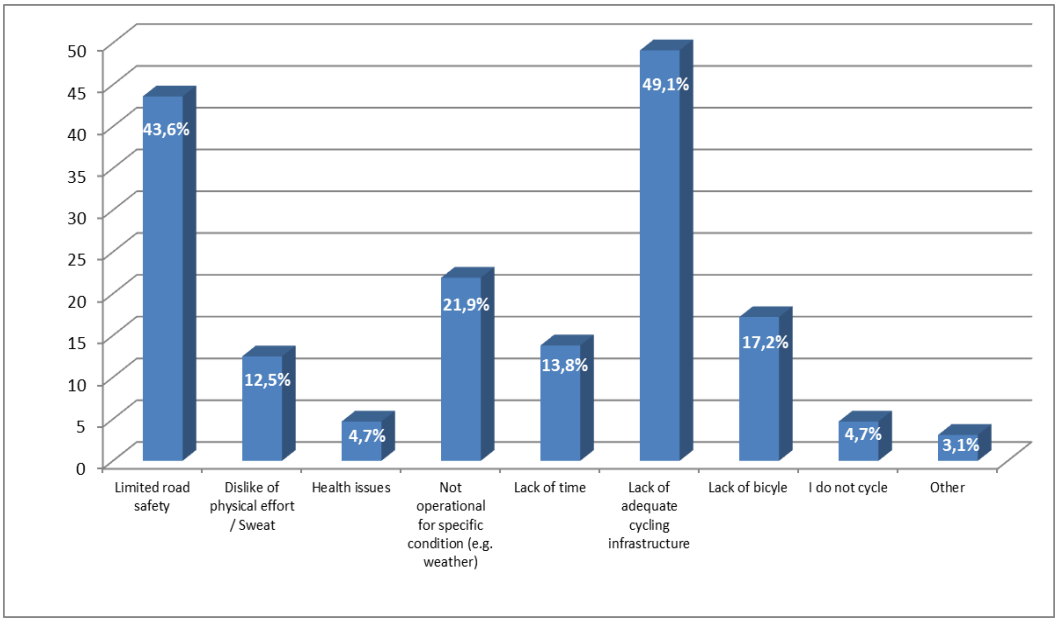

Figure 1 – Reasons for not cycling and not being willing to eventually bike-share (Greece)

Case study analysis:

Perhaps the most critical problem for conventional bike-sharing schemes is the renting and returning station-based operations that do not allow door-to-door convenience; traditional bike-sharing assumes that users can rent a bike from one of the existing bike-sharing stations and return it either to the original station or another station in a different location after using them. Schemes like Seattle's (U.S.) Pronto paid (among other reasons including local politics, hilly topography and mismanagement) its poorly and sparsely placed docking stations and the lack of having a systematic and incremental expansion strategy by ceasing its operations (Small, 2017).

Over the last five years, many operators are actively trying to solve this problem by providing station-less, maintenance-free, intelligent bicycles that lock and unlock through the use of mobile applications. This transition is led mainly by a few Chinese bike-sharing start-ups including Mobike and Ofo, a pair with a combined valuation likely to have exceeded in 2018 the £3bn threshold since they have been supported by two of the biggest internet giants Tencent and Alibaba,

Mobike has now bike-sharing operations in 200 cities and 16 countries around the world and is responsible for as many as 30 million daily trips with a fleet of 8 million bikes including electric options. As of July 2018, Ofo claimed to have around 15 million

bikes in operation in more than 300 cities across 22 countries, as well as 250 million global users but since then it has considerably scaled down its operations outside China.

Introducing with an unprecedented speed, hundreds of schemes of this new breed of 'door-to-door' bike-sharing systems, in China, the wider Asia and finally over the last two to three years in North America, Australia and Europe, the homeland of conventional public bicycle programmes, has the power, in theory, to transform the world of cycle hire, in a similar fashion with the one that saw Uber and other ridesourcing initiatives conquering carpooling and taxi-related services. Nevertheless, this monumental, and in many cases somewhat rushed, "embracement" is neither unproblematic nor without a fair share of early fiascos and overwhelming questionmarks that have recently disrupted the rise and stigmatised the public image of bike-sharing.

Stories of failure

In November 2017, China's third biggest bike-sharing company and the first dockless bike-share system to launch in the U.S, Bluegogo, went bankrupt, creating for the first time a dark cloud over the future of dockless bikes. The bankruptcy of a company that grew at an incredible pace to compete Mobike and Ofo, peaking at 350,000 bicycles in China alone and poised to conquer San Francisco, raised concerns that there are simply too many bikes at very low prices on offer and insufficient demand. Bluegogo collapsed leaving vast bike-share graveyards that challenged the 'sustainability' and 'eco-friendly' value of the dockless bike-sharing concept after falling according to Gillin (2018) $30 million in debt and struggling to repay customer deposits with the surviving bikes being sold as low as $5 per piece. Bluegogo's chief executive apologised for this collapse saying that he had been "filled with arrogance" (Haas, 2017) that practically meant that the company had unrealistic expectations, expanded too soon in an unsustainably big scale and was mismanaged.

Wukong Bicycle, a minor Chinese start-up of 1200 bikes in the notoriously hilly Chinese city of Chongqing went out of business after only six months of operations in July 2017, since 90% of its bikes were lost presumed either missing or stolen. This was the direct consequence of the operators' fatal mistake to not install GPS devices in their fleet. Beijing-based bike-sharing firm 3Vbike also bankrupted in June 2017 after losing more than 1,000 of its bikes in just four months of operations; not having its own mobile app to track the bikes and having to depend on a cycle location tracking function on its WeChat page was the key reason for this downfall. This scheme also failed to get traction due to limited fundraising; the owner had to purchase the bikes himself in lack of other investors (Nikitas, 2017).

The operations of the Mobike Manchester scheme, the first of its kind in the UK, launched in June 2017 is another story of misfortune for the concept of dockless bike-sharing. In a span of 15 months, Mobike had to cease its operations in Manchester because of "unsustainable" losses from theft and vandalism making this the first time the Chinese firm has abandoned a city because of antisocial behaviour. Stationless mobikes have been found dumped in canals and bins, vandalised, and others have been stolen making the company representatives to suggest that the system has been "misunderstood" and that "the learning is already being put to good use for creating a more suitable scheme in the not too distant future".

Ofo in an even more dramatic fashion was forced to withdraw from most of its UK market including the cities of Norwich, Sheffield and Oxford and as of January 2019 from London that was home of 3,000 Ofo bicycles. The company admitted that its UK business was loss-making and had to move to a different direction.

Similarly, Hong Kong-based bike-sharing operator Gobee shut down its operations in France in February 2018 after suffering what the company called "mass destruction" of its fleet. Gobee, which had 2,000 bikes in Paris and claimed around 150,000 users across the country, reported that 3,400 of the company's bikes have been damaged and more than 1,000 have been stolen (Agence France-Presse, 2018). Gobee pulled out of Belgium for similar reasons meaning that this was not an isolated country-specific issue.

OBike, another start-up with international reach, also exited from some of its key markets with most important the ones in Singapore and Melbourne during 2018. These cities having a long track record of supporting environmentally friendly urban growth are now trying to ensure responsible bike-sharing use, introducing stricter licensing regulations that prevent visual pollution and unsustainable public space intrusion. Complying with these regulations and in other cases with the helmet rules that govern bicycle use in Australia, can be expensive, as it requires investments in technology, security, and management. Operators, like OBike, sometimes decide that this extra investment is excessive, so they concentrate on other cities with softer regulations.

These examples have generated concerns about the long-term viability of bike-sharing and mainstream allegations that there is now a body of evidence proving that bike-sharing has been opportunistic or even failing as a concept. de Chardon (2019) concludes that most schemes typically benefit the privileged, help little to increase mass cycling transport and are used as easily deployable technological (false) solutions to contemporary problems while advancing unjust tendencies to privatise public space and services.

Stories of success:

Nonetheless, as the primary data research has indicated there is much more than failure and misfortune associated with bike-sharing operations; there is also hope and genuine potential for improvement that could help restoring the image of bike-sharing.

The government of the city of Hangzhou in China launched Hangzhou Public Bicycle in January 2008 starting with 2,800 bicycles, 30 fixed stations, and 30 mobile stations (stations which can be moved to meet demand). This scheme went on to become the world's largest bike-sharing system with 100,000 bicycles and 4,100 stations as of December 2018. This scheme has been successful in acting as a complement to existing public transit and as a tool for modal shift; members exhibited a higher rate of auto ownership than non-members meaning that bike-sharing was attractive to car owners (Shaheen et al., 2011). Some of the key success factors are: the low subscription fee, the availability of bicycles throughout the city, the subsidies from the local authorities, the fact that this was an initiative that the local transport agency created and is still a not-for-profit scheme (i.e. the riding is free for the first 60 min), its complete integration with the other public transport services, its good real-time information system, the upgrade of the bike hardware and the existence of a 'green corridor' that promotes cycling in general. Hangzhou, a city with a registered population exceeding 9 million, widely considered as an emerging technology hub (home to the e-commerce giant Alibaba) also hosts some dockless bike-sharing fleets from Mobike, Ofo, Hello Bike and Qibei. Chen et al. (2018) argue that Hangzhou Public Bicycle has already become rooted in the city as one of the public transportation modes and because its stable performance and the city's features fit for cycling, the habit of riding bikes has been awakened in Hangzhou, which has in turn provided an ideal environment for free-floating bikes to come into use.

Introduced in 2011, originally as Barclays Cycle Hire, London's bike-sharing scheme, Santander Cycles is a station-based system that can be accessed by anyone with a credit or debit card, with daily usage charged at £2 for unlimited journeys of up to 30 min. There is the option of annual membership charged at £90 (~25p per day). The scheme after incremental strategic expansions, now spreads across 100 km^2 of London and is the largest cycle hire scheme in Europe with 11,500 bicycles available across 750 docking stations (Transport for London, 2019). It has approximately 240,000 active members making over 10 million annual bicycle hires and its continued expansion is viewed as a central component of the Mayor's policy to transform London's transport system into one which is based on sustainable modes (Morton, 2018). Therefore, the scheme is subsidised and promoted heavily by Transport for London and is well linked with all the public transport modes of the city. Santander Cycles have demonstrated the capacity to normalise the practice of cycling in city life; its users are not solely representatives of particular social cohorts like sporty people (Goodman et al., 2014). Also, the scheme has become more equitable over time, encouraging women to use it, and with the eastern extension increasing the share of trips made by residents in poorer areas features that have been partly offset by increased prices (Goodman and Cheshire, 2014). As a whole, this is an award-winning intervention recognised not just for its impact on transport in England's capital city and its sustainability value but also for its innovative design, the public relations exercise and the challenging delivery timescales.

Dublinbikes is a public bicycle rental scheme which has operated in Dublin, Ireland since June 2009. At its launch, the scheme, which is sponsored by JCDecaux in exchange for 72 free advertising spaces around Dublin, used 450 bicycles organised in 40 stations. Now the scheme has 114 stations and 42,000 active annual subscribers and is one of the cheapest schemes in Europe with a €25 annual fee. Dublinbikes was the 17th bike-sharing scheme ever and has been considered one of the most successful local applications in the world as reported regularly in media (e.g. Duly, 2011; Collison, 2017), however occasionally there were reports suggesting that progress has stalled making the scheme loss-making. Synergies with industry have been notable for the Dublin scheme. Coca-Cola Zero was a commercial partner with Dublinbikes for three years (June 2014 to June 2017) with Just Eat taking over on July 2017 for the next three years with plans to invest €2.25 million in the scheme over its tenure; in both cases the name of the scheme was rebranded accordingly.

Discussion: Lessons to be learnt

The primary data analysis provides strong statistical evidence that bike-sharing is still a timely and meaningful proposition for urban policy-makers that is widely accepted even from those citizens not expected to be scheme subscribers or occasional users; the survey respondents coming from two very different urban environments would support their respective cities if they decided to invest on the schemes in both occasions.

The case study analysis identifies that inflexible standardised business models and operation strategies lacking an ability to tailor their offering to different areas, largely adopted from China, are not suitable for all urban environments. Dock-based systems despite their inability to provide door-to-door services seem to do better than dockless schemes for now. Expansion tactics that have been over-aggressive, defied established competition, did not actively seek the collaboration and support of the local hosts and were not adequately justified by travel demand data have failed. Schemes that were tailored to the city needs, were integrated or complemented the public transport provision, had a clear incremental expansion strategy, kept relatively inexpensive prices, secured the support of the local authorities, forged synergies with commercial partners

and embraced technology have been successful and set the bar for the industry. Some recommendations that this work can provide primarily to operators but also to cities looking to host sustainable and long-lived bike-sharing schemes that will add value to their image suggest that they should:

- Make unique city-specific plans for delivering each scheme. The ability to tailor an offering to reflect the character of a city and the norms of its citizens is critical.
- Prioritise the scheme's long-term success over easy profit and unrealistic revenue return expectations; bike-sharing should be user-centric and not profit-centric.
- Realise that that the bulk of benefits that a scheme can deliver refer to avoiding the negative externalities of excessive car usage. This is a profit worth paying so operators should actively seek the support of the cities when possible in subsidies and supporting infrastructure.
- Work together (operators and cities) so the latter will be incentivised to support their local schemes. Private-public partnerships can work.
- Seek strategic commercial collaborations like the London and Dublin schemes. Extra financial support and brand adding value is always helpful.
- Acknowledge that an oversaturated bike-sharing market can be lethal, especially for smaller providers, although bigger operators could be also be in jeopardy as evidenced by the examples of Bluegogo primarily and Ofo to a smaller extent.
- Invest more efforts in regulating the responsible usage of bikes. Protection mechanisms and penalties for vandalism and theft should be in place from day one. Cities should support these efforts with better policing.
- Employ joint market and education campaigns to promote bike-sharing culture and encourage people to adopt a positive attitude towards these bikes. Cultural engagement from the outset is a prerequisite for success.
- Focus on providing fair fares, member subscriptions, and "ways out".
- Finance better business planning and bike management; companies need to constantly innovate to stay on top of this very dynamic market. The option for docking stations and enough people on the ground to ensure schemes are reliable and serve their purpose should be provided.
- Technology is not always a panacea; it is only one of the several tools in the toolbox of successful bike-sharing provision. However, mobile apps, rental machines, GPS tracking should be modern, user-friendly and functional.
- Manage the distribution of bikes more effectively and responsibly. Operators need to be more accountable about visual pollution. In exchange cities could be more flexible with their regulations (e.g. easing helmet use regulations or help supplying shared use helmets).
- Recognise in line with Zhang (2015) that bike-sharing systems need to be carefully developed to appreciate the quality and timely interplay between the physical design of the system and the provision of services being offered.

Conclusion

This work provides an evidence-based roadmap for helping a still growing, but somewhat jeopardised and stigmatised, mobility innovation to avoid an unforgiving path that leads to an unsustainable and ill-fated future. This paper disengages "scheme success" from a strict usage rate perspective and informs policy-makers and scheme suppliers that citizens, want to see systems that deliver sustainability benefits to be supported by city funds. More importantly though it generates policy and business lessons from current practice forming a unique survival guide for running micromobility schemes.

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Do relationships matter?
Linking the advancement of shipper-logistics service provider relationships with green logistics implementation

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Abstract

The contract logistics literature implicitly suggests that establishing advanced relationships between shippers (logistics buyers) and logistics service providers (LSPs) plays a role in facilitating green logistics practices. We systematically test this claim through surveying 335 companies (170 shippers; 165 LSPs) in Sweden. Using factor- and multiple regression analyses, we confirm that implementing green logistics practices is influenced by advanced relationships settings, but not all practices adhere to this. Also, a distinction is made on whether relationship advancement is expressed by the contract design or the degree of integration between the partners; the former better explains the implementation of the practices.

Keywords: LSPs, environmental sustainability, logistics relationships

Introduction

The destructions caused by the logistics industry on the environment have placed logistics service providers (LSPs) under the spotlight when logistics activities are scrutinised (Grant et al., 2017). The transport industry alone is accountable for 23% of total greenhouse gas emissions in Europe (ESLMM, 2016), and such figures are expected to rise in parallel to the growing world economies (Grant et al., 2017). Despite increased LSPs' adoption of green practices over the last decade (Centobelli et al., 2017), there is still a lot to be done; LSPs still possess little control over the emissions released by their operations (Nilsson et al., 2017). However, a substantial share of responsibility lies on the shoulders of shippers (i.e. logistics buyers) as well, since they are the ones choosing the LSPs to work with and the solutions to be deployed (Wolf and Seuring, 2010). Consequently, there is a growing scholarly demand for investigating shipper-LSP dyads to conceptualise how their relationships design and settings could influence the facilitation of green logistics practices (Centobelli et al., 2017; Evangelista et al., 2018).

In parallel to this, the concept of outsourcing logistics activities by using LSPs has surpassed a state where shippers simply exploit the competencies of LSPs, towards a more advanced competence development state that cultivates mutual benefits for both actors alongside advancing their dyadic relationships (Andersson and Norrman, 2002; Bask, 2001; Halldórsson and Skjøtt-Larsen, 2004; Sharma and Choudhury, 2014). Halldórsson and Skjøtt-Larsen (2004) deployed a resource- and competence-based view, together with

a transaction cost economics (TCE) one, to reconceptualise a typology of shipper-LSP relationships, arguing that such relationships advance alongside a triaxial development of competence, degree of integration and asset specificity between the partners. Recent studies on green logistics within the contract logistics domain signal a higher likelihood of conducting green logistics solutions within *advanced* shipper-LSP relationships (Eng-Larsson and Kohn 2012; Jazairy, 2018; Monios and Bergvist, 2016; Sallnäs, 2016). According to these studies, jointly-commenced green logistics practices (particularly those requiring up-front investments) seem more detectible in relationships that are beyond arm's-length arrangements, based on the reasoning that such practices demand: a willingness of shippers and LSPs to share risks/rewards, long-term contracts to enable LSPs' green investments, mutual development of green performance measures, and a sufficient level of trust and transparency between the partners. However, studies making such claims are mainly based on inductive and exploratory methods, where insufficient generalisability forms a clear limitation. Besides, there is a need to distinguish which green practice necessitates such advanced relationship settings for its facilitation, as some practices seem rather cheap and easy to implement with no prerequisite for shippers' substantial involvement (Nilsson et al., 2017; Sallnäs, 2016).

Given the rationale above, and to our best knowledge, no survey study has been conducted to test the linkages between shipper-LSP relationship advancement and the implementation of different green logistics practices, which forms the *purpose* of this paper. A research question is formulated to serve the purpose:

> *RQ. How can the advancement of shipper-LSP relationships explain the implementation of green logistics practices in such relationships?*

The survey utilised in this study is based on a large sample of shippers and LSPs operating in Sweden. In line with Halldórsson and Skjøtt-Larsen (2004), two theoretical lenses are used to describe the advancement of shipper-LSP relationships: resource- and-competence-based view, and TCE. Findings of this paper enable understanding whether the way shipper-LSP relationships are established has an influence on the facilitation of green logistics practices. Understanding this linkage can aid practitioners in shipper/LSP firms in deciding whether or not they should strive for forming advanced relationships with their logistics partners when certain green logistics practices are pursued.

The remainder of this paper is structured as follows: the next section covers a literature review on shipper-LSP relationship advancement, green practices in the logistics industry, and possible linkages between the two. The succeeding section describes the survey used and the data collection/analysis techniques. This is followed by the findings and discussion sections. The last section draws the main conclusions of this study, together with its limitations and directions for further research.

Literature review

Shipper-LSP relationship advancement

Grounded on a TCE standpoint, Cox (1996) guides firms to shape their contractual relationships with their suppliers by considering the competencies needed to provide the goods/services in question and the degree of asset specificity associated with such competencies. Firms should form arm's length alliances when asset specificity is low, and move towards more strategic alliances as asset specificity increases—in conjunction with the strategic importance of the skills needed for creating these goods/services. When the skills are associated with a very high degree of asset specificity, they become the core competencies of the firm, favouring means of internal contracting such as merger

acquisitions or vertical integration. Supplemented with a resource- and competence-based view, Halldórsson and Skjøtt-Larsen (2004) apply Cox's typology onto the contract logistics context as a basis to identify three stages of shipper-LSP relationships: (i) market exchange (i.e. short-term relationships with standard LSP skills and low asset specificity), (ii) customised logistics solutions (a broad range of standardised services is offered over a limited contract period, where LSPs' skills complement those of the shippers with low/medium asset specificity), and (iii) joint logistics solutions (a unique solution is jointly developed by both parties to create mutual advantages and facilitate innovation via assets and information sharing, in which the competencies of both parties complement each other over a long-term contract). As shipper-LSP relationships move towards a more advanced scheme, learning from the other party as well as joint-learning materialise further (Håkansson et al., 1999), together with higher degrees of personnel exchange between the partners and higher potentials for integrating their IT systems (Halldórsson and Skjøtt-Larsen, 2004). It is important to note that companies should not view advanced partnerships as the 'best way' to form an outsourcing relationship, rather, they should consider the *right* ('fit-for purpose') alliance based on the competencies and skills at hand (Cox, 1996). Other notable works can be found on shipper-LSP relationship advancement (e.g. Bask 2001; Sharma and Choudhury, 2014), yet we mainly build on Halldórsson and Skjøtt-Larsen's (2004) typology due to its robust theoretical grounding.

Green logistics practices

The contract logistics literature has comprehensively identified the green logistics practices commenced by LSPs (e.g. Colicchia et al., 2013; Martinsen and Huge-Brodin, 2014; Perotti et al., 2012). We build upon Martinsen and Huge-Brodin (2014), since they inclusively grouped the offerings of environmental practices in the logistics market under ten items (Table 1). We will also add the practice 'green packaging', due to the evident influence of packaging on the environmental performance of logistics; i.e. packaging affects transport efficiency (by increased weight/space of transported goods) and the amount of waste along supply chains (Molina-Besch and Pålsson, 2014).

Table 1 – Green logistics practices (adapted from Martinsen and Huge-Brodin, 2014)

Green logistics practice	Description and examples
1. Mode choice	Shifting to a more environmentally friendly transport mode (e.g. from road to rail, intermodal solutions)
2. Transport management	Increasing fill-rates, route optimisation
3. Logistics system design	Improving distribution networks, reducing haul length
4. Vehicle technology	More efficient diesel engines, engine stop when stationary
5. Eco-driving	Driving techniques to decrease fuel consumption
6. Alternative fuels	Electrical vehicles, trucks operating by biofuels (e.g. hydrotreated vegetable oil)
7. Environmental management systems (EMS)	ISO 14001, EMAS, ISO 5001
8. Choice of partners	Selecting and evaluating suppliers based on their green performance
9. Emissions data	Calculating, reporting and analysing CO_2 emissions
10. Green and efficient warehouses	Increase efficiency in buildings, using renewable energy sources
11. Green packaging	Packaging design, reduction, reuse and recycling for the environment

Linking relationship advancement with green logistics implementation

The underlying assumption of this paper is that implementing green logistics practices within a contract logistics context requires some sort of coordination and risk/reward sharing between shippers and LSPs, which can be translated in (i) high degree of customisation and asset specificity (Jazairy, 2018; Monios and Bergvist, 2016), (ii) shippers' long-term commitment (Eng-Larsson and Kohn 2012; Jazairy, 2018; Monios and Bergvist, 2016), (iii) systems and IT integration (Isaakson and Huge-Brodin, 2013), and (iv) knowledge and personnel exchange (Monios and Bergvist, 2016; Rogerson and

Santén, 2017). Taking investing in a fleet of biofuel trucks for example, Jazairy (2018) remarks instances where LSPs were able to invest in such fleets only after securing five year contracts with shippers–and these were attainable only when customised transport services were offered (e.g. shipping heavy goods with special handling). Jazairy relates this to the oversupply of standardised transport services (i.e. shipping palletised goods), which drove the competition high in this segment, making investing in new trucks unfeasible due to shippers' aversion of long-term commitments (to allow continuous benchmarking among LSPs and lowering costs). Another example is provided by Monios and Bergvist (2016), who studied four intermodal platforms in Europe and found that the common denominator for success in all these platforms is expressed in inter-organisational 'trust, learning, knowledge sharing, coordination and complementarity' (p. 548)—where risks of owning locomotives was shared between shippers, LSPs and other stakeholders over long-term agreements. However, not all green logistics practices should adhere to this; a distinction should be made on which green practice requires advanced settings, and why is this the case. That is, there is a need to understand the contextual factors associated with a respective practice that necessitate advanced relational settings, since one could argue that not all practices need upfront investments for instance (Nilsson et al., 2017). Moreover, all the above mentioned studies are based on exploratory and inductive case studies, calling for large-scale surveys to further generalise their claims.

Figure 1 shows our main theoretical model. Elements of relationship advancement are extracted from Halldórsson and Skjøtt-Larsen (2004), whereas green logistics practices are adapted from Martinsen and Huge-Brodin (2014). As our study takes dyadic views into account, we control for the *role* to find whether operating as a shipper/LSP influences the outcomes. We also control for *size* (in terms of number of employees) due to the commonality of treating it as a control variable in operations management studies. The third control variable is *green strategy* (in a relationship-specific context), since green strategies are likely to influence green logistics practices but also to be associated with relationship advancement.

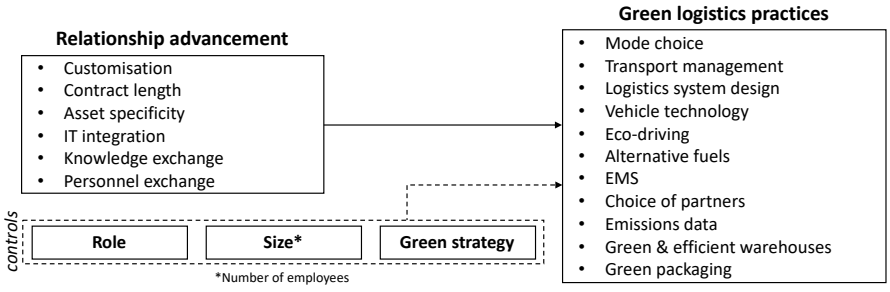

Figure 1 – Theoretical model

Methods

Survey design

This study is based on a web-based survey on green logistics implementation within shipper-LSP antecedents. To include shippers and LSPs, two 'mirrored' versions (one for each) were designed using the web application Qualtrics XM. Questions were asked in a relationship-specific context. First, respondents were requested to identify an ongoing business relationship with an environmentally conscious buyer/provider. This was followed by a question on the importance of green strategy in such relationship (based on a Likert scale that ranges from 1: 'not important' to 5: 'very important'). Then, six questions were asked to describe this particular relationship, one question for each element under 'relationship advancement' (Figure 1). We used 5-point bipolar scales for

these question, with one end reflecting arm's length arrangements, opposed by another that reflects advanced partnerships. Last, respondents were requested to estimate (on a scale from 1: 'very low' to 5: 'very high') the extent of implementing each of the 11 green logistics practices in this particular relationship. An option 'inapplicable' was provided for each question, and questions could be left unanswered. We pre-tested the survey with 3 logistics experts to ensure a proper understanding, and modified our survey accordingly.

Data collection

As clarified above, we targeted two different groups of firms: shippers and LSPs. Finding these was achieved using the database 'Retriever'–a list was extracted for each group operating in Sweden. For shippers, we selected the industries that are likely to purchase logistics services (those who have *goods* to transport and store, e.g. manufacturing, forestry). Shippers with revenues under 100 MSEK (~10 M€) were excluded, as it is mainly large ones who address environmental concerns in their purchasing (Björklund, 2011). This yielded 1,231 shippers. For LSPs, the main selection criterion was providing logistics services. Unlike shippers, we did not exclude the small ones (unless below 1 MSEK), since even those offer green services, and their customer portfolios often include large shippers (Jazairy, 2018). 873 LSPs were found. To give large firms, which are fewer but have more impact on the environment, a higher chance of being included in the sample, we used a stratifying logic to cluster firms into categories based on their revenues, followed by a random selection on each strata (see Table 2)—yielding 1000 firms (500 each). These firms were contacted by phone with an attempt to reach respondents responsible for purchasing/selling logistics services, preferably on a managerial level. We succeeded in sending our survey to 183 shippers and 290 LSPs, whereas the rest did not show interest in participating or could not be reached. After two rounds of reminders, a total of 335 companies (170 shippers; 165 LSPs) have answered our survey, representing a well-balanced sample of logistics buyers and providers in the Swedish logistics market. Data collection took place between mid-November, 2018 and mid-February, 2019.

Table 2 – Stratifying logic

Category	Revenues (MSEK)		Total (*n*)	Desired (*n*)	Revenues (MSEK)		Total (*n*)	Desired (*n*)
	From	To			From	To		
	Shippers				*LSPs*			
1	10,000	∞	53	All	1,000	∞	29	All
2	5,000	9,999	57	All	250	999	110	All
3	1,000	4,999	400	195	50	249	355	181
4	100	999	721	195	1	49	379	180
			Total	**500**			**Total**	**500**

Data analysis

We tested the data for skewness and kurtosis to assess normality: all values fall below the critical value of ±1.96 as suggested by Hair et al. (2010). Data analysis took two main steps using SPSS: exploratory factor analysis (EFA), and multiple regression analysis (MRA). EFA was used to discover possible groupings for the 6 items under relationship advancement–as basis for MRA. Performing EFA with Varimax rotation (chosen because the extracted components are not correlated) revealed the presence of 2 components with eigenvalues exceeding 1.0, explaining 30.914% and 26.393% of the variance, respectively. The choice to retain these 2 components was supported by running a parallel analysis using Monte Carlo PCA, which reported only 2 components with eigenvalues exceeding the randomly generated corresponding values with the same size (6 variables, *n*: 335)—confirming retaining both. To include an item under a certain factor, it must report a factor loading of 0.4 or above on this factor only (Hair et al., 2010). With no co-

loading problems, 3 distinct items loaded above 0.4 on each factor (Table 4). In line with previous studies (Andersson and Norrman, 2002; Halldórsson and Skjøtt-Larsen, 2004), factor 1 represents contractual issues (henceforth 'contract'), whereas factor 2 is about 'integration'. Cronbach's α was checked to test internal consistency for the new scales (Table 4). Hair et al. (2010) recommend accepting values of 0.7 and above, or 0.6 and above for new scales, whilst rejecting values under 0.5. Factor 1 adequately passes this test, whereas factor 2 is below the recommended value—yet not to the level of rejection. Also, low values are common for scales with a few number of items (less than 10) (Briggs and Cheek, 1986). Hence, we retained factor 2. MRA was performed to detect causal relationships between the 2 relationship advancement factors (independent variables–IVs) and the identified 11 practices (dependent variables–DVs). We performed MRA hierarchically, with model 1 including the control variables: role (shipper/LSP), size (logarithmic value for no. of employees), and green strategy (GrStrategy), proceeded by models 2 and 3 where the 2 new factors (IVs) were added (one at a time). All VIF values for the IVs are considerably lower than 10, and all tolerance values are largely above 0.10, indicating that no multicollinearity problem is present in our MRA (Olague et al., 2007). However, we noticed slightly skewed residuals when regressing 'transport management' and 'EMS'—albeit their normality was accepted based on Hair et al. (2010).

Findings

Table 3 shows descriptives for all variables used in our analysis. Note that we combined datasets of shippers and LSPs to report both actors' views. Table 4 reports the performed EFA (see Methods), and Table 5 reports MRA with 3 regression models that treat each green logistics practice as a DV, and the factors 'contract' and 'integration' as IVs.

Table 3 – Descriptive statistics

	n	Mean	SD	Min (*n*)	Max (*n*)
Size (no. of employees)	284	1608 (median:130)	6406.18	-	-
Green strategy (GrStrategy)	211	3.47	1.148	12	44
Relationship advancement					
Customisation	228	2.94	1.357	55	28
Contract length	226	3.39	1.115	17	43
Asset specificity	228	2.96	1.385	54	38
IT integration	228	3.09	1.268	33	38
Knowledge exchange	226	3.65	1.031	8	53
Personnel exchange	227	1.59	0.91	151	2
Green logistics practices					
Mode choice	182	2.73	1.426	53	24
Transport management	220	3.95	1.165	12	90
Logistics system design	184	3.16	1.3	28	32
Vehicle technology	217	3.41	1.292	26	47
Eco-driving	210	3.22	1.384	36	46
Alternative fuels	204	2.95	1.422	45	37
EMS	207	3.71	1.388	23	85
Choice of partners	206	3.13	1.134	24	19
Emissions data	215	3.37	1.374	31	60
Green & efficient warehouses	170	2.41	1.184	49	8
Green Packaging	157	2.85	1.334	36	18

Table 4 – Exploratory factor analysis (rotated solution: Varimax)

	Factor 1: Contract	Factor 2: Integration
Customisation	0.746	-0.035
Contract length	0.745	0.112
Asset specificity	0.802	0.286
IT integration	-0.012	0.821
Knowledge exchange	0.31	0.659
Personnel exchange	0.058	0.617
Eigenvalue	2.254	1.185
Variance explained	30.914	26.393
Cronbach's α	0.671	0.527

We only comment on the third models in Table 5 due to text limitations. These models explain the total variance in each DV as follows: 19% (mode choice), 17% (transport management), 22% (logistics system design), 41% (vehicle technology), 44% (eco-driving), 36% (alternative fuels), 12% (EMS), 35% (choice of partners), 27% (emissions data), 22% (green and efficient warehouses), and 15% (green packaging). From Table 5 we can see that 'contract' significantly explains the variance in 7 out of 11 practices, with the strongest influence reported on *choice of partners*, *vehicle technology* and *alternative fuels*, respectively. With slightly lower β values, 'integration' significantly explains the variance in 5 practices, with the strongest influence reported on *green and efficient warehouses*, *logistics system design* and *transport management*, respectively.

Discussion

Linking relationship advancement with green logistics implementation

Our findings generally indicate that establishing advanced shipper-LSP relationships has an influence on facilitating the majority of green logistics practices in such relationships (Figure 2); only two practices (*emissions data*, *green packaging*) do not adhere to this. Also, a distinction is made on whether relationship advancement is expressed by the contract design or the degree of integration between the partners; the former better explains the implementation of the practices, noting that some (*green and efficient warehouses*, *choice of partners*, *EMS*) are influenced by both.

The combined influence of contractual and integration elements on facilitating *green and efficient warehouses* (and coherently acquiring *EMS* certificates such as ISO 14001) indicates that green solutions in warehouses (e.g. harnessing renewable energy sources, motion sensors to control lighting) do not only require shippers' long-term commitments to secure payback on LSPs' investments in these solutions, but also high levels of IT integration and knowledge/personnel exchange between the two—compatibly with the nation asserting that warehousing services generally fall under complex contractual agreements that differ from routine freight exchanges (Andersson and Norrman, 2002). We find that such advanced partnerships also affect LSPs' *choice of partners* based on their green performance, which could be seen as a result of environmentally conscious shippers' emphasis on greening logistics functions over the entire downstream chain due to the high strategic importance of such functions—if viewed through a TCE lens.

For the practices *vehicle technology* and *alternative fuels*, our findings confirm Jazairy's (2018) assertion that 'modern' eco-fleets are rather relationship-specific assets, and investing in them is particularly feasible for LSPs when long-term contracts are secured, which are typically found when customised transport services are offered. This challenges the idea that investing in eco-fleets is easier in the standardised logistics market (where long-term contracts are rare) due to LSPs' utilisation of economies of scale (Liedtke and Friedrich, 2012). LSPs' acquisition of these fleets appear more problematic in this market due to shippers' (i) diversified demands and (ii) desire to form short-term agreements to lower costs through LSPs' competition.

We notice an influence only from 'integration' on *logistics system design* (e.g. improving distribution networks, reducing haul length) and *transport management* (e.g. increasing fill-rates, route optimisation). This might relate to the complex nature of these practices that is associated with advanced levels of cooperation between the partners (Rogerson and Santén, 2017), regardless of the type of contract that is agreed upon.

As mentioned earlier, *emissions data* and *green packaging* do not require advanced relationship settings, which may indicate that these practices are becoming fixed and imbedded within LSPs' business models irrespective of the type of relationship established with their partners.

Table 5 – Multiple regression analysis

		Dependant variables										
Model		Mode choice	Transport management	Logistics system design	Vehicle technology	Eco-driving	Alternative fuels	EMS	Choice of partners	Emissions data	Green and efficient warehouses	Green packaging
1	β Role°	-0.199*	-0.186*	-0.329**	-0.404**	-0.510**	-0.327**	-0.035	-0.152	-0.325**	-0.284**	0.135
	Size	0.037	0.042	0.107	0.057	0.039	0.049	0.030	0.082	0.071	0.221*	0.040
	GrStrategy	0.357**	0.320**	0.335**	0.477**	0.434**	0.470**	0.257**	0.494**	0.439**	0.273**	0.285**
	R^2	0.152	0.120	0.169	0.336	0.383	0.286	0.068	0.254	0.253	0.137	0.131
	Adjusted R^2	0.135	0.106	0.153	0.325	0.373	0.274	0.052	0.241	0.241	0.119	0.111
	F	9.123	8.279	10.408	30.664	36.700	23.401	4.203	19.850	20.664	7.613	6.512
2	β Role°	-0.166	-0.157	-0.305**	-0.340**	-0.450**	-0.260**	0.006	-0.076	-0.301**	-0.237*	0.126
	Size	-0.019	0.001	0.074	-0.025	-0.038	-0.036	-0.015	-0.006	0.045	0.166	0.053
	GrStrategy	0.336**	0.298**	0.317**	0.426**	0.392**	0.426**	0.231**	0.448**	0.426**	0.246**	0.291**
	Contract	0.166*	0.136	0.086	0.286**	0.234**	0.282**	0.169*	0.281**	0.098	0.183*	-0.044
	R^2	0.176	0.137	0.176	0.409	0.432	0.357	0.094	0.325	0.262	0.167	0.132
	Adjusted R^2	0.155	0.118	0.154	0.396	0.419	0.342	0.073	0.309	0.246	0.144	0.106
	Change in R^2	0.025*	0.017	0.006	0.073**	0.048**	0.071**	0.026*	0.071**	0.009	0.030*	0.002
	F	8.138	7.175	8.102	31.285	33.399	24.167	4.454	20.900	16.143	7.159	4.922
3	β Role°	-0.131	-0.088	-0.215*	-0.321**	-0.409**	-0.251**	0.071	-0.014	-0.256**	-0.146	0.168
	Size	-0.036	-0.027	0.022	-0.032	-0.057	-0.040	-0.044	-0.039	0.027	0.115	0.026
	GrStrategy	0.321**	0.273**	0.277**	0.420**	0.379**	0.423**	0.204**	0.424**	0.411**	0.208**	0.273**
	Contract	0.171*	0.141	0.115	0.286**	0.237**	0.282**	0.179*	0.293**	0.103	0.209**	-0.030
	Integration	0.111	0.180*	0.215**	0.052	0.102	0.024	0.164*	0.163*	0.115	0.241**	0.123
	R^2	0.188	0.166	0.216	0.411	0.441	0.358	0.117	0.348	0.274	0.218	0.146
	Adjusted R^2	0.161	0.143	0.190	0.395	0.425	0.339	0.092	0.329	0.254	0.191	0.113
	Change in R^2	0.011	0.029*	0.040**	0.002	0.009	0.001	0.024*	0.024*	0.012	0.052**	0.014
	F	6.971	7.160	8.315	25.139	27.580	19.266	4.552	18.479	13.641	7.934	4.374

**significant at p<0.01; *significant at p<0.05
°values for role: 1: shipper; 0: LSP

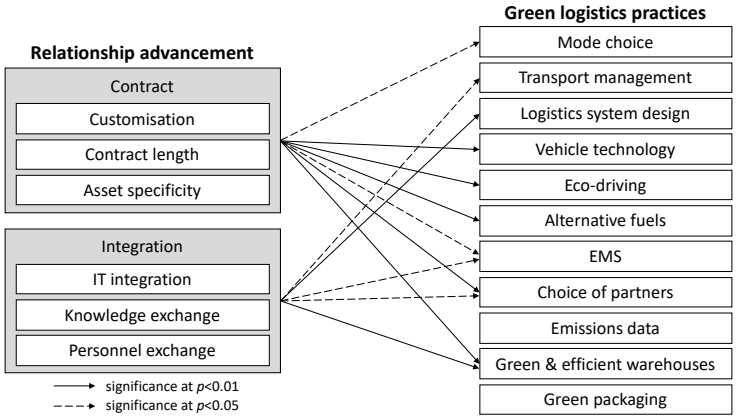

Figure 2 – Verified model with significant relationships

The influence of role, size, and green strategy

Whether a company operates as a shipper or an LSP does influence the linkages between relationship advancement and green logistics implementation in 5 practices (where β values for *role* are negative and significant – Table 5); LSPs appear to engage more than shippers in these practices (in line with Wolf and Seuring, 2010). Noteworthy, firm size (in terms of number of employees) does not have a significant impact on the findings, whereas having a relationship-specific green strategy significantly (p<0.01) impacts the results in all the 11 practices—which is not surprising, since firms with green strategies are obviously more likely to implement green practices (as discussed earlier).

Conclusions

By conducting a large scale survey on shippers and LSPs, we systematically verify an implicit claim within the contract logistics literature: establishing advanced shipper-LSP relationships plays a role in facilitating green logistics practices. Relationship advancement was described through two theoretical lenses: resource- and competence-base, and TCE. Our findings differentiate whether such advancement is expressed by contractual elements (customisation, contract length, asset specificity) or integrational ones (IT integration, knowledge exchange, personnel exchange); the former better explains the implementation of the practices—though some practices are influenced by both, whilst others are influenced by neither (Figure 2). This research connects shipper-LSP relationship advancement studies with green logistics applications ones, laying the foundation to investigate further the contextual factors associated with the practices that require advanced settings for their facilitation. For practitioners, insights are offered for managers in shipper/LSP firms to formulate the *right* ('fit-for purpose') agreement with their logistics partners with respect to the desired green practice (together with other considerations such as level of competence, of course). As our survey covered actors in Sweden only, we recommend replicating our analysis in other countries.

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Implementing sustainable corporate supplier relationship strategies: a case study from a multinational company

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Abstract

In a time where stakeholders increasingly demand social, environmental, and economic sustainability, mismanaging suppliers can harm a corporations' reputation and business severely. By means of a case study, our research explores the challenges and the coping mechanisms in supplier relationships of multinational enterprises from an agency theory perspective. Based on the findings, we propose a framework that can support multinational enterprises in developing corporate sustainability strategies and in implementing them in the supplier network. Our contribution to the literature lies in the integrated approach of combining sustainable strategy implementation within multinational enterprises as well as across their supplier networks.

Keywords: sustainability, supplier management, MNEs, agency relationships

Introduction

In view of the recent corporate scandals and growing societal and environmental challenges around the world, corporations face growing pressure from stakeholders, such as customers, governments, local communities and NGOs, to manage and contribute to the triple bottom line (TBL) of social, environmental, and economic sustainability (people, planet, profits) (cf. Elkington, 1998). Companies tend to promote their sustainability initiatives through sustainability reports, homepages, corporate communications, advertising campaigns, logos, and trademarks, aiming to build global "social brands" (Huber et al., 2011). Recent studies provide evidence that investment in

corporate sustainability may enhance the bottom line (e.g. Fosfuri et al., 2015; Kaul and Luo, 2018). In order to reap the potential benefits, Bettencourt et al. (2013) emphasise the need to move from "intent" to "action", thereby stressing the role of effective implementation. Similarly, Melé and Guillén (2006) propose to integrate sustainability development with strategic management. Strategic decisions tend to have drawbacks in the operationalisation and implementation of sustainability, possibly due to conflicts between the individual and organisation. Understanding the drivers and inhibitors of effective sustainability strategy implementation is particularly challenging in multinational enterprises (MNEs), since it involves subsidiary units that are separated geographically, legally, culturally and politically. Not surprisingly, a growing body of literature acknowledges the potential disconnect between what HQ wants and how subsidiary units actually act in the realm of sustainability (e.g. Asmussen and Fosfuri, 2019). Kostova et al. (2017) propose an agency model for headquarters-subsidiary relationships in multinational organizations with headquarters as the principal and the subsidiary unit as the agent. Agency relationships occur when one partner in a contract-based transaction (the principal) delegates authority to another (the agent) and the welfare of the principal is affected by the choices of the agents (Alchian and Demsetz, 1972). Kostava et al. (2017) suggest that tensions between HQs and subsidiaries are particularly endemic to organizations such as MNEs, which are characterized by significant decentralization and delegation of decision-making authority (Jensen and Meckling, 1976). Distribution of authority and responsibilities creates a level of uncertainty as to whether the subsidiaries will work towards the achievement of corporate sustainability goals or, alternatively, would use the delegated power to engage in undesirable behaviours for their own benefits.

From a supply chain perspective, investigating sustainable strategy implementation from an internal agency relationship perspective appears to be a good starting point but is not sufficient. Instead, companies have realised the necessity to develop sustainability strategies which extend their traditional corporate governance processes beyond the firm's boundary to their suppliers. Mismanaging suppliers in the realm of sustainability can harm a corporations' reputation and business severely. For example, Amazon has been exposed to immense negative headlines due to the unethical and illegal labour standards of its supplier, Foxconn. Adidas and Nike have been criticised for working with a Chinese textile supplier charged for discharging toxins into a river. These cases exemplify supplier sustainability risks, i.e. the harmful impact on a buyer from a supplier's social and environmental misconduct (Hajmohammad and Vachon, 2016). Simultaneously, they reveal that sustainability management in the external buyer supplier relationships share the same assumptions underlying agency theory: between the buyer (principal) and supplier (agent) exist potential goal conflicts, each party acts in its own self-interest and there is information asymmetry between principal and agent (Eisenhardt, 1989; Zu and Kaynak, 2012). Within MNEs, the role of the buyer is assigned to subsidiary managers who hold the direct supplier contact. This said, the subsidiary managers act as agents in the relationships with the HQ and as principal in the supplier relationships. Overall, our paper builds on two bodies of knowledge, which so far, have not been integrated. On the one hand, studies investigating sustainability development in MNE's from a strategy implementation perspective and on the other hand the integration of corporate sustainability in supplier relationship management (Neumüller et al., 2016). This focus comprises two integrated relationships: firstly, between HQ and subsidiary units and secondly, between subsidiary units and suppliers. Our goal is firstly, to explore the challenges and the coping mechanisms in the two overlapping agency relationships. Secondly, from the findings, we aim at developing a framework that can support MNEs

in developing corporate sustainability strategies and in implementing them in the supplier network. The remainder of the paper is structured as follows. Next, we review the literature and derive the empirical research questions and conceptual foundation. The third part describes the methodology of our case study, which is followed by a fourth part summarizing the key findings. In the last part of the paper, our implications propose a framework for sustainable supplier relationship strategy development and implementation in MNEs.

Literature Review

To provide a conceptual foundation for our research, we review the literatures on strategy implementation in MNEs, corporate sustainable strategy implementation and sustainable supplier relationship management (SSRM).

The strategic management literature tends to agree that strategy implementation is often harder than strategy content development (e.g. Hrebiniak, 2006). In the implementation, selected corporate strategy options are translated into various concrete managerial activities (de Wit and Meyer, 2010). According to Roth and O'Donnell (1996), the specific issues identified in the sustainability implementation in MNEs, stem from the geographical and cultural disconnection between corporate HQ and regional subsidiaries. This may lead to an overreliance on financial performance as the most important and easily manageable control mechanism. Additionally, the HQ and the subsidiaries may differ on the level of sustainability engagement they consider appropriate. For instance, Durand and Jacqueminet (2015) demonstrate that when subsidiaries face strong demands from their external constituents, they pay less attention to the internal sustainability norms given by the HQ. Hence, when subsidiary managers take decisions within daily operations, they may be tempted to pinch pennies to increase their subsidiary's profits, increase the output, win contracts, or simply adapt to idiosyncratic competitive circumstances – even if such choices conflict with the social brand of the MNE (e.g. Aguilera et al., 2007; Lyon and Montgomery, 2015). These findings are particularly valuable in the light of the two root causes of the agency problems in the relationships between the HQ and its subsidiaries, i.e. self-interest and bounded rationality (cf. Hendry, 2002; Jensen and Meckling, 1976). For example, subsidiaries may prioritise their own interests over those of the whole organization represented by corporate HQ managers (Mudambi and Navarra, 2004). They may overstate performance results to HQs, misrepresent the subsidiary's capabilities to access resources, or violate the corporate code of conduct for unit level benefits even if such actions are detrimental to the whole organisation (Kostova et al., 2017).

Concerning the mechanisms to overcome the implementation barriers, Kim and Mauborgne (1993) found that the typical mechanisms – incentive compensation, monitoring systems, and rewards and punishments – are not sufficient in MNEs but that other factors which they summarise under the term "due process" are even more crucial: (1) that the headquarter (HQ) is familiar with subsidiaries' local situations; (2) that two-way communication exists in the global strategy process; (3) that the HQ is relatively consistent in making decisions across subsidiary units; (4) that subsidiary units can legitimately challenge the HQ's strategic views and decisions; and (5) that subsidiary units receive an explanation for final strategic decisions.

In SSRM, the boundary of responsibility extends beyond the reach of a firms ownership and control to suppliers (Gimenez and Tachizawa, 2012). Although SSRM covers the three pillars of the TBL, apart from the traditional economic focus, the majority of the SSRM literature has focused on the environmental pillar (Bastas and Liyanage, 2018; Gimenez and Tachizawa, 2012). The literature features some obstacles to SSRM

adoption. For instance, Seuring and Müller (2008) find that SSRCM implementation can trigger significant resistance in organisations, stemming from additional cost implications, inherent complexity and interorganisational communication difficulties. Further complexity challenges have been associated with the multi-dimensional (economic, ecological, social) view which comes with multiple objectives and agendas and the potential risk of inter -and intra-organisational conflicts (de Brito and Van der Laan, 2010).

In their pursuit of SSRM implementation, many companies draw on mechanism such as control through supplier assessment tools, codes of conduct a.s.o. and/or collaboration with suppliers (Andersen and Skjoett-Larsen, 2009; Keating et al., 2008). On the control side, the implementation of ISO14001 environmental management system and use of certified suppliers were identified as influential factors for green SRM implementation (Agi and Nishant, 2017). In their literature review, Bastas and Liyanage (2018) find that several authors emphasise the importance of key performance indicators (KPIs) for supplier sustainability performance in the implementation of SSRM practices, but at the same time highlight the current absence of guidelines, metrics and standards for measurement, monitoring, reporting and improvement of supplier triple bottom line performance. De Brito (2016) state that measurable indicators would allow companies to evaluate the advancement and impact of their strategies, establish priorities, facilitate continuous improvement and thus, contribute to effectiveness of SSRM activities. Still, Gimenez and Tachizawa (2012) question the overreliance on control mechanism and highlight that supplier assessment may be the initial step to identify what actions are needed; yet, companies need to engage in collaborative practices with their suppliers to improve sustainability.

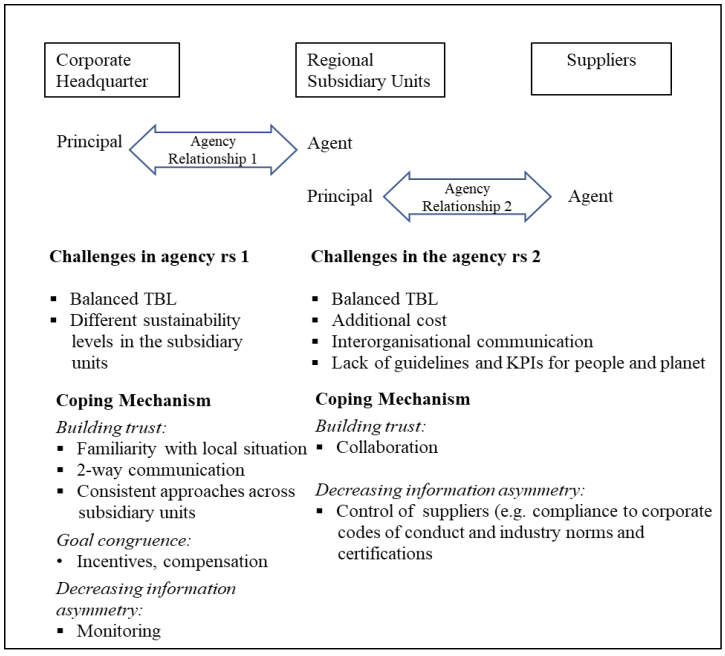

Figure 1: Literature-based conceptual framework

While these existing studies shed some light on SSRM implementation, there is no study which has explicitly investigated SSRM strategy implementation with the combined focus of people, planet, profit in a complex, interorganisational company

context. Our research aims to do this, taking an agency theory perspective (Alchian and Demsetz, 1972; Jensen and Meckling, 1976). We propose that sustainable supplier relationship strategy implementation takes place in two overlapping principal agency relationships. Based on our literature review, we propose the following challenges in the two agency relationships as well as mechanisms to overcome them. In line with the literature (Göbel, 2002), the coping mechanisms can be structured into three categories: building trust, ensuring goal congruence and lowering information asymmetry (see Figure 1).

Method

We conducted a case study (Ellram, 1996). Through purposeful sampling, an information rich case was selected (Patton, 2002). A single case is justified by the context specificity of a strategy implementation process and the demanding sampling requirements, i.e. a MNE with a corporate sustainable strategy in place and substantial preparedness for cooperation with access to data in multiple countries. The selected MNE is a provider of leading mobility solutions in the realm of escalators, moving walkways and elevators. It does business in more than 100 countries including production sites and research and development facilities in the US, Brazil, Europe, China, and India. We broke down our research objectives, i.e. to identify the challenges of a SSRM strategy implementation and to develop a managerial framework for implementing SSRM in complex, interorganisational company contexts, into the following empirical case research questions:

Agency relationship between HQ and regional subsidiary units:

1) Which challenges do HQ managers perceive in their relationships with the regional subsidiary unit managers concerning the countries' contribution to implementing the corporate sustainable supplier strategy and to meeting the sustainability targets?
2) Which measures does HQ apply in order to ensure that the corporate sustainable supplier strategy is implemented by the regional subsidiary unit managers?
3) Which challenges do the regional subsidiary unit managers perceive in their relationships with HQ concerning their role and responsibility to implement the corporate sustainable supplier strategy?

Agency relationship between regional subsidiary units and suppliers:

4) Which challenges do the regional subsidiary unit managers perceive in their relationships with suppliers concerning their role and responsibility to ensure that the suppliers meet the sustainability targets?
5) Which measures do the regional subsidiary unit managers apply in the supplier relationships?

We collected data from multiple sources of evidence: strategy documents, a focus group with five members of corporate purchasing and 11 semi-structured interviews, one with a corporate purchasing manager and 10 with regional sourcing managers. The interviews were selected based on a purposeful sampling approach designed to represent the following structural characteristics of the company's global purchasing organisation: 1) four functional responsibilities within the purchasing function, 2) HQ and four regions (Europe, North America, South America and Asia) and 3) two hierarchical levels (strategic and operational). Data analysis followed a template coding approach (King, 2012). The initial template consisted of: challenges for HQ and zone managers and mechanisms for overcoming agency problems derived from the literature (see figure 1 above). During the coding process, the initial template evolved further through the addition of a number of sub-codes.

Findings

Agency relationships between HQ and regional subsidiary units

Our data confirmed the challenges HQ managers perceive in their relationships with the regional subsidiary unit managers concerning the countries' contribution to implementing the corporate sustainable supplier strategy. Most importantly, the question of how to implement a balanced TBL approach is a key concern. The HQ managers agreed that it is easier to enforce "profit" than the remaining pillars of the TBL because more KPIs exist, which can more readily be measured. They also admitted that they struggle in determining which requirements can and should be set that can also be measured in line with the philosophy of "what cannot be measured cannot be managed". Subsidiary units supported this view by stating that the corporate guidelines, support tools and systems do not cover all aspects of the SSRM implementation. Specifically, hardly any guidelines existed on how to formulate ecological and social requirements in calls of bids for regionally selected suppliers. Interestingly, subsidiary managers expressed a clear desire for more information and education on ecological and social issues. The lack of ecological and social performance targets gives rise to the perception of a perceived lack of a sense of urgency for these pillars from the HQ as well as a perceived lack of incentive provision to implement these pillars regionally. This in turn, triggers uncertainty on behalf of the regional subsidiary units and, consequently, the risk of an overreliance on financial KPIs with the neglect of corporate ecological and social codes of conduct.

Furthermore, the inconsistent implementation of the corporate sustainability requirements across regions was another challenge confirmed by the case study data. HQ managers explained this through the geographical and contextual distance in conjunction with their own limited regional reach. They see that continuous learning across the regional subsidiaries and motivating the subsidiary managers to enter a constructive competition on sustainability performance would be helpful in balancing performance between the regions but struggle with their resource and capacity constraints. At the same time, the HQ managers stressed that equal performance was not feasible, given the differences in the regional markets. Hence, how to manage the trade-off between compulsory HQ requirements and regional context specificities was seen as a further challenge. In the interviews with the regional managers, differences in the mindset, understanding and level of implementation of sustainability were confirmed. The gap appeared to be dependent on the geographical distance between subsidiary unit and HQ as well as the differences between the regional and home market contexts (e.g. developing versus developed economy). While some regional managers seemed to have a lack of awareness and blamed poor communication, others emphasised the special characteristics of their regional supplier market context, which impedes the implementation of the SSRM strategy. For example, a regional sourcing manager pointed out that corporate guidelines to source locally with an emphasis on customised parts are relatively difficult to implement in the Brazilian market where suppliers are more specialised on mass production.

Further challenges raised in the case study interviews which have not been identified in the literature concern the challenge of prioritising between the high number of 45,000 suppliers and the related difficulties in balancing between two potential trade-offs. Firstly, between efficiency and risk and secondly, between volume and resilience. Pursuing efficiency targets is important from an economic sustainability perspective and, according to the HQ managers, a necessity when dealing with such a large number of suppliers. From this perspective, relationships with small suppliers for low value items can have massive saving potential if transparency was provided across the regions. Instead, high risk suppliers are crucial from a social or ecological sustainability perspective. Similarly,

an emphasis on volume suppliers is essential from an economic perspective but since even small supplier glitches can cause media outbreaks or operational disruptions, resilience is not only bound to high volume suppliers. Interestingly, one regional subsidiary manager pointed out that the priorities may or may not be applicable from a local perspective. For example, gaps may exist between corporate und local SRM since the spend and dependency on suppliers is lower. Hence, they have a risk-based assessment of how exact HQ guidelines for supplier qualification are adapted at the regional level.

The measures the HQ managers apply to ensure that the corporate sustainable supplier strategy is implemented across regions relate to all three mechanisms to overcome agency problems from the literature (cf. Göbel, 2002). With the aim to lower information asymmetry, the HQ currently has a project underway to improve transparency and planning. An IT-based supplier relationship system is being introduced providing visibility across the 45,000 suppliers to enforce global standards and focus attention on top 45 suppliers globally. Measures to build trust are e.g. listening to the subsidiary managers and working with external agencies (Ecovadis) for compliance monitoring. This also reinforces credibility of the compliance reports. Finally, an exemplary measure to safeguard goal congruence concerns the HQ approach to KPI definition. Corporate HQ managers first carefully evaluate which KPIs are used how by subsidiary units. From this assessment, KPIs which cannot be consistently measured across regions due to context specificities are excluded and only globally applicable performance indicators remain.

Agency relationships between regional subsidiary units and suppliers

In their role as principals, regional subsidiary unit managers reported the challenges they have when ensuring that the suppliers meet the corporate sustainability standards. Most of the challenges identified from the literature were also reported in the interviews. For example, financial and other resource constraints were frequently stressed by the regional subsidiary units. They feel that they do not have enough resources and capacity to implement corporate guidelines concerning the SSRM strategy in their supplier relationships. For instance, a manager pointed out that her subsidiary is not able to spend enough time with suppliers at their premises to really get them to improve their processes in a more ecological friendly manner. Likewise, resource constraints render it difficult to anticipate supplier deviation from defined standards and KPIs. According to the subsidiary managers, these issues are even more pronounced in relationships with smaller, local suppliers. Here, the supplier's own resource constraints make operational buyer-solicited adaptations almost impossible. Since economic sustainability is operationalized through financial KPIs that are easier to control, well known and established, regional managers emphasised that the ecological and social dimensions of the sustainability strategy suffer. This in turn, highlights the challenge of maintaining a balanced triple bottom line approach in the supplier relationships. Concerning the challenges related to interorganisational communication and inter- as well as intraorganisational conflicts, subsidiary managers referred to the many different contact points. Supplier relationships are managed through a complex network involving contacts between different regional and in some cases also corporate managers and the supplier organisations. Suppliers may use the complex and often inconsistent communication to their advantage. A challenge that was not identified in the literature was an imbalance of guidelines not only across the TBL dimensions but also across the supplier relationship phases. One subsidiary unit manager pointed out that while there are good measures in the early stages of new supplier qualification and selection, once they are in operation, he struggles to detect if the supplier requires additional support in the

development stages or, alternatively, if phasing out a supplier may become a sustainability risk.

The regional subsidiary unit managers also apply a number of measures in the supplier relationships that can be categorised into the three mechanisms to overcome agency problems (cf. Göbel, 2002). To lower information asymmetry, various measures are in place: Firstly, the subsidiaries have a very structured process of selecting new suppliers. The subsidiaries conduct a series of audits regarding supplier compliance with selected aspects of the three dimensions of the TBL. Secondly, subsidiaries engage in continuous monitoring of supplier compliance to their specifications by tracking supplier performance with KPIs. Thirdly, the subsidiaries maintain ongoing communication with suppliers including e.g. order forecast update and supply performance feedback. To ensure goal congruence, subsidiaries use a variety of incentives for supplier. For instance, led by the purchasing or specialist division, they provide active support to smaller suppliers to develop their business. This may be in the form of training, education or support to achieve conformity to new legal requirements. Also, financial incentives are provided, e.g. for supplier endeavours to acquire certain certificates. To build trust and ensure goal congruence, senior subsidiary management meets suppliers on a regular basis. For example, a supplier conference is held on a bi-annual to annual basis where suppliers are informed on the MNE's long-term strategy and how suppliers are expected to contribute to its implementation. Suppliers also have the opportunity to raise questions and discuss pressing issues. Another measure to ensure goal congruence is supplier industrialisation. As part of this process, the subsidiary's supplier development industrialisation teams support the supplier in improving their systems, processes and products to comply with the corporation's standards. Moreover, the team exposes suppliers to new competitive opportunities in this respect which may ultimately also result in a business advantage for the subsidiary due to e.g. cost saving. If necessary, subsidiary management also involves third parties to make the supplier "fit" to stay in business with them which supports trust building.

Contribution and Implications

Overall, our contribution to the literature is the integrated approach we take by investigating sustainable strategy implementation within MNEs and across their supplier networks. By combining both topics through our conceptualisation of two overlapping agency relationships, we identify challenges and mechanisms to overcome potential agency problems in both relationships. This in turn, is the basis for our proposed framework for SSRM strategy development and implementation (see figure 2). The core of the strategy is a balanced TPL sustainability improvement approach. The case study has highlighted the particular challenges of an equal representation of the three dimensions. Future research should support MNEs through further insights into social and ecological KPIs as well as supportive organisational processes and structures. The external layer of our framework reflects the fact that SSRM strategies are relationship strategies. Furthermore, due to the potential agency problems both within and across the company boundaries, specific attention must be devoted to the crucial role that regional subsidiary units play. Further research should address the potential conflicts between their role as agents and principals in greater depth and provide insights into how the agency problems can be overcome. The mid circle of our framework represents a cyclical five-phase process which can be applied in both relationships: those between HQ and subsidiary units and between subsidiary units and their suppliers. Transparency is a key element to foster standard practices and, at the same time, minimise information asymmetry. Our case study suggests that IT plays a growing role in ensuring transparency

about sustainability practices in MNEs which has yet to be researched. In addition, transparency enables a bottom-up-top-down process of setting the sustainability requirements. Next, compliance with the requirements across suppliers and regions is monitored. This in turn represents the baseline from which sustainability improvement targets and appropriate KPIs can be derived. The fact that performance targets are followed by trust stresses one again relationship character of the strategy. Trust is the linking pin between both, taking actions to improve the sustainability performance and the willingness to share this information within and across the organisation.

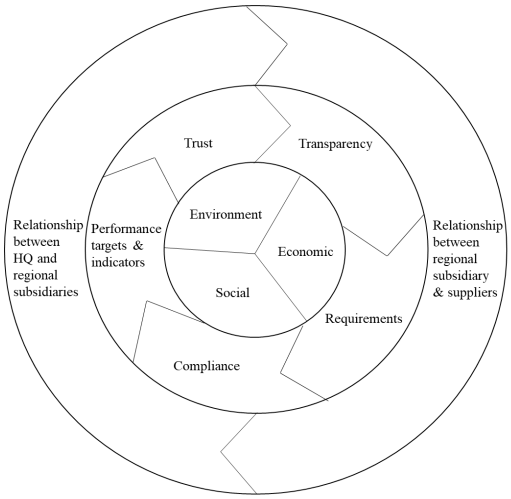

Figure 2: Framework of SSRM strategy development and implementation

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Towards an integrated research agenda for quantitative and qualitative SSCM research: Insights from a Delphi study

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Abstract

Various qualitative and quantitative research approaches are driving research on sustainable supply chain management (SSCM). The ongoing Delphi study attempts to map the theories, methods, and fields of application in SSCM research in order to outline possible integration avenues needed to advance SSCM research on environmental and social aspects in developing, emerging, and industrialized economies. The findings of the second survey round indicate that the circular economy and industrial symbioses as well as reverse and closed-loop supply chains are deemed most relevant for future SSCM research on multi-tier supply chains, particularly in emerging and industrialized economies, to support environmental sustainability.

Keywords: Sustainable supply chain management research, Theories, Methods, Delphi study

Introduction

Research approaches to sustainable supply chain management (SSCM) avail of conceptual frameworks and formal models from Operations Management (OM) and Operations Research (OR) to extend the scope of analysis toward environmental and social aspects relevant for managing operations and supply chains (SCs). However, qualitative and quantitative research streams in SSCM still appear disconnected with regard to a common literature background, which is indicated by low citation numbers between conceptual, empirical, and formal modeling publications that consider

stakeholders and risks in SSCM (Rebs et al., 2018). This observation of rare interactions points to the potential of benefits gained from integrating qualitative and quantitative research approaches for SSCM.

Different research approaches in SSCM have been reviewed thoroughly by recent publications (Reefke and Sundaram, 2017; Rajeev et al., 2017). However, an overarching investigation into the use of different theories, methods, and application contexts in SSCM research is not available, but strongly needed to unveil potentials of considering both qualitative and quantitative approaches.

The Delphi study, as a survey research design, enables a structured debate on the issue by engaging the researchers in the field (Linstone and Turoff, 1975), i.e., the very nucleus of the current split of approaches. This is a crucial step towards the identification of synergies between different research approaches as well as enhanced cooperation opportunities that eventually lead to an overall higher impact of SSCM research. To this end, we pose the following research questions (RQs) to be answered by this survey study:

RQ1: What are the theories, methods, and application contexts that are deemed highly relevant for future SSCM-related research?

RQ2: How is the current maturity and future potential of the use of economic, environmental, and social dimensions of sustainability as well as for different multi-tier SC levels of analysis in SSCM perceived by the SSCM experts?

RQ3: How could qualitative and quantitative approaches be linked to reap the benefits from integrating and extending theories, methods, and application contexts for future SSCM-related research?

Literature background

Delphi studies have proven to be appropriate to capture the scope of complex problems or the structure of emerging research fields like SSCM (see, e.g., Seuring and Müller, 2008a). Reefke and Sundaram (2017) enquired into the key themes for SSCM research using the SC planning matrix as a conceptual basis. While the past use of theories, methods, and applications can be discerned by systematic literature reviews, which typically suffer from the time lag produced by peer-review and publication procedures of up to or even more than one year. The current use and future potential of theories, methods, and applications or other items of interest can only be identified at a current given point in time by a survey research approach so that no considerable gap exists between the research endeavors and their publication.

A range of theories and formal models has been applied in SSCM research. Sarkis et al. (2011) reflect the role of organizational theories in green supply chain management (GSCM) research and identify promising theories for future GSCM research. Touboulic and Walker (2015) provide a systematic literature review to examine the theoretical lenses used in SSCM and find that efforts to build theory in SSCM still remain limited to a few mostly imported theories. Apart from qualitative- and quantitative-empirical research designs, e.g., case studies or surveys, the use of quantitative-theoretical formal models in SSCM-related research articles was reviewed (see, e.g., Brandenburg et al., 2014). In effect, it was evident that the field of SSCM is divided in two streams which can be divided based on their prevailing ontological, i.e., constructivist and objectivist stances, which reflect the use of different qualitative and quantitative research methods in SSCM (see, e.g., Rebs et al., 2018). While the constructivist stance that lends itself to the social sciences is hard to assign to a particular group of SSCM researchers, the objectivist stance with its tendency towards the assumptions and methods from the natural sciences can be assigned to the OR community (see Bryman and Bell, 2011, for the ontology). Despite

this ontological and methodological split, the research foci of both streams overlap and might thus benefit from an integrated evaluation.

Central to the discourse on sustainable management is the role of the economic, environmental, and social dimensions of sustainability, i.e., the so-called triple bottom line (TBL) of sustainability (Elkington, 1998; Carter and Rogers, 2008). Their interplay is of constant interest, particularly with regard to their operationalization by formal models. Finally, multi-tier supply chain management (multi-tier SCM) appears to receive increasing attention for managing sub-suppliers and enhanced SC transparency (e.g., Mena et al., 2013; Grimm et al., 2014; Sauer and Seuring, 2018a,b).

When reflecting qualitative and quantitative approaches in SSCM with regard to a generic "normal research cycle" (Meredith et al., 1993: 4), theoretical frameworks and formal models are involved in an iterative process of describing and explaining certain phenomena to build theory, which is subsequently tested, e.g., by quantitative models. In this context, Rebs et al. (2018), recommend to strengthen the nexus between conceptual, empirical, and formal modeling research for SSCM in order to close the cycle and drive SSCM research further.

Methodology

The study at hand represents a Delphi study, i.e., "a structured group communication […] to deal with a complex problem" (Linstone and Turoff, 1975, p. 3). The method is particularly suitable for exploratory theory building on under-researched, complex, and interdisciplinary topics (Akkermans et al., 2003) such as the outlined interaction between qualitative and quantitative research streams in SSCM. Adopting methodological suggestions by Linstone and Turoff (1975) as well as Okoli and Pawlowski (2004), individual panels are built to gather the opinion and expertise of authors of research articles in SSCM.

Delphi studies feature a high construct validity as the participants comment on their previous answers (Okoli and Pawlowski, 2004). Reliability is ensured by rigorous study design and documentation as well as pre-testing the single questionnaires (Okoli and Pawlowski, 2004). These drivers of validity and reliability are part of our study design and conduction to ensure high quality results.

Adopting a typical three-round structure, the Delphi study encompasses:

- Round 1 (finished; 104 answers): Open questions to comprehensively identify theories, methods, and application contexts as well as the most relevant academic discussions for quantitative and qualitative researchers in SSCM.
- Round 2 (ongoing; 96 answers): Closed questions on (a) which of the academic discussions are perceived as relevant in the single panels and (b) the potential of the selected discussions to induce theoretical advancements of SSCM regarding the (b1) TBL dimensions, (b2) SC levels of analysis, and (b3) industrial, emerging, and developing countries.
- Round 3 (in preparation): Investigation of the differences and integration potentials among the panels. To craft the integrated research agenda, we will also investigate which theoretical and methodological approaches the single panels see in relation to the highly relevant discussions in SSCM research for achieving theoretical advancements.

The addressees of the study were systematically identified according to the selection criteria defined in the following. Authors of research articles in SSCM had to be listed as a first author in the paper samples of at least 2 of 22 analyzed literature review papers on SSCM published between 2008 and 2017. The consideration of only the first author of a

sample papers ensures that the identified person is familiar with the topic. Moreover, in this way, both researchers and practitioners, who once published a research article but are now inactive researchers, are considered as source of expert knowledge with regard to their opinion on and perception of the current use and future potential of theories, methods, and application contexts in SSCM research. Finally, further experts that were recommended by the identified experts could be included. This is a valid approach to populate the panel (Okoli and Pawlowski, 2004), as deeming that the answers given by the initially identified experts are valid, then it is valid to trust their recommendations for further experts. Based on feedback we received on previous conferences, we decided to extend the initial list of identified experts by including further recognized SSCM researchers, particularly young scholars and PhD candidates that currently conduct SSCM-related research, as addressees in the second round.

Results

In this section, we present general information about the panel, briefly summarize the findings from the first round and, subsequently, we concentrate on analyzing the interim results from the ongoing second round.

Information about participants

In total, 104 participants completed the first round questionnaire. The second round, which includes a new young scholar panel as well as all panelists from round 1 regardless of their participation in round 1, yields 96 responses and is still ongoing, hence, additional responses may be expected. Table 1 gives an overview about the characteristics of the respondents of the first and the ongoing second round. It includes the number of years in academia (including PhD years), years in industry/praxis, the last year being involved in SSCM-related research, the familiarity with SSCM, and the institutional sector of current occupation. The descriptive information about the participants helps to consider the respondents' expertise, which can be estimated based on the responses on, e.g., the degree of familiarity with SSCM-related topics in research and practice. The results are displayed in quartiles to show the structure of the data and reveal focal points within the single characteristics.

The results in Table 1 show that the median of years in academia (round 1: 15 years | round 2: 13.5 years) and praxis (round 1: 2.5 years | round 2: 2.0 years) are highly different and that 75% of the respondents have spent 5 years or less in industry. This is clearly a limitation of the study, which is, however, natural to the choice of experts via research publications. Moreover, the vast majority of respondents (round 1: 77% | round 2: 78%) is currently conducting SSCM research and the familiarity with SSCM (rated on 10 point Likert scale; 0=”completely new to me”; 10=”my area of expertise”) is very high with a median of 8 (round 1) and 8.5 (round 2) and the final quartile exclusively covering respondents with maximum familiarity. These results underline the expertise covered by the expert panel which drives the validity of the study results (Häder, 2014). These figures furthermore validate the expert selection process.

Table 1 – Characteristics of respondents (round 1: n=104 | round 2: n=96)

Quartiles	**25% limit**	**50% limit**	**75% limit**
Years in **academia** (incl. PhD years)	10 | 9	15 | 13.5	22 | 20
Years in **industry/praxis**	1 | 0	2.5 | 2.0	5 | 5
Last year involved in SSCM research	2018	2018	2018
Familiarity with SSCM	7 | 7	8 | 8.5	10 | 10 – "my area of expertise"
Institutional sector of current occupation (multiple choice possible)	Academia: 100x | 94x Industry: 7x | 9x NGO: 1x | 1x GO: 1x | 2x Other: 1x | 1x		

Insights from the first survey round

The first survey round yields the sets of theories and methods currently used by SSCM researchers in different application contexts. These items will be used in the third round to investigate possible research approaches to induce theoretical advancements of SSCM research regarding the identified highly relevant discussion.

The experts were furthermore asked to name academic discussions perceived as highly relevant for future SSCM research. In the analysis of round 1, these discussions have been coded inductively based on the responses. As a result, 19 highly relevant discussions were identified (see Table 2).

Table 2 – Current academic discussions perceived highly relevant for future SSCM research

(1) Circular economy, industrial symbiosis	(11) Sustainability of fast moving consumer goods
(2) Reverse and closed-loop SCM	(12) Local sourcing, reshoring
(3) Waste management	(13) Humanitarian logistics
(4) Industry 4.0, automation	(14) 3D-Printing
(5) Blockchain, distributed ledger technology	(15) Public procurement
(6) Stakeholder integration	(16) Traceability
(7) Risk management	(17) Big data analytics
(8) Urban logistics	(18) Base of the pyramid
(9) E-commerce	(19) Modern slavery, human rights
(10) Sharing economy	

From a methodological point of view, the use of formal models and, moreover, the overall practical impact of SSCM research are mentioned as key themes. However, they are not listed as highly relevant academic discussions, since both methods and research contexts will be analyzed with regard to the listed discussions.

Based on the first round results and regarding the maturity and relevance of TBL dimensions and SC levels of analyses, the experts see a clear need for driving the social dimension and extending the scope of researched SC complexity. Both the most relevant academic discussion as well as the results regarding maturity and relevance of TBL dimensions and SC levels of analyses build the basis on the second survey round.

Insights from the second survey round

In the second round, the addressees are asked to (a) select up to 7 of the discussions displayed in Table 2 and, subsequently, evaluate the potential of the selected discussions for inducing theoretical advancements of SSCM research on (b1) environmental and social sustainability, (b2) intra-organizational, dyadic, and multi-tier SCs, and (b3) developing, emerging, and industrialized economies.

Moreover, the experts were provided a list of 13 methods in business research adapted from Bryman and Bell (2011), from which they were asked to select the methods they have used in the last five years of their research. The methods can be assigned to either constructivist or objectivist ontological stances (see, e.g., Bryman and Bell, 2011) that underlie either OM- or OR- based SSCM research. Grounded on this, the respondents could be grouped into "constructivist" (n=48), "objectivist" (n=16) or "intersection" (n=31, meaning no clear tendency in the use of methods) research approaches. According to Okoli and Pawlowski (2004), the size of the ("objectivist") (sub-)panel lying between 10 to 18 experts, is appropriate to reach a group consensus. Still, we are trying to better balance out the groups by sending further reminders to the researchers that have published on the objectivist side of SSCM.

Subsequently, the tendency of respondents from these three groups to select a certain discussion is analyzed by calculating the mean values that indicate if a discussion was selected ("2") or not ("1"). This is presented in Table 3, which also indicates the absolute frequencies of the top ten selected discussions.

Table 3 – Cross tabulation of the top ten academic discussions and their selection by the ontologically distinguished SSCM researcher groups

	Circular econ., industrial	Reverse and closed-loop SCM	Waste management	Blockchain, distrib. ledger technology	Sharing economy	Urban logistics	Big data analytics	Modern slavery, human rights	Industry 4.0, automation	Risk management
Freq.	48	41	29	28	30	20	28	29	28	26
Inters.	1.645	1.613	1.484	1.323	1.484	1.355	1.516	1.290	1.484	1.323
Constr.	1.667	1.479	1.333	1.354	1.375	1.167	1.313	1.521	1.458	1.333
Object.	1.563	1.625	1.313	1.188	1.375	1.500	1.563	1.125	1.250	1.250
Total	1.627	1.547	1.373	1.360	1.400	1.267	1.373	1.373	1.373	1.347

From Table 3, we can infer that both constructivist and objectivist researchers deem the circular economy/industrial symbiosis as well as reverse and closed-loop SCM as highly relevant fields of future SSCM research. Constructivist researchers also view modern slavery/human rights, industry 4.0/automation, and risk management as pressing topics. In contrast, objectivist researchers see the sharing economy, urban logistics, and big data analytics as highly relevant.

Table 4 shows the top ten discussions and indicates the mean values of the evaluated potential to induce theoretical advancements (rated on 5 point Likert scale; 0="very low"; 5="very high"; alternative answer option "no potential") for (b1) environmental and social sustainability, (b2) intra-organizational, dyadic, and multi-tier SCs, and (b3) developing, emerging, and industrialized economies.

Table 4 – Potentials of academic discussions to advance SSCM research on (b1) the TBL of sustainability, (b2) SCs levels of analysis, and (b3) different types of economies

Discussion	Circular economy, industr. symbiosis	Reverse and closed-loop SCM	Waste management	Blockchain, distrib. ledger technology	Sharing economy	Urban logistics	Big data analytics	Modern slavery, human rights	Industry 4.0, automation	Risk management
(b1) TBL: environmental	4.5484	4.6923	4.7143	4.5000	4.3846	4.5769	4.0500	2.5556	4.1750	4,4000
(b1) TBL: social	3.8065	3.7308	3.6286	4.3103	4.3158	4.0800	3.7692	4.9189	4.1250	4.3448
(b2) SC level: intra-org.	3.6393	3.8039	3.9706	4.0333	3.4054	3.8846	4.3750	3.6486	4.2564	4.1034
(b2) SC level: dyadic	3.2727	3.5957	3.7941	3.9310	3.6389	3.4800	4.1842	4.1111	3.6579	4.2069
(b2) SC level: multi-tier	4.6557	4.5385	4.1429	4.4333	4.0789	3.8462	4.4500	4.7568	4.2750	4.5333
(b3) Econ.: Developing	3.3710	3.6000	4.4286	3.8333	3.8205	3.5385	3.5789	4.7027	3.3750	4.0345
(b3) Econ.: Emerging	4.0820	4.1961	4.4571	4.0333	4.1538	4.0000	3.9487	4.5946	3.7750	4.0690
(b3) Econ.: Industrial	4.2295	4.2692	4.1111	4.2581	4.4872	4.4231	4.6250	3.7429	4.3333	4.2333

Table 5 – Summary of findings

Discussions	**(a) Prevalent approach to SSCM**	**(b1) Prevalent TBL dimension**	**(b2) Prevalent SC level of analysis**	**(b3) Prevalent economy type**
Circular economy, industrial symbiosis	all 3 groups	Environmental	Multi-tier	Emerging & industrial
Reverse and closed-loop SCM	all 3 groups	Environmental	Multi-tier	Emerging & industrial
Waste management	Intersection	Environmental	Multi-tier	All
Blockchain, distrib. ledger technology	Intersection and constructivist	TBL	Intra-org. & multi-tier	Emerging & industrial
Sharing economy	Intersection	TBL	Multi-tier	Emerging & industrial
Urban logistics	Objectivist	TBL	None	Emerging & industrial
Big data analytics	Intersection and objectivist	Environmental	All	Industrial
Modern slavery, human rights	Constructivist	Social	Dyadic & multi-tier	Developing & emerging
Industry 4.0, automation	Intersection and constructivist	TBL	Intra-org. & multi-tier	Industrial
Risk management	all 3 groups	TBL	All	All

The figures in Table 4 suggests that the circular economy/industrial symbiosis, reverse and closed-loop SCM, waste management, and urban logistics are most relevant to advance environmental sustainability, while modern slavery/human rights are subject to social sustainability, which is supposed to be tackled by considering multi-tier SCs in developing and emerging countries. Generally, multi-tier SCs feature the highest potential

when being subject to SSCM research regarding the top ten discussions. Table 5 summarizes these findings and Table 6 shows a cross-tabulation of the panel foci regarding the prevalent (b1) TBL dimension, (b2) SC level of analysis, and (b3) economy type.

Table 6 – Cross-tabulation of panel foci

	Panels		
Foci	**Constructivist**	**Intersection**	**Objectivist**
(b1) TBL dimension	TBL	Environmental	
Environmental	5	8	5
Social	4	4	2
(b2) SC level of analysis	Multi-tier		
Intra-organizational	3	4	2
Dyadic	2	2	2
Multi-tier	6	8	4
(b3) Economy type	Industrial & Emerging		
Developing	2	2	1
Emerging	5	6	4
Industrial	5	8	5

Next steps: Preparation of the third survey round

The second round gives an indication of the highly relevant academic discussions, which are evaluated by the respondents regarding their relevance for inducing theoretical advancements regarding the TBL of sustainability, the SC levels of analysis, and the type of economies that need to be considered. Further statistical analyses are planned to make sense of the collected data. Potential statistical tests include, but are not limited to:

- Contingency analysis among the selected academic discussions and regarding the control variables, i.e., the respondent characteristics;
- Kruskal-Wallis-Test to compare the responses among the three different research clusters, i.e., constructivist, objectivist, and both (intersection) research approaches.

The third round is supposed to unveil which theories and methods are deemed useful to conduct research on the highly relevant discussions for future SSCM so that theoretical advancements as well as a high practical impact of SSCM research can be realized.

Conclusion

The paper at hand presents the findings of the first round and the interim results of the second round of a Delphi study on theories, methods, and applications contexts in SSCM research. The findings build the basis for the systematic evaluation of the dominant and underrepresented theories, methods, and application contexts in qualitative and quantitative SSCM research.

From the second survey round, we find that issues relating to a circular economy perspective and approaches to industrial symbioses as well as with regard to reverse and closed-loop SCM are evaluated as most relevance to future SSCM research by focusing environmental sustainability and researching multi-tier SCs.

In the end, the completed Delphi study is supposed to provide a basis to derive guidelines for future SSCM research and a more coherent body of research, ultimately aiming at contributions relevant to academia and praxis. Recent studies particularly called for linking conceptual, empirical, and formal modeling research methods, and, furthermore, to elaborate ways to operationalize the TBL dimensions of sustainability, stakeholder influences, and risks in SSCM (see, e.g., Reefke and Sundaram, 2017; Rebs et al., 2018). Moreover, empirical studies based on or supported by quantitative models

with regard to the industry specifics of sustainable SCs should be envisaged to give managerial recommendations for different industrial sectors (Rebs et al., 2018).

Research approaches in the relatively young field of SSCM need to be continuously revised and refined to capture the complexities and system dynamics between economic, environmental, and social aspects in SCs (see, e.g., Rebs et al., 2019). The integrative consideration of qualitative and quantitative methods will strengthen the validity and impact of SSCM research in both academia and praxis. This study enables a structured debate by engaging the researchers in the field, i.e., the very nucleus of the current split of approaches.

At the same time, focusing on academic researchers represents one of the major limitations of the study. While the expert panels show high ratings on familiarity with SSCM, current engagement in SSCM research as well as on average 14 years of experience in academia, there is a lack of industry experience in the panel. The research activities of the respondents ensure some contact to practitioners, however, this limits the results of the study to academic issues. Moreover, 54 respondents of the first round (n = 104) also participated in the second round, while 42 new experts only stepped in the survey with the second round. Contrasting the open questions in round 1, round 2 is based on a standardized questionnaire for all participants (as suggested by Okoli and Pawlowski, 2004). Thus, all items and necessary control variables (personal background and use of methods) are answered by all respondents so that further analysis regarding the question of which theories and methods are useful to tackle the highly relevant discussions are enabled. Still, these academic issues are at the heart of this research.

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Driving corporate internal green supply chain collaboration through social exchange theory: A case study approach

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Abstract

With the awareness of "Green" aspect, companies around the world have been focusing on green supply chain as a key factor in achieving competitiveness and stakeholder satisfaction. In this current research, an internal collaboration was studied by adopting social exchange theory (SET). Qualitative information was obtained through in-depth interviews. The data shows that employees with high protection motivation theory (PMT) and environmental specific transformational leadership (ESTL) tend to have green behaviors. Moreover, the organization's internal social marketing (ISM) acts as a moderator of the relationship between ESTL and EGB. Finally, ESTL and EGB relate to Internal Green supply chain collaboration.

Keywords: Internal green supply chain collaboration, Employee green behaviour, Environmentally specific transformational leadership

Introduction

The Altruism theory (Comte, 1973) states that altruism is where people generate behavior which appears self-interested is a second, therefore; these people are living for others as the first priority. Rand (1968) initially states that prioritizing what is good for oneself after what is good for others is called 'altruism". The previous literatures mainly highlight the green behavior as a result of altruism. According to Stern et al. (1993), based on Schwartz's norm-activation theory, they investigated the role of social-altruism and egoism on green behaviour to see whether socialaltruism is the only driver that affects environmentally friendly market behaviour. They also pointed out that it might not socialaltruism alone as it might be disturbed by egoism in dealing with extra costs of behaving green. Moreover, the study of altruism and theory of planned behavior (TPB) on the hotel guest intention of supporting a green hotel where the results show that all factors namely altruism , subjective norms, and perceived behavioral control have positive impact on hotel guest intention on visiting green hotel.

Social exchange theory (SET) by Emerson (1976), on the other hand, points out that the people who are involved in the interaction are rationally seeking to maximize their profits. Cropanzano and Mitchell (2005) stated that the reciprocal rules in social exchange theory specify that, in bilateral relationship, the favorable action of one person would be resulted in a return of a kind action by the other person. From the studies of Lee and Choi (2003), it shows that, within organization, the way to successfully promote a knowledge sharing culture is not only by having it in the business strategy, however; the employee attitudes and behaviors must be changed to embrace the willingness and consistency of knowledge sharing. The past literatures indicate that an exchange relationship can happen in many forms, for example, in economic resources which involve money; goods; or services, in socio-emotional resources which involve trust, or social-status. Blau (1964) stressed that Exchange behavior is the highlight of a benefit a person can get from engaging in social exchange, for example, a person who share knowledge can expect any kind of help in return from the other as to ensure the supporting of knowledge sharing process that happening (Kollock, 1999). Therefore, it can be seen that there is no pure altruism and everyone is doing something for some returns or expecting some returns in the future.

Moreover, Andersson, Jackson, & Russell, 2013 suggest that to be able to succeed in environmental sustainability, an organization must have individuals with high level of Employee Green Behavior (EGB). Individuals with high pro-social traits are likely more intrinsically motivated to engage in helping behavior whereas individuals with low pro-social traits are likely more extrinsically motivated to engage in helping behavior, which in this research collaboration will be treated as a helping behavior.

Transactional and transformational leaders have been defines as a new paradigm of leadership and gained attention since its introduction. Leadership was categorized into two types; transactional and transformational according to philosophy of the leaders. Bass et al. (2003) defined transactional leaders are those who lead through social exchange whereas transformational leaders are those who stimulate and inspire followers to both achieve extraordinary outcomes and help followers grow and develop individual capability. Polonsky and Rosenberger (2001) point out that all individuals within the organization must not only concern about the commercial aspect but also to be aware of their behavior that can affect environment. In order to change the whole organization to become green, managers play an important role (Chamorro and Bañegil, 2006).

Therefore; in this current study, protection motivation theory (PMT) model has been used for evaluating the degree of motivation under SET and its impact on green behavior (employee green behavior: EGB) and thus; corporate internal green supply chain collaboration. Besides, it also studies the moderating effect of Internal Social Marketing (ISM) on the relationship between ETSL and EGB.

Research Question

RQ: How does protection motivation theory (PMT); threats and copping appraisals, and environmentally specific transformational leadership (ESTL) affect corporate internal green supply chain collaboration through employee green behavior (EGB)?

Contribution

In terms of theoretical contribution, since 2000, the amount of research within the area of GSCM has significantly increased; however, there has been limited progress in the area of GSCC. Moreover, a majority of the studies were conducted mainly under a customer-supplier context or external collaboration, internal collaboration has still been

overlooked. Therefore, the current study provides a clear understanding of green supply chain collaboration within the organization. In addition, this research challenges the theory of altruism by applying the social exchange theory (SET) to investigate the green behaviour of employees. Thus, a new perspective of explaining green behaviour and internal supply chain collaboration is presented.

The managerial contribution of this research has 2 parts. Firstly, this research signals to organisations to pay more attention to corporate internal collaboration by concentrating on employee green behavior (EGB) and how to motivate them through protection motivation theory (PMT), environmentally specific transformational leadership (ESTL), and internal social marketing (ISM) in order to achieve green supply chain collaboration within an organization.

Secondly, this research testing the impact of internal social marketing (ISM) on the relationship between environmentally specific transformational leadership (ESTL) and employee green behavior (EGB), therefore, organization will be able to know how to apply marketing tools for internal marketing. All of these will lead to the higher internal collaboration and thus higher performance as an ultimate goal of an organization.

Methodology

This research adopts a case study using qualitative data. Data was gathering from semi-structured interviews to analyse corporate internal green supply chain collaboration. Although, sampling strategies for qualitative research can be random, convenience, or purposeful samples of participants. In this current research, purposeful sampling which is quite a unique qualitative research has been adopted since the study is interested in the specific case/participant characteristics. Three manufacturing companies in Thailand were selected based on the following main criteria;

1. **Types of industries**: The main industries of Thailand that have been contributed to the GDP and involved in both green and supply chain management were chosen namely; Automotive industry, Food industry and Energy industry.

2. **The readiness of Green management:** In this study we adopted ISO 14001 (the International Organization for Standardization) as a measurement for readiness. Because ISO (2019) states that *"The purpose of this International Standard is to provide organizations with a framework to protect the environment and respond to changing environmental conditions in balance with socio-economic needs. It specifies requirements that enable an organization to achieve the intended outcomes it sets for its environmental management system".* Therefore; by having ISO 14001 in place, it represents a readiness of a company to embrace green management.

3. **Organizational culture**: Culture can support organizations in adopting a particular strategy if there is a strong relationship between culture and that strategy. In contrast, culture may act as a barrier which can defer an implementation of a strategy (Fernandez et al., 2003). In this study, organizational culture defines upon the nationality of the mother company. Therefore; *Thai and Multi Cultures* can be defined

Three companies were selected in order to see the differences in the nature of corporate internal green supply chain collaboration within each case. Mainly, they were selected based on types of industries which can be seen in table 1.

Table 1 – Cases based on selection criteria

Industry	Readiness	Culture	Size
Food	ISO 14001 (Implemented)	Thai	230
Automotive	ISO 14001 (Fully implemented)	Multi (Thai - French)	400
Energy	ISO 14001 (Planned for)	Thai	30

Organizations are made of several layers that interacting one another. Layers can be divided into divisions, departments, teams, and individuals, where there is always some degree of interdependence that leads to bottom-up and top-down influence mechanisms. As suggested by Kozlowski and Klein (2000), in top-down effect, teams and organizations are contexts for the development of individual cognitions, attitudes, and behaviors. On the other hand, McGrath et al. (2000) mentioned that, in bottom-up effect, individual cognitions, attitudes, and behaviors can also influence the functioning and outcomes of teams and.

Since this current study will be conducted within the organization context, there are many factors from different levels involved. Qualitative information was obtained through interviews with key individuals involved in corporate internal Green Supply chain collaboration at two levels: the management level and the operational level. Altogether; there were 4 management-level informants and 7 operational-level informants (table 2).

Table 2 – Number of informants by Levels

Company name	Management Level	Operational Level
Food industry	1	2
Automotive industry	2	2
Energy industry	1	3

As mentioned earlier that the informants have been divided into two levels; individual and organization upon the nature of organizational structure (Hitt et al., 2007). The questions for collecting all constructs applied in the interview therefore; align with the conceptual framework. protection motivation theory (PMT), and employee green behavior (EGB) will be applied in the question for individual level and reported by employee whereas internal social marketing (ISM), environmentally specific transformational leadership (ESTL), corporate internal green supply chain collaboration will be applied in the question for organization level and reported by management as shows in table 3.

The in-depth interviews were done with four management level informants and seven employee level informants (operational) to explore the questions according to the construct in table 3. The interviews were recorded and later transcribed for a content analysis. The script of the questions for the in-depth interviews was explained and discussed based on theory (Conto et al., 2016).

The process of analysing the interview transcripts began with condensing all the raw data into code, then provide score for each informant, after that the overall score for each construct will be determined to indicate the level; high, medium, low.

The data obtained in this research were discussed and validated to ensure inter-code reliability (Kurasaki, 2000). In addition, experts reviewed and discussed all processes before proposing the final results.

Table 3 - Constructs, Multilevel group, and Level of informants

Constructs	Level	Adopted from
Protection Motivation Theory (PMT)	Individual	• Bockarjova, M., and Steg, L. (2014)
Employee Green Behavior (EGB)	Individual	• Norton, T. A., Zacher, H., Parker, S. L., and Ashkanasy, N. M. (2017).
Internal Social Marketing (ISM)	Organization	• Uusi-Rauva, C., and Nurkka, J. (2010). • Smith, A. M., and O'Sullivan, T. (2012)
Environmentally Specific Transformational Leadership (ESTL)	Organization	• Carless, S. A., Wearing, A. J., and Mann, L. (2000). • Kura, K. M. (2016).
Internal Green Supply Chain Collaboration	Organization	• Sheu, J. B. (2014) • Sakun, B. and Chee, W. (2018)

Results and analysis

Protection motivation theory (PMT) and employee green behavior (EGB)

PMT consists of "threat appraisal" and "coping appraisal" which determine the level of people engaging in risk protective behaviour. The basic idea of PMT is that people engage in adaptive actions when confronted with risks through two main cognitive processes of "threat appraisal" and "coping appraisal" (Rogers, 1983).

After coding each informant, score was provided where pre-determined rules of scoring components for each construct are as follow; + Seldom occur (or strongly disagree), ++ Sometimes (partly disagree), +++ Often (partly agree), and ++++ Every time (or strongly agree). After that the score for each construct will be determined by these following rules; High Mostly +++ or ++++, Medium Mostly ++ or +++, and Low Mostly + or ++. From the results of in-depth interview of seven employees; the relationship between PMT and employee green behavior (EGB) can be analysed using content analysis.

Regarding threat appraisal, higher perceived severity and vulnerability is likely to promote risk adaptive behavior, while higher perceived rewards of current practices will inhibit adaptive behaviour (Bockarjova and Steg, 2014). The results from Org. 2 (automotive) display high tendency of PMT as it presents high scores in overall threats and copping appraisals as seen in table 4.

For perceived severity, it is determined "high" in Org 2 as the informant said

"*…if talking about environmental issue, I would say that it is very connected to our daily life and it is becoming more serious, for example, the problem of plastic waste which was released to the sea destroying many sea lives…. It makes me feel so emotional…" (Strongly agree + + + +)*

For perceived vulnerability, it is determined "high" in Org 2 as the informant said that *"…like inappropriate waste management problem, I think it is so closed and affect*

our life. My boyfriend says we didn't throw it away, so no need to concern about it. But I don't think so…"

For rewards, it is determined "low" in Org 2 as the informant said that "…*We can help as much as we can, if we have ability to protect the environment just a little bit, it is still alright. It is better than doing nothing…" (Strongly disagree +)*

In Copping appraisal, the probability of enacting the adaptive behavior is increased when high levels of the efficacy variables are predicted. Whereas, it is decreased when high response costs associated with performing the adaptive behavior are perceived (Floyd et al., 2000).

For perceived response efficacy, it is determined "high" in Org 2 as the informant said

"…the waste from us just one piece can goes far to the sea. I think if we reduce the waste we throw away, it can help…" (Partly agree + + +),

For perceived self-efficacy, it is determined "high" in Org 2 as the informant said

"…it is something that we can do…" (Strongly agree + + + +)

For perceived costs, it is determined "low" in Org 2 as the informant said

"…it is ok to help protect environment, and at the same time it can also save your money, for example, bringing your own bottle to refill water…" (Partly disagree + +)

"…it is something that we can do; no need extra equipment or anything. We can do it now…" (Strongly disagree +)

Table 4 – Employee PMT and EGB

Industry	PMT						EGB
	Perceived Severity	Perceived Vulnerability	Rewards	Perceived Response Efficacy	Perceived Self-Efficacy	Perceived Costs	
Org 1: Food							
Overall	Medium	Low	High	Low	Low	High	Low
Employee 1	+++	+	++++	++	++	+++	+
Employee 2	+++	+++	++++	++	+	+++	++
Org 2: Automotive							
Overall	High	High	Low	High	High	Low	High
Employee 3	++++	++++	+	+++	++++	+	++++
Employee 4	+++	+++	+	++++	++++	++	++++
Org 3: Energy							
Overall	Medium	Low	High	Low	Low	High	Low
Employee 5	++	+	+++	+	++	+++	++
Employee 6	+	+	++++	+	+	+++	+
Employee 7	+++	+++	++	+	+	++	++

However, the results from Org 1 and Org 3 seem to have low (some medium) in overall threats and copping appraisals for example;

For perceived severity, it is determined "medium" in Org 1 and Org 3 as the informants said

"…it affects our life and other creation…yeah I think it should have the solution for it…" (Employee from Org 3: Partly agree + + +)

For perceived vulnerability, the informant said

"*…it partly affects my life because my house located next to the canal…and yeah I have seen some waste…" (Employee from Org 1: Partly agree + + +)*

For rewards, it is determined "low" in Org 1 and Org 3 as the informant said

"…yeah I have seen a campaign in the department store, like they try to reduce plastic bag buy giving cash back or something, but the understanding of consumer is not 100% correct.." (Employee from Org 1: Strongly agree + + + +)

The results from three organisations show the significant differences between two groups; high overall score (Org 2) vs. low overall score (Org 1 and Org 3). It can be seen that in high overall score group, EGB also rated high. The informants mentioned

"…for example, since I am working with a lots of documents, if my boss want to see some information, I will ask which page I won't print it all out. That way I can save papers…" (Employee from Org 2: Every time + + + +)

"…I have used my own bottle for refill water, first I see other people do and I tried that I think yeah it is good…" (Employee from Org 2: Often + + +)

On the other hand, in low overall score group, it presents quite low EGB. The informants mentioned

"…we want to save water but…you know it really depends on the technology…if we can have the new technology not the old one…" (Employee from Org 3: Sometimes ++)

Therefore, we can see that results clearly explain the relationship between threats and copping appraisals in PMT and EGB. From the analysis, the higher perceived severity, perceived vulnerability, perceived efficacy, perceived self-efficacy, and the higher the tendency of employee to have higher EGB which aligns with the past researches (Floyd et al., 2000; and Bockarjova and Steg, 2014).

Environmentally specific transformational leadership (ESTL), internal social marketing (ISM), and employee green behavior (EGB)

The evidence has demonstrated that transformational leadership can move followers to exceed expected performance, as well as lead to high levels of follower satisfaction and commitment to the group and organization (Bass, 1985).

The results from the in-depth interviews of three organizations present the positive relationship of ESTL and EGB. The higher ESTL, the better EGB. From employee level interview, the informants said

"… He acts as the role model…he tries to reduce the waste and energy…and yeah he ride hid bicycle to the office during weekend…and that it influences me" (Employee from Org 2: Strongly agree + + + +)

"… (Do you have any role model in the workplace?)…Umm I don't think we do have now…" (Employee from Org 1: Strongly disagree +)

"… No I don't have (role model…I do it by myself, for example, reduce the papers...no one influences me…" (Employee from Org 3: Strongly disagree +)

It can be seen that the results support the past literature as researches are demonstrating environmentally specific transformational leadership as a significant predictor of employees' green behavior at work (Graves et al., 2013).

Moreover, the relationship between ETSL and EGB is strengthening through internal social marketing (ISM). An important role for internal social marketing (ISM) is highlighted in identifying environmentally concerned employees, or 'internal customers', creating incentives and removing barriers to pro-environmental behaviour (Smith, and O'Sullivan, 2012). The results align with the previous research as the informants said

"…the corporate value in terms of environment has been informed at the very beginning – orientation training…also there is an environment week that HR informed via email to encourage ideas for improve environment in our company and daily life…" (Employee from Org 2: Strongly agree + + + +)

"…there are some signs to promote ISO 14001 and environmental issues, for example, waste management…I think this kind of communication help encourage green behavior…" (Employee from Org 1: Partly agree + + +)

Even though; ISM can be seen in other organizations as well, the lack of ESTL prevent ISM from moderating the relationship. The information about ISM has been confirmed through the statement of management level as the informant said

"…So, we communicate (the value of the company that related to environments) through the AuditWizard. If something is wrong in the audit, we communicate to the gap. So, like next week we have the environmental week…Oh, this week..." (Management from Org 2: Strongly agree + + + +)

Environmentally specific transformational leadership (ESTL), employee green behavior (EGB) and corporate internal green Supply chain collaboration

Research shows that participative management style and initiation of goal structure by the team leader have a strong influence on internal team dynamics. These characteristics of leaders had a positive effect on functional conflict resolution, collaboration, and communication quality within the team while discouraging dysfunctional conflict resolution and formal communications (Sarin and O'Connor, 2009).

Table 5 – Management ESTL, EGB and Corporate Internal GSCC

Industry	ESTL Idealized Influence	ESTL Inspirational Motivation	ESTL Intellectual Stimulation	ESTL Individualized Consideration	**ESTL**	**EGB**	**Corporate Internal GSCC**
Org 1: Food	**++**	**+**	**+**	**+**	Low	Low	Low
Org 2: Automotive	**+ + + +**	**+ + +**	**+ + +**	**+ + +**	High	High	High
Org 3: Energy	**+**	**+**	**+**	**+ +**	Low	Low	Low

The results from the in-depth interviews of both managements and employees were presented in table 5. From all three organizations, Org 2: Automative is the only corporate that has all four dimensions of ESTL; Idealized Influence, Inspirational Motivation, Intellectual Stimulation, and Individualized Consideration; whereas Org 1:

Food and Org 3: Energy have only one dimension each; Idealized Influence and Individualized Consideration respectively.

Therefore, from the content analysis it can be concluded that both ESTL and EGB has a positive impact on corporate internal GSCC. The statement related to corporate internal GSCC can be found from the interview of management level. The informant said

"… (Do you think that the departments in the company, they collaborate in term of the environmental issue?) … In the company we have, for example, for a new product. After you select the glue, what type of glue and for environmental reason, the company is pushing to get the glue, that best for environment. We have all water-based glue and solvent-base glue, but in term of XXX standard. We need to select that one because it does not impact on that environment. The team works collaboratively to come up with the product decision…" (Management from Org 2: Every time + + + +)

"… we work together, for example, in every Monday, we will have weekly basis meeting which will occupy some general topics include environmental issues…" (Management from Org 2: Often + + +)

Wong et al. (2015) mentioned the term "Internal GSCI" and defined it as *"the strategic collaboration and integration across internal resources, such as top management, management systems, quality control, and functions via an integrated management system for managing the environmental impacts of the supply chain.* From content analysis, it can be summarized that ESTP and EGB tend to have positively impact on corporate internal GSCC because they drive all departments to work collaboratively regarding environmental concerns".

Conclusion

The interpretation of data from the in-depth interviews shows that employees with high PMT tend to have green behaviors both in their personal-life and work-life. Employees who perceived high in severity, vulnerability, response efficacy, and self-efficacy and perceived low in rewards and costs will have high tendency to engage in environmental or greening behavior. They recognize that without proper practice, this issue will then affect their lives. Thus, these employees have a tendency to behave greener, which leads to higher corporate internal green supply chain collaboration. The data from the study also points out those organizations with high environmentally specific transformational leadership (ESTL) often lead to higher corporate internal green supply chain collaboration.

Regarding SET, people who are involved in these interactions are rationally seeking to maximize their profits; in this case, employees were influenced by their leaders, and they wanted to act in line with their leaders' practice and work more collaboratively with different functions/departments in exchange for preference or rewards. Additionally, an organization's internal social marketing (ISM) has a role in promoting collaboration. With high ISM activities (e.g., vision statement, announcements, special events), employees acknowledge the rewards and drawbacks of green behaviour; thus, they tend to behave greener, which results in higher green collaboration between functions.

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Treasure from waste - How Circular Economy start-ups manage their supply chains

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Abstract

The Circular Economy concept drives innovative practices and business models targeting sustainable economic growth while increasing resource efficiency. The study reported in this paper aims at bringing together supply chain research and industrial cases inspired on circular economy. It represents empirical investigations into the start-up companies, who are using waste or left-over material as a resource and explores how do these companies develop and manage their supply chains. The results of this paper highlight the importance in getting control over the supply and challenges in attracting partners. The study also identifies needs for the future research to support the implementation of circular supply chains.

Keywords: Supply Chain Management, Circular Economy, Start-ups

Introduction

As concerns about the growing global population and over-consumption of finite resources are increasing, it is apparent that todays linear so-called take, make and dispose models can no longer be continued. The industrial supply chains of today are wasteful, and industries need to rethink their approach to resources. There is an urgent need to create new ways for harnessing and using resources (Brown et al., 2019). Circular economy (CE), as an economic system that minimizes resource input into and waste, emission, and energy leakage out of the system is proposed to offer an alternative solution for these challenges (Geissdoerfer et al., 2018). Reuse in different levels lies in the core of a CE: at the product level, i.e. repair or refurbishment; at the component level, i.e. remanufacturing; and at the material level, i.e. recycling (Zink and Geyer, 2017).

This paper represents the first in a series of empirical investigations into the companies, who are using waste or left-over material as a resource. More and more companies are starting to recognize and extract the value that lies in resources (Bansal and McKnight, 2009), and new roles emerge. For example, those called “decomposers” transform or recycle waste resources into new materials or fractions (Ghisellini et al., 2016). Decomposers play a critical role in closing the resource loop, and in upcycling, which refers achieving higher-quality materials and improved functionality (Lüdeke-Freund et al., 2018).

In reality, there are only few examples of successful circular business (Parida et al., 2019). One reason for that is that implementing these new CE activities requires holistic

and sometimes radical changes beyond the boundaries of a single company (Nußholz, 2018). The decomposers do not work in isolation. They integrate into current supply chains, creating certain disruption on those, while at the same time they need to build their own new supply chains.

The aim of the paper is to create new knowledge related to supply chain implications of companies using waste and / or left over material of other companies as input resources to make as high value new products as possible. In specific, we look at companies that are start-ups as those are often performing this decomposer role with innovative upcycled products. The research questions of this paper are: *How do start-ups creating value from waste develop and manage their supply chains? What are the main challenges? What research is needed to advance supply chain management in a CE?* We follow Carter et al.'s (2015) approach to supply chains and consider them specific to one product and bounded by the visible horizon of the focal company.

This paper contributes to a research gap on implications of circular economy to supply chains, as supply chain configurations that are aligned with the principles of the CE are largely absent in both practice and academia. Instead our current knowledge on supply chains in the CE is fragmented between several fast-growing research streams with some overlapping constructs.

Literature review

The CE can be defined as a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling (Geissdoerfer et al., 2017). This definition considers both environmental and economic benefits simultaneously under the notion of 'regenerative performance' (Lieder and Rashid, 2016). The definition highlights the idea of putting private business into the service of the transition to a more sustainable system and identifies innovative circular business models as important means in the transformation towards circularity (Geissdoerfer et al., 2018). A circular business models term is used to describe business models that are suited for the CE (Bocken et al., 2016). While the proposed CE strategies are not new by themselves, their combination into a single concept provides a platform for academia and practice to engage constructively (Blomsma and Brennan, 2017).

The business model strategies can be categorized according to the mechanisms by which resources flow through a system. According to Bocken et al. (2016) the three mechanisms are:

(1) Slowing resource loops, by extending or intensifying the utilisation period of products, e.g. design of long-life goods and product-life extension through repair or remanufacturing.

(2) Closing resource loops, by enhancing recycling practices the loop between post-use and production can be closed.

(3) Narrowing resource loops, by using fewer resources per product. This paper focuses on closing the loop by recycling. A

Although material is often recycled because of inefficiencies in current linear supply chains (Bocken et al. 2016), some recycling at the material level will always be needed (Lüdeke-Freund et al., 2018). Recycling can be categorized to down- and upcycling. The former converts used materials into materials of lower value (e.g., turning clothing into stuffing), and the latter achieves higher-quality materials and improved functionality (Lüdeke-Freund et al., 2018), the latter being the scope in this study. Post-society, post-consumer, post-business or own wastes, products and components flow to manufacturers

either directly or via intermediaries, allowing waste to become input for new products (Wells and Seitz, 2005). There is a plethora of actors operating in recycling supply chains, such as waste generators, collectors, processors end users, and entrepreneurs, who are setting up new ventures around recycling (Lüdeke-Freund et al., 2018). Here "scavengers" and "decomposers", refer to companies that are capable to extract resources out of waste by applying innovative recovery technologies (Ghisellini et al., 2016). Scavengers collect the waste in points of the disposal and redistribute them into the system to companies that can reuse or recycle such materials making their work easier. After the collection of waste materials, some of the scavengers perform dismantling, sorting, and transport to the decomposers in a form that is readily accessible for them to process. The decomposers in turn transform or recycle waste resources into new materials or as fractions of the same input flows for which they were initially designed (Ghisellini et al., 2016).

Supply chains are assumed to be a critical unit of action for the implementation of the circular business, as supply chains keep material circulating and the complexity and interdependencies of a CE mean that no single company can achieve circular business alone (Aminoff and Kettunen, 2016). For example, recycling business models often connect the downstream and upstream ends of supply chains, requiring the capability to organize comprehensive reverse logistics that connect users, raw material suppliers, and parts manufacturers (Lüdeke-Freund et al., 2018). The term circular supply chain management (CSCM) is used to refer the configuration and coordination of the supply chain to close, narrow, slow, intensify and dematerialise resource loops (Geissdoerfer et al., 2018). Geissdoerfer et al. (2018) suggest a framework for CSCM in which they see supply chains as enablers and drivers for the CE in value network level. The research on CSCM is still very nascent, instead current knowledge on supply chains in the CE is fragmented between several fast-growing research streams, with overlapping constructs and a failure to produce consistent findings (Ghisellini et al., 2016; Masi et al., 2017).

A related literature stream is sustainable supply chain management (SSCM), including closed loop supply chains. In the last two decades, interest towards sustainability has increased in supply chain management (SCM) research, and it has moved to the mainstream and is now an area of significant research activity (Beske and Seuring, 2014; Pagell and Shevchenko, 2014). The conventional view of supply chains depicts them as linear flows of physical goods, information and funds between firms and the end users of products. A more recent stream of research is also considering the disposal of the end-of-life products. Products at their end-of-life stage have little value to the end consumer; yet there remains residual value in the waste (Guide et al., 2009). Reverse supply chains reuse, recycle and remanufacture end-of-life products for inclusion in forward supply chains (Govindan et al., 2014). This practice closes the supply chain loop. Although the research related to reverse loops is growing, it is still in a much more immature state than forward SCM (Govindan et al., 2014). Moreover, this stream of literature focuses mostly on the closed systems where the product returns back to the original manufacturer and thus, don't fully support the decomposers. Genovese et al., (2015) distinguish between open-loop chains (involving materials from several producers) and closed-loop chains (focusing on a particular manufacturer). However, the terminology is not established and research related to open loop supply chains is still scare.

Our research setting is start-up companies. This creates some SCM challenges compared to large enterprises, related to for instance supply chain integration and relationship management (Kanyoma et al., 2018; Vaaland and Heide, 2007). The traditional small and medium sized enterprise (SME) view of SCM seems to be the exertion of power by customers (Quayle, 2003). Similarly, SMEs do not employ supply

chain management, rather they are managed at arm's length by larger customers. Another view is that failure by a large company could disrupt the entire supply chain but, as few SMEs are unique, if they failed they could easily be replaced (Quayle, 2003). However, in the setting of this paper, the focal start up companies are trying to create new business, conflicting with this traditional view of SCM in the SMEs.

Conceptualization of a supply chain

To research the current practice of circular supply chains, we adapt the conceptualizations of SCM developed by Carter et al. (2015) and Sweeney et al. (2015) (as summarized in the Figure 1). Based on Carter et al. (2015), we see the focal company as a node, node being defined as 'as an establishment which is an agent that has the ability to make decisions and maximize its own gain within the parameters in which it operates' (Carter et al., 2015, p. 90). Node is connected by links to other companies. Each node in the supply chain has control over resources and has accountability. The supply chain is relative to a particular product and agent and is bounded by the visible horizon of an agent (Carter et al., 2015). We further adopt the four fundamentals of SCM developed by Sweeney et al. (2015), defining the essence of SCM as:

(1) (Setting) SCM objectives, which are mostly linked to customer service, financial optimisation and sustainability.
(2) SCM philosophy, which is based largely on the integration concept.
(3) Managing supply chain flows, particularly material, financial and information flows.
(4) Supply chain relationships, in specific their creation and management.

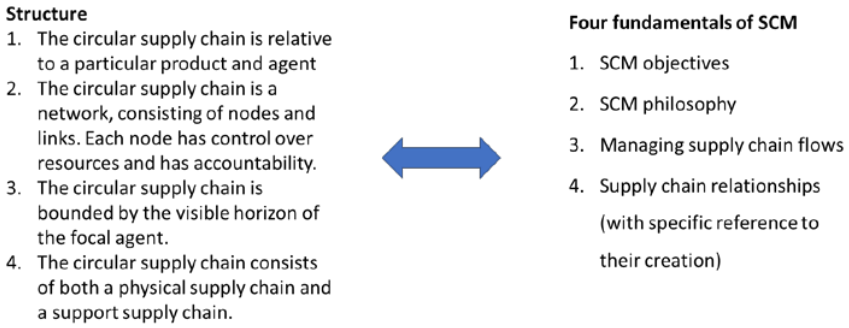

Figure 1 – Conceptualization of CSC, modified from Carter et al. (2015) and Sweeney et al. (2015).

Method

This study extends and complements earlier literature by adding a new understanding of implications of novel circular business models to SCM, in specific in industrial settings where companies performing new ways of creating value from previously wasted materials. A multiple case study design was chosen to match the state of current theory and the exploratory goals of the study (Yin, 2009). The approach is well-suited to new research areas when new perspectives are sought and/or when there is little knowledge available about the complex phenomenon being studied (Eisenhardt, 1989).

The two case companies where selected based on theoretical sampling (Eisenhardt and Graebner, 2007). We searched for and selected the industrial cases that (1) are creating value from previously wasted materials, (2) have new roles in a supply chain

(decomposers), (3) are start-ups. Our unit of analyses is one agent and one product, and is bounded by the visible horizon of the focal company (Carter et al., 2015).

Our main data collection method is semi-structured interviews. The interviewees were selected on the basis of their central role in their respective company (see table 1). The interview instrument relied on the conceptual framework (see Figure 1). Following a replication logic (Eisenhardt and Graebner, 2007) the cases are first analysed and coded individually. Afterwards, data is revisited in cross-case analyses where patterns across the cases are matched and explanations are built for the occurrences in the data.

Table 1 Overview of the studied cases

Company pseudonym	Alpha	Beta
Short description of activities	Converting pre-consumer food waste into high value inputs for the agricultural industry	Converting textile waste, both post-use and post-production, into high-value textile garments
Interviewees' profiles	CEO	Director
No of interviews	1	1
Interviews length	1 hour	1 hour 20 min

Company Alpha: Alpha is a start-up that has developed a proprietary technology enabling the transformation of pre-consumer food waste into high-value inputs to agricultural processes, in particular to agri-food. Alpha operates in a challenging regulatory environment due to legal and safety constraints. They are working together with governmental regulators to create updated standards and regulations to cover their activities as well as focusing on achieving scale and raise funding to grow their business. These issues create additional challenges in supply chain management and engaging new partners.

Company Beta: Beta collects post-use or post-production textile waste materials, and convert them into high-end consumer products. They gave a strong focus on timeless designs and durability for their final products. Although the company competes with other high-end garment companies, they do not feel direct competition due to the uniqueness of their products (i.e. made out of reclaimed textiles). Additionally, Beta works with a zero waste goal for their manufacturing processes and facilities and their energy use is based on renewable sources.

Results

This section presents the findings from the analysis of the two cases and proposes future research needs building on these results. The cross-case analyses is summarized in the Table 2.

Table 2 – Cross-case table

	Case Alpha	**Case Beta**
CE aspect	Can be considered a case of upcycling. Alpha converts (low value) pre-consumer food waste into high value inputs for agricultural (agri-food) industry based on the innovative technology the company has developed. The final product is fully consumed when used as input for agroindustry.	Can be considered a case of upcycling. It converts post-use or post-production textile materials into high value consumer products. The final products are life-long durable products; the company also offers repair services for the products. The products cannot be further recycled after use, so the focus of the company is on providing a long-lasting products (made out of reclaimed material).
Business objective	Reducing environmental impact while bringing more value and higher positive impact into the agricultural food systems. Achieving competitiveness.	Keeping materials from going to landfill (in the short term) and transitioning towards a systemic closed loop of resources at industry level.
SCM objective & philosophy	'Trying to survive' in very regulated environment due to technology not being widely use – it is a new market.	To have control over the supply chain. Creating long-term partnerships with the suppliers of waste materials. Beta is vertically integrated, and is doing designs, collection of waste and manufacturing all in-house.
Structure: physical SC Upstream	Pre-consumer food waste suppliers are large vegetable packaging and processing companies, up to supermarkets, including transport loses and damages of fruits. Alpha has problems in engaging suppliers.	Suppliers: various waste producing operations (for instance cut-offs from textile processing factories) All input materials (raw material) are reclaimed, even for packaging.
Downstream	B2B customers: Agri-food manufacturing companies. The end users would be the farms.	B2C customers: Beta sells through their website directly to consumers. They rarely collaborate with carefully selected retailers.
Structure: Support SC	Alpha collaborates with investors and governmental regulators. It works together with regulators to advance regulations.	Beta's scarce collaborations with selected retailers or short-term pop-up sales points are a key part of their support SC.
Material flow management	The main challenge is to match supply and demand, i.e. matching food waste availability, which is currently just samples, and feed buy-in (thousand tonnes are required for the technology investment to be viable). Alpha struggles to get a constant food waste flow. Alpha aims to get partners (suppliers) to be more involved.	For Beta, it is important to have control over the supply chain; and the company is vertically integrated. Beta carefully assess opportunities to work with new reclaimed materials, as new input materials will require new designs and manufacturing processes. Beta is concerned about growing and losing the capacity to have full control and visibility over the supply chain.
Supply chain relationships	Alpha is trying to balance between the development of the legal framework via engaging with regulators, investors, who require viability proofs and engaging suppliers, and the securement of supply collaborations. The main challenge on the supply side is that potential suppliers of food waste require assurance of this scheme to work and want to wait until the whole supporting system is ready.	Beta considers their suppliers as partners and has established win-win collaborations with them. These relationships are based on trust and strong environmental values. It is difficult to engage big suppliers. Beta needs to prove its reliability by for instance short term contract agreements until it can establish a long-term collaboration agreement.

Next, we rise some interesting observations from the results. These observations highlight both the major challenges in the SCM of these kinds of circular business models and the aspects that would need more research. To streamline the presentation of our findings we link the emergent findings with existing literature already in this section. This tying of emergent findings to the enfolding literature "enhances the internal validity, generalizability, and theoretical level of theory building from case study research" (Eisenhardt, 1989, p. 545).

Observation 1: The environmental objectives are highlighted instead of financial optimisation. Even that prior research (Johnsen et al., 2017; Sweeney et al., 2015) has identified sustainability as one of the objectives of the supply chain, the financial objectives almost tend always win (Montabon et al., 2016). However, in our cases the environmental objectives come first, and it seems that financial optimising of SCs is not the priority of the companies.

Observation 2: Building a supply chain and enganging partners is challenging for companies operating in an unconventional business area. Both our case companies struggle with how to build a supply chain and attract partners. Both companies find hard to collaborate with big companies and to get their voice heard. Representative of Beta highlighted that some of their potential partners are big companies and it is hard to engage them. Also, collaboration does not happen fluently as the working practices and objectives do not often match well between small and big companies. Due to being a start-up in an unconventional business area, Beta needs to prove its reliability, by for instance engaging in short term contract agreements until it can establish a long-term collaboration agreement. Alpha in its turn struggles to even get the suppliers engaged (to get a contract). The company gets relatively easily samples of food waste for free but struggles more to get (future) contracts for a constant food waste flow. This challenge has been recently addressed also in purchasing and supply management literature, in particular under concept of customer attraction, although the maturity of the literature focuses on the situation where the customer has a power (Hald et al., 2009; Tanskanen and Aminoff, 2015). The key question is how to make the business attractive in the eyes of the potential partners.

Observation 3: Companies look for partners who share their sustainability values and morality. In line with the first observation, both of the companies emphasize that they look for partners with similar values. Especially case company Beta found difficult to find partners that share same values and morality. Previous literature (see Johnsen et al., 2017) focuses mostly on price and quality aspects in supplier selection, and the sustainability aspects are often related 'not selecting (too) unsustainable' suppliers.

Observation 4: Getting control over the supply is crucial to build effectively their operations. Getting control over the supply is one of the main objectives for both of our case companies. For Company Alpha, it is difficult to match the supply and demand, as it only has managed to get samples from the potential suppliers, and at the same time the customers are expecting thousands of tons volume. Company Beta is vertically integrated from raw material collection to final products sales. A key for it is to keep control of the origin of all materials, even the in small quantities, and it has put a lot of effort on it. Beta carefully assess opportunities to work with new reclaimed materials, as new input materials will require new designs and manufacturing processes. The final product will be designed depending on what are the intrinsic properties of the reclaimed materials. Getting material it cannot store or develop a good solution for would not be any use for them. Beta is concerned about growing and losing the capacity to have full control and visibility over the supply chain.

Observation 5: Investors and regulators are identified as important actors in larger support supply chain. Alpha collaborates both with investors and governmental regulators and considers them as part of its wider support supply chain. Collaborating with regulators to solve the regulatory hindrances is one of the main objectives of their SCM. The regulatory unclarities complicates Alpha's effort to involve partners. Processing the food waste by a novel technological process raises concerns and falls outside current legislation. While there is no evidence that processed food waste could introduce food safety hazards used within this novel approach, there is no evidence of the contrary neither. Taking investors and regulators as part of wider support supply chain would need more attention in academic debate. Also the results of Geissdoerfer et al. (2018) emphasize the importance of a proactive multiple stakeholder management as part of SCM. Carter et al (2015) argue that our current perspective of the supply chain may be oversimplified. According to Carter 'we tend to think of the members of the supply chain through which products physically flow and generally fail to explicitly take into account the many additional members of the supply chain that play a vital but indirect, supportive role in the movement, storage, and transformation of product across organizations'.

Conclusions

Our research enriches both the current SSCM and CE literature by bringing together concepts from SCM, in particular conceptualizations developed by Carter et al. (2015) and Sweeney et al. (2015), and CE industrial cases. The case companies are start-ups who are using waste or left-over material as their input and are aiming to upcycle, i.e. make high value products out of that. SSCM literature can learn from the analyses of these cases as research in these spaces that try to do things totally differently could help us to identify what the truly sustainable supply chains might look like (Pagell and Shevchenko, 2014), potentially leading to more sustainable supply chains and, in general, to more sustainable industrial systems and defining a way towards sustainable development. The previous research on sustainable supply chains has been critized to apply an instrumental logic that asks how can a supply chain benefit from addressing environmental or social issues as compared to how can a supply chain become sustainable (Montabon et al., 2016). For instance, the emphasis in supply chain research is often waste reduction within a firm, and supply chain research has not 'fully won the battle on waste' (Bansal and McKnight, 2009).

This study links the discussions of CE and SSCM. Although research in supply chains and CE both aim to reduce waste between organizations, and closing the loops, surprisingly little CE research has penetrated the research stream on supply chains. As the linkages of these streams are scare, it may also lead to a fragmented literature, with overlapping constructs and a failure to produce consistent findings.

We identified some major hindrances in achieving efficient supply chains and circularity. More research is needed to provide guidance for companies on how to overcome these hindrances. In particular, following topics raised from our results:

- How to get control over the incoming flow?
- How to build the supply chain and to attract the partners in an unconventional business area? How to involve partners with same values?
- How to manage and collaborate with the various actors in a physical and support SC?

This paper represents the first in a series of empirical investigations into the companies, who are using waste or left-over material as a resource. As a next step we will

have more cases (in total 7-9) to get more in-depth understanding of the supply chain implications and challenges.

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The diffusion of circular economy practices in agri-food supply chains: a transaction cost economics perspective

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Abstract

Circular Economy is one of the more robust pro-sustainability schools of thought. It proposes a change from a take-make-use-dispose economic model in favour of a restorative, regenerative approach and is also applicable to agri-food supply chains, where different CE practices are already in use. The relationship between supplier and buyer plays a role in this adoption process. This paper draws from the literature on CE practices, diffusion processes – drivers, barriers and enablers – to CE and Transaction Cost Economics to propose a framework for the identification of the characteristics and the role of transactions in the diffusion process.

Keywords: Circular Economy, Transaction Cost Economics, Circular Economy diffusion

Introduction

Organisations are increasingly required to prioritise pro-sustainability practices not only into their operations but also in the supply chains they are part of (Batista et al. 2018a; Batista et al. 2018b). Circular Economy (CE) is one of the most robust approaches to such an end, with frameworks supporting managerial and operational practices, like closed and open loops of materials, green strategies, and 'R' practices (reuse, reduce, recycle, redistribute, reclassify, etc.) (The Ellen MacArthur Foundation, 2013; Weetman, 2017). CE is understood, therefore, as both a pro-sustainability philosophy and a practical guide for policy, organisational operations and consumption.

Sustainability is a serious concern in the agri-food industry (Dani, 2015), with CE practices being increasingly adopted throughout agri-food supply chains (Vlajic, Mijailovic and Bogdanova, 2018) forming circular agri-food supply chains (CAFSC). This paper offers a conceptual model for the analysis of the diffusion of CE practices in agri-food supply chains, encompassing the identification of CE practices and related drivers, barriers and enablers. The role of transactions in such process is also considered.

Transactions - the exchange of products/services between actors in a supply chain – can also play a role in the diffusion of CE operations. For instance, contractual obligations to specific standards and practices can make organisations adopt CE practices to sell their products. However, previous research (Célio *et al.*, 2018) has shown that contractual obligations can also lead to higher food waste, thus jeopardising one of the central tenants of CE. Adding to the complexity of this issue, it is also possible that transactions and governance structures vary according to different stages of production and supply chain (Maaß and Grundmann, 2018). To better understand the role that transactions can play in CE diffusion in agri-food chains, it is first necessary to clarify the characteristics (dimensions and types of contract) of the transactions in CAFSC. The framework proposed here uses Transaction Cost Economics (TCE) as the theoretical bases to that end.

This paper is structured as follows: Circular Economy overview and practices, Circular Economy adoption, transaction characteristics in CAFSC, proposed conceptual framework and final considerations.

Circular Economy overview and practices

Different authors have described CE in various ways, such as a pro-sustainability collection of schools of thought and as a framework for policy, business models, organisational relationships and production (The Ellen MacArthur Foundation, 2013; Ghisellini, Cialani and Ulgiati, 2016; Michelini *et al.*, 2017; Weetman, 2017). The basic concept, however, remains the same throughout both the history of CE and the different works that discussed it: the change from linear 'take-make-use-dispose' production and consumption systems to circular 'restorative and regenerative' approaches (Stahel, 1982; The Ellen MacArthur Foundation, 2013).

Urbinati *et al.* (2017) identified the principles of CE as product life extension, redistribution/reuse, remanufacturing and recycling. Similarly, Batista *et al.* (2018) pointed out three core elements in CE: closed and open loops, with resources kept in the economy through reuse, repair, remanufacture and recycle of products not only in the original supply chain but also in different supply chains or industries; functionality and experience over ownership of a product; and collaborative and shared consumption models whenever possible. Another relevant characteristic of CE is the possible uses in different industries, whether they are on technical products, (e.g. cars or cell phones) or biological products (e.g. food), although they have different operations associated (The Ellen MacArthur Foundation, 2013; Weetman, 2017).

One of the major themes in the operations and practices regarding CE are the 'R' practices. Reduce, reuse and recycle (3Rs) are the more well-known operations linked with CE (Jun and Xiang, 2011; Govindan and Hasanagic, 2018) but other R practices were developed for greater differentiation of possible operations within CE, such as redistribute or repurpose (Ghisellini, Cialani and Ulgiati, 2016; Jawahir and Bradley, 2016; Kirchherr, Reike and Hekkert, 2017; Weetman, 2017). Other examples of CE practices that are not within the 'R' categories also exist, including green-purchasing and audits for CE performance evaluation (Govindan and Hasanagic, 2018; Masi *et al.*, 2018).

In the framework proposed in the present paper, not all 'R' practices discussed in CE literature are included. Considering quality standards in food and more importantly, food safety legislation (The European Parliament and Council of the European Union, 2002; Secretary of State, 2013), some of the R were excluded: repair, remanufacture, refurbish and recondition. Table 1 shows the range of CE practices considered in the framework, based on the works cited above.

Table 1 – CE practices in agri-food supply chains

Reduction of inputs and/or reduction of waste (Kirchherr *et al.*, 2018)	**Renewable** energy use (Vasconcelos, Viana and Batista, 2018)
Reuse (Kirchherr, Reike and Hekkert, 2017; Weetman, 2017)	**Auditing** for evaluation of CE operational performance (Govindan and Hasanagic, 2018; Masi *et al.*, 2018)
Recycle (Stahel, 1982; Kirchherr, Reike and Hekkert, 2017; Weetman, 2017)	Identifying the **correct prices** for CE products (Govindan and Hasanagic, 2018)
Redesign products, services and/or processes (Balboa and Domingues Somoente, 2014)	**Green-purchasing** (Masi *et al.*, 2018)
Redistribute (Weetman, 2017)	**Cooperating** with other organisations to implement and use CE operations (Masi *et al.*, 2018)
Recovery of products for disposal and/or recovery of materials for energy use (Jawahir and Bradley, 2016; Kirchherr, Reike and Hekkert, 2017)	Staff and managers **training** (Govindan and Hasanagic, 2018)
Reclassify (Ghisellini, Cialani and Ulgiati, 2016; Vasconcelos, Viana and Batista, 2018)	New **logistics** systems (Govindan and Hasanagic, 2018)
Repurpose (Kirchherr, Reike and Hekkert, 2017; Weetman, 2017)	Marketing products to **green customers** (Govindan and Hasanagic, 2018)

In summary, to understand the diffusion of CE practices in an agri-food supply chain, it is necessary first to identify what are those practices. Table 1 compiles possible operations, both already used or potentially useful for organisations in those supply chains according to the literature. The next section addresses the adoption of CE practices by organisations and the supply chains they are part.

Circular Economy adoption

To understand the diffusion of technologies, practices, operations and other such multifaceted constructs (Eveland, 1986; Peng, 2011) it is necessary to understand the adoption process made by organisations. According to Dossa *et al.* (2018), several elements can influence the decision maker of an organisation to adopt new technology. Technology is not only hardware or information and communication technologies (ICT), but any application of knowledge to solve a problem, even an operation, a managerial practice or know-how. Therefore, the adoption of CE practices can also be discussed as the adoption of technology and benefit from the use of models linked to this issue.

It is beneficial to use a model to simplify and allow the operationalisation in research or practice considering the complexity involved in decision-making processes. The framework proposed in this paper adapts the model proposed by Dossa *et al.* (2018) since it is linked with the adoption of new practices and technologies in an agri-food supply chain setting. There are several possible elements influencing decision-makers, and the model proposed by the authors classifies them in three categories: drivers, barriers and enablers.

Drivers (also called motivators) to adopt CE have been considerably investigated and discussed by previous works. Academic papers and policy reports have approached this topic in several levels - organisational, supply chain, sectoral and national - both in academic papers and policy reports (Jesus and Mendonça, 2017). The work of Govindan and Hasanagic (2018) is used as the basis for the list of potential drivers in this proposed framework, and the reasons are twofold: the considerable depth of Govindan and Hasanagic (2018) literature review and the focus on supply chains. Table 2 shows the

different drivers compiled by those authors, divided into five categories: policy and economy, health, environmental protection, society and product development.

Table 2 – Drivers for CE implementation in supply chains

A. Policy and economy	A1. Compliance to regulation
	A2. Governmental incentives
B. Health	B1. Concern to public health
	B2. Concern to animal health
C. Environmental protection	C1. Fight climate change
	C2. Adapt agriculture
	C3. Reduce environmental impact
	C4. Concern with sustainable development
D. Society	D1. Urbanisation and its influences
	D2. Organisations expansion
	D3. Consumer demands
E. Product development	E1. Increase product efficiency
	E2. Increase in product value

Source: (Govindan and Hasanagic, 2018)

Not only drivers should be counted when discussing the diffusion of CE practices. Barriers to the adoption also need to be contemplated (and overcome) for the implementation of CE in supply chains. Barriers are obstacles or hindrance that thwart the transition to CE practices (Jesus and Mendonça, 2017). It is possible, therefore, to consider as a barrier any element that can difficult, slow down, increase costs or completely stop the implementation of CE practices in organisations and supply chains. Many works have discussed barriers for CE practice implementation (Jesus and Mendonça, 2017; Govindan and Hasanagic, 2018; Kirchherr *et al.*, 2018; Mangla *et al.*, 2018) using different approaches, such as systematic literature review, expert interviews, organisational surveys, among others.

The framework used for this thesis employs the barriers identified by Kirchherr *et al.* (2018). The study conducted by the authors allowed not only the identification of barriers but their hierarchy and the relationship among the different types of barriers. Figure 1 presents the findings of the authors. Although they do not specifically address agri-food supply chains, there is no indication that it does not apply to such context.

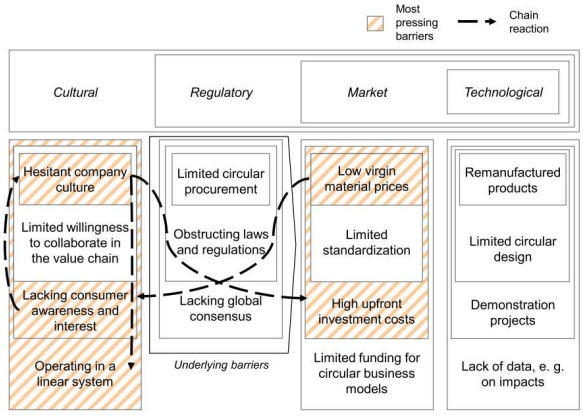

Figure 1 – Key CE barriers and their interaction (Kirchherr *et al.*, 2018, p. 270).

Enablers are elements that aid in overcoming barriers to adoption. They can be technological, institutional or cultural aspects that facilitate, increase the interest or reduce the risks or costs of adopting CE practices. Table 3 lists the enablers considered in this current paper, based on the work of Mishra *et al.* (2018) regarding system enablers linked to CE.

Table 3 – Enablers for CE implementation

Partnerships and collaboration across the value chain	Access to finance
Digital tools	Existing systems of support
New internal incentives	Organisational characteristics
Working with regulators and policymakers	

Source: (Mishra, Hopkinson and Tidridge, 2018)

When the information presented in Figure 1 and Tables 1, 2 and 3 are considered together, it is possible to construct the first part of the proposed framework, as shown in Figure 2 below. From the Circular Economy theory, a set of operational concepts (OC) are derived, encompassing the practices to be investigated, as well as the drivers, barriers and enablers to the adoption of them.

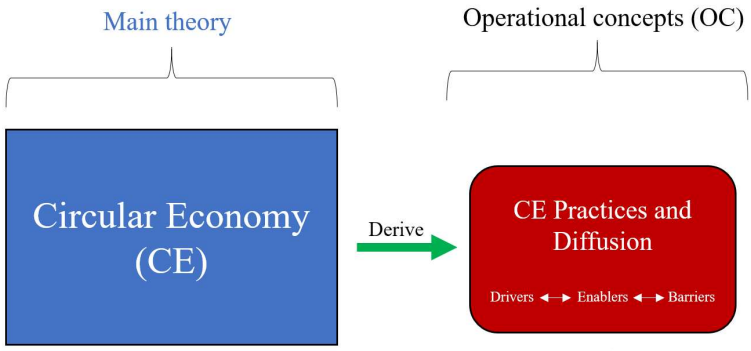

Figure 2 – First part of conceptual the framework

The next section of this paper introduces the supporting theory to the framework. With it, the final theoretical elements for the model are added to support the use of the conceptual framework.

Transaction characteristics in CAFSC

Every time a product (tangible or not) is provided to a client, an (economic) transaction occurs (Douma and Schreuder, 2013). Transactions are defined here based on Dietrich (1994) as the exchange of good and services, as well as their property rights and related contractual obligations. Considering that organisations in a given supply chain continually trade goods, funds and information with clients and suppliers, transactions are a relevant element to be further understood in the discussion of CAFSC. The study of transactions and the economic elements (e.g. costs) associated with it, was introduced by Ronald Coase and further developed by Oliver E. Williamson (Defee et al., 2010; Kolmar, 2017) and is known as transaction cost economics (TCE) or transaction cost theory.

TCE arguably emerged as a theory (or framework) of buyer-supplier interactions, inter-firm governance and vertical integration. While vertical integration was the first problem systematically studied in TCE, it is not the only one, since the theory evolved into a broader explanation of organisations, their boundaries and governance, including property rights, supplier selection, channel structure, among others (Williamson, 1998;

Defee, Williams and Randall, 2010; Klein, 2013; Kolmar, 2017). In the framework presented in this paper, the TCE approach is used to explore/discuss the buyer-supplier interaction and inter-firm governance in the CAFSC, following the recommendation of other scholars like Meixell and Luoma (2015) and Maaß and Grundmann (2018).

It is relevant first to understand the characteristics of said transactions to accomplish the identification of transactions role in CAFSC (Maaß and Grundmann, 2018). Two basic underlying assumptions regarding transactions must be clarified for it to be feasible. The first is 'bounded rationale' and describes the limited capacity that humans possess to be able to comput large amounts of data and complex problems (Williamson, 1998). It relates to uncertainty and complexity, and the impossibility of accounting for every potential scenario in all situations (Douma and Schreuder, 2013), and how to anticipate that. The second is 'opportunism', that is, 'seeking self-interest with guile' (Williamson, 1998). Opportunism can be *ex-ante* (before the transaction) or *ex-post* (after the transaction) (Douma and Schreuder, 2013; Klein, 2013). All of this is contained and influenced by culture, institutions, traditions, norms, legislation, etc. (Williamson, 1998, 2008; Douma and Schreuder, 2013).

Transaction costs are generated in transactions by several factors such as identification of buyers and sellers and negotiations and successful conclusion of contracts (Davies and Lam, 2001). Considering this context (costs origins and behaviour assumptions), TCE identifies three dimensions of transactions that are critical to discuss their characteristics (Williamson, 1998; Douma and Schreuder, 2013):

- **Asset specificity**: the degree in which resources are tied to a specific transaction, and redeployment to alternative uses is doubtful, leading to a decrease in the value of the asset. It can be human, physical, location or dedication (Jraisat, 2010);
- **Uncertainty**: Often paired with complexity, it relates to the level of possible unexpected changes (disturbances) in the environment surrounding the transaction, leading to difficulty in adaptation, especially if the parts are contract-bound (Williamson, 1998; Wever *et al.*, 2012).
- **Frequency**: how often actors transact with each other (Wever *et al.*, 2012). It is connected with reputation effects and setup costs (Williamson, 2008; Jraisat, 2010). For this paper, its operationalisation is proposed as 'short' (<1 year) or 'long-term' (>1 year) and 'sporadic' (random occurrences) or 'common' (regularly repeated).

The final element to be considered are the types of contractual schemes possible. The framework follows Ménard (2004) categories of hybrid organisations plus the pure forms of *spot market* and *hierarchies* as described by (Williamson, 1998, 2008).

Table 4 – Transaction characteristics

Asset Specificity	Frequency
Uncertainty/Complexity	Types of contract

Source: (Williamson, 1998, 2008; Ménard, 2004; Jraisat, 2010; Wever *et al.*, 2012)

The information in Table 4 supports the empirical identification of the characteristics of the transactions occurring in CAFSC. Although it is not possible with such data to compare vertical integration versus market purchase nor test the efficiency of different contracts for CAFSC, it is a first step needed to grasp the role of transactions in the diffusion of CAFSC, following a similar pattern to transaction identification of previous works (Williamson, 2008; Maaß and Grundmann, 2018). Figure 3 shows the second part of the framework, based on the information discussed in this section.

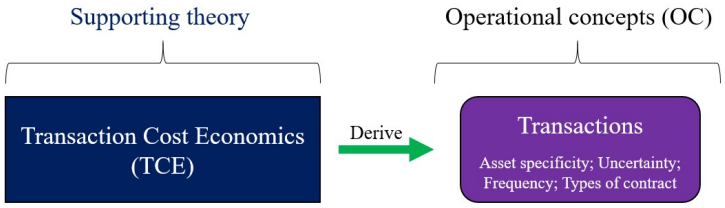

Figure 3 – Second part of the conceptual framework

As Figure 3 shows, TCE is the supporting theory in this discussion of CE diffusion in agri-food supply chains. Since it is a well-developed field of research, it is essential to delimit its use to be able to operationalise it as research. Therefore, the OC examines a set of characteristics of transactions with concepts derived from the TCE. The next section presents and discuss the complete conceptual framework.

Proposed conceptual framework

The use of any framework depends on the application to a specific setting. For this particular case, it is recommended the application in agri-food supply chains given the specific issues related to those supply chains (Batista, Saes and Fouto, 2015; Vlajic, Mijailovic and Bogdanova, 2018), such as different CE practices, high environmental uncertainty, location differences, among others. Therefore, the field of application (in this case CAFSC) is the setting where the actors of a given supply chain execute the CE practices, the transactions, and that encompass the drivers, barriers and enablers.

Figure 4 shows the linkage between the parts of the framework. The bi-directional influence between the different OC also needs explanation. Although contractual transactions might *drive* the adoption of CE practices (consumer demands, Table 3, D3), other roles are possible in this interaction of concepts. For instance, the client might require specific criteria of food standards (e.g. fruit beauty standards), leading to edible food being wasted, thus becoming a *barrier* for CE-practice (e.g. waste reduction). Formal ties might also *enable* the adoption of CE practices, such as to share farming equipment (service over ownership).

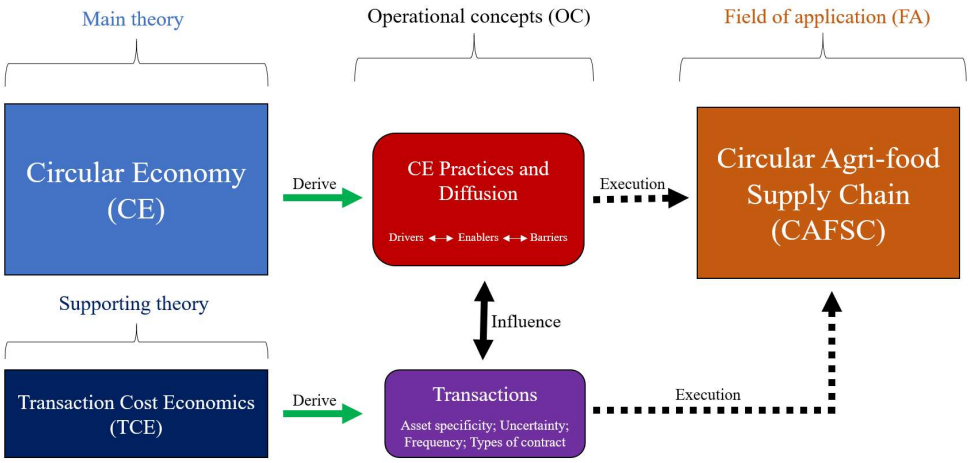

Figure 4 – Proposed conceptual framework

On the other side of it, it is viable to consider that the diffusion of CE practices might lead to the need for transactions adaptation via contractual obligations. For instance,

increased asset specificity (e.g. investment in silos for grain segregation for traceability) might require adaptation in a buyer-supplier relationship, like increased premiums or third-party usage (e.g. grain storage cooperatives) (Maaß and Grundmann, 2018). Therefore, the role of the transactions in CAFSC can be multiple and vary according to the stage of the supply chain, type of products (e.g. cereal, meat and dairy, fresh products, etc.), different practices, among others.

It is recommended to use the framework with a case-study approach considering the number of possible variations and unknown specific elements per food-type, supply chain design or location. It is also recommended to differentiate the supply chains in terms of location (i.e. different countries) or main agri-food product (e.g. cereal, meat-diary, horticultural products). Different contextual constraints (legislation, institutions, edaphoclimatic elements, among others) can affect the operations and the transactions differently, therefore requiring customised approaches to the topic of CE diffusion.

Final considerations

The framework proposed in this paper can be used to investigate CAFSC, both in academic and policy-related research empirically. Its use can bring data that allow the comparison of different agri-food supply chains regarding practices, drivers, barriers, enablers and transaction roles. This especially relevant for actors that wish to promote CE as a pro-sustainability economical system.

Future research should focus on the study of CAFSC cases, thus allowing the specific CE practices, drivers, barriers, enablers and transaction characteristics, to be identified for each agri-food supply chain. With greater specificity, the resources needed to implement CE practices can be used more efficiently if fewer errors happen because of maladaptation. Too many unknown variables in specific industries reduce the possibility of quantitative large-scale CAFSC studies.

Different theoretical frameworks like Resource-Based View (RBV) and Stakeholder Theory can be used to discuss the role of various supply-chain actors in the diffusion of CE practices in supply chains. Nevertheless, TCE has at least three differentiating factors. First, it has a more specific concern in the buyer-supplier relationship if compared to other theoretical options, an element still needed for further clarification within CE theory (Meixell and Luoma, 2015). Second, the amount of microeconomics and finance research in CE is minimal if compared to other areas such as operations or environmental management and the use of a well-established field within microeconomics can improve on that front. Finally, the use of TCE to discuss the role and characteristics of transactions in CE diffusion facilitates future research exploration on costs to implement and govern circular supply chains (Maaß and Grundmann, 2018). Future studies that analyse contractual details of circular supply chains can also benefit from the pre-identified characteristics from the use of this framework.

Some limitations of the proposed model need to be made clear. The model does not attempt to use the entire TCE theory potential. This means that possible TCE studies within CE can be done in the future such as those proposed by Meixell and Luoma (2015). The present paper is constrained to the identification of the characteristics prevalent in transactions in CAFSC and clarify the role of transactions (e.g. contractual demands for CE-related operations) in the diffusion of CE practices.

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Multi-tier sustainable supply chain management – A study on the electronics industry

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Abstract

This case study offers empirical insights on how actors of supply chains (SCs) for fair(er) electronics engage in multi-tier sustainable supply chain management. A content analysis was conducted to analyze semi-structured interviews and public documents from companies at multiple SC stages. The results suggest that direct and long-term relationships are essential in order to enhance the sustainability of lower-tier suppliers. Furthermore, differences were found on how companies work with third parties for the management of lower-tiers. The study follows the call to analyze enterprises with a social purpose to gain possible insights on how truly sustainable SCs might be created.

Keywords: multi-tier supply chain management, sustainability, electronics industry

Introduction

The 'chain liability effect' (Hartmann and Moeller, 2014) in conjunction with the 'supply chain position paradox' (Schmidt *et al.*, 2017) put considerable pressure on companies – particularly on those with a high visibility towards the final customers. Many companies are driven to ensure the sustainability among multiple tiers, as they face the risk of being held accountable for social and environmental issues stemming from other members of their supply chain (SC). However, managing so-called 'lower-tier suppliers' has become significantly more difficult because outsourcing and global sourcing trends have led to more complex and longer SC structures in which the visible horizon of firms decreases with the increase of distance (Carter *et al.*, 2015). Especially labor-intensive production activities have shifted to low labor-cost countries, in which low social and environmental legislations are common (Di Mauro *et al.*, 2018).

In recent years, sustainable supply chain management (SSCM) has attracted the attention of industry and academia as a concept to deal with sustainability issues and risks. Despite that the majority of sustainability threats are caused by lower-tier suppliers (Tachizawa and Wong, 2014; Grimm *et al.*, 2014), research on SSCM is still largely centered on the management of direct and first-tier suppliers as well as simple dyadic relationships (Miemczyk *et al.*, 2012). The recently emerged multi-tier SSCM (MT-

SSCM) aims at filling those research gaps by extending the unit of analysis to lower-tiers. However, since MT-SSCM has just started to gain momentum, empirical studies are still quite rare (Villena and Gioia, 2018).

For this reason, this study aims at answering the following research questions (RQs): (1) How is the sustainability managed in multi-tier supply chains? (2) What governance approaches and sustainable supply chain management practices are adopted to manage lower-tier suppliers?

In order to answer the RQs, the study focuses on the electronics industry in which even the large companies frequently struggle to ensure the sustainability of their global and highly fragmented SCs. However, instead of researching conventional SCs, the analysis focuses on three social enterprises (SE) and their SCs that are currently challenging the prevailing management strategies of the industry. The companies with a social purpose search for new and innovative ways to produce their electronic devices as sustainable as possible. Despite of their small size and limited power, the SEs are often regarded as pioneers with respect to sustainability. By analyzing this unique case – SC for fair(er) electronics, the gathered insights might serves as starting points for truly sustainable SCs (Pagell and Shevchenko, 2014).

Theoretical background

Sustainable supply chain management and practices

While the literature on supply chain management (SCM) has grown over the last decades, links have been increasingly made between SCM and sustainability management. This ultimately lead to the development of SSCM that can be defined as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements" (Seuring and Müller, 2008, p. 1700). In order to successfully implement SSCM, different practices have been identified that can be group into five categories (Beske and Seuring, 2014). The five categories and related practices are presented in the following table:

Table 1: SSCM practices and categories

Category	**Description of SSCM practices**
Orientation	A '*Dedication to TBL'* and '*Dedication of SCM'* are both important for the successful and devoted implementation of SSCM. Especially top-management support and the integration of SSCM thinking into the corporate strategy have been found to be crucial success factors. (e.g. Pagell and Wu, 2009; Beske and Seuring, 2014)
Continuity	This category groups practices which set the structural foundation for SSCM. '*Long-term relationships'* are important prerequisites for successful SC collaborations and should be established at least with key SC partners. Since the SC performance is defined by its weakest link, '*SC partner development'* and '*SC partner selection'* can help to achieve the desired SC performance outcomes. (e.g. Seuring and Müller, 2008; Pagell and Wu, 2009)
Collaboration	Practices of this category are of structural and operational nature. '*Technological integration'* (e.g. installing of mutual IT infrastructure) and '*Logistical integration'* (e.g. collaborative planning and forecasting with suppliers and customers) are practices that support SC collaborations. The actual practices for collaboration are '*Enhanced communication'* (e.g. sharing of relevant information and knowledge and the '*Joint development'* (e.g. inter-

	organizational meetings with SC members) of new products and sustainability solutions. (e.g. Vachon and Klassen, 2006; Seuring and Müller, 2008)
Risk management	This category groups practices which can be adopted when companies are exposed to SC risks. One of the simplest ways to deal with sustainability risks are '*Standards and Certification'*, which define minimum requirements that must be met by SC members. '*Selective monitoring'* can not only ensure desired performance outcomes, but also help to identify potential risks and improvement. Even though '*Pressure groups'* (e.g. NGOs) are able to run campaigns and boycotts, they can also be valuable sources of knowledge to identify and prevent potential risks. (e.g. Pagell and Wu, 2009; Beske and Seuring, 2014)
Pro-activity management	Practices of this category aim at enhancing the SC performance and gaining competitive advantages. Through '*Stakeholder management'*, new insights and knowledge can be acquired for sustainability improvements and solutions. This knowledge can be valuable for mutual '*Learning'* and '*Innovations'*. Furthermore, '*Life cycle assessment'* helps to enhance the environmental performance of products and process, e.g. by identifying potentials for recycling or reused materials. (e.g. Pagell and Wu, 2009; Srivastava, 2007; Seuring and Gold, 2013)

Multi-tier perspectives in SSCM

One of the first major MT-SSCM contributions stems from Tachizawa and Wong (2014) who explored how sustainability in multi-tier SCs can be managed. The authors found four governance approaches ('*Direct*', '*Indirect*', '*Work with third parties*' and '*Don't bother*') that can be applied by companies for the management of lower-tier suppliers and contextual factors ('contingency variables') that determine the adoption and effectiveness of governance mechanism. A description for each governance approach is provided in the following table:

Table 2: MT-SSCM governance approaches

Governance approach	**Description of MT-SSCM governance approaches**
Direct	Companies can reach out to lower-tier suppliers and establish direct contact by bypassing the first-tier supplier. The governance approach is most likely applied when companies possess the required capabilities to manage lower-tier suppliers and face risks related to stakeholder pressure and/or material criticality. (e.g. Tachizawa and Wong, 2014)
Indirect	Companies indirectly manage their lower-tier suppliers through first-tier suppliers – often to avoid complexities. The application of the '*Indirect*' governance approach requires some form of power over the first-tier supplier and is most likely used by focal firms that face stakeholder pressure but lack the resources to manage lower-tier suppliers. (e.g. Grimm *et al.*, 2014; Wilhelm *et al.*, 2016b)
Work with third parties	Companies manage the sustainability of lower-tier suppliers with the help of third parties. For instance, firms engage with third parties (e.g. NGOs, competitors) for their management know-how or to develop sustainability standards. The governance approach is most likely applied when companies face stakeholder pressure but lack SC power or management knowledge. (e.g. Villena and Gioia, 2018; Dou *et al.*, 2018).
Don't bother	Companies have no information or intention to manage lower-tier suppliers. They simply focus on the management of first-tier suppliers. This governance approach may be applied by firms that have limited SC power, face low

	institutional pressure and material criticality, and/or lack the required management knowledge (e.g. Meinlschmidt *et al.*, 2018; Grimm *et al.*, 2014).

Apart from Tachizawa and Wong (2014), other authors have also contributed to the MT-SSCM field. For instance, Grimm *et al.* (2014) identified critical factors that determine the sub-supplier compliance with sustainability standards. Dou *et al.* (2018) studied enablers for sub-suppliers' environmental performance improvements and found that especially top-management support is a crucial prerequisite for green multi-tier SCM. Grimm *et al.* (2016) investigated how the sub-suppliers' compliances with corporate sustainability standards can be managed and propose assessments (e.g. audits, site-visits, supplier questionnaires) and collaboration (e.g. training, workshops, corrective action plans) as management practices. Wilhelm *et al.* (2016b) studied the crucial role of first-tier suppliers in the management of sub-suppliers and found that first-tier suppliers can act as agents which fulfill the focal firms' sustainability requirements and implement those requirements in their suppliers' operations and thus in the lower-tiers of the SC. Based on a multi-case study, Meinlschmidt *et al.* (2018) suggest different strategic management approaches for lower-tier suppliers and also contextual factors leading to sustainability risks. Sauer and Seuring (2018) explored the major sustainability challenges in mineral SCs and suggest management approaches to address them. Roehrich *et al.* (2017) studied how supplier selection and value internalization drive green SCM and found both to be crucial mechanisms for performance improvement at second-tier supplier levels. Jia *et al.* (2018) studied how multi-national corporations facilitate the learning of sustainability practices in multi-tier SCs and suggest that pro-active focal firms adopt a transformational leadership style and directly approach extreme lower-tier suppliers to implement sustainability initiatives. Gong *et al.* (2018) explored how multi-national corporations arrange their internal and external resources to facilitate the sustainability knowledge in multi-tier SCs and found that many focal companies integrate third parties in the SC to gain the required knowledge for sustainability initiatives. Wilhelm *et al.* (2016a) explored the MT-SSCM strategies used in different industries and identified that the sustainability focus impacts how focal firms manage the sustainability of sub-suppliers. Villena and Gioia (2018) built a grounded theoretical model for managing the sustainability of supply networks and suggested that lower-tier suppliers engage more in sustainability practices when they serve downstream customers that are sustainability leaders.

Methodology

A case study is conducted in order to answer the derived RQs. Case studies are the detailed and intensive analysis of one or multiple cases (Eisenhardt and Graebner, 2007). The method is particularly suitable when phenomena and contexts are difficult to distinguish – as it is with the global and complex SCs of the electronics industry (Yin, 2014). As previously outlined, the electronics industry was selected due to its highly fragmented and global SCs that are responsible for different sustainability issues (e.g. Brix-Asala *et al.*, 2018). This research follows the design of a single case study with multiple embedded units of analysis. The SCs of three social enterprises in the electronics industry represent the single overarching case – SCs for fair(er) electronics. Individual units of analysis are companies that are members of those SCs. Different to a multi-case study, the data from the SCs are not distinguished or compared with each other. Instead, the results of all actors are pooled together to create a single universal case that enhances the generalizability of results (Eisenhardt and Graebner, 2007; Yin, 2014).

The data sample in this study consists of three Focal firms (FFs) with a social purpose that aim at promoting sustainability changes from within the electronics industry; six Mid-tier firms (MT-firms) that produce intermediate parts or offer assembly services; and three Low-tier firms (LT-firms) that are metal refiners or mining companies. In total, 11 semi-structured interviews (total: 562 min; 2 FFs; 6 MT-firms; 3 LT-firms) were conducted with interviewees at a management level. All interviews were carried out either face-to-face or by phone by two researchers together from April to May in 2018. Furthermore, secondary material (total: 511 pages) stemming directly from the actors was taken into account in order to gain additional insights and to triangulate the primary interview data (Saunders *et al.*, 2016). Even though no interview could be arranged with Focal Firm 3 (FF_3), the company was included in the data sample because it extensively communicates (e.g. via blogs, webpage) about its SC management practices, challenges and shortcomings. Therefore, it seemed justifiable to include the company in the study – despite of the fact that no primary data was gathered.

To guarantee an objective and systematic analysis, a qualitative content analysis following the coding process based on Weber (1990) was conducted to analyze the gathered primary and secondary data. To ensure the validity of the coding scheme, the categories and items were based on two theoretical frameworks. While the categories for the MT-SSCM governance approaches are based on Tachizawa and Wong (2014), the categories for the SSCM practices are based on Sauer and Seuring (2017) who slightly modified the original framework of Beske and Seuring (2014) for mineral SCs. During the coding process, the coding scheme and categories were revised and slightly adjusted to ensure their quality and suitability.

Findings

The results indicate that especially FFs and LT-firms in SC for fair(er) electronics engage strongly in the management of lower-tiers. While nearly all MT-firms have a strategic orientation towards sustainability and engage in activities to enhance the SC sustainability, the results also show that only the two large(r) MT-firms (one mid-sized, one multi-national) have implemented more advanced measures to ensure the sustainability at lower-tiers. Those two companies were the only MT-firms in the sample which also have production facilities outside of Europe.

For the management of lower-tier suppliers, the ***Direct*** and ***Work with third parties*** governance approaches are the two most common management approaches applied by firms in this study. The application of the ***Indirect*** governance approach was found only seldom. In the following, the main findings for each of the three groups of actors in SCs for fair(er) electronics are presented. Due to space restrictions, these findings are not presented in full details, but the most notable results are highlighted.

Focal firms

The FFs generally put a strong emphasis on *Long-term relationships* with suppliers as part of their strategy to promote sustainability changes and improvements. For that reason, the companies frequently use the ***Direct*** governance approach to manage lower-tier suppliers. The FFs engage themselves in the *Selective monitoring* of lower-tier suppliers to check and evaluate the current sustainability performance of their SC partners. In many cases, the FFs take the opportunity to also engage in *Enhanced communication* in order to provide sustainability requirements to lower-tier suppliers and raise their awareness for social and environmental concerns. One of the FFs noted: "*We find those visits very important, on the one hand, to present once more our idea to the suppliers by a direct conversation and sensitize them for the topic […]. On the other hand,*

those visits give us valuable insights with regards to the production method, used materials (raw materials, intermediates), sub-supplier, etc." (FF_3). Furthermore, FFs are also directly involved in activities to improve the SC performance at lower tiers as part of their strategy to promote sustainability changes from within the electronics industry. For that purpose, they implement practices aiming at the *SC partner development* of lower-tier suppliers or the FFs collaborate with lower-tier suppliers for *Joint development*, e.g. "*to explore opportunities […] in sourcing more responsible minerals and developing other types of worker empowerment projects*" (FF_2). In order to guarantee that suppliers at lower-tiers meet the specific criteria and/or are willing to engage in the required sustainability activities, *SC partner selection* is crucial for the FFs. The companies invest considerable amount of time and efforts to determine the suitability of supplier. It is also not unusual that the FFs reach deep into the SC to select directly their lower-tier suppliers. One of the LT-firms told: "*In the case of FF_2 was the expectation that we source the material […] from Africa and ethically okay and conflict free and preferably from the mine which they visited*" (LT_3).

It was also found that FFs use the *Work with third parties* governance approach to manage lower-tiers. Since *Stakeholder management* and the interaction with non-traditional SC members is crucial for the FFs, it is no surprise that the companies seek the help of third parties (especially NGOs) for their sustainability know-how and experience with the management of (lower-tier) suppliers located in the global South. FFs and third parties collaborate to identify opportunities for *SC partner development*. Moreover, FFs delegate some responsibilities related to first-time audits of new suppliers and the sourcing of fairly traded minerals to third parties. For instance, one of the FFs noted that they employ a NGO for *Selective monitoring* in order to conduct social assessments "*to understand the current conditions with regards to applicable labor law and best practices. Importantly, it is also a baseline to start working together on improvements, as well as to identify areas for innovation and future cooperation*" (FF_2).

Mid-tier firms

As previously indicated, the analysis indicates that most MT-firms engage significantly less in lower-tier supplier management. Particularly small(er) MT-firms in the data sample adopt a *Don't bother* governance approach and/or infrequently use the *Indirect* governance approach, e.g. to demand from first-tier suppliers that lower-tier suppliers are committed to specific *Standards and Certification*.

In contrast, large(r) MT-firms have implemented more advanced measures to manage lower-tier suppliers. The findings suggest that those companies primarily manage their lower-tiers by adopting the *Work with third parties* governance approach. Large(r) MT-firms employ certifiers and NGOs that carry out *Selective monitoring* and ensure that *Standards and Certifications* are met by (lower-tier) suppliers. In addition, one (multi-national) *MT-firm* in the data sample also collaborates with other electronics companies (incl. competitors) via industry associations to develop and drive industry-wide *Standards and Certifications*. The firm stressed this by saying: "*And the best way to do is to deal with it together. And that is something that is very different from other industries. […] they are way behind the electronics industry in dealing with [sustainability] because they have not got together to set standards. […] we could not have done it on our own, we all did it together*" (MT_6).

The application of the *Direct* governance approach was also found to be used by larger(er) MT-firms, but it is less frequently applied to manage lower-tier suppliers. For instance, in order to ensure that their sustainability requirements are met, the companies engage also by themselves in the *Selective monitorin*g of (lower-tier) suppliers. While the

large(r) MT-firms have implemented measures to ensure the sustainability of lower tiers, the companies also acknowledge that they do not manage certain suppliers and therefore adopt the *Don't bother* governance approach. It was noted that "*it is a big effort to monitor also [the first-tier suppliers'] supply chain. We do it partially but we cannot always do it. It is also a capacity problem" (MT_5).* One company noted that they neglect the management of (lower-tier) suppliers with *"highly qualified skilled people [because] there is low risk*" (MT_6).

Low-tier firms

Due to the high pressure that is put on LT-firms to source ethically and responsibly, the management of lower-tiers is crucial to them. The companies use the *Direct* governance approach commonly for *Selective monitoring* and *SC partner selection*. One of the LT-firms noted that they combine "*mine site visits prior to the first delivery, annual re-visits, plausibility assessments and participation in an acceptable traceability program*" to ensure that minimum requirements are met (LT_3). Moreover, the companies engage in *Enhanced communication* to provide their requirements to miners. The requirements are often defined in *Standards and Certifications* (e.g. CoC) covering topics such as "*labor rights, environmental protection, business ethics and conflict-free origin*" (LT_3). LT-firms also engage themselves in *SC partner development* activities to develop mines and ASMs in order to enhance their economic performance and sustainability. One of the companies noted: *"[…] we support the concept of continuous improvement. For example, we had a training with mining engineers last year […], who are employed at a mine from which we source. And they invited neighboring mines and we provided a three-day course*" (LF_3-PrMa, p. 11). *SC partner development* is also the preferred solution when (lower-tier) suppliers are non-compliant with the requirements of LT-firms. The companies strongly focus on *Long-term relationships* with lower-tier suppliers not only to ensure supply stability, but also to foster economic development in the global South. One of the companies noted: "*It is important to understand that disengagement with mines not conforming with our due diligence criteria is not a solution for [our company]. […] We have developed tools to appropriately communicate non-conformity situations and outline corrective measures, including remediation, in order to support the mines that are willing to improve the way they operate*" (LT_2).

Apart from actions in which the LT-firms are directly involved, the use of the *Work with third parties* governance approach appears to be equally important for managing lower-tiers. The analysis showed that LT-firms seek the collaboration with third parties (e.g. NGOs, governmental actors, competitors) to develop *Standards and Certification* for the responsible sourcing of minerals. One of the firms explained: "*All our [sourcing] commitments are achieved by the application, maintenance, and continuous improvement of [our] management systems, processes, and procedures. We do this by engaging with the broader industry […] and by engaging with a broad range of local and international stakeholders*" (LT_2). Furthermore, LT-firms also outsource some responsibilities to third parties, which take over tasks that are concerned with *Selective monitoring* and *SC partner development* of lower-tier suppliers. For instance, one of the firms mentioned that they employ a third-party consultant who monitors "*that there is at least basic safety equipment, helmet and boots and things like that, and that there is also some technical progress. Those are simple tools, that help them to work more efficiently*" (LT_3).

Even though the governance approach was seldom found, the *Indirect* governance approach is also adopted by LT-firms. One notable example is that, first-tier suppliers agree to ensure the compliance of their suppliers (the lower-tier suppliers of the LT-firms) by committing to the *Standards and Certification* of LT-firms.

Discussion

This study aims to contribute to the relatively new MT-SSCM discussion by providing insights on how companies in SC for fair(er) electronics engage in the management of lower-tiers. Even within the MT-SSCM field, the study is one of only few that gathered primary data from suppliers beyond the second-tier (Villena and Gioia, 2018; Jia *et al.*, 2018; Gong *et al.*, 2018). Furthermore, exploring this unique case can contribute to the understanding of how to create truly sustainable SC (Pagell and Shevchenko, 2014). In SC for fair(er) electronics, lower-tier suppliers are most commonly managed with the *Direct* and *Work with third parties* governance approaches.

The results suggest that companies with a strong commitment to ensure the sustainability in multi-tier SC are at least to some extent directly involved in the management of lower-tier suppliers. In order to find suitable and likeminded partners with a similar commitment to sustainability, the direct selection of lower-tier suppliers seems to have strategic importance for companies. In addition, companies seek the direct communication with lower-tier suppliers to raise their awareness for social and environmental concerns and their commitment to engage in sustainability improvements. Such management strategies have been previously found to be significant drivers for sustainability performance improvements in multi-tier SCs (Roehrich *et al.*, 2017). It might be one explanation for how even FFs manage to have a relatively big influence on the sustainability of other SC members, despite of their small size and power. In general, lower-tier suppliers are more likely to engage in sustainability initiatives when the focal companies actively promote sustainability in the SC (Villena and Gioia, 2018; Jia *et al.*, 2018), as it is the case in SC for fair(er) electronics.

Collaborations and the work with third parties has been proposed to be very valuable for companies when the (physical, social or cultural) distance is high and the need for sustainability learning is extensive and complex (Tachizawa and Wong, 2014; Gong *et al.*, 2018). This is most certainly the case for suppliers in countries of the global South. The results support this preposition by showing that firms commonly seek the collaboration with third parties to manage especially those lower-tier suppliers that are located in high-risk countries of the global South. Similar observations have been made in other MT-SSCM studies (Wilhelm *et al.*, 2016a; Grimm *et al.*, 2016). The 'conventional' companies (MT-firms and LT-firms) in this study tend to be more indirectly involved in the work of third-party organizations by simply delegating responsibilities (e.g. monitoring, trainings) to them and/or developing sustainability standards and certifications – often by getting together with other industry actors (incl. competitors). In contrast, the FFs are quite actively involved in the activities of third parties even though they also delegate some responsibilities to them. The FFs primarily approach NGOs to identify sustainability improvements and jointly define supplier development plans. Compared to other firms in this study, FFs are not engaged in industry associations because the industry standards and certifications do not meet the sustainability requirements and expectations of the SEs. One of the FFs even noted: "*Different to [other companies of the electronics industry], we do not have promising code of practices/code of conducts and we do not belong to any of those half-hearted initiatives. We rather take it seriously and do everything in our power guarantee good working conditions in our supply chain*" (FF_3).

Despite that almost all members in SC for fair(er) electronics have a strategic orientation towards sustainability, primarily the FFs and LT-firms are the main groups which engage strongly in lower-tier supplier management. While LT-firms are externally driven by downstream SC members, governmental actors, and the general public to

guarantee that their products are ethical and conflict-free, FFs in this study have a strong internal motivation to enhance the SC sustainability as part of their aim to promote industry changes from the inside out. Those findings are in contrast with the 'SC position paradox' proposed by Schmidt *et al.* (2017), who suggest that firms engage more in sustainability activities the closer they are to the final customer.

Limitations and Research proposals

Even though the validity and reliability were considered throughout the research process, there are limitations that must be acknowledged. The generalizability and thus the external validity of results is limited since the case study focusses solely on the electronics industry and includes only three SCs and their members. Furthermore, even within the electronics industry, SC for fair(er) electronics represent a unique case because their focal firms are SE with a particularly strong emphasis on sustainability. Moreover, the majority of companies in this study are of small- and medium-size, often with limited power and resources. This makes the results quite case specific (Yin, 2014). Finally, a Eurocentrism bias is given because all analyzed firms in this study are European.

By taking those limitations into account, the following research directions can be proposed. Future studies could focus on SCs of conventional and larger electronics companies and/or analyze other industries with global and fragmented SC – such as the textile and automotive industry. This would allow the design of a multi-case study which enables cross-case comparisons that enhance the generalizability of results. To overcome the Eurocentrism bias, studies should include actors from the BoP and emerging economies as well as from different cultural backgrounds. Moreover, it would be also interesting to explore the role of third parties (e.g. NGOs, governmental actors) in multi-tier SCs. Finally, there is still a common perception that SC networks are built around one focal company. Sauer and Seuring (2018) have recently proposed that there are several focal firms at different parts of the SC that interact and delegate multi-tier management responsibilities among each other. The findings in this study indicate similar. LT-firms engage strongly in the management of lower-tier suppliers as they are pressured by downstream SC members. Future studies could adopt a similar network perspective and explore the 'focal firm-focal firm' relationship in multi-tier SC.

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Reduction at source of product packaging: A longitudinal analysis of the impact of market-based instruments

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Abstract

This study investigates at a panel level the relationships between market-based instruments, reduction at source of product packaging, and environmental performance. The research model, grounded on green institutional theory, was tested using a longitudinal data set of plastic packaging produced by 923 firms operating in eight important industries in the Canadian province of Quebec. We found that recycling costs negatively affect reduction at source of packaging. An inverted U-shaped relationship is found between taxation and packaging weight, and between recycling costs and packaging weight. These relationships are intensified by sectorial regulatory stringency. Market-based instruments also affect the environmental performance directly.

Keywords: Reduction at source of product packaging, Market-based instruments, Longitudinal analysis

Introduction

Packaging is increasingly seen as a major issue for today's societies. It represents a significant waste stream that accounts for about 30% to 35% of the municipal waste in industrialized countries and about 15% to 20% in developing countries (Tencati *et al*. 2016: 35; Wiesmeth, 2018: 1004). Most packages either end up in incinerators and landfills or are thrown into nature (e.g. Yamaguchi *et al*., 2016). The recent closure of the Chinese waste management market, which was the main buyer of recyclable materials, could aggravate the situation. Many thousands of tons of material are likely to accumulate in sorting centers and cause a multitude of environmental, social and economic problems. This challenge leads academic communities, businesses, and governments to reflect on the environmental impact of packaging (Accorsi, 2014; Pålsson *et al*., 2016).

According to the Waste Management Hierarchy (Directive 94/62/EC), the best solution is to reduce the amount of packaging at the source by using less packaging materials in manufacturing and in product designs. To encourage firms to adopt this practice many governments in developed countries have launched various market-based instruments (Sharma, 2000). Although several studies have examined the effects of environmental policies on managers' decisions to adopt various environmental practices (e.g., Tsireme *et al*., 2012; Zailani *et al*., 2012; Wang *et al*., 2018), none of them has examined at a panel level the influence of market-based instruments on reduction of packaging at the source. Many scholars have recognized that external factors that induce firms to implement this green practice need to be explored further in future research (Hazen *et al*., 2012; Bartl, 2014; Çakir *et al*., 2014; Yamaguchi *et al*., 2016).

This study seeks to address this research gap by investigating the relationships between market-based instruments, the reduction of packaging at the source, and the environmental performance outcome. We examine these relationships following the green institutional theory. We obtained interesting results from the econometric analysis of a longitudinal data set of the packaging weights of products from 923 firms between 2005 and 2017. This research could help decision makers in companies to recognize the antecedents and the effects of reducing their packaging at the source. Our results are also helpful for policy-makers willing to formulate better targeted instruments.

The remainder of this paper is structured as follows. We outline the theoretical background and the hypotheses development. Then we present the methods and the empirical results and discussion. After that we conclude.

Theoretical background

The reduction of product packaging at the source is one of the most important measures of a firm's environmental innovation (Chappin *et al*., 2009). This practice is implemented through two main approaches: package “downsizing” and package “eco-compatibility” (Hazen *et al*., 2012). According to Vernuccio *et al*. (2010), “package eco-compatibility” minimizes the environmental impact of packaging materials by reducing their quantity and variety, while ensuring at the same time that an optimal combination is used to guarantee the effectiveness of the packaging/product pairs. According to Çakir *et al*. (2014), “package downsizing” optimizes packaging size, volume, and weight. These practices provide more efficient physical distribution of products (i.e., transportation, handling, storage, recovery, or reuse) due to volume/weight efficiency and overpackage elimination. This has direct influence on the performance of sustainable supply chains (Verghese and Lewis, 2007; Accorsi *et al*., 2014). Many researchers pointed out the need to investigate external factors that induce firms to adopt such green practice (e.g., Hazen *et al*., 2012; Çakir *et al*., 2014). As suggested by Hoffman and Ventresca (2002), we explore these external drivers following the green institutional theory.

Institutional theory investigates how external institutional forces influence firms’ decision-making (Seo and Creed, 2002). These forces drive firms to make specific strategic choices and adjust their policies, structures, and processes accordingly (Clemens and Douglas, 2006; Zailani *et al*., 2012). Many environmental studies use institutional theory because it provides plausible explanations of how firms address green issues and, in particular, how they implement green strategies (Zailani *et al*., 2012; Liu *et al*., 2014). However, firms’ strategic choices are heterogeneous depending on how they respond to these various institutional drivers and according to their needs and specificities of the sector in which they operate (Clemens and Douglas, 2006). Liu *et al*. (2014) add that they would be influenced by the firm’s evaluation of the impacts these choices have on its competitiveness. Otherwise, Wang *et al*. (2018) pointed out that government incentive-

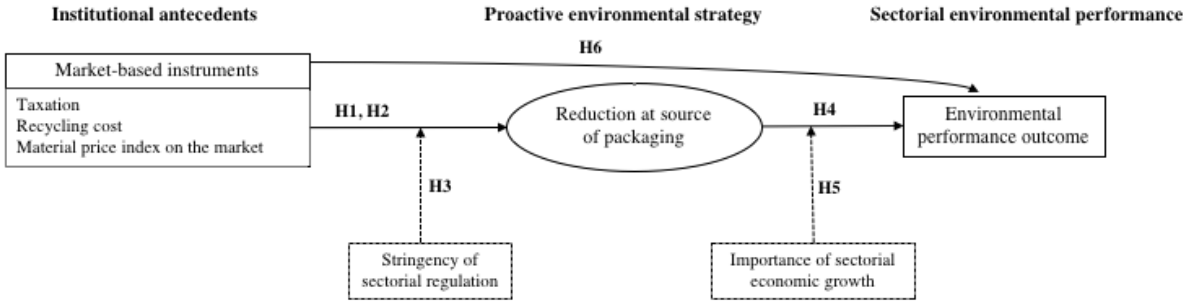
based measures represent a major formal institutional driving force that induce firms to set up a proactive environmental strategy. That's why this study will focus mainly on the effect of market-based environmental tools on reduction of packaging at the source.

Governments have launched specific market-based instruments to induce firms to adopt sustainable practices. They are based on price and market mechanisms (Porter *et al*., 1995; Sharma, 2000) and take a variety of forms including subsidies, tax abatements, or tradable emission permits. According to Porter *et al.* (1995), these incentives are a major driving force because they enhance economic and environmental performance of firms (win-win theory). However, Chappin *et al*. (2009) suggest that these market mechanisms present firms with the following dilemma: either decision-makers adopt green practices to avoid potential costs related to environmental sanctions, or they bear these costs when they are lower than those incurred by adopting green practices.

Hypotheses development

Figure 1 presents our conceptual framework. In line with the green institutional theory, we suggest that the external institutional antecedents associated with market-based instruments precede firms' decisions to implement reduction of packaging at the source. We argue that this practice has an impact on the environmental performance outcome.

Figure 1. Research framework



- ***Effect of market-based instruments on the reduction of packaging at the source***

Several authors argue that manufacturers are responsible for managing the negative impacts that their product packaging generates at the end of the life cycle (e.g., Fullerton and Wu, 1998; Wiesmeth *et al*., 2018). Particularly in developed countries, many governments have tried to remedy this situation by setting up economic incentives to encourage firms to undertake more appropriate environmental initiatives (Porter *et al*., 1995; Sharma, 2000). "Extended Producer Responsibility" is one of the main measures that extends the manufacturer responsibility to the post-consumption stage of packaged products. This policy specifies the type of recovery to be used and the recycling objectives to be achieved, and it recommends that the costs of packaging waste be borne by the producers of packaged products. Thus, these producers are induced to make optimal packaging choices related to volume and weight, and to the materials used (e.g., Verghese and Lewis, 2007; Yamaguchi *et al*., 2016; Arnaud, 2017; Wiesmeth *et al*., 2018). However, Arnaud (2017) shows that the "Extended Producer Responsibility" policy coupled with "bonus/penalty systems" has proven to be a more effective economic instrument for inducing firms to adopt environmental packaging practices. Moreover, the Directive 94/62/EC on packaging and packaging waste focuses on increasing the recycling of packaging material and reducing the level of packaging waste (Prendergast and Pitt, 1996), and this has major implications for producers' packaging decisions (Yamaguchi *et al*., 2016). Therefore, we propose the following hypothesis:

Hypothesis 1 (H1). *The recycling costs borne by companies are positively related to packaging reduction at the source.*

Many researchers have discussed the effect of these price mechanism instruments on firms' decisions to undertake environmental practices. Lin and Ho (2011) maintain that the regulatory pressure is positively related to the adoption of green practices by Chinese logistics firms. The latter seem to be more encouraged to optimize the ecological quality of their packaging when there are economic incentives. Williams *et al*. (2011) show that market-based environmental regulation is an important way to encourage managers in food processing industry to adopt environmental packaging practices. Moreover, Zhang *et al*. (2008) and Tsireme *et al*. (2012) find that incentive-based environmental instruments play a critical role on managers' decisions to adopt green supply chain practices. They argue that the high environmental taxes positively affect managers' decisions to introduce green practices in their supply chain. In fact, many researchers maintain that decision-makers are only willing to adopt environmental packaging practices when the costs are appropriate (e.g. Pullman and Wikoff, 2017; Arnaud, 2017). Kassaye (2001) points out that cutting waste and garbage removal costs is one of the main reasons that large, medium, and small companies engage in green packaging practices. In the same line of thinking, Verghese and Lewis (2007) argue that sustainable packaging innovation is only adopted by firms when it delivers economic benefits such as increased efficiency and cost reductions. Arnaud (2017) shows that manufacturers improve the environmental performance of their packaging when they bear the financial burden of eliminating waste from their packaging. Furthermore, Orzan *et al*. (2018) find that protecting the environment by implementing ecological packaging practices represents a cost-reducing and profit-maximizing approach particularly when significant economic benefits are expected. Therefore, it is plausible to assume the following hypothesis:

H2. *The economic incentives based on price mechanisms are positively related to packaging reduction at the source.*

Otherwise, Wang *et al*. (2018) point out that firms who operate in the more stringently regulated Chinese industries are the ones that are more engaged in environmental management practices. This fact is particularly noticed among those who operate in heavy-pollution industries. Consequently, they are obliged to comply with stricter regulations to avoid potential penalties for noncompliance (Zhu and Sarkis, 2014). Conversely, firms who operate in environmentally friendly industries are not subject to stringent regulations. In sum, firms adjust their buying behavior mainly to comply with the level of regulatory stringency they face (Gray and Guthrie, 1990). Wang *et al*. (2018) and Brunel *et al*. (2016) capture regulatory stringency influences by using sectorial gas emission. They find that stricter sectorial regulation reduces emissions faster than weaker sectorial regulation. In the same line of thinking, Zhang *et al*. (2012) explain that local governments implement more specific measures in environmentally disruptive industries to encourage targeted firms to engage in environmental practices. Thus, we propose:

H3. *The relationship between market-based instruments and reduction of packaging at the source is intensified by the stringency of sectorial regulation.*

- ***Effect of reduction of packaging at the source on environmental performance***

The reduction of packaging at the source minimizes the environmental impact of packaging materials by reducing their quantity and variety, while ensuring at the same time that an optimal combination is used to guarantee the effectiveness of the packaging/product pairs (Vernuccio *et al*., 2010). When this practice is adopted, the materials used for the packaging are limited to what is needed to protect products (Accorsi *et al*., 2014; Molina-Besch *et al*., 2018). Thus, reducing packaging at the source

minimizes its negative impact at the end of the life cycle and positively affects the green performance (Prendergast and Pitt, 1996). Prior research has shown that eco-designed packaging has a direct positive influence on environmental performance of industry (Zailani *et al*., 2012). The environmental performance construct has been studied using a wide variety of measures. It has been linked to the preservation of resource and energy (e.g., Accorsi *et al*., 2014), to the reduction of waste and the maximisation of packaging material reuse and recycling (e.g., Tencati *et al*., 2016). It has also been linked to the use of renewable natural resources and to the reduction of industrial gas emissions (e.g.,Wang *et al*., 2018), and to increased compliance with environmental standards (e.g., Zhu and Sarkis, 2004). Thus, we argue that the reduction of packaging at the source positively affects the environmental performance of industry. However, this relationship is contextual because it depends on the economic growth, the productivity, and the competitiveness of each industry. For example, the environmental impact of packaging used for consumer products may differ from the one of packaging used for industrial products (Zailani *et al*., 2012). Thus, it is plausible to assume the following hypothesis:
H4. *The reduction of packaging at the source is positively associated with environmental performance outcomes*.
H5. *The relationship between the reduction of packaging at the source and environmental performance is intensified by the importance of the economic growth of the industry*.

- ***Effect of market-based instruments on environmental performance outcomes***

Governments put in place green economic incentives through their regulatory agencies mainly to enhance environmental performance (Clemens, 2006). Ren *et al*. (2018) show that market-based environmental regulation provides economic incentives for firms to reduce the environmental impact of their activities. Based on the prior literature and the green institutional theory, it is plausible to assume that:
H6. *Market-based instruments positively affect environmental performance outcomes*.

Methodology / Research design

- ***Choice of area to conduct the research***

The province of Quebec is an interesting study area to conduct the research because of emphasis put on the transition to a green and responsible economy consigned in the Sustainable Development Strategy (2015–2020). The Quebec government has introduced economic incentives to discourage environmentally harmful activities. These incentives mainly involve cost internalization based on the 'user-payer' or the 'polluter-payer' principle. They include fiscal measures such as taxation and tax exemptions and non-fiscal measures such as regulatory fees and subsidies. Therefore, the province of Quebec provides a relevant setting to examine the relationships between market-based instruments, the reduction of packaging at the source, and environmental performance.

- ***Data and sample characteristics***

We used a longitudinal data set for the plastic packaging weights produced by 923 firms operating in the most important Quebec industries (table1) and observed between 2005 and 2017. This data was obtained from Éco Entreprises Québec (ÉEQ), the organization that finances municipal curbside recycling services in Quebec. It should be noted that Quebec companies have the obligation to report the quantity of packaging material that they put on the market. They accordingly pay their contributions to the compensation program of ÉEQ, and the funds are used to finance the selective collection of packaging material. We also used other longitudinal data from the Quebec Institute of Statistics, the

Official Gazette of Quebec, Recyc-Québec, and the Ministry of the Environment and the Fight against Climate Change in Quebec. The use of longitudinal data enhances the size of the data set, which improves the research data representativeness. It allows researchers to examine changes in the phenomenon of interest over multiple periods to determine whether variables have short or long-term effects (Wooldridge, 2010).

Table 1. Sample characteristics

Industries	Number of firms (percentage)
Food processing	445 (48%)
Furniture and related products	119 (13%)
Retail industry	102 (11%)
Electronics	83 (9%)
Chemical and pharmaceutical	83 (9%)
Accommodation and restaurants	45 (5%)
Clothing	30 (3%)
Beverage and tobacco	16 (2%)
Total	923 (100%)

- ***Description of variables and measures***

The selection of variables and their measures were based on our literature review. The collaboration of ÉEQ specialists helped ensure that variables choices and database manipulation are appropriate, which enhances the internal validity of the study.

Dependent variables: The reduction of packaging at the source is the variable of interest in this study. Since one of the important aspects of this practice is the optimization of the weight of packaging, we used the weights of two categories of packaging as a proxy: the high-density polyethylene (HDPE) and the low-density polyethylene (LDPE) plastic packaging. The data were obtained from ÉEQ and present the annual packaging weights of products from 923 firms (table 1) between 2005 and 2017. Regarding the environmental performance variable, we used greenhouse gas emissions by industry. The latter represents a relevant indicator because it is the main regulatory target to protect the environment (Zhang *et al*., 2012). These variables were log-transformed.

Independent variables: Considering the characteristics of market-based instruments and the accessibility of provincial data, three indicators are retained. First, the tax imposed on plastic packaging, which represents the contribution of firms to the compensation scheme. Second, the share of recycling costs borne by Quebec firms. Third, the sales price index of plastic packaging material on the market.

Control variables: We used three control variables. First, we controlled for the stringency of sectorial regulation by calculating the percentage of variation of greenhouse gas emission in each industry over the past five years, as suggested by Wang *et al*. (2018) and Brunel *et al*. (2016). Second, we controlled for the importance of the economic growth in each business sector using the log-transformed GDP at basic prices of each industry. Third, we controlled for the number of firms operating in each industry because there are firms in some industries that are more represented in the sample than others.

- ***Regression method***

Because of the high variation in the values of variables between industries, the results obtained by including all industries could be biased. Hence, to obtain more realistic results, we first conducted a Pareto analysis based on the plastic packaging weights values across industries. The retail, the food processing and the chemical and pharmaceutical industries represent the "vital few" industries (Group 1). They are generating around 86%

of the average quantity of the HDPE and LDPE plastic packaging put onto the market every year. The remaining industries represent the "trivial many" industries (Group 2) because they are producing for around 14% of this quantity. Based on these results, we categorize the industries into two main groups. Longitudinal regression models were then employed to estimate relationships among variables. The Hausman specification test for fixed versus random effects model yields a p-value to be greater than 0.05, suggesting that the random effects model represents a valid model (Hausman, 1978).

Empirical results and discussion

Hypothesis 1 was supported. The results show that the recycling costs borne by companies have a significant negative effect on the reduction of packaging at the source in both groups of industries. This suggests that extending manufacturer responsibility to the post-consumption stage plays a significant role in the environmental packaging decisions of firms. This instrument incentivizes companies to use product packaging with optimal weights in order to decrease the disposal costs that they bear at the end of the product life cycle. These results provide empirical support for the effectiveness of the "Extended Producer Responsibility" policy, which provides highly practical economic instruments for inducing companies to adopt sustainable packaging practices.

Hypothesis 2 was not supported. The results show that there is an inverted U-shaped relationship between taxation and the reduction of packaging at the source with turning points of $319 and $610 in Group 1 and Group 2 respectively. In other words, these are the optimal values for taxation to decrease packaging weights. It is important to remember that Group 1 consists of the "vital few industries" that generate around 86% of the HDPE and LDPE plastic packaging on the market every year, and that Group 2 consists of the "trivial many industries" that produce around 14% of this packaging. Because of the high quantities of plastic packaging produced by the industries in Group 1, it is not surprising that the taxation turning point for Group 1 is significantly lower than the taxation turning point for Group 2. This means that firms operating in the industries in Group 1 react quickly to the increase in taxation in order to decrease the costs they bear, but that firms operating in the industries in Group 2 react more slowly to the increase in taxation. Therefore, taxation has significant influence on companies producing high quantities of plastic packaging, and it has less influence on companies producing smaller quantities. Moreover, our study demonstrates that there is an inverted U-shaped relationship between material prices and the reduction of packaging at the source with a turning point of $56 per ton in Group 1. In other words, this is the optimal value for material prices to decrease packaging weights. These results contradict those of Tsireme *et al*. (2012), for these authors claim that there is a linear relationship between environmental taxes and green practices. Since decision-makers focus predominately on costs (e.g. Pullman and Wikoff, 2017; Arnaud, 2017), they are only willing to adopt policies aimed at reducing packaging at the source if the economic benefits are significant. When this is the case, they take full advantage of economic incentives based on price mechanisms (Chappin *et al*., 2009).

Hypothesis 3 was supported. The results show that the stringency of the sectorial regulation in the "vital few" industries has a moderating effect. The inverted U-shaped relationship between taxation and packaging weight, or between recycling costs and packaging weight, is intensified by the regulatory stringency. This suggests that the increased regulatory pressure in environmentally disruptive industries strengthens the effect of market-based instruments on the reduction of packaging at the source. As an industry becomes more polluting, the stringency of regulation rises, and this induces firms to adopt more environmental practices. Therefore, our findings provide empirical

evidence to support the claim that firms tend to adopt a proactive environmental strategy (Zailani *et al*., 2012) when they operate in heavy-pollution industries (Wang *et al*., 2018).

Hypothesis 4 was not supported in Group 1 but *was supported in Group 2*. The results show how changes in packaging weights affect environmental performance in each industry group differently. For the "vital few" industries, we find that there is a U-shaped relationship between packaging weight and environmental performance with a turning point of 20.3 tons of plastic packaging. In other words, below this packaging weight value, greenhouse gas emissions decrease, but above this value, both variables increase. These findings suggest that the ecological attributes of the plastic packaging that is used in the retail, the food processing, or the chemical industries can delay the negative effect on environmental performance, but only up to a certain point. This non-linear relationship is not consistent with the findings of Zailani *et al*. (2012). Indeed, for the "trivial many" industries, we find that there is a significant negative relationship between packaging weight and environmental performance. These latter findings provide empirical evidence for the positive impact of eco-designed packaging on environmental performance.

Hypotheses 5 and 6 were supported. The economic growth of industry strengthens the effect of packaging weight on the environmental performance of industry. These results add empirical evidence to the findings of prior studies (e.g., Seo et Creed, 2002; Clemens and Douglas, 2006). Moreover, the results demonstrate that market-based instruments affect the environmental performance of the industry directly, which validates the findings of Ren *et al*. (2018). We show that an increase of 1% in the recycling costs borne by companies in the "vital few" industries decreases greenhouse gas emissions by 1%. An increase of 1% in the price of plastic decreases greenhouse gas emissions by 0.1% in the "trivial many" industries and thus improves their environmental performance.

Conclusion

To our knowledge, this is the first cross-sectorial empirical study that examines at a panel level the relationships between market-based instruments, the reduction of packaging at the source, and environmental performance outcomes.

- ***Managerial and policy-makers implications***

Without effective economic incentives, few companies are likely to deliver optimal packaging weight. Thus, the results of this research are helpful for policy-makers and government agencies to evaluate the implementation effect of market-based instruments. Our study demonstrates the turning points for the inverted U-shaped relationship between taxation and reduction at the source of packaging (i.e., $319 and $610 for the "vital few" and the "trivial many" industries, respectively). Our results also determine the turning point of the inverted U-shaped relationship between plastic price on the market and reduction at the source of packaging (i.e., $56 per ton for "vital few" industries). These results would be of great help for policy-makers to formulate better targeted instruments that encourage companies to reduce their product packaging at the source. Furthermore, policy-makers and government agencies might focus on the crucial role of reduction at the source of packaging in improving environmental performance of industries. Our results demonstrate a U-shaped relationship between packaging weight and environmental performance with a turning point of 20.3 tons of plastic packaging for "vital few" industries. Moreover, policy-makers and government agencies should not underestimate the direct impact of economic incentives on environmental performance of industries. Our results show that an increase of 1% in the recycling costs borne by companies in "vital few" industries decreases greenhouse gas emissions by 1%. An increase of 1% in plastic price would decrease greenhouse gas emissions by 0.1% in the

"trivial many" industries. These relevant results would help advance the cause of effective environmental management. Otherwise, our results would help decision makers in companies operating either in "vital few" or in "trivial many" industries. Since the trend to implement reduction at the source of packaging is intensifying, it is important to understand the antecedents and outcomes of such green practice at the firm level.

- ***Limitations and avenues for future research***

Our study has some limitations. First, qualitative evidence would have been useful to develop deeper understanding of our quantitative results. Future research could conduct in-depth interviews with key informants who are involved in the development of the environmental policy instruments. Furthermore, extensive interviews with managers who are involved in packaging decisions could help to clarify the implementing effect of these instruments in different industries. Second, because of the absence of a direct measure of sectorial regulatory stringency, we used the changes in greenhouse gas emission in each industry over the past five years as a proxy. Future research could further explore how firms in different industries perceive the level of regulatory stringency they face. This would add to our understanding of how the latter strengthens environmental decisions of firms. Third, our study examines the effect of the reduction of packaging at the source on the environmental performance of industries. However, it would be useful, both theoretically and empirically, to examine effects of this practice on firm performance. Future research could shed more light on its effects on the environmental and operational performance of firms by using intra-firm indicators. This could add richness to the measure of performance outcomes. Fourth, firms in developed countries face different incentive-based green instruments. In addition, the idiosyncratic environmental regulations of the developed countries limit the generalizability of our findings to the less developed countries. Future research might collect data from different countries to explore the effects of different incentive-based instruments on reduction of packaging at the source. This could reinforce our findings and provide more in-depth understanding of antecedents and outcomes of this practice in different contexts.

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Dissemination Process of Sustainability in Supply Chain: An analysis on the contribution of a Roundtable

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Abstract

This study aims to analyse the dissemination process of sustainability in a supply chain, through the multi-stakeholder partnership roundtable. We conducted a case study with the Brazilian Roundtable on Sustainable Livestock. Preliminary results indicate that Roundtable contributes to the dissemination of definitions, values, successful initiatives, and, therefore, the legitimacy of sustainability among stakeholders in the Brazilian beef supply chains. However, the impacts of this dissemination in the supply chain businesses are mainly related to legislation. Understanding the dissemination process of sustainability seems to be a good direction to recognize the role of different actors for supply chain sustainability.

Keywords: Supply Chain Sustainability, Dissemination of Sustainability, Roundtable.

Introduction

Sustainability in supply chain has become an established area of research (Rebs et al., 2018). Discussions on sustainability and supply chain generally share a focus on concepts that aim to meet economic, environmental and social performance, based on the Triple Bottom Line approach (Elkington, 1998), and investigate this performance over an extended period of time (Pagell and Shevchenko, 2014).

The literature has been highlighting the focal company perspective for supply chain sustainability (Montabon et al., 2016). However, this firm is not exclusively responsible for sustainability in supply chains. Stakeholders also play an essential role to introduce and to disseminate sustainable initiatives in the supply chain (Searcy, 2017). For example, there are cases in which the first movement towards sustainability in supply chain starts from a stakeholder. Thus, the starting point of this study emerges: how does the dissemination process of sustainability occur when the first movement does not start from the focal company?

To develop this understanding, we use institutional theory as theoretical support. Institutional theory provides a lens to understand, for example, the existence of

interorganizational relationships (Parmigiani and Rivera-Santos, 2011) and the adoption of sustainability initiatives in supply chains (Touboulic and Walker, 2015). Based on organizational field, legitimacy and especially isomorphism concepts (DiMaggio and Powell, 1983; Suchman, 1995), we understand that institutional theory supports the analysis of the dissemination process of sustainability in supply chains, including when this process starts from different stakeholders.

We argue that efforts to disseminate sustainability in supply chains are more complex when the first movement does not start from the focal company. Thus this complexity requires the establishment of new discussions and new partnerships between organizations in a supply chain. In this context, multi-stakeholder partnerships (MSPs) seem to be a strategy to deal with the complexity and challenges of the supply chain sustainability, since MSPs provide a way to address complex issues that businesses cannot address on their own (Searcy, 2017). Several initiatives can be considered MSPs, including roundtables. Roundtable is a voluntary initiative aiming to discuss complex issues into a form that improve the participation of all stakeholders and give them equal standing at the table of negotiations (Ponte, 2014).

Even though studies about sustainability in supply chains are growing significantly (Pagell and Shevchenko, 2014), further research is needed on the role played by other elements and actors. Therefore, this study aims to analyse the dissemination process of sustainability in a supply chain, through the multi-stakeholder partnership roundtable. We argue that roundtable analysis can contribute to the understanding of the disseminating process of sustainability in supply chains, particularly when this process is initiated by a stakeholder.

We are investigating the Brazilian beef supply chain. Brazil has the largest commercial herd in the world and the country is considered one of the biggest beef exporting countries (Abiec, 2018; Knoll et al., 2017). Concomitantly, Brazilian beef industry has been facing criticism related to socio-environmental issues along the supply chains. Taken together, these circumstances have created a sense of urgency to re-examine sustainability in this food supply chain (Kirwan et al., 2017).

This paper is structured in four sections in addition to this introduction. Section two presents the theoretical background which supports this study. In section three, we describe the methodological procedures. In section four, we present the preliminary results. Finally, we highlight the final considerations.

Theoretical Background

The theoretical background is divided into two topics. In the first topic, we discuss sustainability in supply chains. The second topic addresses the roundtable as a multi-stakeholder partnership that aim to improve the stakeholders' interaction and their participation in industry, supply chain and organizations decisions.

Supply Chain Sustainability

Sustainability in supply chain has become a topic of interest for academics and practitioners in the last decade (Dubey et al., 2017; Gold and Schleper, 2017), since the publication of seminar papers (see Seuring and Müller, 2008; Carter and Rogers, 2008; Pagell and Wu, 2009). Discussions on sustainability and supply chains generally are focused on concepts that aim to meet economic, environmental and social performance, based on the Triple Bottom Line approach (Elkington, 1998). The Sustainable Supply Chain Management (SSCM) concept emerges in this context.

Carter and Rogers (2008) define SSCM as the strategic and transparent integration of an organization's social, environmental and economic goals in the systemic

coordination of the key interorganizational business processes, aiming to improve the economic performance. In this concept, the authors highlight the focal company role to the supply chain sustainability. The focal company plays a relevant role in SSCM context, since this company must to manage and coordinate sustainability strategies e operations beyond its own organizational boundaries (Reefke and Sundaram, 2017).

Researchers use different theoretical lenses to understand the supply chain sustainability. Institutional theory tends to be used in studies that explore the complex nature, challenges and drivers of sustainability in supply chains (Touboulic and Walker, 2015). Studies have been using institutional theory to understand and to analyse supply chain sustainability (Sayed et al., 2017; Sancha et al., 2015; Tate et al., 2014).

According to the institutional theory, the legitimacy and other types of symbolic performance (such as status or reputation) are key drivers for interorganizational relationships. Organizational actions are socially constructed and constrained by exogenous forces in the organizational field. The organizational field is formed by organizations that share common meanings systems and interact more frequently with each other than with actors outside the organizational field, thus constituting a recognized area of institutional life (DiMaggio and Powell, 1983).

These exogenous forces – or isomorphic pressures – lead organizations to seek an acceptable template by suffering coercive pressures, mimicking successful cases or following norms. In some organizational fields, the isomorphic template may be related to relationships with certain partners (Parmigiani and Rivera-Santos, 2011). Following Sayed et al. (2017), we mobilized the concept of organizational field to theoretically interpret the supply chain. Therefore, according to the institutional theory, the dissemination process of sustainability occurs through isomorphic mechanisms to gain legitimacy within the organizational field (Alves and De Barcellos, 2017).

Pressures and incentives of governments, customers, rivals and other stakeholders are constantly indicated as pushing focal companies towards the dissemination of sustainability and to take care of the behaviour of other businesses along their supply and demand chains (Gold and Schleper, 2017). However, the adoption of sustainability in supply chains is not exclusively related to the focal company. Silvestre (2016) argues that different supply chain members can voluntarily adopt sustainable practices and then disseminated these practices to the other partners. However, how does the dissemination process of sustainability in supply chains occur – especially when the organization that initiates this process is not the focal company – is a question that still requires further exploration (Silvestre, 2016).

Searcy (2017) affirm that the stakeholders play an essential role to introduce and to disseminate sustainability initiatives in the supply chain, since they are influenced by the supply chain operations, but also can influence these operations. According to the author, stakeholders can especially exert their influence through participation in multi-stakeholder partnerships (Searcy (2017). These partnerships improve multi-stakeholder interactions by allowing groups to work together to solve a large and complex problem and to exploit new opportunities (Brouwer et al., 2016). Thus multi-stakeholder partnerships are playing an increasing role in supply chain sustainability (Searcy, 2017). We discuss in the following topic the roundtable, a specific multi-stakeholder partnership.

Roundtable: a multi-stakeholder partnership

Multi-stakeholder partnerships (MSPs) have gained popularity as mechanisms to address complex problems whose resolution requires the alignment of different purposes (Fowler and Biekart, 2017). This popularity can be explained by the fact that

MSPs provide a way to address complex issues that businesses cannot address on their own (Searcy, 2017). For example, there are the challenges related to supply chain sustainability, since these issues increase the complexity of the supply chain (Pullman et al., 2009).

MSPs are generally defined as joined voluntary activities in which different sectors of society are involved (Castro and Swart, 2017), including consumers, associations, non-governmental organizations, political actors, research centres, universities, governmental agencies, suppliers, competitors (Roloff, 2008). According to Searcy (2017), MSPs are focused on the collaborative efforts of a range of stakeholders to address shared interests and challenges.

There are several terms and definitions are used to describe partnerships and interactions between multi-stakeholders (Brower et al., 2016; Castro and Swart, 2017). Considering these terms, we are focused on the roundtables. Roundtables have become more common to tackle sustainability issues improving stakeholder interactions (Ponte, 2014). Companies, therefore, are one of the multiple interest groups doing the standard-setting in roundtables (De Man and German, 2017).

According to Schouten et al (2012), roundtables are arrangements based on a deliberative democratic rationality, because of their communicative processes, which include a variety of stakeholders, are able to create a common good and are open, and mainly consensus-based. The roundtable is an open space of multi-stakeholder integration and engagement, enabling them to create shared value by solving a jointly problem or opportunity (Aakhus and Bzdak, 2015).

Compared to others MSPs, a key distinguishing characteristic of roundtables is the equal right to participate for all stakeholders. The development of standards, and the certification and accreditation schemes, is also a common characteristic of roundtables. Additionally, Ponte (2014) affirm that some specific institutional features are required for multi-stakeholder partnership to be considered as roundtables – such as an executive director, an assembly or council, committees or working groups with experts on the concerning topics, and support staff. The management structure is an essential condition for the achievement of the roundtable purposes (Fowler and Biekart, 2017).

In this context, Castro and Swart (2017) define roundtables for sustainability as initiatives consisting of different stakeholders, from different societal levels, which aim to jointly tackle sustainability issues of an industry, supply chain or product mainly by developing and disseminating standards for better sustainable practices. The Forest Stewardship Council (FSC) is considered the first roundtable for sustainability model. This model was applied to a number of initiatives for sustainable agribusiness (De Man and German, 2017), including the livestock activity.

Although studies have been conducted on roundtables, the question of how MSPs contribute to addressing globally relevant and complex sustainability issues remains under discussion among academics, policy makers and managers (Dentoni et al., 2018). Thus we need to move further and recognize the role of different stakeholders for the dissemination of supply chain sustainability – especially when this dissemination is is encouraged by another actor than the focal company.

Moreover roundtables discussions generally are industry-level debates. However, although it occurs at the industry level, the decisions also impact the supply chains and the organizations (Alves et al., 2018). In this study, we focused on the impacts at the supply chain level. We argue that the dissemination of sustainability seems to be facilitated by the roundtable, since this MSPs allows the stakeholder involvement in the discussion of sustainability issues. Based on this facilitation, the dissemination should have a positive impact on the supply chain sustainability.

Method

A qualitative approach is used in this study. To develop this ongoing research, we are conducting a case study (Yin, 2014). Case selection followed three criteria: (a) stakeholder partnership in roundtable format; (b) partnership formed to discuss sustainability issues; and, (c) participation of all stakeholders from the beef supply chain. Brazilian Roundtable on Sustainable Livestock was selected.

In order to achieve research purpose, the research is being conducted in three phases, since June 2018. The first phase aimed to gain an early understanding of the Roundtable and the perception of its contribution to the beef supply chains in Brazil. In this phase, 14 semi-structured interviews were conducted with different experts, Roundtable's members and professional staff. The second phase aimed at understanding the dynamics of Roundtable discussions and meetings in practice. Thus, six Roundtable meetings were observed using an observation research protocol.

Finally, we are conducted semi-structured interviews with supply chain members aiming to analyse the impacts of the Roundtable meetings at the supply chain level. To date, we interviewed two cattle ranchers, the livestock association director and the sustainability manager of the slaughterhouse, considered a key informant. Following a request from the interviewees, the organizations names will not be revealed. The slaughterhouse is considered one of the three largest companies in Brazil, operating in the domestic and international markets. In turn, the properties have about one thousand hectares of production. In addition, documents are being collected in the three research phases.

Data collected from different sources are being consulted for results confirmation and validation. Therefore, data are being triangulated to ensure reliability and validity. Additionally, data has been discussed in an attempt to understand the complexity of relationships from emerging findings.

Data analysis is being performed based on content analysis. According to Bardin (2011), the content analysis is based on performing a dismemberment of the text into units from the different sense nuclei and then regrouping these units into categories. Categories are classes that gather elements by their common characteristics, and can be derived deductively or inductively. The analysis is providing insights for the understanding of the dissemination process of sustainability in the Brazilian beef supply chain. In the following section, we present the preliminary results of this research.

Findings

In this section, findings are presented in two different topics. First, we present the panorama of the Brazilian beef supply chains. This panorama allows understand the context of these supply chains. Second, the preliminary results related to the Roundtable contributions are presented and analyzed in order to achieve the research purpose.

Brazilian Beef Supply Chain: a 'sensitive' supply chain

Brazil has the largest commercial herd in the world with 221.81 million head of cattle (Abiec, 2018). Therefore, the country is considered one of the biggest beef exporting of the world (Knoll et al., 2017). In 2017, beef exports increased 9.6% in volume and 13.9% in sales, reaching incomes of US$ 6.2 billion. Although exports are important, approximately 80% of the Brazilian beef production was destined for the domestic market in 2017 (Abiec, 2018). In the last years, the beef industry has been responsible for approximately one third of the value of Brazilian agribusiness production. Thus, the beef industry is an activity of large representation for the economy and agricultural production in Brazil (Florindo et al., 2017).

Brazilian beef supply chains may be labelled as 'sensitive', since its activities are prone to impact the environment and the society as a whole (Gold, 2016). Brazilian beef supply chains have been under pressure from national and international organizations especially because of deforestation (Walker et al., 2013), global warming (Ruviaro et al., 2016) and carbon footprint issues (Florindo et al., 2017). Although the pressures are mostly related to environmental issues, it is necessary to include other aspects for a sustainable beef supply chain. According to Ruviaro et al. (2016), it is important to consider social aspects, such as the promotion of social responsibility, improvement of working conditions, ethical relationships with employees, clients, suppliers and other stakeholders, occupational health and safety at work and compliance with human rights and labor laws.

Motivated by these pressures, organizations have begun to invest in sustainable initiatives in the beef supply chains – mainly after the publication of Greenpeace reports Eating Up the Amazon (2006), *A Farra do Boi na Amazônia* (or Bull Party in Amazon, free translation) and *Carne ao Molho Madeira* (or Beef with Wood Sauce, free translation). The organization reported irregularities in the beef supply chains in the Amazon region and highlighted the lack of knowledge of the beef traceability by companies, whose suppliers were involved in illegal deforestation and slave labor (Greenpeace, 2006; 2009; 2015).

In this context, Brazilian Roundtable on Sustainable Livestock (BRSL) was formally constituted in 2009, in São Paulo, Brazil. According to the interviewees, the creation of the Roundtable is related to the publication of the first report by Greenpeace in 2006. The involved organizations decided to discuss sustainability issues in the Brazilian beef value chain in a workshop in 2007, formalizing the Roundtable two years later. The participants of the BRSL are representatives of all stakeholders from the beef supply chains. Among them, we mention: producers, slaughterhouses, producers associations, suppliers, retailers, financial institutions, civil society organizations, government institutions, research centres and universities. As explained by the interviewees, there are two possibilities for participation: members and observers. The members are those who are able to express directly their opinions, understandings and objectives related to the topic discussed. Observers are those who participate in the debate just as listeners.

According to their official website, the main purpose of the BRSL is to discuss and to formulate the common principles, standards and practices adopted by the beef supply chains in order to build sustainable, fair, environmentally correct and economically viable livestock. However, Silvestre et al. (2018) highlight that the multi-stakeholder partnerships might not be always a "good thing" or "as good as they aimed to be". According to the study conducted with Brazilian beef supply chain and corruption, the authors suggest that multi-stakeholder interaction might lead to unanticipated negative outcomes, i.e., some organizations might maliciously use stakeholder management mechanisms (such as the Roundtable) to deceive the public and to opportunistically manipulate partners to pursue their own self-interests. Considering this context, this study aims to analyse the dissemination process of sustainability in supply chains through the Roundtable.

Preliminary Analysis

Preliminary results indicate that sustainability becomes a criterion of legitimacy in the Brazilian beef supply chains mainly due to a report published by Greenpeace in 2006. Interviewees agree that this publication motivated the first stakeholder meeting, since the organizations realized that they individually would not be able to react to the socio-environmental issues indicated in the report. Understanding the complexity of

sustainability issues and the nature of livestock activity, the Brazilian Roundtable on Sustainable Livestock was formally constituted in 2009.

Once sustainability is legitimized in the organizational field, the legitimacy refers to the adoption and the dissemination of sustainability definitions, values and successful initiatives, understood by the stakeholders as being appropriates. Firms seek to adopt legitimized values and initiatives (through isomorphism) or to legitimize their values and initiatives with other stakeholders from the organizational field. These processes occur at the Roundtable meetings. Therefore, the dissemination process of sustainability occurs during the stakeholders' interactions and discussions at the Roundtable meetings. Being a member of the Roundtable gives legitimacy to organizations, since sustainability is a relevant criteria in beef industry and supply chains, improving their reputation with their stakeholders and the international market.

Roundtable meetings include rounds of discussion among stakeholders. According to the observations, the agenda for the meeting is presented by the Roundtable staffs, and the discussion is open. Roundtable discussions usually focus on the sustainability definitions, values and initiatives in the Brazilian beef supply chains. After rounds of debates, decisions are made and agreements are signed. Therefore, Roundtable meetings allow sustainability to be disseminated in Brazilian beef supply chains.

Thus the impacts on the supply chain analysed are directly related to the participation in Roundtable. Participation allows the sustainability dissemination and the value sharing in the supply chain. The slaughterhouse manager emphasizes that the company follows terms of conduct adjustment, and already adopted best practices to comply with the current environmental legislation. However, the interviewee highlights that the Roundtable must continue to contribute as the open space in which sustainability is discussed and disseminated in the Brazilian beef supply chains.

Posteriorly, organizations evaluate the impacts of the decisions made during these meetings. At this point, we are analysing the impacts at the supply chain level, for the following supply chain members: cattle ranchers, livestock association, and a slaughterhouse. Preliminary analysis indicates that slaughterhouses are more impacted with sustainability issues, especially because of the compliance with legislation.

We have identified that the sustainability issues discussed at the Roundtable are more general, and refer, for example, to the definition of sustainable livestock meaning and sustainability indicators applied to livestock. Thus, we perceive a more general dissemination of sustainability, rather than the dissemination of initiatives to adopt sustainability in the Brazilian beef supply chains business. The impacts of this dissemination in the supply chain businesses are mainly related to legislation. This is an ongoing research.

Final Considerations

The focal company perspective has been ostensibly explored in the literature (Montabon et al., 2016). In this study, we investigate the contributions of the roundtable to the dissemination of sustainability in supply chain, following the recommendations on the literature related to the inclusion of different stakeholders' perspectives (Pagell and Shevchenko, 2014). Managers can be encouraged to interact with stakeholders through roundtables, aiming to become their supply chain businesses more sustainable.

This study highlights the role played by the Brazilian Roundtable on Sustainable Livestock to the sustainable supply chain. Therefore this case study provides some empirical evidences related to the roundtable contribution. Preliminary results indicate that Roundtable contributes to the dissemination of definitions, values, successful initiatives, and, therefore, the legitimacy of sustainability among stakeholders in the

Brazilian beef supply chains. However, the impacts of this dissemination in the supply chain businesses are mainly related to legislation.

Theoretically, this study contributes to the understanding of the dissemination process of sustainability in supply chain when the first movement does not start with the focal company. Considering the starting point question of this research, we identified that the dissemination process occurs during the stakeholders' interactions and discussions at the Roundtable meetings. Thus we can understand the importance of the Roundtable to the beef supply chain sustainability. Understanding this dissemination process seems to be a good direction to recognize the role and importance of different actors for supply chain sustainability.

Considering the importance of the sector to Brazil and the impacts of livestock activity, we understand that more studies and discussions related sustainability must to be development. In addition, we understand that more studies and discussion about the relation of multi-stakeholder partnership and sustainable supply chain management must to be development. We hope that this study will stimulate future research on the subject.

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Incentive alignment, collaborative carbon reduction in supply chains and performance

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Abstract

The purpose of this study is to explore the antecedents and consequences of incentive alignment in performing collaborative carbon reduction in supply chains (CCR-SC). To fulfill the research objective, an empirical study was carried out in China, an emerging economy that has in recent years started to undergo a transition towards a low-carbon economy. The statistical technique of structural equation modelling (SEM) was used to analyze the questionnaire data collected from 120 Chinese companies. The research results reveal that incentive alignment has a positive impact on CCR-SC, which is instrumental in the improvement of both financial and environmental performance.

Keywords: Incentive alignment, Collaborative carbon reduction, Supply chain.

Introduction

Incentive alignment refers to the extent to which an organization is able to achieve its goals whilst meeting the requirements of the partner at the same time (Theißen *et al*., 2014). In the context of supply chain management (SCM), it is recognized as an important factor that motivates the chain members to create value that benefits all members in the supply chain (Simatupang and Sridharan, 2008), ensuring that collaboration outcomes are quantifiably beneficial to all, and securing sufficient levels of cooperation and minimize opportunistic behaviour (Harland, 2004). Given its significance in managing and operating supply chains, particularly its essential role in supply chain collaboration, incentive alignment has received considerable attention from academia. For example, Simatupang and Sridharan (2002, 2005, 2008) recognized incentive alignment as one of the five main elements of the architecture of supply chain collaboration. Chao and Zhang (2011) defined incentive alignment as one of the seven interconnecting components of SCC in a study of the nature of supply chain collaboration and its impact on firm performance. Hinkka *et al*. (2013) were aware of the role of incentive alignment between buyers and suppliers in supply chains and

explored this issue with reference to inter-organizational system implementation projects.

As awareness of carbon reduction management in supply chains has increased, concern has been raised about the role of incentive alignment in supply chain members performing collaborate carbon reduction. For example, based on a multiple case study, Theißen *et al*. (2014) ascertained that incentive alignment is one of the five determinants influencing an organization' readiness to engage in collaborative carbon reduction management. Nevertheless, a close examination of the existing literature finds that the issue remains conceptualized and empirical investigation remains scarce. To fill this gap, this study intends to examine the antecedents and consequences in the setting of collaborative carbon reduction in supply chains (CCR-SC).

The paper proceeds as follows. Section 2 provides a review of the literature on incentive alignment and CCR-SC. The conceptual model and hypotheses of antecedents and consequences of CCR-SC are then presented in Section 3. Section 4 describes the research design for the investigation. Finally, the results and the conclusions of the study are presented. The paper concludes by discussion the limitations of this study and the future research agenda.

Literature review

Incentive alignment

Incentive alignment is described as the motivation to fairly share the benefits of collaboration among members, and to enable members within the supply chain to self-enforce, aligning their individual decisions with the common goal of increasing total profits (Simatupang and Sridharan, 2002, 2005). According to Simatupang and Sridharan (2005), incentive alignment works as a scheme that motivates chain members to act in a way that is consistent with mutual benefit, including making optimal decisions, revealing accurate private information and calculating costs, risks and benefits. It is necessary to be aware of the effect of incentive alignment in reducing anxiety and uncertainty and increasing the prevalence of trust. Sahay (2003) pointed out that it can be seen as a way of initiating increased trust in supply chain relationships. Sierra (2013) ascertained that in the process of greening suppliers, providing suppliers with incentives is an important approach to the improvement of firm performance. Some studies report the results of misaligned incentives. For example, Narayanan and Raman (2004) reveal that misaligned incentives are the main cause of excess inventory, incorrect forecasts, and poor customer service. Voigt (2014) claimed that credible information-sharing cannot be established if misaligned incentives exist. In addition, Lee and Whang (2004) argued that a well-designed mechanism is needed to align incentives across the supply chain; this should enable chain members to commensurately share gains in terms of their investment and risk. Simatupang and Sridharan (2005) suggested that pay-for-effort and pay-for-performance are two major reward mechanisms.

In initiating CCR-SC, firms often estimate whether they can achieve incentive alignment by assessing the congruence of goals. Incentive alignment can only be built on the basis of identical goals among members in order to achieve shared objectives. Goal congruence is referred to "the extent to which firms perceive the possibility of common goal accomplishment" (Lejeune and Yakova, 2005, p.18). Goal congruence can enable firms to interact synchronously (Angeles and Nath, 2001) and reduce the incentives for opportunism. It is identified as an estimator when calculating the degree of alignment throughout the supply chain. Goal congruence is in conjunction with trust

and information sharing, a low rate of exchange of information will result in behaviour invisibility and thus lead to an absence of goal congruence.

Lejeune and Yakova (2005) considered that the degree of goal congruence varied and assumed it to have three levels, namely absence of congruence, moderate goal congruence, and true goal congruence. In the first two levels, goal congruence is weak or even non-existent in the supply chain. The deficiency of goal congruence can be attributed to an inadequate formulation of supply chain incentives (Narayanan and Raman, 2004). In the context of collaborative supply chains, Lejeune and Yakova (2005) also noted that goal congruence is weak to moderate, mainly because the trust in the collaborative supply chain is limited to its openness component. In the third level, i.e. true goal congruence, firms believe that they can achieve their goals by working simultaneously towards the objectives of the whole supply chain.

Collaborative carbon reduction in supply chains (CCR-SC)

CCE-SC has been recognized as an effective way for supply chain members to reduce carbon reduction. For example, Theißen *et al*. (2014) identified collaborative carbon reduction management as offering firms the ability to establish unique value-added processes through organizational boundaries that better match customer needs. Based on observation and investigation, many researchers support the view that collaboration is a more advanced approach in environmental management. Seuring and Müller (2008) emphasized that cooperation between buyers and suppliers is the only way to achieve an environment-oriented supply chain. Sustainable practices such as carbon reduction require the participation of all members in the supply chain. Chiou *et al*. (2011) suggested firms solve environmental problems by building a close relationship with their supply chain partners and creating competitive advantages through innovative environmental products. Through joint efforts in the supply chain, firms can simultaneously minimize carbon emissions and climate impacts, reduce waste and energy costs, meet the standards set by policy-makers and improve corporate reputations. To be specific, this includes the process of sharing data, knowledge, assets and other resources related to carbon reduction.

In addition, prior studies also ascertained that CCR-SC is more effective than enforcement under legal compliance, and more likely to produce benefits such as improved public reputation (Sundarakani *et al*., 2010). Carballo-Penela *et al*. (2017) demonstrated the effectiveness of CCR-SC through the measurement of carbon footprints. The results of their study show that the lack of mandatory legislation for measuring carbon footprints leads to an unsuccessful CCR-SC. Giurco and Petrie (2007) found that many opportunities for carbon reduction at the supply chain level have been ignored, since most of them focus on the organizational level. To better understand the environmental impacts of products and increase environmental performance, Sharfman *et al*. (2009) suggested that it is crucial for firms to conduct CCR-SC across supply chains.

Conceptual development and hypothesis development

Incentive alignment and CCR-SC

Many studies have classified incentive alignment as an important dimension of supply chain collaboration (Simatupang and Sridharan, 2005; Cao *et al*., 2010; Cao and Zhang, 2011). In order to be effective, an incentive alignment mechanism needs to be designed to correlate overall and partial performance, enabling members to consciously make individual decisions under the overall profit target, thus ensuring the successful implementation of the project (Hinkka *et al*., 2013; Chen and Lee, 2017).

Chen and Lee (2017) found that a well-defined incentive contract design can effectively avoid incentive misalignment by constructing a two-level supply chain game model. Drawing on the viewpoint on trust, Harland (2004) argued that incentive alignment is a sufficient guarantee for supply chain collaboration and commitment while minimizing the opportunism of members. Simatupang and Sridharan (2008) demonstrated that the effective implementation of incentive alignment can increase the enthusiasm and productivity of supply chain members and create value and benefit for the entire chain. Gunasekaran *et al*. (2015) highlighted the importance of incentives for green supply chain collaboration.

As such, this study argues that incentive alignment ensures the equitable sharing of costs, risks, and benefits, increases trust in the supply chain, and effectively avoids misalignment and opportunism. This should make companies willing to trust their partners and participate in initiating CCR-SC. Therefore, the first hypothesis in this study is as follows:

H1: Incentive alignment is positively related to CCR-SC.

Goal congruence and incentive alignment

Goal congruence encourages companies to implement incentive alignment to ensure that their members continue to move in the same direction and avoid misalignment. It requires a degree of mutual understanding and consistency in terms of a firm's attributes, values, beliefs, and practices, which is strongly linked to the scheme of incentive alignment. According to Theißen *et al*. (2014), the first step when building an effective partnership in supply chains is setting a consistent goal. Lambert *et al*. (1999) argued that supply chain members should reach an agreement on the management of goals and the key processes to be employed in supporting them. Inconsistent goals can lead to an unreasonable division of work among members, thus reducing efficiency and leading to incentive misalignment. Rossetti and Choi (2008) maintained that incentives work as an intermediation of goal congruence and buyers should consider aligning goals through incentives with their partners. Samaddar *et al*. (2006) stated that, in the absence of common goals, firms have no incentive to participate in activities such as information-sharing or supply chain collaborations. To a large extent, incentive alignment requires a high degree of information sharing. Governance mechanisms such as goal congruence can mitigate opportunism in incentive alignment. The greater the goal congruence between firms, the greater the strategic nature of their work, and the closer their incentive alignment.

Congruence can lead members to coordinate with each other under the guidance of an overall goal that contributes to the efficiency of incentive alignment. This study therefore argues that goal congruence is an important enabler of incentive alignment if firms are to initiate CCR-SC, hence the following hypothesis:

H2: Goal congruence is positively related to incentive alignment.

CCR-SC and firm performance

Bowersox (1990) pointed out that collaboration can bring economies of scale to firms whilst simultaneously reducing costs and increasing profits. Vargo and Lusch (2004) emphasized the importance of collaboration for a firm's business strategy and considered collaboration to be a source of competitive advantage. Cao and Zhang (2011) noted that partnerships can increase profits and reduce risk. Effective supply chain collaboration can reduce conflicts and uncertainties, resulting in collaborative advantages and better financial performance. Kalwani and Narayandas (1995) agreed that a long-term collaborative relationship is a unique resource that enables companies

to achieve a higher profit. From a relational perspective, Priem and Swink (2012) elaborated that supply chain relationships between suppliers and buyers can be viewed as intangible resources for value creation. In general, the higher the level of supply chain collaboration, the better the firm's financial performance. In addition, supply chain collaboration can increase the efficiency of operations management, allowing companies to better respond to market opportunities.

In the context of environment-oriented supply chains, collaboration is also recognized as an effective approach for improving firm performance. For example, some studies have clarified that strategic collaboration among supply chain members allows firms to move beyond organizational boundaries and find new ways to reduce environmental management costs, thereby improving environmental performance (for example Giurco and Petrie, 2007; Theißen *et al*., 2014). The results of their study confirmed the positive effect of CCR-SC on firms' performance.

In addition, there is a correlation between environmental performance and financial performance. Carbon reduction has been observed to improve a firm's environmental performance, which in return strengthens the firm's financial performance. For example, a reduction of transportation costs in the firm's logistics will also enhance its financial performance. Previous studies have shown that sustainable management practices, especially supply chain collaboration, contribute to the financial performance of firms (Hollos *et al*., 2012). On one hand, improving environmental performance can reduce costs and waste, improve resource utilization and operational efficiency, and further improve financial performance. On the other hand, improving environmental performance helps to increase corporate social responsibility and reputation, leading to a growth in market share.

CCR-SC allows firms to obtain economies of scale through resources and knowledge-sharing, both internally and externally. Firms can gain competitive advantages and reduce costs whilst simultaneously improving their environmental performance and financial performance. Thus, three hypotheses were formulated:

H3: CCR-SC is positively related to a firm's financial performance.

H4: CCR-SC is positively related to a firm's environmental performance.

H5: A firm's environmental performance is positively related to its financial performance.

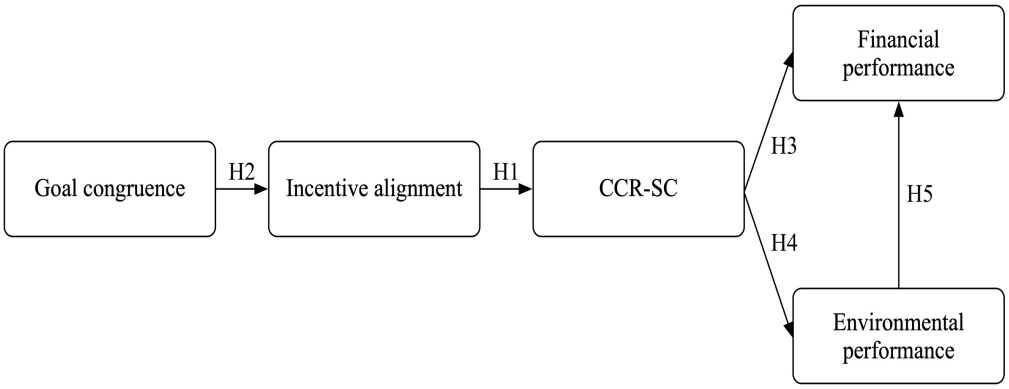

Figure 1- Research framework of incentive alignment in CCR-SC

Instrument development

Item generation

To achieve the content validity of constructs when generating items, a critical review of the relevant literature, such as research streams regarding CCR-SC (Theißen *et al*., 2014) and green SCM (Doran and Ryan, 2014) was carried out. After consulting with both academic and industrial experts, 32 measurement items were created for five constructs, namely, CCR-SC, incentive alignment, goal congruence, financial performance and environmental performance. A 5-point Likert scale was used to indicate the extent to which managers agree or disagree with each statement (1=strongly disagree, 2=disagree, 3 = neutral, 4 = agree, and 5 = strongly agree).

Sampling design and data collection

A data sample was collected from 900 Chinese companies engaged in SCM and operations. An online survey was used to administer the delivery of the questionnaire. After eliminating invalid questionnaires with blanks and deletions, 120 valid samples were obtained with a response rate of 13.3%.

The target respondents of this study were middle and senior managers in the company, particularly those involved in SCM practices. The sample respondents were expected to have a comprehensive acknowledge of collaborative and carbon reduction management in supply chains.

The non-response bias of samples was examined using the method recommended by Armstrong and Overton (1977). After comparing those responses returned early (80) with those returned late (40), the result of t-test shows there was no significant difference between early samples and late samples when randomly selecting samples, which means that non-response bias is not a problem with a 95% confident interval.

Table1- Respondents' profile

Type of owner ship		Number of employees		Firm size (million yuan)	
State-owned enterprise	27	<100	14	<5	13
Private company	61	100-200	10	5-10	5
Joint Venture	14	200-500	22	10-20	6
Foreign-funded enterprise	18	>500	74	20-50	12
				50-100	9
				>100	75
	120		120		120

Data analysis and research results

Reliability and validity analysis

In terms of the creation of measurement items, Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were employed to assess the reliability and validity of the scales developed. The indicators used for assessment include Cronbach's α, normalized factor loading, composite reliability (CR) and average variance extracted (AVE). All indicators were significant at $p<0.01$, and all five constructs identified exhibited acceptable fit. The results demonstrated that the model fit indices meet the recommended criteria. Cronbach's α has a minimum number of 0.821 and a maximum of 0.952; all have alphas greater than 0.70 and are therefore considered reliable. Discriminant validity was tested using the approach recommended by Fornell and Larcker (1981); that is, the AVE of each construct is higher than the shared variances between each of the constructs, as shown in Table 2. Overall, the results show that the scales used had good reliability and validity.

Table2- Exploratory and Confirmatory Factor Analysis

Constructs	Items	Factor loading	CR	Cronbach's α	AVE
Incentive alignment	SCIA-1. Co-develop systems to evaluate and publicise each other's performance	0.776	0.887	0.885	0.611
	SCIA-2. Share cost among supply chain partners	0.752			
	SCIA-3. Share benefits among supply chain partners	0.808			
	SCIA-4. Share risks among supply chain partners	0.782			
	SCIA-5. Have incentives commensurate with investment and risk	0.788			
Goal congruence	SCGC-1. Agree on supply chain goals	0.821	0.903	0.902	0.652
	SCGC-2. Agree on supply chain collaboration	0.867			
	SCGC-3. Recognize the importance of improving overall interest of the supply chain	0.802			
	SCGC-4. Agree to achieve personal goals and satisfy the requirements of the supply chain at the same time	0.795			
	SCGC-5. Collaborate to develop plans in order to achieve supply chain goals	0.747			
CCR-SC	CCR-SC-1. Develop carbon reduction plans in conjunction with supply chain partners	0.843	0.947	0.952	0.783
	CCR-SC-2. Share carbon reduction technology with supply chain partners.	0.870			
	CCR-SC-3. Joint procurement of carbon reduction equipment with supply chain partners	0.887			
	CCR-SC-4. Work with supply chain partners to achieve common goals for reducing carbon emissions	0.906			
	CCR-SC-5. Collaborate with supply chain partners to develop carbon reduction methods	0.915			
Financial performance	SCFP-1. Increase in sales revenue	0.875	0.939	0.945	0.721
	SCFP-2. Increase in net profit	0.875			
	SCFP-3. Decrease in total cost	0.817			
	SCFP-4. Increase in return on investment (ROI)	0.860			
	SCFP-5. Increase in market share	0.859			
	SCFP-6. Increase in market competitive position	0.807			
Environmental performance	SCEP-1. Reduce emissions	0.860	0.931	0.927	0.728
	SCEP-2. Reduce effluent emissions	0.898			
	SCEP-3. Reduce solid waste emissions	0.869			
	SCEP-4. Reduce the use of dangerous, toxic, hazardous materials	0.814			
	SCEP-5. Reduce energy cost	0.823			

Results of hypothesis tests

To test the hypotheses proposed in this research framework, structural equation modelling (SEM) was used to assess the model fit with the data. The path coefficients

for the SEM model were shown in Table 3. The fit indices for the model were χ^2 = 495.035, df = 293, normed = 1.690, CFI = 0.926, IFI = 0.927, RMSEA = 0.076, indicating that the model was of good fit.

The results of the hypothesis tests were shown in Table 3. The path coefficient was 0.34 and was statistically significant at the level of 0.001, which supports Hypothesis 1. This result showed that incentive alignment was significant and positively related with CCR-SC. Hypothesis 2 was also supported with a path coefficient of 0.64, which was statistically significant at the level of 0.001. The finding indicated that goal congruence was positively related to incentive alignment. Hypotheses 3, 4 and 5 were also supported.

Table 3 - Results of hypothesis testing

Hypothesis	Path	Path coefficient	p-value	t-value	Results
H1	SCIA→CCR-SC	0.34	< 0.001	3.427	Support
H2	SCGC→SCIA	0.64	< 0.001	6.082	Support
H3	CCR-SC→SCFP	0.58	< 0.001	5.814	Support
H4	CCR-SC→SCEP	0.57	< 0.001	6.232	Support
H5	SCEP→SCFP	0.22	0.016	2.417	Support

Conclusion and limitation

The present study provides an empirical analysis of the antecedents and consequences of incentive alignment in the setting of CCR-SC, a topic that has been under-researched in previous studies. It verifies the enabling role of incentive alignment to CCR-SC and its antecedent, namely, goal congruence. The resulting CCR-SC can however affect environmental and financial performance. From a research perspective, this study advances empirical investigation in the research areas of low-carbon SCM and supply chain collaboration. From a practical perspective, this study is of interest to managers involved in initiating CCR-SC. As shown by the empirical analysis, managers should collaborate with their supply chain partners, developing common goals and designing aligned incentives, in order to ensure that CCR-SC has a positive effect.

While the research has made significant contributions to the existing literature, there are still limitations that need to be avoided in future study. First, because of the difficulty of data collection, the sample size used in this paper was relatively small. Future research could increase the sample size in order to improve the effectiveness of reliability and validity. Furthermore, this research is based on questionnaire data, which means that the conclusion might reflect the current status of firms, although environmental management practices are dynamic under sustainable development. Future research should consider using a longitudinal study in order to incorporate the changing dynamics of CCR-SC.

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Understanding trade-offs among sustainability pillars through triangulation

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Abstract

Profit is the primary objective that every company aims to achieve but, in pursuing it, a company can no longer afford to overlook two aspects, i.e., social and environmental, closely connected to the economic dimension. Scholars are trying to understand what link exists among these three aspects. However, to date researchers have achieved inconsistent results regarding the impact of Corporate Social Responibility (CSR) on Corporate Financial Performance (CFP). This article aims to explore, through a quantitative analysis, the CSR-CFP relationship, namely, to analyze how CSR actions influence a company's profitability and if the industry is a relevant contingency to consider.

Keywords: Sustainability, Corporate Social Responsibility, Sustainability reporting

Introduction

Corporate social responsibility (CSR) intrinsically entails to take actions towards the simultaneous achievement of the three pillars of sustainability, or, in other words, of the triple bottom line (Elkington, 1998). In fact, CSR has been defined as "context-specific organizational actions and policies that take into account stakeholders' expectations and the triple bottom line of economic, social, and environmental performance" (Aguinis, 2011). Over the years, multiple attempts have been done in order to test the actual relationships existing among the pillars. As an example, Aupperle et al. (1985) summarize various efforts made between 70s and 80s to examine the relationship between CSR and profitability. Moreover, the authors found evidence of a negative relationship between the economic component of sustainability and non-economic ones, as well as, the companies tendency to consider the non-economic components altogether (Aupperle et al., 1985). Other authors focused their studies on the relationship between CSR and financial performance, finding inconsistent results (McWilliams & Siegel, 2000). Although, Orlitzky et al. (2003), by integrating previous researches through a meta-analysis that allowed to compare studies in an objective way, concluded that a positive association between Corporate Social Performance (CSP) and financial ones exists. In this context, a big challenge is linked to how to measure CSP. Chatterji et al. (2009) found

evidence that environmental and social ratings might not reflect the actual companies' behavior, when it comes to environmental and social practices. Companies themselves are struggling in measuring their environmental and social performance. Even if some standards to measure environmental (e.g. ISO 14000, ISO 140001, ISO 14031) and social (e.g. SA8000, ISO 26000) performance exist, none of them provide benchmarks about acceptable performance (Hubbard, 2009). To complicate this picture, also multiple CSR reporting standards have been developed, all using different measures and practices. Some examples are Global Reporting Initiative (GRI), UN Global Compact and AccountAbility's AA1000 standard (Chen & Bouvain, 2009). Consequently, the analysis of the relationships among the three pillars becomes challenging, making it extremely important to clearly define context of analysis, as well as to triangulate information from multiple sources.

Related literature

Over the decades, the topic of CSR has been a central research topic for many scholars and authors that have contributed to creating a real scientific, business-economic debate not only at national level but also an international one. This interest has continued to grow in importance and significance (Carroll & Shabana, 2010). The basic tenet of corporate social responsibility is that society and business are tightly interwoven but scholars are still trying to understand the precise mechanisms behind this link (Wood, 2010).

Nowadays companies have high pressure to be greener. An increasing number of shareholders, analysts, regulators, activists, labor unions, employees, community organizations, and news media are asking companies to be accountable for an everchanging set of CSR issues (McWilliams et al., 2000).

Regarding the definition and measurement of CFP, no significant problems are found in the literature. The indicators used to measure financial performance in studies investigating the relationship between CFP and CSP are generally of two type: accounting-based indicators (indicators derived from accounting data, such as ROE, ROA, ROI) (Aupperle et al., 1985; Margolis, Elfenbein, & Walsh, 2009; Tsoutsoura, 2004) and market-based measures (market indicators, such as the share price) (Moskowitz, 1972).

Instead, Wood (1991, p. 691) defines the CSP as "*the configuration in the business organization of principles of social responsibility, processes of response to social requirements, and policies, programs and tangible results that reflect the company's relations with society".*

Indeed, CSP is a very complex system, and therefore its measurement requires equally complex tools, and despite three decades of research, there are no consistent metrics for measuring CSP (Mitnick, 2000; Peloza, 2009). In the literature, there are dozens of metrics that manager and researchers used to analyze CSP. Many scholars have used those indicators that embrace more than one dimension of CSP, for which, therefore, it is not possible to accurately identify principles, processes, and results (e.g. McWilliams & Siegel, 2000; Tsoutsoura, 2004). In addition, despite social and environmental rating agencies seek to make corporations' environmental data more transparent (Peloza, 2009), many companies are still skeptical in publishing sensitive data and relevant information. Nevertheless, we must emphasize how new sources are becoming increasingly available for researchers including standards and data (Wood, 2010).

Academia has so far focused on the relationship between CSP and CFP to have empirical results able to demonstrate whether socially responsible behaviors are recommended (i.e., improve financial performance) or not. CSR supporters intend to prove that CSR has positive impacts for the company that is reflected directly on the

bottom line (Ambec & Lanoie, 2008; Flammer, 2015; Margolis et al., 2009; Surroca, Tribó, & Waddock, 2010). Opponents, on the other hand, want to show that CSR is expensive and goes beyond the legitimate interests of the company unless there is a direct and studied strategic connection between responsible behavior and profits (Barnett & Salomon, 2006; Bromiley & Marcus, 1989; Frooman, 1997). According to Wood (2010), this inconclusiveness is primarily due to difficulty on the measurement on how the social policies examined directly influence firms' bottom lines (Russo & Fouts, 1997).

In conclusion, we can say that there is no convincing evidence that the CSR is too expensive; the majority of the evidence leads to the opposite: for companies, it is costly to be socially irresponsible (Wood, 2010). In fact, analyzing the results of the literature, it appears that the most recent studies are showing that there is a positive correlation between the CSR-CSP (Ambec & Lanoie, 2008; Flammer, 2015; Margolis et al., 2009; Surroca et al., 2010). This recent result could be connected to the fact that companies today are called to be more transparent about social and environmental aspects.

Literature gaps and research questions

The relationship between CSP and CFP is a thorny topic much debated in the literature. Besides, the analysis of the literature has shown that it has not been identified yet whether there is a relationship between the CSR and CFP and the direction of this relationship. Researchers have tried to understand how the CSR initiatives influence the economic indicator, but also how financial performance has consequences on CSR. The relationship between CSR and profitability could be seen as a two-way association. In this context, gaining a better understanding over the causal relationship between CSP and CFP and its direction is an urgent gap to fill.

Therefore, this article seeks to address the following dual research question:

- RQ1a: *Do CSR's activities (environmental and social) have an impact on the company's CFP?*
- RQ1b: *Do CFP has an impact on the company's CSR's activities (environmental and social)?*

In addition, we believe industry to be a relevant contingent variable when it comes to assessing the relationship between CSR and CFP. In fact, many articles dealing with the topic of sustainability build on a multi-industry approach and find in the industry a relevant contingent factor to base the discussion of results on (Ciliberti, De Haan, De Groot, & Pontrandolfo, 2011; Formentini & Taticchi, 2016; Schneider, Marcus Wallenburg, & Fabel, 2014). As a consequence, in this article we aim to explore a second research question:

- RQ2: *Does industry is a relevant contingent variable to consider when studying the CSR-CFP relationship?*

Figure 1 displays the model framing the research.

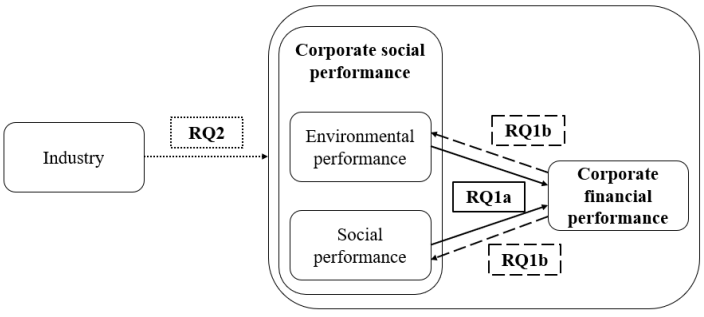

Figure 1 - Research model

Methodology

Sample

Within the international and national scenario, various forms of social reporting have been developed, thanks to the work of institutions and companies, trying to standardize the reporting formula, in order to avoid falling into self-referentiality (Chen & Bouvain, 2009). Among the various initiatives that aim to define the guidelines for a reporting tool that also includes sustainability issues, the one considered most relevant has been promoted by the multi-stakeholder process of the Global Reporting Initiative (GRI) (Global Reporting Initiative, 2019). Consequently, the sample of firms for this study was drawn from the Global Reporting Initiative (GRI)'s list of corporations. Firms that have published their social report respecting the guidelines developed by the GRI in the time frame from 2010 to 2016 were selected. This choice of this time frame is due to the fact that some data presented in the sustainability reports were not clearly shown in previous years when the theme of sustainability was still not widespread within companies. Moreover, for greater consistency of data, the dataset include data ranging from 2010 to 2016, so that the trend effect over time is taken into account.

According to the numbers of available companies, three industries were selected in order to explore the second research question: automotive, hardware technologies, and telecommunication. The final sample include 64 large (with more than 500 employees) companies with data along the selected timeframe. Table 1 report a summary of the sample.

Measures

Corporate financial performance

From the study of the literature, the most used indicators to correlate the relationship between CSR and CFP are: Return on Equity (ROE), Share Price, Return on Asset (ROA) and Return on Investment (ROI). CFP data were retrieved from Thomson Reuters's EIKON Database (Financial performance) and Orbis Bureau Van Dijk's Database (Balance sheet data).

Table 1 reports the detail of the four variables in terms of mean and standard deviation across industries. In order to have normal distributions all the variables were log-transformed.

Table 1 - Summary statistics of CFP variables

Variable	# Obs	Mean	SD
Automotive			
ROE	150	14.27	11.52
ROA	150	5.27	3.78
ROI	148	8.15	5.81
Share Price	152	46.95	61.44
Hardware technology			
ROE	176	7.17	27.23
ROA	180	5.25	7.97
ROI	179	6.64	12.11
Share Price	196	35.35	51.94
Telecommunication			
ROE	139	13.27	8.06
ROA	151	6.59	4.14
ROI	151	8.70	5.74
Share Price	152	42.10	99.66

Environmental performance

The measures of environmental performance were obtained through a content analysis of the reports published by the companies along the analysed timeframe. Content analysis is a method of codifying written text into various groups or categories, so as to be able to compare texts (Krippendorff, 2018; Unerman, 2000). For that reason, the collection of such data was a part of a long process because companies, despite the directives published by the GRI, released different indicators with different units of measurement.

Therefore, in order to obtain more homogeneous and comparable data for each sector, we decided to use four measures for environmental performance derived from the reports and one measure derived from Environmental, Social and Governance (ESG) module accessible in Thomson Reuters's EIKON Database. Table 2 reports the summary statistics of the variables by industry. The four variables derived from the report (CO2, Waste, Water and Energy) were normalized with respect to the net sales of the companies, thus assuming that emissions and consumptions are proportional to the amount of output produced by a company. Instead the variable derived from EIKON (Environmental) was measured as a total environmental performance as the sum of the single indicators reported in EIKON (Resource use, emissions and innovation). For all the variables high values indicate worst environmental performance. To reach a better shape of the distributions all the variables were log-transformed.

Table 2 - Summary statistics of environmental performance variables

Variable	# Obs	Min	Max	Mean	SD
Automotive					
CO2/Net sales [Tons/$]	149	0.00	0.14	0.03	0.03
Waste/Net sales [Tons/$]	145	0.00	0.10	0.08	0.14
Water/Net sales [m^3/$]	123	0.00	0.89	0.18	0.15
Energy/Net sales [GJ/$]	132	0.00	1.28	0.34	0.29
Environmental	174	3	30	8.89	4.16
Hardware technology					
CO2/Net sales [Tons/$]	167	0.01	0.68	0.10	0.14
Waste/Net sales [Tons/$]	166	0.00	0.02	0.01	0.00
Water/Net sales [m^3/$]	165	0.03	4.39	0.91	1.07
Energy/Net sales [GJ/$]	160	0.11	2.98	0.81	0.72
Environmental	160	3	22	9.10	4.47
Telecommunication					
CO2/Net sales [Tons/$]	143	0.01	0.14	0.04	0.03
Waste/Net sales [Tons/$]	132	0.00	0.00	0.00	0.00
Water/Net sales [m^3/$]	137	0.01	0.35	0.07	0.08
Energy/Net sales [GJ/$]	140	0.00	1.92	0.41	0.38
Environmental	189	4	28	9.30	3.86

Social performance

Regarding the social performance, we realized that the content analysis of the social reports was not suitable in order to retrieve comparable information about the companies. The measures of social performance were thus obtained from the EIKON database. In particular, both the elementary indicators (Workforce, Human Rights, Community and Product Responsibility) and the sum of the scores (Social) were used in the analysis. Table 3 reports the summary statistics of the variables by industry. For all the variables high values indicate worst social performance. The elementary indicators were not transformed in the analysis, since they were already showing a normal shape, instead the summary score was log-transformed.

Table 3 - Summary statistics of social performance variables

Variable	# Obs	Min	Max	Mean	SD
Automotive					
Workforce	174	1	11	3.34	2.17
Human Rights	174	1	10	4.16	2.82
Community	174	0	12	4.70	3.46
Product Responsibility	174	1	10	2.56	1.81
Social	174	4	40	14.39	7.84
Hardware technology					
Workforce	167	1	8	2.60	1.72
Human Rights	167	1	9	3.44	2.30
Community	167	1	11	3.49	2.44
Product Responsibility	167	1	9	3.02	2.15
Social	167	4	31	12.56	5.19
Telecommunication					
Workforce	189	1	9	3.11	1.83
Human Rights	189	1	9	2.88	1.86
Community	189	1	11	3.83	2.75
Product Responsibility	189	1	10	3.19	1.97
Social	189	4	29	13.02	5.18

Analysis

To answer to the research questions time-series cross-sectional data regression analyses were carried out. First, the non-stationarity of the time series was checked with the Dickey-Fuller test (Dickey & Fuller, 1979). Moreover, the Hausman test to check the suitability of a model with fixed effects against a model with random effects was performed (Hausman, 1978); the more consistent model with fixed effects was selected for all the analyses. The analysis of correlograms allowed us to select a one-year lag as the most suitable to explain the data. Finally, we relaxed the hypothesis of identically distributed errors by clustering the observations according to the company they belong to. In order to capture the variables direct effect, we adopted a hierarchical linear regression model, by adding variables in subsequent models. Moreover, the analyses were replicated in the three industries analysed, in order to assess the industry effect.

Results

The structure of the data allowed us to test causality among the variables. Particularly, we tested both directions of the relationships, as reported in Figure 1. Table 4 reports the results of the models with CFP as dependent variables, and environmental and social performance as independent variables. In all the models, we added the logarithm of the number of employees as control variable and run separate analyses for each industry.

Table 4 - Results of the regression analyses of CSP on CFP

	Automotive			
	ROE (t)	**ROA (t)**	**ROI (t)**	**Share price (t)**
Employees				+ (***)
Environmental (t)				Water + (**) Energy - (*)
Social (t)	Social + (*)	Social + (*)	Social + (*)	
Financial (t-1)		ROA + (*)	ROI + (**)	Share price + (*)
Environmental (t-1)	*Environmental + (**)*	*Environmental + (**)*	*Environmental + (**)*	
Social (t-1)	*Workforce + (***)*	*Workforce + (**)*	*Workforce + (**)*	

	Community - (*) *Social + (**)*	*Social + (**)*	*Social + (**)*	
Hardware technologies				
	ROE (t)	**ROA (t)**	**ROI (t)**	**Share price (t)**
Employees				
Environmental (t)	Energy - (**)	CO2 + (*) Energy - (**)	CO2 + (*) Energy - (**)	
Social (t)				Human rights - (**)
Financial (t-1)				Share price + (***)
Environmental (t-1)	*Water + (***)* *Waste - (*)*	*Water + (***)* *Waste - (**)*	*Water + (***)* *Waste - (**)*	*Water + (***)*
Social (t-1)	*Workforce - (*)*			
Telecommunication				
	ROE (t)	**ROA (t)**	**ROI (t)**	**Share price (t)**
Employees				
Environmental (t)	Environmental – (**)			
Social (t)				Product responsibility - (**)
Financial (t-1)				Share price + (***)
Environmental (t-1)	*Water - (**)* *Energy - (**)*	*Water - (*)* *Energy - (*)*	*CO2 - (*)*	
Social (t-1)		*Community + (**)*	*Community + (*)*	

Generally, the results highlight a significant relationship between the environmental performance and CFP. The relationship is different depending on the environmental indicator considered. For some indicators (e.g. environmental in case of automotive, water in case of hardware technologist) the results show that an increase of the environmental indicators, that corresponds to a worse environmental performance, imply an increase in CFP. Instead. other indicators (e.g. waste in case of hardware technologies, water and energy in case of telecommunication) are characterized by the opposite relationship: better environmental performance means better CFP.

Concerning the social indicators, few results are significant and generally better social performance means worst CFP (e.g. in case of automotive).

In order to assess the direction of the relationship between CSP and CFP we performed the analyses also in the other direction. Table 5 and 6 report the results of the models with environmental and social performance as dependent variables, and CFP as independent variables. In all the models, we added the logarithm of the number of employees as control variable.

Table 5 - Results of the regression analyses of CFP on Environmental performance

Automotive					
	CO2	**Waste**	**Water**	**Energy**	**Environmental**
Employees	- (***)		- (***)		
Financial (t)	Price - (**)	ROE - (**)		Price - (**)	
Financial (t-1)	*Price - (**)*	*ROE - (*)*		*Price - (**)*	*ROA - (***)* *ROI - (***)*
Environmental (t-1)					Environmental + (***)
Hardware technologies					
	CO2	**Waste**	**Water**	**Energy**	**Environmental**
Employees		+ (***)	+ (*)	+ (***)	
Financial (t)	ROI + (*)			Price - (*) ROA - (*) ROI - (*)	
Financial (t-1)	*Price - (*)*				*ROA - (*)* *ROI - (*)*

Environmental (t-1)	CO2 + (***)		Water + (***)	Energy + (***)	Environmental + (***)
Telecommunication					
	CO2	**Waste**	**Water**	**Energy**	**Environmental**
Employees					
Financial (t)				Price - (*) ROA - (*) ROI - (*)	ROE - (**)
Financial (t-1)				*Price - (*)*	
Environmental (t-1)	CO2 + (***)	Waste + (***)	Water + (***)	Energy + (***)	Environmental + (***)

Concerning the environmental indicators, the results interestingly show that, in general, a negative relationship exists among CFP and environmental indicators. This result is stronger when considering CFP measured at the same time as the environmental indicators for the telecommunication industry. Instead, it is stronger when considering CFP measured with one-year lag with respect to the environmental indicators for the automotive industry. The hardware technology industry instead shows mixed results.

Table 6 - Results of the regression analyses of CFP on Social performance

Automotive					
	Workforce	**Human rights**	**Community**	**Product responsibility**	**Social**
Employees					
Financial (t)	Price + (**)				ROA + (**) ROI + (**)
Financial (t-1)					
Social (t-1)	Workforce + (***)	Human rights + (***)		Product responsibility + (***)	Social + (***)
Hardware technologies					
	Workforce	**Human rights**	**Community**	**Product responsibility**	**Social**
Employees			- (**)		
Financial (t)		Price - (**)			
Financial (t-1)					
Social (t-1)		Human rights + (**)	Community + (***)	Product responsibility + (**)	Social + (***)
Telecommunication					
	Workforce	**Human rights**	**Community**	**Product responsibility**	**Social**
Employees					
Financial (t)				Price - (**)	
Financial (t-1)	*Price + (*)*		*Price - (**)*	*ROE - (**)*	
Social (t-1)	Workforce + (***)	Human rights + (***)	Community + (***)	Product responsibility + (***)	Social + (***)

Concerning the social indicators, few significant results are present. The telecommunication industry seems to benefit the most form better CFP, when deciding to invest on social sustainability.

Having conducted the analysis on three different industry allows to answer to the second research questions, by concluding that the results about the previously analysed relationship are context dependent.

Discussion and conclusions

The relationship between CSR and CFP has been extensively explored in literature. Even if the latest research defines that a positive relationship exists (Flammer, 2015; Margolis et al., 2009; Surroca et al., 2010), the review of the literature showed that the analysis conducted by the scholars engendered varying and mixed results (Wood, 2010).

The results of the analyses allowed to answer to the three research questions of this study. First, through the analysis of time-series cross-sectional data we were able to test causality between CSP and CFP. Concerning environmental performance, we found significant causal relationships in all the industries, but with different environmental indicators being significant and with different signs according to the industry under analysis. By looking at the relationship in the opposite direction, usually different environmental indicators, with respect to the ones identified in the previous direction, are significantly affected by CFP. The most interesting result is that the relationships from CFP to environmental performance are usually negative, meaning that companies with better CFP are more prone to invest also in environmental sustainability, even if it may not pay. Concerning social performance, we found few significant causal relationships, with most of them being from the automotive industry. This industry is generally characterized by the association between better social performance and worst CFP. By looking the relationship in the opposite direction, the casual relationship between CFP and social performance seems to exist only in the telecommunication industry, in which better CFP supports a reduction in the community and product responsibility indicators, but a worsening of the workforce indicator. In summary, the results support the bidirectionality of the relationship between CSP and CFP identified in literature, but this study takes a step further by highlighting that the relationship is beneficial when developed from CFP to CSP (negative relationships), while the opposite is not always true (positive relationships). This represent a major implication for companies, that have better to become first solid from a financial point of view and then start investing on CSR, in order to enlarge the company strategy to embrace also the environmental and social dimensions. In addition, from the analyses it has emerged that the relationships differ among the industries chosen and analyzed, thus answering to the second research question. This generates a warning for companies aiming to move towards full sustainability, given that the context in which they operate strongly affect the benefits they can obtain. Joint efforts should be carried out by companies within industries with similar characteristics in order to accelerate the path towards complete sustainability. Policy makers will play a critical role in supporting this kind of efforts.

In conclusion, this research contributes to bring evidence about the relationships among CSP and CFP, by relying on multiple data sources from which information was retrieved about companies' effort towards sustainability. In addition, both qualitative and quantitative indicators to measure sustainability are defined in this study, thus leading the way for future analyses in different contexts and on a wider scale, allowing to overcome the main limitations of this study.

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Sustainable supply chains in Latin America: cocoa production in Ecuador

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Abstract

Sustainability in supply chains around the world have an increased importance due to the complex systems involved in different geographical regions. Sustainable supply chain management (SSCM) literature was reviewed along with the Base of Pyramid (BoP) and Triple Bottom Line (TBL) approaches. It is noticed that several factors remain understudied when it comes to Latin America, as the agricultural practices and traditions, cultural influence, geographical and climatic aspects, and institutional considerations. Two cases in the cocoa production industry in Ecuador were compared analysing their drivers and challenges for sustainability and, their strategies used for sustainable supply chain management.

Keywords: sustainable supply chain, Latin America, cocoa production

Introduction

Sustainable Supply Chain Management (SSCM) research in the bottom of the pyramid markets (Prahalad, 2012) had been developed in few developing countries. Authors have claimed that Latin America as a region is an important contributor to the global economy and thus deserves more scholarly attention because its rich potential source of data for research (Martínez and Kalliny, 2012).

Sustainable supply chain management in Latin America should be studied beyond the triple bottom line (Fritz and Silva, 2018) because of various reasons that limit companies to develop stronger business models and supply chains, e.g., the lack of infrastructure, poverty and security issues, local conditions, routines and institutions (Blanco and Paiva, 2014; Fritz and Silva, 2018). In particular, the study of SSCM in Latin America, and specifically in the Andean Region, is relevant given its cultural background that involves traditions influenced by climate conditions, history and social interactions and routines (Fritz and Silva, 2018). According to Fritz and Silva (2018), in Latin America the main motives for SSCM are innovation, risk management, trust, power, working conditions, traditions and culture, among others, which are overall similar for developed countries except for how to manage trust and power, traditions and culture. Considering that Ecuador, counts with up to 98% of micro and small companies (INEC, 2016), their approach for sustainability is expected to differ to the traditional view.

The study analyzes the cocoa production and transformation in Ecuador considering companies that produces chocolate bars in different configurations, with certified or non-

certified cocoa, and address different consumption markets. Hence, the aims in this study are i) to identify the main sustainability issues, challenges and competitive advantages for applying SSCM in the cocoa production in Ecuador, and ii) to identify the possible SSCM strategies that companies apply in this sector, in this country. The paper is organized as follows: the research background is set around sustainability and supply chain management, in particular in Latin America and the bottom of the pyramid sectors. Afterwards, the research questions and methodology are presented, followed by the cases description and analysis; finally, the discussion and conclusions.

Research Background

Sustainability and SDGS

A big start to develop the sustainability subject was the World Committee in Environment and Development in 1987 where the Brundtland report was published and the urge to consider sustainable ways of production and consumption to preserve natural resources for next generations was proposed (WCED, 1987). The 2030 Agenda for Sustainable Development provides the Sustainable Development Goals (SDGs), which are a call for action by all countries to contribute in a global partnership to tackle climate change through strategies that spur economic growth and reduce inequality (UN, 2015). In relation with our study, the SDGs that are considered in cocoa production are 1. No poverty, 2. Zero hunger, 8. Decent work and economic growth, 9. Industry, innovation and infrastructure, 12. Responsible consumption and production, 16. Peace, Justice and Strong Institutions, and finally number 17. Partnerships for the goals.

The Brundtland report brought into consideration corporative strategies such as Corporate Social Responsibility policies (CSR) and the Triple Bottom Line (TBL). In one hand CSR is defined by the World Business Council for Sustainable Development (WBCSD) as the *"continuing commitment by business to contribute to economic development while improving the quality of life of the workforce and their families as well as of the community and society at large"* (WBCSD, 1998). In particular, the food and beverage manufacturing sector face similar challenges concerning sustainability, food security, ethical sourcing of raw material, and increasing demand for healthier products. Firms in the food-manufacturing sector also face issues within CSR like responsible use of natural resources, responsible usage of energy and water, as well as labor standards and supply chain management (Puggioni and Stefanou, 2019). The shared view about economic strategies in business recommend that sustainable development approaches and CSR should be considered to ensure a balance between natural resources reserves, economic growth and social progress (Pirnea et al., 2011).

In the other hand, the Triple Bottom Line (TBL) considers the economic, environmental and social factors explored to obtain sustainability in business. When it comes to sustainable business practices, the economic factor is always important, the environmental factor is generally important, and the social factor is important at some extend. The TBL framework helps firms as a guide to plan, implement and follow-up corporate considerations (priority and importance) of the longitudinal aspects of sustainable business practices (Høgevold et al., 2019).

Furthermore, new concepts and methodologies have arisen regarding sustainability implementation. According to Visser (2015), system change is a multiplayer game that includes issues such as Safety and Social issues (S2), Quality issues (Qu), Environmental, Economic and Ethical issues (E3), Labour issues (L), Carbon or Climate issues (C), and finally Health and Human rights issues (H2) called by the author as SQuELCH issues. Creating integrated value (CIV) aims to help a company to integrate governance practices and value chain linkages applying life-cycle thinking.

Sustainability and SCM studies

Sustainable Supply Chain Management (SSCM) was defined by Seuring and Müller (2008) as, *"the management of materials, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social into account which are derived from customer and stakeholder requirements. In sustainable supply chains, environmental and social criteria need to be fulfilled by the members of the networks to remain within the supply chain, while it is expected that competitiveness would be maintained through meeting customer needs and related economic criteria"* (Seuring and Müller, 2008, p.1700). These processes of innovation in SSCM are, however, important due to the considerable impact showed as sustainable practices and because of the complex intra-firm challenges (Koster et al., 2017). In the other hand, poverty alleviation is still a main subject to tackle through rural development. The environmental and social crisis can be addressed by community engagement with their skills in managing resources, larger farmers dominate the best agricultural land and small farmers take control of more fragile lands.

Sustainability change agents from developing and developed countries seek to contribute to sustainable development; however, most of the studies are Eurocentric when it comes to sustainable practices according to Demssie et al. (2019). Nonetheless, a base of the pyramid context (BoP) refers to socioeconomic characteristics of mainly developing countries including some common characteristics as rural population, limited infrastructure and low per capita income (Demssie et al., 2019) remain understudied.

Following some literature review from the base of the pyramid (BoP), Prahalad (2012) refer to it as the bottom tier of the world income pyramid where most of the people live in moderate and extreme poverty. Furthermore, Hahn (2009) suggests a holistic view that embraces poor communities as a main part of international supply chains and productive processes. Consequently, Gold et al. (2013) analysed food projects in the BoP as an option to achieve sustainable supply chain management (SSCM) and as a path to TBL approaches for organizations worldwide. Authors exemplified that multinationals like Danone, BASF and Nestlé provided cooperation through education, technical assistance, implementation of Good Agricultural Practices, and, training to conduct quality checks. These initiatives resulted in a combination of SSCM and BoP focused on the double bottom line (social and economic) and it could be transferred to other regions of the world or business fields (Gold et al., 2013).

Sustainability studies in Latin America

According to Jabbour and Jabbour (2014) when it comes to address sustainable development it is important to consider the region of study and the social and environmental aspects involved to understand the possible opportunities and restrictions in management. The authors propose a wide opportunity of research in Latin America since it has similar problems as other regions in the world such as the role of government, CO_2 emissions control, generation of clean energy, institutional economic, social and environmental issues and changes.

The authors Blanco and Paiva (2014) mention how the Latin American region is underrepresented in SCS research and therefore the opportunity of addressing relevant issues in the region. Latin America is considered a diverse place due to the geographical aspects, different cultures, highly urbanised populations and climates. Even though Latin America is a potential market to develop, the search for sustainable supply chain management must include businesses and academics in the region willing to leverage the

future growth of Latin America (Blanco and Paiva, 2014). The two additional elements to study in sustainable supply chains, according to Fritz and Silva (2018) are cultural and institutional. The former refers to local traditions that could influence the meaning of sustainability in the region. The latter implies the political environment that could foster or prevent sustainable practices in the region.

Hence, the need for further information in Latin America, since most of the literature about sustainability in the supply chain, about cocoa production refers to regions in Africa, Asia, and mainly in Brazil, as part of South America, call for research in the region. For instance, other producing countries as Ecuador, that is in the top 10 world cacao producers according to FAO statistics (FAO, 2019), have specific characteristics that could determine its approach to sustainability. Agricultural practices, land use for agricultural production, dependence on agriculture as main income for economic and social development, smallholders' size, sustainable management of natural resources, population growth, and access to technology, among others are features that could shape the strategies that companies deploy for growth and sustainability.

Research questions and method

In line with Fritz and Silva (2018), our study intends to contribute to supply chain sustainability (SCS) theory and practice by including local characteristics in the analysis of sustainability in food industry beyond the triple bottom line. Hence, our study aims at understanding how sustainability is approached in this industry in Ecuador, given the special production characteristics, challenges and opportunities, and identifying the benefits and challenges of implementing sustainability –beyond the triple bottom line-. Moreover, considering that regional specificities draw the SCS strategies in Latin America, according to Fritz and Silva (2018), our study aims at identifying the strategies that companies in Ecuador, in the cocoa production and transformation, are applying for managing their supply chains while considering sustainability as part of it. Thus, the research questions in this study are:

RQ1. What are the main sustainability issues and challenges in the SSCM in the cocoa production in Ecuador, and how they contrast with the traditional SSCM view?

RQ2. What are the possible strategies of sustainable SCM in the in the cocoa production in Ecuador?

Research Methodology

Considering the most recent academic research developed in Latin America (Jabbour and Jabbour, 2014, Fritz and Silva, 2018) in the topic of sustainability in supply chains, we identified the main areas, methodologies, objectives and industries covered in previous contributions. Following, our study analyzes two cases dealing with cocoa transformation and production in Ecuador, a country in the Andean Region. As Martínez and Kalliny (2012) mentioned, the case study methodology represents a complementary perspective for research in Latin America. The authors explain how case studies could address complex phenomena and provide in-depth and inductive understanding in the region (Eisenhardt, 1989; Eisenhardt and Graebner, 2007; as cited in Martínez and Kalliny, 2012). The analysis is performed first within case and then cross-case with the goal of finding commonalities and differences that shape each one´s strategy for sustainability.

Findings

Cocoa production, transformation and trade

Cocoa chains are globalized and complex and their concern for sustainability extends from the producing regions or origin to the consumption stages. Africa is the main

producer, accounting for around 65% of the bean's world production, while the European Union is the world's leading grinder (ICCO, 2018a). Approximately 2/3 of world production is exported in the form of beans, with almost 1/3 being exported in the form of cocoa products (liquor, butter, cake or powder) (ICCO, 2018b). Farmers with an average of 3 Ha, and average production of 350 Kg /Ha mostly produce cocoa. Around 14 million workers in the world depend on cocoa production (FAO, 2010; Vorley and Fox, 2004). Cocoa tree varieties produce two bean categories: fine of flavour, and bulk. The ICCO defines *fine or flavour* cocoa as the category coming from tree varieties with specific genetic and morphological characteristics that produces beans with especial aroma and flavour (ICCO, 2017). From all the cocoa world production, 5% is fine cocoa (ICCO, 2017). The bulky or ordinary is the most produced cocoa bean in the world (ICCO, 2018a; ICCO, 2018b).

Once harvested, the cocoa beans go through two main processes: fermentation and drying, and, bagging and delivery. Quality control or grading is applied to a random sample before shipping, and after delivery. Cocoa trade associations and national authorities establish the type of test to be performed. Trading and shipping can happen in two kind of markets, physical and futures (ICCO, 2018a; ICCO, 2018b). Cocoa market liberalization resulted in new market structures: increase dominance of national trade networks by multinationals (intra-firm trade), and, few opportunities have emerged for smallholders to upgrade to higher value 'buyer-driven' cocoa chains (ICCO, 2018b; Vorley and Fox, 2004).

Hence, the cocoa supply chain is wide and complex due to the structure and characteristics of the main agricultural producers in Africa, Asia and the Americas, combined with the features of the cocoa manufacturers in Europe and Northern America (ICCO, 2018b; ICCO, 2016). In the upstream, cocoa bean production represents an important income for developing countries around South America, Asia and Oceania, according to the FAO (FAO, 2019). The World Cocoa Foundation announced that more than 90% of the world´s production of cocoa comes from small producers and it generates dependence on crop production for their livelihood of approximately 50 million people (World Cocoa Foundation, 2013). In the downstream, SSCM strategies had been applied in North America and Europe, where 70% of the top 10 chocolatiers belong to these regions according to the ICCO (2016).

Cocoa industry in Ecuador

Ecuador is said to be the largest fine or flavoured cocoa producer and exporter in the world (Ecuador and chocolate, s.d) and is in the top 10 world cacao producers according to FAO statistics (FAO, 2019). Cocoa production in Ecuador is dedicated up to 75% production to the fine or flavour category (ICCO, 2017; Anecacao, 2015). Its geographical location and biological resources favour fine cocoa production with its high level of purity and special flavour and aroma.

The cocoa production and export have been fundamental in the country´s economic development since before the Europeans arrived and colonized the continent, representing today up to 700 million dollars industry (Anecacao, s.d; Ecuador and chocolate, s.d). In the 16th century, as Spanish colony, the cocoa production in Ecuador flourished and was recognized for its quality and aromas. In the late 19th century, Ecuador becomes the first exporter in terms of volumes thanks to its soil and temperatures that favoured especially the ´National´ variety. Pest and diseases at the beginning of the 20th century gravely reduced production to the lowest levels in history. Moreover, lack of transport means and international market difficulties due to the World War I, caused the Ecuadorian economy crisis and instability (Anecacao, s.d.)

In the National Development Plan of Ecuador (2017) for the year 2021 the aim is to shift from being a country that mainly extracts resources to be a local producer of finished goods, in this case, cocoa that becomes chocolate. According to the National Secretary of Development and Planning of Ecuador (SENPLADES, 2017), sustainable practices are mainly supported due to the objective of managing natural resources in a responsible way, creation of win-win situations, and increased value through alliances with local suppliers to achieve local development. The increasing demand for fine chocolate beans means there is a potential chance for growth, thus, cocoa provides an alternative production for small-scale farmers threatened by food insecurity and climate change (FAO, 2018). Hence, in the last years, the industry is moving toward an adding value strategy and several local brands have focused on producing with ´fine or flavour´ cocoa and exporting chocolate bars to the main North American and European markets (Ecuador and chocolate, s.d).

Case 1: Chocolate manufacturer

This company is a non-profit organization producing mainly food (but also small handcrafted objects) founded in the 70's. Today the company merges 60 cooperatives and associations and it is based a small town located in the Ecuadorian Andes. Profits are reinvested in public works as roads, building improvements and infrastructures. These positive actions have reduced the migration phenomenon and led to a balanced social and economic growth in the respect of the environment.

Case 1 produces mainly food products using Ecuadorian raw material as cocoa, nougat or cheese. Cocoa is only a segment of their production (5-8% of sales) but focusing on that, the key partners are the cocoa cooperative in Esmeraldas province producing the cocoa and the logistics provider for the export, even if most of the customers are domestic. About export, the company has few relationships, in France and Japan, and these customers share the commitment to fair trade. The plant is also organic certified for the European standards. They work mainly in a make-to-order configuration with both national and international customers. Key activities in cocoa processing are the chocolate manufacturing and commercialization, managed by their 'export centre' that manages also the customers' relationships. Distribution channels are mainly focus in national markets, while in export are the customers that resell the products. Case 1 produces high quality organic products.

The company complies with all the regulations and requirements of the organic certification by keeping records and visiting the farms. For Case 1, law, regulations, and transparency are the main drivers for traceability. The company is also devoted to highlight the quality of the product and the commitment to the promotion of local Ecuadorian products. Instead, barriers for traceability are the setup costs and documentation associated to the organic certification that requires dedicated processing in the production line other than long cleaning and preparation. Besides, the cost of the certification itself that is very expensive for the business it represents.

Specifically, about sustainability, the company´s commitment to social development is its main axe of action. First, the company buys cocoa beans at a higher price than the stocks, in order to guarantee supply and safeguard the environment, but also for helping better quality of life in the communities. Additionally, the company supports the local community through helping senior and handicapped citizens, collaborating with the social welfare ministry, supporting education and provides housing and food. Case 1 is also a religious foundation and they support to develop new leaders in the community. The foundation works also with women associations for the handicrafts and textile industries, working to help them organize and define a line of production. In this way, women can

identify and develop their products, giving them the possibility of an income that is also a way of emancipation.

These company values and top management commitment is the basis of Case 1´s business strategy, for which to continue the social work, the products selling, and export are to be developed. Instead, the barriers are the costs, complexity and effort, because of the multitude of projects absorb many resources and time to be implemented as well as the cost certification, and low domestic demand for certified products.

Case 2: Coffee roaster and chocolate manufacturer

This company was created by the merge of two family businesses. The main operations in the company are chocolate manufacturing and coffee roasting. The company is based in Quito and is completely committed to high quality Ecuadorian chocolate (*Nacional*) and specialty coffee, all organic certified. With cocoa, they process the green beans brought up to the production plant into different varieties of chocolate bars. The brands are growing in visibility, in the local and international markets. For export, the company got the organic certification for the European and US markets. The only own point of sale is in Quito for smaller or private customers buying directly. Larger customers, as supermarket chains, require direct delivery. The company have their own small fleet for that. On-line sales are the third channel.

About traceability, the company controls every shipment and makes sure all the documentation regarding certification and origin is compiled. This documental traceability system allows the company to demonstrate the "from bean to bar" philosophy. Traceability for Case 2 is complex because ensuring organic origin for all the ingredients is challenging and costly. This is also a limitation for product innovation and new product development, and only the compliant ingredients are blended in exported products. Therefore, drivers for traceability are law and regulation compliance, quality. Barriers are instead the cost of the certification, most of the time not attractive for farmers, and documentation and formalities.

The company values are grounded in sustainability and collaboration and are supported by top management commitment. For the upstream chain, the company pays higher prices than the price stated by the government. For Case 2, it is not a matter of beating competition, but of loyalty and trust. In addition, it is a strategic choice because the company does not have the competencies to work the land; therefore, it needs to create strong, close and loyal relationships with suppliers. This, however, entails some challenges as higher costs, and a complexity and effort in managing numerous close supplier relationship, and the effort to motivate suppliers to be certified. This is accompanied by low domestic demand for certified products that create a strong barrier for the company.

Discussion

Sustainability drivers and barriers in the cases studied

For answering the first research question, the coding for the cases' analysis was based on the constructs proposed in previous literature regarding the drivers for sustainability. Regulations and stakeholder pressures, company´ social and environmental concern (company values), green image and reputation and top management commitment, economic benefits and collaboration (Walker et al. 2008; León-Bravo et al. 2018; Bloemhof et al. 2015) are commonly cited. From the cross-case analysis, it was noticed that the cases shared some reasoning when developing sustainability initiatives or projects. Similarly, both cases reported commonalities that restrain their sustainability adoption, as cost, complexity for implementing sustainability and adopting certifications,

difficulty to locate the product in the market expecting premium prices, e.g. low domestic demand for certified products (FAO, 2010, León- Bravo et al. 2018, Bloemhof et al. 2015, Fritz and Silva, 2018).

Although the drivers and barriers for sustainability observed in the Ecuadorian cases are somewhat aligned with previous literature (Walker et al. 2008; Bloemhof et al. 2015), they also provide some insights pointing at a wider consideration of sustainability in the cocoa production and transformation in Ecuador. Drivers as "export potential" and "collaboration" delve into the need for understanding first, the probability of achieving business opportunities abroad if sustainability is part of their activities. Such probability depends as well on the current institutional structure that may or may not facilitate expanding operations to a more adding value manufacturing strategy, facilitate access to exporting procedures and actually perceive economic gains from exporting. Second, collaboration in our cases meant to build closer relationships mainly with suppliers, either for ensuring quality and quantity of supply, or for being a part of the social and economic development in the cocoa growing areas. In turn, this could enhance the brand image in the local and international markets.

Similarly, the barriers for sustainability observed in our cases are in line with previous literature (Walker et al. 2008; FAO, 2010; FAO, 2018), they also reflect the specific cultural, social and geographical characteristics of the cocoa production in Ecuador. For instance, being the local market small and the international difficult to access, sustainability results costly to implement and indeed not worthy. Even though the cocoa quality is renowned, companies feel compelled to adopt certifications in order to access markets that could appreciate the effort and pay higher prices.

Strategies for SSCM in the cases studied

Building on Fritz and Silva (2018) framework that called for including the regional specificities in sustainable supply chain research, the cases analyzed here suggest the adoption of different SCS strategies than the traditional triple bottom line. Case 1 prioritizes its attention to the social problems and institutional complexities affecting the communities when deciding its business strategies and sustainability activities. Moreover, the focus on the local market preferences, the company opted for engaging the community, highlight the cultural and social value of its product, empowering and integrating the community. On the other hand, Case 2, being a for-profit company, prioritize its economic development leveraging on the institutional needs for farmers to count with a structured buying scheme that keep prices constant and appreciate the beans quality. In addition, Case 2 differentiates the product for national and international markets considering consumer preferences including local ingredients connected with the national traditions, which in turn as in Case 1 promote local development.

Therefore, the initiatives, projects and practices implemented in these Ecuadorian cases as their SSCM strategies can be shaped within the Fritz and Silva (2018) five-star framework. Case 1 considers the institutional, social and cultural angles as priorities for sustainability; while Case 2 takes into account the economic, cultural and institutional ones (See Figure 1). The SSCM strategies in these Ecuadorian cases are also in line with the *double bottom line,* i.e., economic and social, that should be prioritized in bottom of the pyramid markets as Gold et al. (2013) explained.

Conclusion

This study intends to contribute to literature on two main streams. On one side to sustainability management in developing countries, given the scarce research in the Latin America, specifically in the Andean region. This study provides empirical evidence about

the particularities, drivers and barriers that characterize sustainability understanding and implementation in the cocoa production and transformation industry in Ecuador. On the other side, this study investigates how cocoa producers in Ecuador deal with stakeholder expectations for sustainability in the local and international markets and shape their strategies according to the specific context characteristics (Figure 1). Similarly, findings in this study could be interesting for practitioners to identify the possible strategies of sustainable SCM in the Andean region, in the cocoa production industry. As pointed in literature and evidenced in the cases in our study, sustainability in Latin American companies encompasses institutional and cultural aspects along with the traditional triple bottom line and are still understudied. Hence, future research in this topic could also study intermediate actors in the chain as traders and logistic carriers, or enlarge the sample with buying companies in other geographies that have an established sustainability strategy that could contrast the ones in the supplying markets, to include companies dealing with non-certified crops. Other avenues of research could also involve the access to technological and financial tools for developing sustainability in the region.

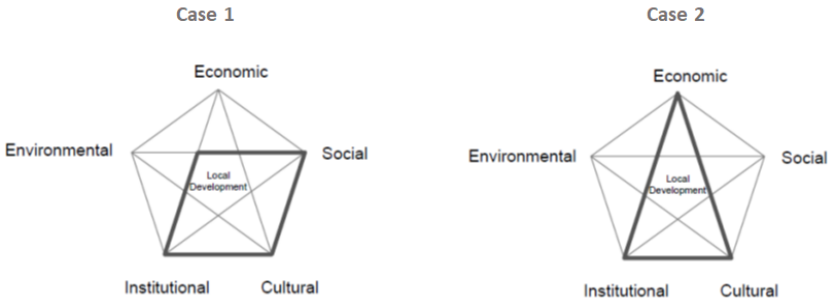

Figure 1 – SSCM strategies derived in the Ecuadorian cocoa cases

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Traceability for sustainability in the coffee industry

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Abstract
Traceability can serve multiple goals in the food industry. This study focuses on the coffee supply chain, which is globally dispersed and in which different traceability solutions respond to the need of mandatory and voluntary quality standards, certifications of origin, but they also create the ground to report on sustainability related practices and performance. By analyzing 10 case studies at different stages of the coffee supply chain, this study provides a taxonomy of the traceability systems and investigates *how* these systems are implemented, i.e. technological solutions, information width and depth, as well as the relationship with sustainable value creation.

Keywords: traceability, sustainability, coffee industry

Introduction
Consumers around the world increasingly demand for food that is not only safe but also ethical, organic, generates low carbon footprint, etc., which in turn calls for better and more efficient traceability systems (Dabbene et al., 2014). Nonetheless, traceability requires substantial investments in technology and processes aimed at tracking goods along the supply chain. Cost is still proving to be a difficult barrier to overcome (Norton et al., 2014; Kuit and Waarts, 2014; International Trade Centre, 2015), especially in the first production phases (Dabbene et al., 2014; International Trade Centre, 2015). On the other hand, the benefits of traceability could be spread along food supply chains (Dabbene et al., 2014): for managing risks, keeping consistency and market specific product features, efficient recall procedures, keeping a chain of custody (Norton et al., 2014; International Trade Centre, 2015; Karlsen et al. 2013). Traceability helps to achieve operational efficiencies, cost reductions, increased productivity and reputational benefits (Norton et al., 2014; Karlsen et al. 2013; Stranieri et al. 2017). In particular, traceability for sustainability in food chains can be a tool to guarantee products features, e.g., origin, quality, respect for people and environment, all along the supply chain (Norton et al., 2014; Kuit and Waarts, 2014).

In this vein, traceability can represent an interesting mean to "reduce the information distance", typical of a global supply chain. Coffee supply chain represents an interesting and challenging context in these regards. Coffee industry employs millions of farmers throughout the tropical and subtropical regions of the globe (DeFries et al, 2017). As means to gain control of the more remote activities in their value chains, different traceability solutions are emerging in this context. In addition to the standard voluntary certification schemes developed in the industry (i.e. Fairtrade, UTZ and Rainforest Alliance), some well-known coffee roasters in the western economies have developed their private certification initiatives (Alvarez et al., 2010; Longoni and Luzzini, 2016). Current debate in the literature questions whether these forms of traceability systems are driven by quality or sustainability needs and goals (Garcia-Torres et al., 2019). Moreover, other technological options could serve the same scope, allowing also to shorten the information distance in a supply chain that typically expands globally.

In light of these considerations, the objectives in this study are i) to identify the traceability systems implemented by different actors along the coffee supply chain, and, ii) to analyse how traceability systems are related with the achievement of sustainability goals in the coffee industry. This study analyses multiple cases covering different stages in the coffee supply chain. Companies are located in different geographical areas, allowing for a broader view of traceability and sustainability implications.

The paper is organized as follows: in the next section, the research goal and design are reported; then the methodology is described. Following, it illustrates the main findings of the cross-case analysis and then conclusions end the paper.

Conceptual Background

Traceability in commodity chains

Food quality and safety are expected from food supply chains and they could be ensured through traceability (Dabbene et al., 2014; Karlsen et al. 2013). Several definitions of traceability are proposed. For instance, the Food and Agriculture Organization (FAO) defines traceability as "the ability to follow the movement of a food through specified stage(s) of production, processing and distribution" (Codex Alimentarius, 2006). In Europe, a definition of traceability in agri-food supply chains is stated as "the ability to trace and follow a food, feed, food producing animal or substance intended to be, or expected to be incorporated into a food or feed, through all the stages of production, processing and distribution" (European Commission, 2002). Other organizations as the International Trade Centre, the International Organization for Standardization also offer their definitions considering identification, tracing and tracking.

Traceability systems (TS) provide information on the components, parts, and materials as well as information on product transformations throughout the value chain. TS ensure the accuracy of information, such as product quality, safety and labelling (Norton et al. 2014). According to the International Trade Centre (2015), the key components of traceability systems are the identification of units, the registration of information and the system linking and sharing information. In addition, according to McEntire at al. (2010) and as cited by Stranieri et al. (2017), four elements characterize the level of traceability: breath (number of attributes), depth (how far upstream or downstream in the supply chain), precision (how accurately is the attribute characterized) and access (how fast a supply chain member can visualize the tracking and traced information).

The information gathered through traceability systems has huge potentials in efficiency gains (Costa, et al., 2013), food process control and, quality and identity preservation (Dabbene et al., 2014; Smith, 2018). In particular, traceability for sustainability in food supply chains addresses diverse challenges due to company

capabilities, skills, interest and willingness and, multiple requirements are needed for implementation (International Trade Centre, 2015). Indeed, only a very small percentage of food commodities are traceable on sustainability attributes (Norton et al., 2014; Kuit and Waarts, 2014), maybe because of its barriers: often suppliers are dispersed in the world, language, legal or technology barriers exists (Norton et al., 2014).

Certification schemes became popular as traceability systems addressing a wide range of attributes, among which sustainability. Certifications on agri-food commodities have become particularly important given an increased stakeholder pressure (Rajeev et al., 2017; Kolk, 2012; Reinecke et al., 2012) among which also governments have progressively increased their attention (Vermeulen and Kok, 2012). DeFries et al. (2017) identified four main reasons why commodities, as coffee, are focused of certification schemes. These reasons are: low state-level governance opening the development of certification standards by private sector and NGOs, poverty in the producing regions where farmers deal with low prices and climate change issues, the need for habitat conservation, and the effects on trade in global supply chains (DeFries et al., 2017; United Nations, 2015). The authors also highlight the recognition of premium prices, as consumers "will only be willing to pay more if they trust the certifying entity to achieve positive impacts" (DeFries et al., 2017)

Coffee certification schemes as traceability systems for sustainability are varied in their scope, premium prices paid and requirements. The most known certification schemes in this industry are Fairtrade that focuses on social elements; Rainforest Alliance that fosters ecosystem and biodiversity preservation; the Organic certification; UTZ certification that is specialized in coffee and cocoa, and focuses on traceability. Currently, UTZ and Rainforest Alliance are merging and they announced a completion of a single standard by the end of 2019 (Utz, s.d.).

Sustainability in the coffee industry

Latin America is the main coffee producer region, particularly Brazil. Two main species are recognized, Arabica and Robusta (ICO, 2017). The quality criteria is related to the altitude/region, rain feed or irrigation, species or varieties, processing method (wet or dry), bean size, density, shape and colour, number of imperfections, roast and appearance (ICO, 2017). Half of the world's coffee supply comes from small farms with less than 5Ha (ICO, 2017; Vorley and Fox, 2004).

Commodity chains, as coffee, are said to be important contributors to global greenhouse gas (GHG) emissions, from food production (and its inputs) through food processing, food distribution and consumption, to the disposal of waste (FAO, 2010). Processing, trading, transport, roasting, packaging, retailing, brewing, serving, etc., have also important contribution to emissions, communities' well-being and employment (FAO, 2010; ICO, 2017).

Particularly the upstream actors face sustainability challenges as they deal with several constraints and restrictions. For instance, regarding economic development: price volatility, lack of long-term contracts and spot transactions that create a huge uncertainty for farmers and cooperatives, limited access to credits or financial aid, side selling for solving short-term liquidity problems (Ortiz-Miranda et al., 2015; Luna and Wilson, 2015). Instead, in the environmental side, farmers struggle with pest and diseases and the need of using pesticides and fertilizers (Ntiamoah and Afrane, 2008), climate change i.e., rising temperatures and rainfall variability, decrease yield, reduce quality as well (Ovalle-Rivera et al., 2015). These economic and environmental challenges are in turn closely related to the social development in the producing regions (Vorley and Fox, 2004; Pay, 2009; Winston et al., 2005).

Coffee industry employs millions of farmers from whose sales often represent a significant portion of export. Coffee prices are determined in the futures markets. Selling far ahead is considerably risky (Pay, 2009). Low prices are driving poverty, ill health, unemployment, lack of education and forced migration, and a risk of increasing crop diversification (Pay, 2009; Winston et al., 2005). Besides, farmers in producing regions face lack of technical competences for specialty or organic production that require specific agronomic knowledge to improve yields and quality (Ovalle-Rivera et al., 2015).

On the buying side the demand is strong in many countries, particularly in North America, Europe and Japan; but the biggest potential is in emerging markets and coffee exporting countries, e.g., Brazil, Indonesia, India and Mexico (ICO, 2019; Pay, 2009). Mature markets as Europe and North America observe a higher preference for specialty coffee (ICO, 2019; Pay, 2009; Reinecke et al., 2012) for which buyers pay premium prices. In the downstream, buyers are motivated to deploy sustainability initiatives mainly by external drivers i.e., to face competition, due to legal requirement and policies, because of stakeholder expectations as NGOs, important suppliers or local communities (Emamisaleh et al., 2017; Karlsen et al. 2013).

Research questions

As explained by Karlsen et al. (2013), in the supply chain management field, traceability is an issue when dealing with risk management, supplier management, logistics and distribution. In consequence, implementation of traceability systems is increasingly appealing for companies in search of efficiencies, consistency, differentiation, and for ensuring customers the product features they expect (Norton et al., 2014; International Trade Centre, 2015; Karlsen et al. 2013). Furthermore, in many companies, traceability is implemented as a tool to assure and verify sustainability on commodity chains; however, only a very small percentage of commodities are traceable on sustainability attributes (Kuit and Waarts, 2014; Norton et al., 2014).

Specifically, traceability for sustainability, as defined by Garcia-Torres et al. (2019) is the "ability to combine SC information sharing and visibility […] for operational reasons and to ensure the reliability of sustainability claims". The authors stress the need for managing capabilities that enhance better performance in SCs and allow sustainability goals to be implemented and evaluated (Garcia-Torres et al. 2019). Companies that invest on increased transparency and traceability could have a competitive advantage and reputational benefits through traceability systems that demonstrate a commitment to sustainability (Norton et al. 2014; International Trade Centre, 2015). However, the implementation of traceability systems along multiple tiers of the supply chain is still to be studied in commodity´s industry where actors are spread around the world, have different capabilities and interests for sustainability. Hence, the research questions addressed in this study are the following:

RQ1: What are the traceability systems implemented in the coffee industry?

RQ2: How are traceability and sustainability related in the coffee industry?

4. Methodology

This study is based on multiple exploratory case studies selected standing on their overall strategy for sustainability reflected in their mission, vision, communication, awards winning, etc. Furthermore, the set of cases are companies of different sizes, belong to different supply chain stages in different geographical locations. In addition, a certification entity is included as well (See Table 1). Multiple cases are chosen per supply chain tier aiming at more robust findings following a replication logic (Yin, 2009) and for grasping the heterogeneous behaviours along the chain.

Data collection and analysis

Data is collected by means of semi-structured interviews, visits to production plants and from secondary sources, ensuring validity and reliability (Yin, 2009). Interviews lasted between 60 and 120 minutes, with follow-ups via email or by phone when needed. Multiple researchers performed the interviews outlined in three parts:

- General business aspects: company characteristics (size, product lines, markets), business model and relationships with other supply chain actors
- Sustainability: sustainability practices implemented, drivers and barriers, the role of certification, if available
- Traceability: traceability systems in use, drivers and barriers, and future perspective toward new traceability systems

Table 1 – Cases analysed in this study

Company	Location	Product	Role in the SC
A	Italy	Coffee	Artisan roaster
B	Italy	Coffee and chocolate	Retailer and distributor
C	Italy	Tropical commodities	Certification entity
D	Germany	All	Logistic carrier
E	Ecuador	Coffee and chocolate	Roaster and exporter (Chocolate manufacturer)
F	Italy	Coffee	Roaster
G	Italy	All	Retailer
H	Italy	Coffee	Artisan roaster
I	Switzerland	Coffee	Trader
J	Italy	Coffee	Roaster

The coding was performed for all the companies interviewed, then the cross-case analysis per SC tier and finally at supply chain level.

5. Findings

In light of the primary evidences collected from the cases, we were able to identify and describe different traceability systems adopted by different actors along the coffee supply chain. Traceability systems can be distinguished on the basis of three key dimensions. In the following subsection we present first, the three type traceability solutions detected from our case studies, considering the systems adopted for *tracing* the information as well as the technological solutions adopted for *trasmitting* the traced information to the customers (e.g. a QR code positioned on the packaging). Following, we present the different ways of implementing the traceability systems. Finally, we describe the relationship between sustainability and traceability.

Traceability systems

Option 1 - Simple documental traceability: in this scenario, the product along the supply chain is tracked thanks to the registration of transportation documents and invoices at the different tiers of the coffee supply chain. This kind of essential information is then reported on the product packaging. For instance, Case H (roaster) relies on HACCP standard for the internal traceability and on the documentation released by suppliers, i.e. transportation documents and invoices.

Option 2 - Advanced documental traceability: these types of solutions rely on private database systems. This is the case of companies (e.g., Case G, Case I) that relied on

certified purchases guaranteed by the certification entities (e.g. Organic, Fairtrade, Rainforest Alliance, Utz). Thus, along with the simple documental traceability, the goods are tracked and monitored also in the ledger of certification entities that authorize the use of the label. The information is transmitted to the end customer through the packaging, including not only mandatory information but also the certification labels. This is complemented by extensive information reported on the website and about processing methods and sustainability initiatives, if present. Case I (trader) and case G (retailer) demand traceability to the certification entities that are in control of the certified product in their ledgers. Case C is a certification entity itself and adopts a system that enable certified companies to connect and communicate with each other, report and verify certified volumes.

Option 3 - Integrated platform: this system allows the different actors in the supply chain tiers to register and upload information on the traced product. The administrator of the platform regulates information visibility to the other actors and controls how information is managed. The only case in the sample which adopts this type of system, i.e. Blockchain system, is Case A. This technological option allows to a have complete set of information through a QR code that reaches the end customer. In Case A, by reading the QR code, consumers are directed to the company website in which the "journey" of the product as well as additional information about certifications and sustainability practices is available.

Implementing different traceability systems

Traceability systems adopted by the companies in the sample can be distinguished also on the basis of the information *width* and *depth*. Information width refers to different types of information that are traced. In addition to some mandatory information of product origin, ingredients and nutritional value, the traced data include quality and safety certifications as well as sustainability practices. Information depth refers instead to: how much upstream the supply chain the different traceability solutions allowed tracing, and at which granularity level. This is, traceability is possible at country, region, cooperative (i.e. organized group of farmers) or individual farmer level. In terms of granularity, traceability systems can be applied to all products (all the different product variants that are offered by the company) or to just some variants. Table 2 shows the 10 case studies classified according to the abovementioned dimensions.

Relationship between traceability and sustainability

The companies under investigation explained that they do not necessarily look at traceability and sustainability together. Sustainability and traceability are considered important but they are usually managed separately. Traceability is mainly required by law and regulations compliance. Whereas, sustainability is driven by company values and commitment. It was interesting to note that no company in our study considered sustainability as traceability driver, or vice versa.

Nevertheless, there are cases which leverage on forms of *Advanced documental traceability (Option 2)* as the certifications, to implement sustainability practices in the coffee countries of origin. Sustainability practices are required to third parties, i.e. the certification entities, who guarantee not only origin but also sustainability. The three mostly adopted certifications in the coffee industry and which have dedicated traceability solutions are: Fairtrade system (managed by FLOCERT) and the so-called "Chain of Custody" for Rainforest Alliance and Utz. The respective third-parties (i.e. Fairtrade, Rainforest Alliance, and Utz) guarantee that sustainable practices are carried out with

certified producers. In the cases of our sample adopting these type of certifications (i.e. Case G and I) traceability coincides with sustainability.

Table 2 – Classification of companies in the sample in terms of traceability systems, information width and information depth

	Traceability systems			Information width			Information depth	
Case	**Option 1**	**Option 2**	**Option 3**	**Origin/ ingredients/ nutritional value**	**Certification/ quality/ safety**	**Sustainability practices**	**How in depth upstream?**	**Granularity level**
A			X (with QR code)	X	X	X	Region	Few products
B		X (with QR code.)		X	X	X	Producer	All products
C		X		X	X	X	Producer	All products
I		X		X	X	X	Cooperative/ region	All products
E		X		X	X	X	Country	All products
F		X		X	X	X	Producer/cooperative (with reference to Brazil and Colombia)	All products
D		X		X	X		Producer	All products
G		X		X	X		N/A (demanded to certification entities)	All products
J	X			X	X		Country	All products
H	X			X			Region	All products

Case A instead adopts an integrated platform (i.e. *Option 3*) as the main traceability solution. This technology, which brings information depth at its utmost, enables Case A to report to consumers also the different sustainability practices implemented in the origin countries.

Interestingly, Case F is the only company within the sample that holds no certifications. This is a precise choice made by Case F managers who believe that the certification schemes available for the coffee industry are too much focused on quality. Thus, the company develops its own certification scheme, validated by a neutral international accredited registrar and classification society. The proprietary certification scheme is grounded on four main pillars: ethic, social sustainability, economic sustainability and environmental sustainability. Upstream in the supply chain, in origin countries this certification entails a path to quality and sustainability merged together. The main practices include direct purchases (or as much direct as possible, depending on

the geographical region), growers' selection, training and motivation, right price for high quality coffee and the creation of sound relationships with producers that are developing a high quality culture. Therefore, this means: investment plans for local grower's communities (e.g. schooling facilities, sanitation), investments to sustain integrated sustainable agriculture (and not organic or conventional agriculture) that offers benefits both for people and environment. All these practices are structured in the proprietary certification scheme, which represent a pivotal condition for the implementation of sustainability practices in Case F.

In these three cases (Case G and I, Case A, Case F), traceability appears therefore to be *synergistic* with sustainability.

The approach adopted by Case J is different. The company purchases from traders a share of organic certified coffee, but at the same time develops sustainability activities in almost all the countries where the traders source from, adopting a multiple stakeholders approach collaborating with NGOs, other roasters, local communities and traders as well. However, the company is not able to link its efforts on sustainability with traceability: no initiative is able to provide enough coffee to make a distinct product line and thus to make any specific sustainability claim over a product. Committed to sustainability, Case J prefers to carry out these initiatives without linking it with direct purchases, counting on spill-over effects in the local realties that over time will spread best practices within the country. In this specific case in our sample, traceability appears to be *disconnected* with traceability.

6. Discussion and conclusion

Observing Table 2, findings in this study suggest that the most common traceability system implemented in the coffee supply chain is the *advanced documental traceability* that traces the most complete information width, from origin and quality to sustainability practices (Cases B, C, I, E, F). Moreover, regardless of the supply chain tier, these companies prefer to invest in a traceability system that go as much in depth as possible, i.e., up producer or cooperative if possible, to all products. The white rows in Table 2 refer to this type of strategy. Nonetheless, other companies, shaded in dark grey in Table 2, are interested in tracing only origin and quality, but not sustainability. Hence, they adopt either a *simple documental traceability* system or an *advanced documental one*. The lack of interest on tracing sustainability practices in these cases (Cases D, G, J, H) could also be determined by the supply chain tier, type of product or even company size. Finally, it can be observed that the only one case that opted an *integrated traceability* system, covering all the information width possible, is in turn not focused on information depth or granularity, allegedly because of the difficulty to apply the technology to a highly fragmented supply base, as is the specialty coffee chain. Traceability at region level is common in specialty coffee sourced from poor countries where higher detail is impossible to get but the specific quality requires keeping trace at least up to the region to be categorized as specialty.

Therefore, the implementation of traceability systems along the coffee supply chain could be influenced by the type of information width and information depth that the company is interested in, along with the supply chain tier, country of origin or company technological capabilities.

On the other hand, from our findings we could observe that the relationship between traceability and sustainability for coffee roasters might be influenced by two main contingencies: volumes purchased and product type. The largest company in our sample, that purchases up to four million bags (Case J) depicts a *disconnected* relationship between traceability and sustainability, because the complexities of tracing back upstream

to many producers spread around the world. This company deals with coffee in bulk. Alternatively, smaller companies dealing with specialty coffee are able to deploy systems that trace at a higher level of detail up to the cooperative or even to the single producers where sustainability practices are carried out. These companies show a more *synergistic* relation between traceability and sustainability. Moreover, according to Case C, if we enlarge the view to consider also other commodities, as cocoa, in addition to the two approaches detected, we can retrieve an additional case, which refers to traceability and sustainability in *trade-off*. This is for example the case of specific certified cocoa for which the certification entity adopts a mass-balance approach.

In conclusion, our study is in line with previous literature stating that traceability systems are a tool in the supply chains in order to ensure that responsible social and environmental practices are used (Norton et al. 2014). Moreover, with the present work we contribute to literature by identifying three types of traceability systems adopted in the coffee supply chain, along with the information width and depth. In addition, we contribute to the debate around the relationship between traceability and sustainability (e.g., Garcia-Torres et al., 2019) by characterizing two types of relationships, disconnected and synergistic, that are influenced by the volume and product types purchased.

Findings in our study could be of interest for practitioners as well for identifying the needs for traceability according to their technological capabilities and the product type they deal with. Similarly, managers could adopt a certain strategy relating sustainability and traceability according to their needs and interests. Further research in this topic could extend the study to a larger sample, to involve other commodities and other industries or to delve into the contingency variables that determine the adoption of certain traceability system and its relationship with sustainability.

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Designing Inclusive Supply Chains for Sustainability: Empirical Insights from the Bottom of the Global Economic Pyramid

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Abstract

Integration of the population at the Bottom of the Pyramid (BOP) within company operations was identified as pivotal for realizing both value for companies operating in these challenging markets, as well as for harnessing the full potential of the BOP proposition in fostering value for individuals living in them. However, research on the topic remains predominantly simplistic, with nuanced and empiric based argumentation relatively scarce. In this paper we address this gap and provide a clear overview of how companies integrate BOP individuals in the different stages of their supply-chain, and how this integration facilitates different levels of sustainability depth.

Keywords: Base of the Pyramid, Sustainable Development, Co-creation

Introduction

The importance of a supply chain (SC) focus when addressing sustainability concerns is widely established in research on developed economies. The discourse on sustainable supply chain (SSC) practices in these contexts focuses on environmental issues, aiming at altering companies' existing operations to conserve resources and reduce environmental damage (Seuring and Muller, 2008). Research on SSC practices carries additional urgency in Bottom of the Pyramid (BOP) markets. BOP markets span geographic borders and their population ranges from farmers, to day-labourers and even bonded-labour, with a daily income as low as 1 United States Dollars (USD; Rangan et al., 2011). The widespread farmer suicides in India are a sobering example for what these figures mean in practice for people living in poverty. Carleton (2017) found that a one-degree Celsius increase in temperature leads to 70 more farmer suicides, annually. This characteristic vulnerability of the BOP to fluctuations in external conditions makes it crucial for companies in these markets to not stop at reducing the "un-sustainability" of their SC practices, but also to actively design them for creating sustainable value.

Integration of the BOP population within company operations was identified as pivotal for realizing the full potential of companies in fostering sustainability (Nahi, 2016). However, despite many researchers echoing this sentiment, there is still a stark lack of scrutiny and specific, empirical-based understanding of how this integration takes place and how it facilitates sustainable poverty alleviation. In this paper we address this gap, aiming to shed clarity on the topic by providing a more nuanced, empiric based understanding on how BOP integration at various stages in companies' supply chains can contribute to different depths of sustainable value.

State of the Art

Supply Chain Challenges at the BOP

The phrase "Bottom of the Pyramid" was coined by Prahalad and colleagues (Prahalad and Hart, 2002), and refers to the population at the bottom of the world's economic pyramid, originally defined by Prahalad as those whose annual purchasing power parity (PPP) is less than 1500 USDs annually. This original definition has since been expanded upon (see for example Rangan et al., 2011) to incorporate a more nuanced and arguably more appropriate segmentation of people in BOP markets, who have a vastly diverse geographic, class and religious background (Webb et al., 2010), in addition to their various levels of (limited) financials means (Rangan et al, 2011). The full spectrum can range from people who earn 1 USD or less daily and live in extreme poverty, to people earning up to 5 USD a day, living on a relatively regular, albeit low, income (Rangan et al, 2011). In management disciplines, the interest in the BOP market had been first and foremost for economic benefit to companies, particularly multinational corporations (MNCs; London and Hart, 2004), who sought growth opportunities abroad following the increased saturation and stagnation in industrialized markets (London and Hart, 2004).

Despite the great potential, companies wishing to succeed in BOP markets must overcome several key issues, two of which are its informal economy and gaps in the supply chain. First, the informal economy prevalent in BOP markets essentially means that transactions are primarily grounded on social and not legal contracts (Kolk et al., 2013) and are not regulated by formal bodies. The lack of competent formal institutions in place to mitigate the issues resulting from companies transacting with parties outside their own social network can be a great deterrence for companies thinking to enter the market, as they could result in lack of dispute resolution mechanisms, and issues such as corruption and property rights. Secondly, the often poorly developed educational, legal, political and business systems at the BOP (Webb et al., 2010) cause significant gaps in companies' value chains. Services such as electricity, water supply and support activities like financing distribution or information infrastructure (Wheeler et al., 2005) are lacking or missing altogether. This means that companies operating at the BOP must find innovative solutions to overcome these gaps and their effect on the various SC stages.

The Need for Co-Creation in General and BOP Integration in Particular

The challenges companies face often prove too difficult to be overcome by a single stakeholder; *"No firm can do this [succeed in BOP markets] alone […]"* (Prahalad and Hart, 2002, pp.6). By working together, the various stakeholders at the BOP can achieve a solution that is greater than the sum of its parts, as different organization types or stakeholders bring different degrees of technical know-how, local understanding, production capacities, financial resources, sales and marketing insights and connections to their respective industry (Ravn, 2010; Wheeler et al., 2005). This notion of working

together with various, also non-traditional stakeholders such as non-governmental organization or the BOP population itself, is often dubbed "co-creation" and *"[…] has become a central tenet of second generation BOP strategies that seek to create a fortune with rather than at the BOP."* (Nahi, 2016, pp. 416).

In research, co-creation is an umbrella-term used by different papers to refer to companies working together with different proposed actors and for different purposes (Nahi, 2016). The purpose of engaging in co-creation and the consequent sustainable value in it differs, and can range from shallow, business driven ties aimed at company legitimization within the local market and increased operational efficiency, to deeper, empowerment-driven integration. In the scale proposed by Nahi (2016), the purpose of co-creation, also known as its "sustainability depth" (see Nahi, 2016; pp. 294) ranges from co-creation for the purpose of creating **legitimation** for the company, co-creation for **efficiency**, co-creation for **sustainability**, ensuring environmental and social value, and lastly, co-creation for **empowerment** of the low-income population itself. The participants of co-creation range from least-inclusive, i.e. companies co-creating with either own-company employees, or other business partners, to more inclusive, i.e. companies co-creating with non-business partners, or the BOP population itself. **Of these potential stakeholders, engaging with individuals at the BOP is considered the most inclusive category of co-creation, as its sustainability depth ranges across the entire spectrum, from creation of legitimation for the company, to empowerment of individuals** (Nahi, 2016; Kolk et al., 2013). Indeed, whilst BOP research initially supported a "consumer oriented" perspective of selling to the individuals at the BOP (Khalid et al., 2015), it has since transitioned to considering them as an integral and active stakeholder in companies' success, rather than passive consumers. *"[…] consumers are seen as key co-creators."* (Nahi, 2016; pp. 421) or more specifically; *"[…] firms have found mutually beneficial ways of engaging the people at the BOP not just as consumers but as co-creators of value – as suppliers, distributors, partners and employees"* (Gollakota et al, 2010; pp. 365). Therefore, in this paper we do not consider all possible configurations of co-creation, i.e. with all the different possible stakeholder, but rather focus specifically on co-creation as the integration of BOP individuals as active participants within company processes and the consequent potential value incurred for all parties involved.

One crucial recommendation for research in this field noted by Khalid et al., (2015; pp. 692) is that *"BoP-related research often takes a too simplistic and positive turn on related corporate activities, and thus a more detailed analysis of such integration activities [of BOP individuals within the SC] would be required. This would be an opportunity for SCM [supply-chain management] researchers to address this gap in research and thereby contribute to SSCM-related [sustainable supply-chain management] research, which is rarely based on empirical data from BoP-related research."*. The purpose of this paper is to address this critical void and provide a nuanced, specific and empiric-based exploration of BOP integration within different SC stages at the BOP. More specifically we aim to answer: how do companies integrate BOP individuals in various stages of their supply-chain and how does this facilitate different levels of sustainability depth?

Methodology

Data Collection

To answer this question, we draw on insights from integration practices of over 100 small and medium sized ventures operating in BOP markets, across countries and industries. Our aim was not to assess the prevalence of companies practicing integration in BOP markets, but rather the scope and depth of integration in companies that do so, and do so well. Therefore, we decided for a best-practice oriented case-selection. An initial list of 213 cases was composed, of initiatives that have already been proven successful by winning the prestigious "SEED" award, jointly founded by several prominent institutes to identify outstanding ventures that actively target sustainability concerns at the BOP, such as provision of clean electricity, safe drinking water, sanitation and accessible healthcare. Publically available data from the award website was compiled using a self-developed web-crawler. Descriptive data on each venture, such as year founded, product offering, geographic market and industry was aggregated systematically and automatically. The data was cleaned, standardized and inputted into a robust case-study protocol in Excel.

Extensive manual secondary data collection was then carried out by two coders on the processes each venture employs at each stage of its SC (Procurement, Production, Distribution, Return). This included extensive and meticulous, manual data collection of supply-chain practices from a wide-range of secondary sources, with multiple sources per venture as well as different data types, both video and text. For most ventures, sources included a diverse combination of financial reports, news articles, official social-media presence, as well as videos of interviews by founders or key employees in each company in reputable news sources or from the ventures' own (official) online outlets, thus ensuring the highest levels of data triangulation (Yin, 2014). At this stage, due to a stark lack of publically available information, "Return" processes were removed from the study. The coders also documented the level of technology sophistication of each venture's key value offerings (very low, low, medium, (very) high) to ensure an adequate spectrum is covered. Very low technology sophistication refers to ventures where almost no additional processing into a final product is carried out (for example, ventures in the agriculture industry that sell their aggregated and packed produce). Low refers to little or some additional processing into a final product (such as bio-pellets for clean cooking), medium refers to more robustly developed products (such as solar lamps) and (very) high refers to advanced products and services or complex offerings more heavily entwined with technology (such as home systems or off-grid energy providers). Additionally, at this stage, ventures for which an insufficient amount of information could be found on SC practices were excluded. For each remaining venture, the coders marked a binary yes / no for whether integration of BOP individuals takes place at each of the SC stages. Ventures for which proof of integration practices could not be found in at least one stage were removed from the study. This process resulted in a final database of 135 front-running ventures that were included for subsequent analysis.

Table 1 – Brief Overview of Research Design

Stage 1: Data Collection	**Stage 2: Data Exploration**
Extraction of publically available data through self-developed web-crawler.	Second-order thematic categorization of SC integration practices and clustering to first-order categories by Nahi (2016).
Extensive, manual secondary data collection by two coders, on integration practices and technology sophistication, from multiple sources per venture, ensuring triangulation. Case selection based on availability of	Quantitative exploration of patterns of integration, sustainability depth, and relationship to technology level of product offering as a moderating factor.

secondary data on SC processes. Case selection based on practices of BOP inclusion in the SC.	

Data Analysis

The subsequent qualitative data analysis explored the purpose of BOP integration in ventures ("Integration: for what purpose?"; see table 2) based on the scale of integration "sustainability depth" proposed by Nahi (2016). We also explored the specific patterns of integration used across the SC to achieve this depth ("Integration: how?"; see Table 2). Bottom-up thematic pattern derivation of integration activities was conducted, deriving codes iteratively as needed from the ventures and aggregating into second-order patterns. The patterns were then assigned to the relevant first order categories for purpose of integration by Nahi (2016). For the detailed thematic categorization and example codes, refer to Table 2.

Table 2 – Coding BOP Integration in the SC: Categories and Patterns

Integration: for what purpose? First Order Categories by Nahi (2016)	**Integration: how? Second Order Patterns**	**Example Codes**
Legitimation	Legitimization	elder / community elders / business owner / shop owner / existing businesses / church / word of mouth / leaders / demonstrations / graduates / dialogue / ambassadors
	Localization	locally procure / indigenous / traditional / artisanal / local production / locally produce / local skills / artisan / mason / crafts / artisans / time-honoured techniques / door to door / hyper-local
Efficiency	Accessibility	local sales-agent / micro-entrepreneur / village level entrepreneurs / commission-based / indirect employment / micro-franchisee / franchise / additional source of income / micro-entrepreneurs / collectors / part-time / indirect jobs / additional source of income
	Aggregation	peer group / bulk / centralization / aggregation / centralized demand / drop-off points / collection-points / women group / youth group / pool resources / self-managed groups / community groups / self-organizing / collection yards / collection centres / savings groups

	Training and Support	monitor / guide / mentor / support / consult / guide / train / develop / know-how
Sustainability	Provision of Tools or Assets	certification / provide inputs / provide land / micro credit / micro loans / micro-finance / low-interest / no interest / loans / micro-savings / social lending / health insurance / scholarships / on site housing / market linkages / on-site childcare
	Provision of Economic Premium	fair prices / premium prices / fair market value / above market value / above market wage / export / premium quality / high quality / gourmet / niche / organic / export / niche / premium / upcycling / tourist / boutique / organic
Empowerment	Formalization	local employees / full-time employees direct employment / regular income / directly employed / formalized / full-employment
	Ownership and Agency	independently-owned / women-owned/ micro-business / micro-cooperatives / cooperatives / community-owned / local-ownership / women-owned / woman-led / cooperative /
	Focus on Fringe Stakeholders	unemployed / youth / marginalized / mothers / school-dropouts / seasonal workers / disadvantaged / vulnerable / illiterate / disabled / refugees / ex-combatants / HIV / mothers / marginalized / disabilities / underprivileged

Lastly, a quantitative, exploratory analysis was carried out on the relationship between the depth of integration at various stages in the SC, as well as the relationship of the technology sophistication level of a venture's key product as a moderating factor for integration depth. First, we explored the purpose of BOP integration by cumulating all instances of specific patterns according the categories legitimation, efficiency, sustainability and empowerment (see Table 2). For example, we were interested in understanding how many of the ventures that integrate BOP individuals in their distribution did so with the purpose of legitimation? How many did so and led to the individuals' empowerment? Alternatively, how many of the ventures that integrate the BOP in production do so with the purpose of legitimation or efficiency? How many result in empowerment? The relative frequency of each integration purpose at each of the three SC stages was used to generate the heat-map shown in Figure 1. Then, we expanded our exploration with regard to the technological sophistication of each venture, thus allowing

the comparison of the relative frequencies of the purpose of BOP integration in each of the three SC stages with respect to technological sophistication, as shown in Figure 2.

Findings

In this section, we discuss the key findings distilled from the previously elaborated upon research design. In particular, this section will outline at which SC stages companies integrate the BOP and in particular the resulting sustainability depth; i.e. business-oriented integration for the purpose of creating legitimation or efficiency, or more empowerment-oriented integration, for the purpose of also building agency for the BOP locals integrated (see Figure 1). We also shed light on the characteristic patterns of how integration at each SC stage takes place, thus providing a nuanced understanding on how integration at different stages of the SC can lead to different depths of sustainable depths. Lastly, we explore the relationship between the technology-sophistication of the venture's key product offering to where in the SC they integrate the BOP and for what purpose.

The findings show that ventures integrating BOP individuals in their SC do so within their upstream processes; with 64% of all ventures integrating the BOP in their procurement processes and 61% in their production. Integration is also done in ventures' distribution, though to a lesser degree (42%). Ventures tend to focus on either upstream or downstream processes, with only 17% of ventures integrating BOP individuals in all SC stages. When we assess the correlation with the purpose of integration at the different SC stages of ventures (see Figure 1), the overwhelming majority of BOP integration results in business-level sustainability depth, i.e. efficiency or legitimation, across both upstream and downstream SC stages. The business-oriented integration is carried out across all ventures, by those with very low product technology sophistication, as well as high (Figure 2), thus empirically supporting the claim that integration of the local population is at least perceived as useful if not necessary for businesses operating in these markets. However, here we note a difference between the different SC stages. **Integration practices in distribution processes in particular tend to "stop" at business-oriented integration**, **whilst upstream processes incorporate to a larger degree also sustainability and empowerment characteristics.**

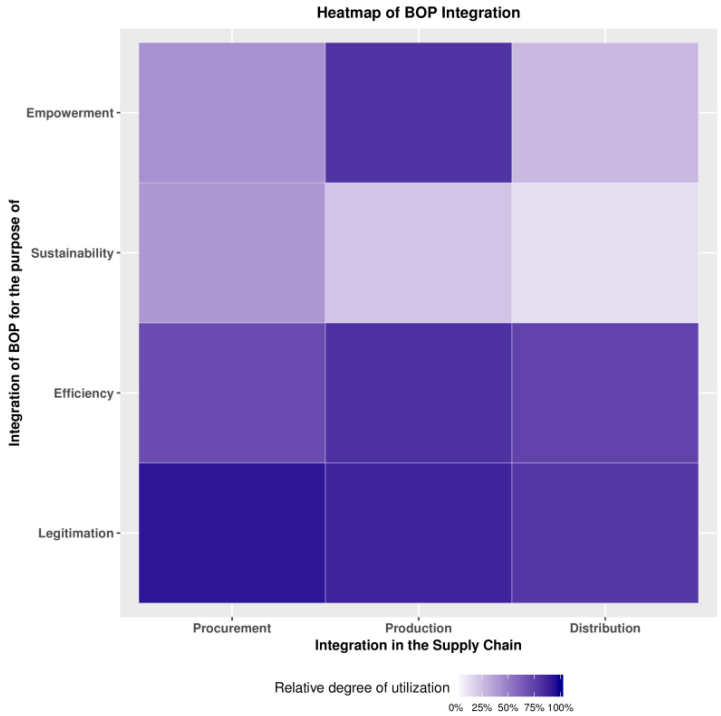

Figure 1 – Overview of BOP Integration in Supply Chains and Consequent Sustainability Depth

BOP Integration Patterns and Purpose in Downstream SC Processes

BOP integration predominantly in downstream processes tends to be lower in depth and business-driven, and characterized by employment of a very large number of locals for door-to-door sales and maintenance jobs for increased efficiency and creation of accessibility in ventures' sales and after-sales networks. Integration of the BOP in downstream processes contributes to ventures' legitimation (in 79% of cases, see Figure 1) and efficiency (74%) but to a significantly lesser extent to sustainability (26%) or empowerment (26%) of the BOP individuals involved. One reason for the halt at business-oriented integration depth, is due to the fact that in distribution processes in particular the BOP are often integrated into the supply chain on a commission-basis as opposed to full time, formal employees; *"[…]in addition to these direct jobs [of full-time, official staff], several hundred indirect jobs are created in the distribution chain."* (Lagazel, 2019, pp. 6). The decision to separate the large employee pool stems from practical reasons of working hours and localization; *"For practical reasons, Kumudzi Kuwale has decided to assign charging station operators as agents and not employees. The agents are to a large extent choosing their own working hours, using their own home as a base for Kumudzi Kuwale activities, which often is combined with other business."* (Kumudzi Kuwale Annual Report, 2017; pp. 38). Alternatively, motivation was noted for the commission-based configuration of integration; "*The agents get a fixed percentage of their earnings to keep for themselves, instead of a salary […] as a fair way to reward agents that perform well."* (Kumudzi Kuwale Annual Report, 2017; pp. 38). Lastly, financial reasons stemming from the exponential costs often associated with a large employee-pool were noted; *"being a small entrepreneur everything is about your cash flow […] you don't actually need employees, you can buy services and get somebody to render a service for you without you putting out and paying a monthly salary and monthly taxes for employing somebody." (Malherbe, 2019).*

BOP Integration Patterns and Purpose in Upstream SC Processes

In contrast to integration in distribution, BoP integration within upstream processes addresses business-oriented purposes, but also deeper outcomes such as sustainability and empowerment. Typically, ventures' upstream chain is highly localized and aimed at company-legitimation; in procurement, this is often achieved by ventures utilizing locally available material or waste as inputs or develop local smallholder farmers, and in production through utilization of local knowledge and skills, with value adding steps characterized by "traditional", "artisan" or "time-honoured techniques". In addition to business-oriented outcomes, we see that particularly **production at the BOP and with the BOP is key for empowerment outcomes**. Value-adding processes in production at the BOP are human-intensive and ventures extensively train and fully-employ people, often specifically targeting marginalized actors in local communities, such as refugees, single-mothers and youth. Consequently, they heavily contribute to empowerment of local populations, with integration in production processes contributing more than any other SC stage to empowerment purposes. 80% of ventures who integrate the BOP in production result in empowerment outcomes, as opposed to 42% of integration in procurement and 26% in distribution (Figure 1). This is achieved primarily through formalization of work conditions, wages and contracts (in 65% of ventures), a focus on inclusion of marginalized members of local communities (26%) and additional creation of ownership and agency (17%).

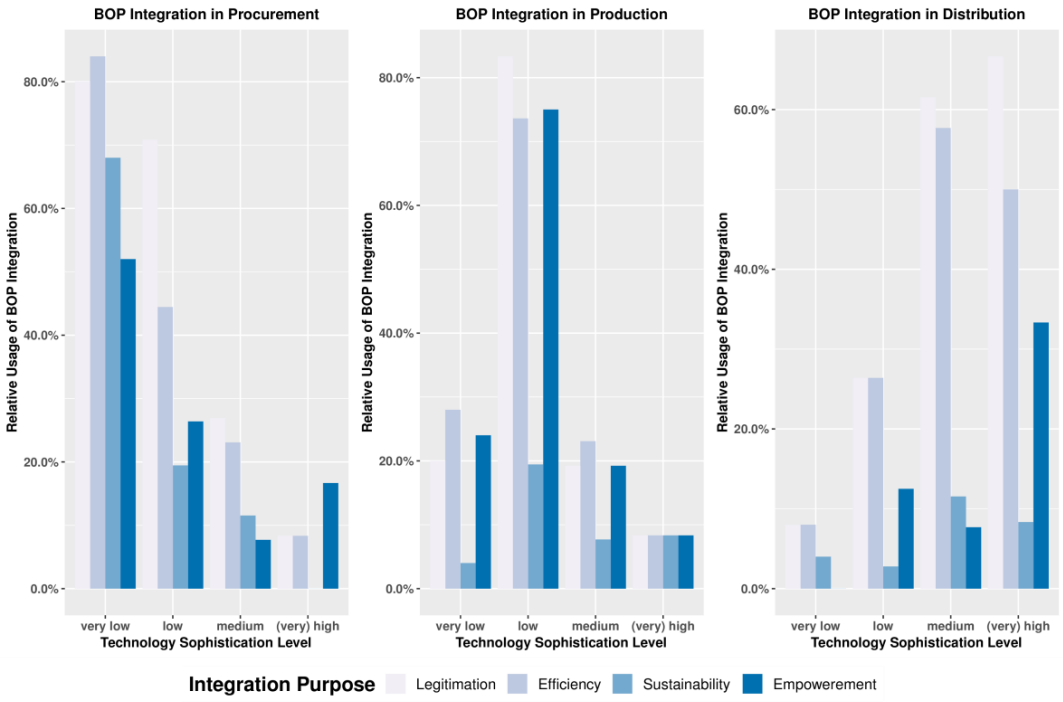

Figure 2 – Technology Sophistication as a Moderating Factor for Integration Purpose

Concluding Remarks

Previous research focused on showing that integration of BOP individuals within the SC of companies, rather than only as consumers, could be a key mechanism for sustainable value creation, as these individuals are *"[..] experts in their own needs and capabilities, as well as masters in manoeuvring their operating environment*". (Nahi,

2016, pp. 421). This paper has addressed existing calls to delve deeper, and concretely and systematically show where and how ventures integrate local populations in their SC to achieve different sustainability depths. To the best of our knowledge, this is the largest empirical investigation scrutinizing how and where in the SC integration is carried out, and its sustainability depth. This is crucial for advancing our understanding of sustainability, and particularly SSCs, in BOP contexts. Based on the abovementioned findings, we note the prevalence and perceived necessity of business-oriented BOP integration across all stages of the SC, but also the stark discrepancy in the ability to achieve more empowerment-oriented integration, which takes place primarily within production processes. These nuanced insights on highlight the importance of several future avenues of research. In particular, the distinct importance of production at the BOP and with the BOP is shown, despite the current focus of BOP research on marketing and modification of products. BOP integration in production contributes more than any other stage of the SC to empowerment of individuals through formalization of work-contracts and conditions, creation of ownership and agency, and a focus on integrating fringe stakeholders in local communities, as opposed to more prominent members.

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Understanding the impact of leagile manufacturing on environmental sustainability

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Abstract

Supply chains have become more ‘customer-centric' requiring more agility. Previous research focuses on economic benefits of lean and agile operations and overlooks its impact on environmental sustainability despite its emergence as a core business need. Though some studies have hinted a link between lean and environmental sustainability, little is known on the effect of agile operations**.** This research resolves some inconsistences in the literature and shows how sustainability outcomes could be affected by lean and agility within the furniture manufacturing industry. An in-depth case study is used to illustrate how the leagile strategy could be a more environmentally sustainable option.

Keywords: Lean, Agility, Sustainability

Introduction

Sustainability management is increasingly a normative behaviour expected of supply chain managers. Though not yet a universal order winner for supply chains, there is no denying its significance as a market qualifier (Potter et al., 2015). Environmental sustainability is an even more critical issue as supply chains become more 'customer-centric' with increased customer involvement. Meanwhile, lean and agility have remained relevant best practices for gaining competitive advantage and addressing customer needs as is evidenced by their continued presence in the supply chain literature (Chatha & Butt, 2015). Research has shown that lean operations could be positively linked with environmental sustainability (King & Lenox, 2001). However, much of the previous research into lean and agile focuses on economic benefits and overlooks the environmental impact of supply chain management despite its emergence as a core business need (Pagell & Shevchenko, 2014). This paper does not question the benefits of operations management but seeks to understand the nature of its relationship with environmental sustainability as supply chains become more agile. The paper contends that lean and agile paradigms share common practices that positively affect environmental sustainability and that with innovative technologies, the environmental impact of lean and agile operations is not significantly different in the furniture manufacturing industry. However, lean tends to address environmental impacts in the production processes, while agile impact is significant around design, procurement, and distribution.

This research highlights some inconsistences in lean and agile operations literature and shows how sustainability outcomes could be affected by lean and agile operations within the furniture manufacturing industry. An in-depth case study is used to understand how lean and agile practices affect environmental sustainability outcomes and what specific initiatives can be taken to mitigate any negative effects.

Sustainability

Sustainability broadly means development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). Environmental sustainability (hereafter referred to as green) entails recognising the finite limits of the earth as a source of resource and sink for waste (Borland et al., 2016). To be green, society should strive to create a closed loop system that can support itself in perpetuity without external inputs. In supply chain management, green focuses on reducing the generation of pollutants and waste in production processes (Alves & Alves, 2015). Supply chains need to reduce the environmental impact from production, raw materials, energy use, emissions from transformation, and recycling of products post-consumption to be truly sustainable (Piercy & Rich, 2015). However, the adoption of green management should be complementary with the organisation's operations and cooperate level strategy (Siegel, 2009). There must be an alignment of business operations and green management to achieve truly sustainable supply chains (Pagell & Shevchenko, 2014).

Lean, agile and leagile operations

The lean, agile and leagile debate has continued for two decades since the influential paper by Naylor et al. (1999). Confusion arises when authors entangle 'what' the underlying values and principles are, with 'how' they should be implemented (Purvis et

al., 2014). Narasimhan et al. (2006) references to these two main levels of analysis as paradigmatic and pragmatic.

Paradigmatic studies treat lean and agile as systems of practices guided by philosophical and cultural elements. Lean aims for excellent quality at low cost and is therefore explicitly focused on removal of waste (non-value adding activities or Muda) (Shah & Ward, 2003). By contrast, agility represents the ability of a manufacturer to thrive in the face of continuous change in market demand, technology, customer requirements and social factors (Sharifi & Zhang, 2001). It seeks rapid and adaptive response to variable customer requirements (Yusuf et al., 1999). This adaptive response to uncertainty is generally perceived as flexibility. Qamar et al. (2018) categorises flexibility as product mix, process flexibility and volume flexibility. Mix flexibility refers to the ability of the firm to change the range of products made within a given time period, while maintaining the same aggregated output. Process flexibility is the ability to reconfigure the process without significantly increasing cost, and volume flexibility means the ability to change the level of aggregated output.

Research has consistently distinguished lean and agile based on the emphasis on cost and flexibility (Hallgren & Olhager, 2009; Naim & Gosling, 2011; Qamar et al., 2018). Cost and flexibility emerge as key order winners for lean and agile respectively. Naylor et al. (1999) argue that the most important differentiator of lean and agile is flexibility. They argue that while it may be desirable to have some flexibility in a lean system, flexibility is not a prerequisite for lean as it is more focused on standardisation. However agile manufacturing calls for a high level of rapid reconfiguration and will eliminate as much waste as possible but does not emphasise the elimination of all waste as a prerequisite. Hallgren et al. (2011) suggests that flexibility and cost efficiency are developed in parallel and not sequentially. This means that flexibility does not build upon cost efficiency, and cost efficiency does not build upon flexibility. Instead, a balanced approach is necessary for these two capabilities, such that the decision on one of these capabilities cannot be taken in isolation, without considering the other one. This interrelatedness of the lean and agile paradigms makes their distinction murky, mainly because both paradigms share common practices targeted at minimal waste, flexible response and short lead-times (Martin & Towill, 2000).

Earlier research is inconsistent on what practices characterise each paradigm, thus diluting the unique attributes (Purvis et al., 2014). For example, Just in Time (JIT) is often considered as a lean practice (Shah & Ward, 2003), yet others argue that it is an agile practice or even both (Qamar & Hall, 2018). Several studies use quality management, supplier management, and JIT flow, as identifiable practices of lean firms (for examples see Cherrafi et al., 2018; Garza-Reyes et al., 2018; Longoni et al., 2015). In contrast, Narasimhan et al. (2006) found these practices had significantly higher emphasis in agile firms than lean firms. A possible explanation for these inconsistencies could be that lean is more conceptually developed than agility, thus most of the efficiency focused practices are attributed to lean (Purvis et al., 2014). These inconsistences have important implications when trying to understand lean and agile impact on environmental sustainability.

The identifiable lean and agile attributes tend to occur regularly at a pragmatic level (Purvis et al., 2014). At this level, disentangling lean and agility focuses on ‘how’ they are implemented. It is necessary here to clarify exactly what is meant by lean and agile. According to Narasimhan et al. (2006) production can loosely be considered lean if it is

accomplished with minimal waste from to unneeded operations, inefficient operations, or excessive buffering in operations. On the other hand, production can be considered agile if it efficiently changes operating states in response to uncertain and changing demands placed upon it. Thus, lean firms develop performance capabilities to compete on costs while agile performers exhibit performance capabilities that reflect 'service' to increase availability and flexibility (Narasimhan et al., 2006). Fisher (1997) classified products into two types, functional products characterized by stable demand, long life cycles, low profit margins and low variety, and innovative products with volatile demand, short life cycles, high profit margins and high variety. He argued that Lean supply is suitable for functional products, and responsive supply is suitable for innovative products. However, lean and agile concepts are not mutually exclusive in practice but can co-exist in a supply chain.

Previous research suggests ways of marrying lean and agile to present a more robust supply chain design that benefits from both strategies. Figure 1 shows how lean and agile can be combined in three ways but never in the same space at the same time (Towill & Christopher, 2002).

	Same Time	**Different Time**
Different Space	Separate Processes	De-coupling Strategies
Same Space	Not Viable	Change according to time e.g. season

Figure 1: Leagile Time/Space Matrix (adapted from Christopher and Towill 2002)

In figure 1, using lean and agile at the same time in different space requires having separate processes operating in parallel. differentiating 'base' from 'surge' demand. This may mean separating standard components from more bespoke products which would require agility. To have them in the same space at different times requires changing your supply according to seasons. Stock is built at low cost through lean during the quiet period in anticipation for demand during the busy period which is satisfied through agile supply. De-coupling strategies postpone the assembly of the final product in order to handle demand uncertainties efficiently. Naylor et al. (1999) coined the term leagility to represent this kind of integration of lean and agile in different space at different times. A decoupling point acts as a buffer between the variable demand for a wide variety of products and the level production schedule for a smaller variety of components, allowing for leanness upstream and agility downstream. In this way, the supply chain combines lean and agile through 'postponement' of final assembly to benefit from both philosophies.

Operations management and environmental sustainability

Early research hinted at the accidental environmental benefits of lean methods (Florida, 1996; King & Lenox, 2001). Subsequent studies suggest that lean and green practices result in synergetic outcomes regardless of whether managers implementing such practices fully understood or simply dismissed potential synergies (Campos & Vazquez-

Brust, 2016). A recurring argument is that practices that support lean manufacturing are aligned in focus as those that support environmental performance (Garza-Reyes et al., 2018; Simpson & Power, 2005). For example, cultural elements such as kaizen (continuous improvement), cross-functional teams, employee empowerment have been found to facilitate higher environmental sustainability performance through an integrated system of management (Alves & Alves, 2015). While these practices have a positive impact on environmental sustainability, they are not exclusive to Lean. JIT, TQM (continuous improvement) and cellular manufacturing are not strong differentiators of leanness (Narasimhan et al., 2006). These form vital foundational capabilities for agility. One possible implication of this is that agility could positively contribute to environmental sustainability. The true impact of individual lean and agile manufacturing on environmental sustainability needs further investigation (Sarkis & Zhu, 2017). This is what this paper seeks to address.

Methodology

In this study, a theory-driven inductive approach is adopted largely due to the exploratory nature of the subject. A case study based qualitative research method is appropriate for generating deep insights and causal explanations for a complex system within a real-life context. This paper adopts a critical realist position that combines the ontological strengths of realism with the epistemological value of both positivism and constructivism. A systematic review of literature was conducted to develop the research question and identify critical initial theory to form the basis for possible explanations of the causal powers of lean and agile. To guard against bias while ensuring external validity, multiple data sources where used. Data collection involved semi-structured interviews with managers, site visits, and analysing company documents. Interviews were transcribed and coded for thematic analysis. The case was selected based on its ability to illustrate how lean and agility impact green performance.

The furniture manufacturing industry was selected as the context for the study for several reasons. First, companies in the furniture industry are less likely to implement green practices except those required by law. There is a relationship between the type of product sold by a firm and its inclination to engage in green management. McWilliams and Siegel (2001) makes a specific distinction between experience goods and search goods. Experience goods must be used or consumed before their true value to the consumer can be determined. Examples of experience goods are automobiles, and appliances. Firms supplying experience goods will stress their reputation for high quality in advertising. On the other hand, search goods and services are readily evaluated prior to purchase, and most advertising will involve information about product availability and price. Examples of search goods include clothing and furniture. They argue that a firm selling an experience good is more likely to engage in green management than a firm producing a search good. Therefore, the furniture manufacturing industry presented a good context for understanding the effect of lean and agile on green since firms selling furniture, a search good, are less likely to engage in green management. Secondly, several key processes are common to many other manufacturing industries (e.g. coating processes using solvent-based paints, solid waste, paper packaging). Lastly, several of the key processes have significant environmental implications and faces primarily the same legislative initiatives faced by many manufacturing sectors.

Findings from case study

FurnCo (pseudonym) is a UK based medium sized coffin manufacturer offering coffins and veneered boards supplied to funeral directors and coffin manufacturers respectively. Its product offering can be regarded as low volume high variety. A customer can choose from over 28 coffin types, 6 colour indexes, 10 moulds and 40 different sizes resulting in over a thousand different combination of the final product. Waste sources includes wood waste, paper and packaging. Figure 2 shows the supply chain for FurnCo.

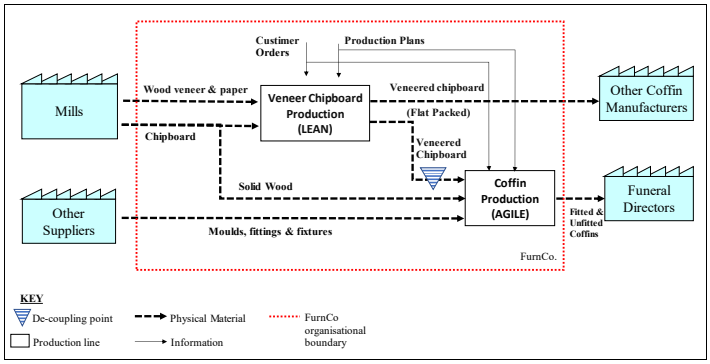

Figure 2: FurnCo's supply chain

The company implemented lean initiatives to reduce cost and waste from the production process. Table 1 shows a comparison of the green impact from literature and the case study.

Table 1: Evidence of impact from case and literature

Operations Management impact on green performance	
Literature support	Evidence from FurnCo
Lean practices have a positive impact on waste reduction initiative by streamlining of production	Veneer production line from 'sides and ends' resulted in about 5% waste reduction.
TPM ensures that production equipment runs at optimum condition to process materials efficiently and use less energy (Garza-Reyes et al., 2018)	FurnCo has upgraded its production line to include multi-functional and more energy efficient equipment. They also carry out routine maintenance.
TQM - Quality contributes to green performance through perfect process yields without scrap and defects (King & Lenox, 2001)	FurnCo compressive quality program ensures that products are 'right the first time.' The company does not currently have waste from defects or scrap.
Agile practices In a make to order system, the variety in product offerings could negatively affect waste generated, especially if the products come from a few raw materials.	Reduction of variety in flat packed options allowed lean production and reduction of wood waste. By contrast, a wide variety on the coffin production line resulted in waste from offcuts.
Product flexibility could necessitate excess capacity which consumes resources (Ciccullo et al., 2018).	The bespoke section contained assemble equipment that was used for about 5% of the orders but this did not significantly impact waste generation nor energy consumption.
Leagile practices Early customisation (i.e if first part to be produced is customisable) reduces flexible movement of customer de-coupling point and creates storage problems (Akinc & Meredith, 2015).	FurnCo faced a storage problem because of early customisation of the product. The coffin lids and bottoms needed to be veneered and cut early in the production process, thereby making make-to-forecast not feasible with the current storage space.

Lean impact on environmental sustainability

Findings suggest that lean practices contribute to reducing environmental impact by tackling internal wastes and pollution. At FurnCo, practices such as quality management (TQM), employee empowerment and Total Preventive Maintenance (TPM) had positive effects on green. Fixing production defects before they happen significantly reduced environmental risks related to rework. As stated by the Operations Director, whether in the agile or lean side of production, FurnCo implemented some 'input and output' criteria between different stages of production. The defects are caught early when they are cheapest to fix, reducing the need for full product re-work. Here is an example of quality management's positive impact on both the lean and agile sections of production. Similarly, TPM ensured that production equipment ran at optimum conditions to process materials efficiently and used less energy. FurnCo empowered its employees to own the process quality and identify areas of improvement. All these benefits were reinforce by cultural transformation of the company, similar to the findings by Alves and Alves (2015). However, Lean did not address all environmental concerns (e.g. formaldehyde and toxins in glues) thus there is a need to integrate lean and green practices (Inman & Green, 2018). Nevertheless, lean's positive contribution to and synergy with green is undeniable, despite its limitations in addressing all environmental concerns.

Some lean practices led to unsustainable outcomes. For instance, firms could place emphasis on more efficient processes rather than less polluting initiatives (Pagell & Shevchenko, 2014). A waste reduction programme undertaken by the company showed that waste could be significantly reduced if the size of the purchased chipboard is changed. Besides a reduction in cost of other materials (i.e. veneer and paper), this improvement could reduce annual waste by 10%. However, when the supplier was asked to supply the desired size, it declined because its standard size. By so doing, the mills pushed waste material downstream even when they were better able to handle the waste through recycling. This is a case where lean results in waste generation downstream. Of course, there are other factors that contributed in this case for example, the buyer-supplier power differences and the nature of the material. FurnCo's Operations Director stated that, "We can sometimes be arm strung by our suppliers as well as our customers. Sometimes the customers will want a lower price but still want the agility in specifications. Then, our suppliers come along, and they want the lean in the specification and the flexibility to increase the price. So, we end up sitting at some sort of halfway towards both". However, though better placed to handle the waste through recycling, the supplier preferred to maintain the standard sized chipboard to have greater efficiency.

Agile impact on environmental sustainability

Research suggests that agile firms address environmental concerns at design, procurement and distribution stages but rarely at production (Kumar & Rodrigues, 2018). According FurnCo's Managing Director, "Agile is about responding to change but it also places high value on people versus process. Verbal human interaction is important in the design and development stage where higher quality designs can be achieved through successful prototyping and close communication with the people who will have to produce the product." However, the product offering at FurnCo did not require frequent new product development but only occasional adjustment to the product features. Thus, little evidence was found to support the argument that organisations operating in agile

environment tend to address sustainability at the design stage (Kumar & Rodrigues, 2018).

Procurement was an important aspect of agility that contributed to sustainability. Product flexibility may require purchase of a wide variety of raw materials resulting in increased waste generation. At FurnCo, wide variety of product offered affected waste generation. An initiative to reduce product variety showed that a variety reduction would allow the purchase of two chipboard sizes, which would be cheaper and reduce waste. In this case, high variety of products affected green because the raw materials bought were discrete and standard. By contrast, for flexible products such as rolls of fabric, it wouldn't matter how many sizes are offered, as the waste is at the end of the roll. The variety did not affect the moulds which were bought as rolls because the offcut is the last cutting and not at every cut that is made. Therefore, if flexible alternative material can be sourced, it could reduce the waste.

JIT practices can reduce energy consumption by having lower inventory levels. However, carbon emissions could increase from transportation, packaging, and handling of the materials. This could be seen in downstream of FurnCo in its supply chain. FurnCo's customers demanded a JIT delivery due to lack of storage space at their premises. To reduce the number of trips and ensure full truckloads, customers were grouped into zones to consolidate delivery. Customer demand outside these zones was satisfied through outsourcing to third party transporters. FurnCo planned its production based on delivery schedule and location of customers. Although, delivery-led production created unevenness in the production processes especially at the assembly point, this distribution strategy resulted in less costs and CO_2 emissions from transportation. Therefore, though JIT can have both negative and positive impact on environment, the negative impact can be mitigated in distribution. This is more likely to be the case in agile which is people focused than in lean which is process focused.

Leagile and environmental sustainability

FurnCo adopted the leagile approach to draw on the strengths of lean and agile to improve sustainability performance by separating the part of the supply chain that directly responds to the customer needs. FurnCo implemented separate production lines based on the components of the products. A 'veneer production line' dedicated to producing sides and ends of the coffins which were standardised for all coffins, and a 'Coffin line' for the lids and bottom of the product. Whereas standardised operations in veneer line enabled efficient production of few variances with minimal waste, wide variety on the coffin line, made it challenging for FurnCo to apply lean production. Early customisation of production reduced flexible movement of the customer order de-coupling point and created storage problems on the coffin line (Akinc & Meredith, 2015). Nonetheless, technology played an important role to reduce the impact of variety on the environmental impact by addressing both efficiency of the processes and energy consumption (Sarkis & Zhu, 2017). FurnCo invested in a CNC machine capable of nesting the various sizes onto a standard chipboard in the most efficient and cost-effective manner. Nesting resulted in 30% reduction in waste generated from offcuts whilst allowing the company to offer a wide variety of sizes.

Conclusion

This paper makes a key contribution by exploring the impact of agile and lean operations on various environmental outcomes. Past research has focused almost exclusively on synergies and alignment of just lean and green. This paper attempts to conceptualize the role and impact of agile operations on environmental sustainability. It demonstrates how Leagile could be extended to be a more sustainable strategy. This theoretical contribution has important implications for managers as it informs how agile related capabilities can also increase environmental performance. Without a clear understanding of the environmental outcomes associated with agility, supply chain managers have little guidance on what results to expect from the implementation of agility-focused practices.

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Prompting the diffusion of supplier codes of conduct: The role of content

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Abstract

Supplier codes of conduct are an important tool for establishing sustainability in supply chains. They can serve to simultaneously govern multiple direct relations with suppliers. However, companies are also expected to ensure sustainability at lower-tier suppliers, which they have no direct relation with. Consequently, codes have to diffuse, which refers to their spread amongst the members of a supply chain who adopt them. Based on diffusion of innovations theory, we highlight the crucial role that their contents play in prompting this process and compile a framework for future scientific inquiry.

Keywords: Supplier Code of Conduct, Diffusion of Innovations, Sustainability

Introduction

Sustainability has become one of the central topics in both business research and practice. Companies have answered the pressure executed on them by both customers and governments by increasing internal efforts to establish sustainable behaviour. However, it is far from enough for companies to assume responsibility within their boundaries. Much rather, their performance in regard to sustainability is judged on the behaviour of their affiliated companies who are located upstream in the supply chain, as well. They consequently have to ensure compliance with both environmental and social standards by their suppliers (Porteous et al., 2015).

Codes of conduct (CoCs) have been implemented to foster sustainable or ethical behaviour for almost a century. Codes of conduct typically comprise a set of rules that constitute which behaviour, especially regarding situations that show some sort of critical relation towards environmental and/or social issues, is considered to be acceptable (Kaptein, 2004). These were found to take a primary role in achieving the aforementioned change towards more sustainable or ethical behaviour (Kaptein, 2011). Consequently, companies have picked up on their experiences with CoCs and designed supplier codes of conduct (SCoCs), which have become the most commonly applied practice to implement particularly social sustainability in supply chains (Yawar and Seuring, 2017). Both research on and practice of SCoCs has focused on their establishment in close dyadic relationships between focal companies and a small number of suppliers. In this sense, SCoCs can serve as a means to effectively and simultaneously govern multiple dyadic relations with suppliers and to prevent misconduct (Schleper and Busse, 2013).

However, when companies have to deal with large numbers of suppliers, it becomes impossible to govern the SCoCs in dyadic relationships, even if it can be done simultaneously to some extent. This problem weights even heavier when considering suppliers that are located on lower tiers and are not in direct contact with the focal company, but who

are nonetheless expected to comply with the requirements set out in the SCoC. Reaching a larger amount of suppliers is unfortunately not as easy as dictating that the SCoC has to be followed by all of them (Awaysheh and Klassen, 2010). Instead, the SCoC has to diffuse. Diffusion refers to the process that leads towards a spread of the SCoC from members of the supply chain towards other members who adopt them (Meqdadi et al., 2018).

Research on codes of conduct has provided indications that their contents are a factor that determines their effectiveness in influencing behaviour (Kaptein, 2011). The contents of a SCoC are particularly important in the described situations, where suppliers solely have to rely on them. So far, research has widely neglected the connection between contents of SCoCs and their effectiveness. We argue that the effectiveness of a SCoC is highly related to its described ability to diffuse, as a prerequisite for its implementation, and that consequently, their contents play a crucial role in this process. We thus propose the following research question:

How does the content of a supplier code of conduct affect its diffusion?

In order to approach an answer to the proposed research question, we first review content-oriented research for both CoCs and SCoCs. Thereafter, diffusion of innovation theory (DOIT), as established by Rogers (2010), is introduced in order to identify factors that can affect diffusion. As the last step, a framework which combines research on both CoCs and SCoCs with DOIT is compiled. We aim to theoretically derive the role that the contents of a SCoC play for its diffusion and propose a new path for future research.

State of research

According to Kaptein (2004) a code of conduct defines the responsibilities of the corporation towards its stakeholders and the conduct it expects of employees. Supplier codes of conduct serve the same purpose with the key difference being, that the target corporations are suppliers.

Research on the content of CoCs can be categorized into two main streams. First, research regarding which actual contents (e.g. labour laws or waste management) are included. Second, research which examines code content on a structural level and attempts to unveil guidelines or quality criteria (Garegnani et al., 2015) regarding their complexity (e.g. in form of wording) and the presentation of contents. Both research streams have highlighted that the content of a CoC is one decisive component for determining their effectiveness in influencing behaviour (Kaptein, 2011). Since our goal is to identify generalizable insights regarding the relevance of SCoC content for influencing suppliers´ behaviour, we focus on the latter research stream.

As shown in table 1, Schwartz (2004) examined five criteria that can be used to evaluate the contents of a code of conduct and guide its creation. The author conducted 75 interviews in four large Canadian corporations to determine their value. All of the identified aspects were assessed as important by the interviewees. Surprisingly, justification received the lowest importance compared to the other included criteria.

Erwin (2011) used the characteristics depicted in table 1 to determine the relationship between code quality and ethical performance within rankings on ethical corporate behaviour. He found that code quality is related to CSR performance on both a meso- and macro-level and hence concludes that high quality codes of conducts are more effective in establishing a responsible organizational culture and guide employee behaviour.

Research regarding whether or not the quality of supplier codes of conduct affects their effectiveness is not available to the best of our knowledge. Although creating a SCoC is not as easily done as simply including the word supplier in the title of an existing CoC, we argue that the overall findings from research on CoCs can be transferred to SCoCs and used as a ground for conducting research into this matter.

Table 1 – Quality criteria for CoCs

Authors	Quality Criteria	Explanation
Schwartz 2004	Justification	The contents are perceived as appropriate by the employees
	Examples	Should be used in order to increase the codes understandability
	Tone	Negative tone ensures that expectations are being understood
	Relevance	Code content needs to be relevant to the company
	Length	Overarching length of the codes is negatively related to their adherence by the employees
	Realistic	The described behaviour has to be achievable by employees
Erwin 2011	Public Availability	Code should be available to all stakeholders
	Tone from the Top	Top management of the company should be visibly committed to the code
	Readability and Tone	Code should be easy to read and fit its target audience
	Non-Retaliation and Reporting	Possibilities for reporting misbehaviour have to be promoted and clearly pointed out
	Commitment and Values	Code should highlight the overall company values
	Risk Topics	Code should address all relevant risk topics
	Comprehension Aides	Code should include comprehension aides such as examples, Q&As, FAQs
	Presentation and Style	Layout should contribute to creating understandability

The aim of increasing the quality of CoCs is that employees intuitively know what to do and understand what is expected of them to be able to act accordingly (Kaptein, 2011) and are motivated to do so. Most of the highlighted quality criteria aim at promoting this notion. The underlying assumption is, that it is impossible to directly govern the behaviour of employees in the variety of critical situation that they might face and thus rather provide them with a basis for acting in an appropriate manner on their own. This is exactly what the goal of supplier codes of conduct is as well (Andersen and Skjoett-Larsen, 2009), since, as we highlighted before, the large numbers of suppliers do not allow for governing their behaviour in dyadic relationships. Especially lower tier suppliers have to be able to transfer the requirements into actions on their own.

Diffusion of Innovations Theory

One of the most influential works in the field of innovation diffusion research was conducted by Everett M. Rogers in the early 1960s. Rogers defines diffusion as "[…] the process in which an (1) innovation is (2) communicated through certain channels (3) over time (4) among the members of the social system." Five main variables determine the rate of adoption: The perceived attributes of an innovation, the type of innovation-decision, communication channels, the nature of the social system and the extent of change agent´s efforts. The first element of Rogers´ definition is the innovation itself, which he views as "[…] an idea, practice or object that is perceived as new by an individual or other unit of adoption" (Rogers, 2010, p. 12).

Newness is not necessarily expressed by a lack of knowledge of an innovation. Much rather, it describes that a subject may have had knowledge of an innovation for some time, but is yet to develop an opinion, either positive or negative, towards it and has hence not yet decided whether to adopt or reject it. This decision can also be related to the continuous application of an innovation after the decision to adopt was made and efforts related to do so. The five attributes that influence a subject´s opinion regarding the adoption of an innovation are its perceived relative advantage, compatibility, complexity, trialability and observability. These have been found to explain between 49 and 87 per cent in the variance of the rate of adoption in earlier studies (Rogers, 2010).

A plethora of additional attributes has been applied throughout the history of innovation diffusion research. Tornatzky and Klein (1982) were able to identify 25 additional attributes. However, the authors found that relative advantage, compatibility and complexity provide the most consistent results in terms of their effects. Given the fact that this finding has been confirmed afterward (Kaur Kapoor *et al.*, 2014), we limit our research to those three attributes.

Relative advantage describes the extent to which an innovation is recognized as better than the current state. Its degree is often expressed through economic profit or social status. Incentives can be used to increase the relative advantage of an innovation.

Compatibility expresses a similarity regarding the existing situation. The decisive factors for similarity are most commonly related to sociocultural values and beliefs, already existing ideas and needs for the innovation. The first is very hard to anticipate since they are deeply rooted within a society´s intangible norms. The second factor takes into account that existing ideas, which are applied in similar situations as the new innovation is supposed to, are the basis which possible adopters use to judge the value of the new innovation. The third factor expresses that a subjects motivation to adopt is higher if the innovation meets a so far unsatisfied need.

Complexity describes whether or not the innovation is difficult to understand and apply. One way of decreasing complexity is to provide possible adopters with knowledge regarding how to apply an innovation, instead of merely making them aware of their existence.

While most of the studies on the diffusion of innovations take individuals as their focal point, it is also possible to examine groups such as communities or organizations. It is utterly important to note that, while key differences regarding the diffusion of innovations among organizations exist, research has found no significant difference regarding the role of the attributes of innovations (Rogers, 2010).

Conceptual Framework

Research on SCoCs has picked up on diffusion of innovations theory in the past, without explicitly stating to do so. Mamic (2005) proposed a collaborative process between focal companies and suppliers which postulates a move from authority towards collective decisions and thus change the type of innovation-decision. Roberts (2003) highlights that the diffuseness of a supply chain and the power between members are decisive factors, which is in line with how Rogers conceptualizes the influence of the social system. Porteous et al. (2015) highlight the significance of incentives and penalties issued by the focal company, which corresponds to efforts of the change agent in DOIT. However, research has so far neglected the role of the innovation and its perceived attributes.

As we highlighted, an innovation is defined as “an idea, practice or object that is perceived as new by an individual or other unit of adoption” (Rogers, 2010, p. 12). The innovations that we examine are SCoCs, which arguably fit all three different aspects or characteristics that Rogers defined. A SCoC can be viewed as an idea since it transmits

an image (or idea) of how a company (the supplier) should deal with issues related to sustainability. A SCoC can also be considered as a practice, given that they contain precise guidelines for how business is to be conducted by suppliers. Lastly, SCoCs in their written form as a document are an object as well, which the suppliers are passed on to and which they are expected to pass on to their suppliers. Thus, a SCoC can clearly be considered as an innovation in the sense of Rogers' definition. Furthermore, an innovation in a supply chain can be characterized as "[…] a change within the supply chain processes that takes place in a company or the supply chain as a whole, which aims at the creation of new value for stakeholders" (Arlbjørn et al., 2011, p. 8), which additionally underlines this fit. When considering SCoCs as the innovation we want to examine, the perception of Rogers´ attributes of innovations by suppliers is influenced by the contents of a SCoC. Especially in situations where lower-tier suppliers are not in direct contact with focal companies and thus heavily rely on the SCoC´s contents, as we described before. Of course, this perception can also be influenced by other measures, such as communication activities by the focal company. However, we argue that the contents play an important role in influencing the supplier´s perception, without stating that they are solely responsible for doing so.

The idea, that SCoCs are subject to diffusion has been picked up by research before. Meqdadi et al. (2018) analyse the influence of different forms of power on the diffusion of sustainability practices, which includes codes of conduct, from focal company to suppliers. However, the authors do not consider the actual contents in their research. Kaptein and Schwartz (2007) note that this has been a gap in many research approaches in the past. Schleper and Busse (2013) follow a similar train of thought as proposed within this article in order to create a universal supplier code of conduct, which they argue could be applied throughout various industries. The authors connect the content of their proposed artefact to relative advantage and compatibility.

The importance of relative advantage, compatibility and complexity have been highlighted by past research on SCoCs as well. Grimm et al. (2014) identify perceived value, which is similar to relative advantage, by suppliers and sub-suppliers as the most important factor in adopting SCoCs. Andersen and Skjoett-Larsen (2009) argue that a key pre-requisite for SCoC success is that suppliers understand what is expected from them, which we consider as code complexity. Additionally, the authors found that the supplier's corporate history and available assets are key determinants, which is related to how we conceptualize compatibility. We aim to explore the role that the contents of a code play in promoting these perceptions by suppliers, since it was again not considered in these past studies.

Since no framework or scale for the assessment of the role of SCoC content, especially as perceived by the suppliers, exists, new constructs have to be defined. The constructs are derived from a combination of Rogers' attributes of innovations and research on CoCs and SCoCs. The constructs aim to assess how the contents of a SCoC influence a suppliers perception. We do not explicitly consider which actual contents in terms of e.g. the triple bottom line are mentioned within the SCoCs, but rather focus on the established quality criteria. For every construct, we highlight how they are expected to influence the suppliers´ perception and their relation to SCoC content. Additional sources, that highlight their relevance, and which were not explicitly referred to within the course of this paper, are also provided.

In line with Rogers, we expect the influence or relative advantage on diffusion to be positive. The SCoC has to explicitly outline the relative advantage that suppliers can achieve through its adoption to increase its diffusion. The corresponding constructs and their relation to SCoC content are outlined in table 2.

Table 2 – Relative Advantage of SCoCs

	Constructs	Supplier Perception	Relation to SCoC Content	Source(s)
Relative Advantage	Tone from the Top	The supplier perceives that the focal companies top management is committed to the principles of the SCoC.	The SCoC includes a statement from the top management of the focal company.	Erwin (2011); Garegnani et al. (2015)
	Rewards / Benefits for Compliance	The supplier is aware of possible rewards or benefits that can be achieved through the adoption of the SCoC.	The SCoC provides clear insights into possible rewards for and benefits of compliance.	Stevens (2008); Andersen and Skjoett-Larsen (2009); Porteous et al. (2015); Meqdadi et al. (2018)
	Blunt and realistic about sanctions	The supplier is aware of possible sanctions that can follow misbehaviour.	The SCoC provides clear insights into possible sanctions for violations or misbehaviour.	Welford and Frost (2006); Preuss (2010); Grimm et al. (2014); Meqdadi et al. (2018)
	Non-Retaliation and Reporting	The supplier feels encouraged to report mis-behaviour to the focal company.	The SCoC provides opportunities for and encourages the reporting of misbehaviour.	Schwartz (2004); O'Dwyer and Madden (2006); Erwin (2011); Garegnani et al. (2015)

First, the construct tone from the top expresses that the focal company´s top management declares its commitment to the SCoC. Second, relative advantage can be promoted through pointing out rewards (in the sense of e.g. increased order volumes) and benefits (such as e.g. decreased operational costs) that can be achieved through adopting the SCoC. Third, relative advantage can also be increased by avoiding negative consequences such as sanctions. The supplier should be made aware of those consequences in the SCoC. Fourth, we included the possibility to report misbehaviour for the supplier as a construct that constitutes relative advantage. There is a broad consent that the ability to report wrongdoing is a key determinant for the effectiveness and perceived value of CoCs. It presents a relative advantage to the supplier by giving him the impression that his activities are important to the issuing company. Since SCoCs are a kind of preventive innovations (Rogers, 2010), we expect the effect of relative advantage to be particularly high. We formulate the following hypothesis regarding the influence of relative advantage:

H1: Relative Advantage is positively related to the diffusion of SCoCs.

Compatibility expresses that the SCoC has to be specific to its target audience. Its constructs are defined in table 3. First, the requirements of the SCoC have to be compatible with the values and strategy of the supplier. Additionally, compatibility is also expected to increase if the requirements from the SCoC are compatible with other SCoCs that the supplier has to comply with. A high degree of compatibility between those SCoCs could dramatically decrease the supplier´s efforts to implement the necessary measures.

Lastly, the compatibility between the requirements of the SCoC and the supplier's internal capabilities plays a major role as well. If the supplier does not possess the knowledge or financial resources to implement the requirements from the SCoC, its adoption and diffusion are less likely, since it can appear like an overwhelming task. However, their relation to overall code content is hard to generalize. Compatibility serves as a proxy for covering the actual contents of the SCoCs in terms of its requirements and statements, which was suggested as an important factor as we highlighted before as well. We thus do not explicitly outline the relation to code content for these constructs as we do for relative advantage and complexity, but rather highlight that it is an important aspect that has to be included in future research. If compatibility were to be found as the most important factor for the adoption and diffusion of SCoCs, then e.g. companies would have to consider creating different SCoCs for different suppliers in varying cultural settings. We expect compatibility´s effect to be positive, and thus formulate the second hypothesis:

H2: Compatibility is positively related to the diffusion of ScoCs

Table 3 – Compatibility of SCoCs

	Constructs	**Supplier Perception**	**Source(s)**
Compatibility	With own values	The supplier perceives that the SCoC is compatible with his company values.	Adam and Rachman-Moore (2004); Andersen and Skjoett-Larsen (2009); Schleper and Busse (2013)
	With own strategy	The supplier perceives that the SCoC is compatible with his overall strategy.	Ibid.
	With other SCoCs	The supplier perceives that the SCoC is compatible with other SCoCs that he has to implement.	Risso (2012); Schleper and Busse (2013)
	With internal capability to comply	The supplier possesses the internal capability to implement the requirements from the SCoC.	Andersen and Skjoett-Larsen (2009); Grimm et al. (2014); Wilhelm et al. (2016)

The last construct, complexity, is related to the presentation of the SCoC and its accessibility in terms of e.g. language and scope. Its constructs are depicted in table 4. We aim to assess whether or not suppliers actually comprehend the contents of SCoCs and which particularities of their presentation and style have an impact on this. As discussed, the length of the document can play a crucial role. A SCoC should neither be too short, since in this case, it probably will not cover all relevant aspects, nor too long, since this could appear dissuasive for the supplier. Comprehension aides such as examples and case studies can be used to increase the understandability of the SCoC and thus reduce complexity. The overall readability and tone relate to aspects such as the style of writing (e.g. long explanations vs. bullet points) and how principles are stated (e.g. negative or positive). Lastly, complexity can also be decreased if the SCoC includes clear guidelines regarding management systems and processes that have to be implemented in order to ensure its governance. The last two variables also aim at assessing whether or not the SCoC provides the supplier with how to knowledge instead of awareness knowledge, as it was discussed by Rogers. Overarching complexity is expected to negatively influence diffusion, which results in the third hypothesis:

H3: Complexity is negatively related to the diffusion of SCoCs.

Table 4 – Complexity of SCoCs

	Constructs	Supplier Perception	Relation SCoC Content	Source(s)
Complexity	Length	The supplier perceives that the length of the SCoC is appropriate.	The length of the SCoC is appropriate for it to include all necessary requirements without being excessively long.	Schwartz (2004); Erwin (2011); Schleper and Busse (2013)
	Comprehension Aides	The supplier understands the requirements from the SCoC.	The SCoC includes comprehension aides, such as examples and case studies.	Schwartz (2004); Erwin (2011);
	Readability and Tone	The supplier perceives that the information within the SCoC are presented in an understandable manner.	Language and tone of the SCoC are matched to the target audience in order to allow for easy understandability.	Kaptein (2004); Erwin (2011); Garegnani et al. (2015)
	Related Processes	The supplier is informed about concrete processes that are to be adapted for the implementation of the SCoC.	The SCoC includes statements regarding which processes have to be adapted for its implementation.	Mamic (2005); Stevens (2008)
	Required management systems	The supplier is informed about necessary management systems that accompany the implementation of the SCoC.	The SCoC includes clear statements regarding which management systems have to be established for its implementation.	Mamic (2005); Stevens (2008); Garegnani et al. (2015)

Conclusion

The goal of this research paper was to highlight the role that the contents of supplier codes of conduct play for prompting their diffusion in supply chains, which has so far been neglected by research. We analyzed content-oriented research on both CoCs and SCoCs and introduced diffusion of innovations theory, as established by Rogers (2010), as the frame for our analysis. We arrive at the conclusion that especially in situations where suppliers are not in direct contact with the company that issued the SCoC, its contents are an important driver for both its adoption and further diffusion and thus play a crucial role. They have to promote the notion of relative advantage, compatibility and low complexity among those suppliers.

The presented paper adds to the knowledge regarding the establishment of sustainability in supply chains in three ways. First and most importantly, it guides scholarly attention towards the relevance of the contents of supplier codes of conduct, which has been pointed out as a shortcoming of past research approaches. Second, it provides the possibility for their inclusion as constructs in future research. Third, it can be applied to create a deeper understanding for the general drivers that affect the diffusion of SCoCs from the supplier point of view. It contributes to what Zorzini et al. (2015) call “theory suggesting and explanation”. It enables theory-driven and deductive, rather than a-theoretical and

exploratory empirical research.

Possibilities for future research are manifold. We encourage researchers to empirically validate the framework in different geographical or industrial settings and thus create an understanding of the perception of suppliers and how SCoCs can reach higher rates of adoption. An interesting approach could be to distribute two different supplier codes of conduct, one that adheres to the proposed design principles and one that does not, to two subsets of suppliers of a company and evaluate whether or not the SCoC content actually does play a crucial role in influencing suppliers´ perception.

The conceptualization of Rogers rate of adoption has not been discussed in detail. The rate of adoption is traditionally measured as the number of subjects that adopt an innovation relative to the total number of subjects of a social system. One interesting avenue would be, to assess whether or not SCoCs, which adhere to the proposed quality criteria, show higher rates of adoption among second and even lower tier suppliers. Based on the highlighted hypothesis, we expect that the contents of a SCoC play a crucial role in their diffusion from first to lower tier suppliers, as it is often demanded by focal companies. One large shortcoming can be identified with this approach. A broad consensus amongst scholars exist, that the adoption of a CoC is only a first step in establishing an ethics program, which promotes organizational change (Kaptein, 2011). If not followed by the implementation of supporting management systems, this adoption remains of symbolic nature. Arguable, this is the case for SCoCs as well. We thus propose for future research to assess first how suppliers implement the requirements from SCoCs, which has so far been treated as a black box (Andersen and Skjoett-Larsen, 2009), and second, whether or not their perception of the SCoC content has an influence on those efforts.

Aside from assessing the drivers of diffusion, DOIT can also assist in compiling diffusion programs. In this sense, as we highlighted before, the constructs represent guidelines for the design of SCoCs by companies. For example, in order to increase relative advantage, SCoCs should include statements regarding possible sanctions that suppliers might face for violations.

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Removing the parasite without damaging the host: A framework for mitigating illegal supply chain infiltration

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Abstract

Otherwise legal supply chains are sometimes exploited by criminals for their illegal purposes. This research offers a conceptualization of such supply chain infiltration (SCI) as a general problem in contemporary supply chains. The study explores a specific form of SCI, namely illegal wildlife trafficking (WLT) in maritime supply chains. By drawing on criminology theories and empirical evidence from approximately 20 crucial stakeholders, the study develops a framework on how WLT emerges in maritime supply chains and how it can be mitigated. WLT is an important, albeit previously neglected, driver to biodiversity loss.

Keywords: Sustainable supply chain management; supply chain infiltration; wildlife trafficking

Introduction

Despite decades of practical and scholarly efforts to create more responsible and sustainable supply chains (Gold and Schleper, 2017), supply chains are sometimes used not only for illegitimate, but even for illegal purposes. Research in the supply chain management field has addressed these cases under the umbrella of sustainability, business ethics and corporate social responsibility. Topics such as modern slavery (Gold et al., 2015), conflict minerals (Hofmann et al., 2018), corruption (Arnold et al., 2012) or child labor (Lund-Thomsen and Nadvi, 2010) have been widely discussed in the literature.

However, contexts of supply chain infiltration (SCI), defined as *a situation in which an unauthorized actor succeeds in inserting illegal products into a legitimate supply chain* (cf. D'Amato and Papadimitriou, 2013), have received only scarce scholarly attention so far. Noteworthy exceptions appear in the counterfeiting literature as well as in the literature on cyber security and digital supply chains (Green and Smith, 2002; Corera, 2018). Examples of these SCIs oftentimes refer to either human trafficking or the smuggling of drugs, cigarettes, alcohol or weapons.

Consequently, this study aims to tackle a rather neglected issue in the operations and supply chain management field, namely wildlife trafficking (WLT), often also referred to as illegal wildlife trade. Although WLT has never been officially defined in treaties, the common understanding of this concept involves "the poaching, capture, collection or processing of animals and plants taken in contravention of national laws, and any subsequent trade in such animals and plants, including their derivatives or products" (McLellan et al., 2014, p. 2). Despite extensive efforts by international regulations, laws and initiatives aiming at preventing WLT, recent media reports still list examples of failure, including the auctioning off of hippo teeth in Tanzania (Bale, 2018), tortoise smuggling in Madagascar (Gerety, 2018), or rhino poaching in South Africa (Carnie, 2018). The magnitude of WLT is illustrated by a drastica increase of detected rhino poaching cases from 13 to 1004 between 2007 and 2013 (WWF, 2018). Overall, Interpol (2018) estimates that up to 20 billion USD are annually illegally generated by dealing either with dead or living animals, plant species, insects and orchids, making it a lucrative business for organized crime and casting serious doubt on the effectiveness of existent measures and instruments for preventing wildlife poaching and trafficking (UN DESA, 2018). Together, these illegal activities severely thwart the international community's conservation efforts and pose a serious risk to the above-mentioned species.

With a few exceptions (e.g., broader risk management and due diligence approaches), supply chain management is hardly concerned with the specific issue of WLT and the more general problem of SCI. In absence of suitable theoretical frameworks, the design of SCI countermeasures in corporate and regulatory practice remains a matter of chance. A key problem in mitigating SCI is to tackle illegal activities without disrupting the legal supply chain or, metaphorically speaking, to remove the parasite without damaging the host. Accordingly, our research-guiding questions are 1) *how does organized crime infiltrate legal supply chains and* 2) *how can SCI be mitigated*?

As WLT can take place through many different supply chains and transportation modes, this study's scope is narrowed down to so-called "WLT hotspots" in maritime supply chains. WLT hotspots are locations in which a relatively large portion of illicit WLT occurs, allowing for crime problems to be dealt with in a more efficient way (Braga et al., 2014). Furthermore, besides air transportation modes, WLT is mainly present in maritime supply chains. Due to the standardization of transportation

equipment through containerization and the resulting extreme cost reductions, container ships have become dominant in maritime goods transportation (Kaukiainen, 2009). Consequently, criminal activities, such as smuggling and illegal trade, have taken advantage of the efficiency and limited visibility of this international transport mode (Martin, 2015). For this reason, particular emphasis is given to this specific transportation mode in the remainder of this study. Figure 1 depicts a typical legal containerized transportation process, using an idealized activity sequence including an optional stopover at a transshipment hub and derives an overview of links between supply chain infiltration and most risky situations.

*** Please insert Figure 1 here ***

From a theoretical perspective, this study eclectically incorporated perspectives from criminology, i.e. rational choice theory (RC) (Cornish and Clarke, 2014; Hayward, 2007; Pratt, 2008) and situational crime prevention theory (SCP) (Clarke, 2009; Cornish and Clarke, 2003; Gilling, 2005; Newman and Clarke, 2016). Following RC, criminal behavior is seen as the outcome of various choices (Cornish and Clarke, 1987). Thereby, SCP posits that situational conditions are fundamental in preventing crime (Clarke, 1997). Considering the infiltration of legal supply chains not from a specific issue, but rather as a general phenomenon, criminals as well as the circumstances of a supply chain seem constant. In this manner, SCP and RC seem to be a promising theoretical lens to begin the study of preventing WLT.

Due to the exploratory nature of this study and in order to obtain relevant information on the sensitive topic of WLT, a qualitative data collection approach based on semi-structured interviews with approximately 20 crucial stakeholders along maritime supply chains has been chosen.

The main findings of this study contribute to the literature on supply chain management in the context of WLT and SCI in the following way: 1) This research is one of the first to offer a conceptualization of supply chain infiltration as a general phenomenon that stretches beyond specific issues such as counterfeiting and cyber-attacks. 2) It is among the first papers which tackles the problem of WLT in a (sustainable) supply chain context, with a focus on maritime supply chains. WLT is an important, albeit neglected, driver to biodiversity loss and it has rarely been considered in previous sustainable supply chain management studies. 3) This study furthermore transfers informative criminology theories to the field of (sustainable) supply chain management research and 4) provides methodological novelty insofar as it engages in empirically augmented theorizing.

The next section reviews theoretical foundations related to SCP and its application to SSCM. Thereafter, the case study method is introduced, along with a brief description of data collection and coding techniques. Subsequently, the findings are delineated, which are eventually expected to culminate in a research framework and testable propositions.[*] The paper concludes with a discussion on the theoretical and practical implications as well as limitations and opportunities for further research.

Conceptional background

Supply chain infiltration in the context of WLT

In general, wildlife transportation within maritime supply chains can take several different forms, contingent on the legality of the transported good (i.e., legal vs. illegal)

[*] *Please note that this paper illustrates work in progress. The authors are still working on the backend of the paper, particularly the propositions and the overall framework, which will be developed and presented at the time of the conference.*

and the legality of the transportation channel as such (i.e., legal vs. illegal). A transported good is regarded as illegal whenever its transportation – specifically, its import and/or export – is legally prohibited. In the same vein, vessels that are used for the sole purpose of criminal activities are classified as illegal channels, independently of whether they are owned or hired by criminal groups. For a start, wildlife may occasionally move through maritime supply chains for perfectly legitimate reasons, such as repopulation and conservation efforts. In light of the base motivation of this study to explore situations in which an unauthorized actor succeeds in inserting illegal products into a legitimate supply chain, this situation will not be analyzed further.

From other smuggling contexts such as human trafficking or trafficking of drugs and cigarettes, it is known that illegal products often move through illegal channels. Thus, illegal channels are also viable means for engaging in WLT. However, findings from the data and prior literature on WLT and trafficking in general suggest that the maritime transportation of illegal goods through purely illegal channels does not occur very often. It appears that smugglers possess their own sense of economic rationality which leads them to consider expected monetary rewards, associated monetary costs, and detection risks in their transportation planning. As wildlife products, especially animal parts and artefacts, can easily be hidden within maritime containers smugglers can physically be detached from these. Thus, there may simply not be a major need for using illegal maritime channels for WLT purposes.

Applying the aforementioned economic rationality argument reversely, co-relying on legal channels is often much more efficient for smugglers, thereby rendering this situation much more relevant with regards to mitigating WLT and prohibiting SCI. Maritime WLT occurs presumably first and foremost via legal channels. Consequently, a key problem in mitigating SCI is to tackle illegal activities without disrupting the legal supply chain or (i.e. removing the parasite without damaging the host). The remainder of this study therefore focuses on this situation.

Conceptional lens

Assuming that SCI is a criminal activity, this study bases on criminology theories (i.e. RCT and SCP) as a theoretical angle for its analysis. RCT and its cognate field of study, SCP, have a major influence on contemporary crime reduction practice, with many supporters claiming that such strategies represent the most efficient and cost-effective approach to current crime problems (Hayward, 2007).

The RCT approach to crime assumes that crime can be understood from a cost-benefit analysis of the (potential) perpetrator's situation (Becker 1968; Ehrlich 1974; Eide 1994; Schmidt and Witte 1984). Just like any other individual, perpetrators are self-interested goal maximizer, seeking to maximize their personal benefits (Gul, 2009). Thus, the decision to offend is influenced by people's preferences, their attitudes toward risk and time discounting, and their estimates of an illegal opportunity's availability, costs, and benefits versus a legitimate opportunity's availability, costs, and potential for realizing the same or comparable returns.

In response to this RCT approach explaining crime, SCP comprises opportunity-reducing measures that "(1) are directed at highly specific forms of crime, (2) involve the management, design or manipulation of the immediate environment in as systematic and permanent way as possible, (3) make crime more difficult and risky, or less rewarding and excusable as judged by a wide range of offenders" (Clarke, 1997, p. 4). The need to addapt specific measures to individual offenses implies hat the commission of specific kinds of crime depends crucially on a constellation of particular environmental opportunities and that these opportunities may need to be blocked in

highly specific ways (Clarke, 1997). Changing the environment is designed to affect assessments made by potential offenders about the costs and benefits associated with committing particular crimes (Clarke, 1997). This implies some rationality and a considerable degree of adaptability on the part of offenders. All offenders, however emotionally aroused or determined, take some account of the risks and difficulties of particular situations (Clarke, 1997). However, the SCP has failed to pay sufficient attention to the array of criticisms of RCT that have emerged from disciplines such as behavioural psychology, political science and sociology that centre around the simple alternative hypothesis that 'not all actors are economically self-interested' (Hayward, 2007).

Given that both RC and SCP have found broad empirical support (Freilich and Newman, 2017; Kliemt, 2018), it will be assumed that these theories are also accurate representations of the behavior of SCI criminals, specifically in the context of maritime WLT (Busse et. al, 2017). This implies that inference from the economic attractiveness of WLT opportunities to the expected behavior of the criminals is possible and that, even more importantly, rendering ssmuggling opportunities economically unattractive facilitates mitigating WLT. This seems to be particularly true if the mitigation strategies target WLT hotspots where they are supposed to enfold their highest efficiency.

Methodology

Research design

SCI can happen in relation to all kinds of crimes (e.g., smuggling of drugs, human trafficking or WLT) and in connection with various modes of transportation (e.g., air-bound, sea-bound or ground transportation). In view of the fact that single case studies facilitate a particularly deep understanding of the subject matter, this study focuses on a single case, namely WLT in maritime supply chains. As it is virtually impossible to investigate organized crime empirically by means of interviewing the criminals, this study strives to collect empirical evidence from 20+ crucial stakeholders along maritime supply chains to generate potential starting points to effectively combat WLT and SCI.

Due to the exploratory nature of this study, the analysis followed an iterative interview method. Semi-structured interviews allow researchers to adapt the data collection process according to their needs whenever new insights or relevant topics emerge, by continuously moving back and forth between the data and emerging findings (Dubois and Gadde, 2002; Eisenhardt and Graebner, 2007). This technique facilitated identifying key respondents' insights and opinions and applying these interim findings in subsequent interviews.

Data collection

As WLT is almost never clearly allocated to in specific corporate functions and in order to gain specialist knowledge about detailed processes within maritime supply chains, targeted respondents were preferably experts who have a special or even better exclusive position in the social context of decision-making processes that are impacted by or could potentially impact WLT (Meuser & Nagel, 2009). Overall, the data comprises mainly informants from the purchasing/supply chain, legal and CSR/sustainability department.

Whenever possible, interviews were jointly conducted by two researchers, based on a semi-structured guideline. To this aim, a comprehensive list of 90 relevant parties in the maritime supply chain was created as a first step, including NGOs, public authorities, logistics companies, port authorities, cargo interests, terminal operators, cruise ship operators, and further relevant actors. Out of the 90 contacted SCUs, 16 participated so

far, resulting in 18 interviews yet[†]. All interviewees agreed to participate under conditions of confidentiality and anonymity. Another 24 SCUs declined explicitly, whereas 50 SCUs did not respond to any interview request at all or changed their mind at a later point. Whenever the respondents consented, the interviews were recorded and subsequently transcribed. In all other cases, extensive notes were taken by the interviewers.

Coding

In order to evaluate the statements in the interviews, qualitative research frequently uses categories and types as well as interpretations in order to grasp meaning in addition to content (Titscher et al., 2000; Bryman, 2004; Mayring 2000; Kohlbacher, 2006). To this aim, a qualitative content analysis (Mayring 2000) was employed. Content analysis developed in the 1920s in the United States initially focused on the systematic analysis of large quantities of textual data from the mass media (Mayring, 2004; Titscher et al., 2000). The qualitative content analysis is a systematic procedure that serves to capture text meanings. Within the data analysis process of this study, critical themes emerged which were grouped under more abstract higher-level codes and then linked to existent concepts from the literature.

Preliminary findings

Emergence of the problem

Although this paper presents an early stage of the analysis and therefore work in progress, the following findings are anticipated:

When considering the plurality of legal channels, a distinction can be made among luxury crafts and yachts, cruise ships (incl. ferries and other passenger ships), bulk carriers and container ships as the most important categories. The former three transportation modes are supposed to be particularly suitable for transporting live animals, whereas containers are not. On the contrary, containers present a preferred and convenient transportation solution for inanimate wildlife products. Seizures of any scale occur regularly as the sheer quantity of containers globally used offers vast opportunities to smuggling.

Illegal products may also be included in shipments that have an import or export certificate and which thus appear to be legal. Another important distinction between the legal channels refers to their relative share in maritime WLT. Due to the standardization of transportation equipment through containerization and the resulting extreme cost reductions, container ships are so dominant in maritime goods transportation nowadays that criminal activities, such as smuggling and illegal trade, have taken advantage of the efficiency of this international transport mode (Martin, 2015).

SCI mitigation in the case of WLT

To ensure the protection of the goods and proprietary information (privacy) of the shipper, the container remains sealed and inaccessible throughout nearly the entire voyage. The ensured secrecy of the container content entails important implications for the search of potential entry points for mitigating WLT. However, this lack of visibility is often an integral and intentional part of the transport itself. Sealed containers allow a comprehensive protection of shipped products and prevent external interference. This is particularly important when companies ship confidential goods.

Referring to the idealized chain of operational activities in Figure 1 above, a

[†] *Please note that the data collection, coding and overall data analysis is still ongoing.*

substantial probability of interference with containers exists during (1) the filling of containers, (4, 10) any inspections, and (14) the process of container stripping. In the context of WLT, it seems to be most likely that smugglers interfere at the container stuffing and stripping steps as these are the most accessible activities for hiding and removing wildlife products in and from containers. Interference during inspections also seems possible, but it would require bribery and corruption of authorities. Every inspection has disruptive effects on the flow of goods. Against the background of the vast number of containers transiting through ports each month – with a range of between hundreds of thousands and even millions for the largest hubs – these external disruptions have an immense impact on supply chains.

Based on the preliminary and ongoing data analysis, propositions are anticipated which 1) relate to the likelihood of WLT incidents in maritime supply chains as a specific example of SCI (e.g. different structural antecedents (sustainable supply chain risks, monitoring costs, transportation mode, supply chain position, etc.) that make WLT/SCI more/less likely to occur) and 2) link mitigation strategies and practices to these scenarios.

Concluding discussion

Assuming further analysis will proceed as expected, four significant and unique contributions are anticipated. First, to the best of our knowledge, this is one of the first papers to offer a conceptualization of SCI as a general phenomenon that stretches beyond specific issues such as counterfeiting and cyber-attacks. In doing so, SCP represents the most comprehensive approach, as a successfully infiltration presumes feasible situations. In particular, as this study focuses on WLT hotspots. Thereby, firms, governments and NGOs are able to deduce more effective measures and instruments for preventing wildlife poaching and trafficking, as these are novel issues for practice and research. Second, this paper is among the first to tackle the problem of WLT in a (sustainable) supply chain context, with a focus on maritime supply chains. WLT is an important, albeit neglected, driver to biodiversity loss and it has received scarce attention in previous research on sustainable supply chain management. Thereby, this paper provides first empirical insights and a thorough snapshot of corporate practices, key enablers, and barriers regarding WLT among the maritime transport and logistic industry. Third, the finalized study will facilitate the transfer of informative criminology theories to the field of (sustainable) supply chain management research. Previous research in supply chain management has not only shown impacts of supply chain disruptions but also the linking of these to sustainable related risks within supply chains. However, these disruptions haven't been considered as an infiltration that is occurred because of situational related facts. The afore mentioned first empirical insights can therefore be seen as starting points of a first direction for future theory testing research in the context of SCI as a situational issue. Lastly, the final version of this study will provide methodological novelty insofar as it will engages in empirically augmented theorizing.

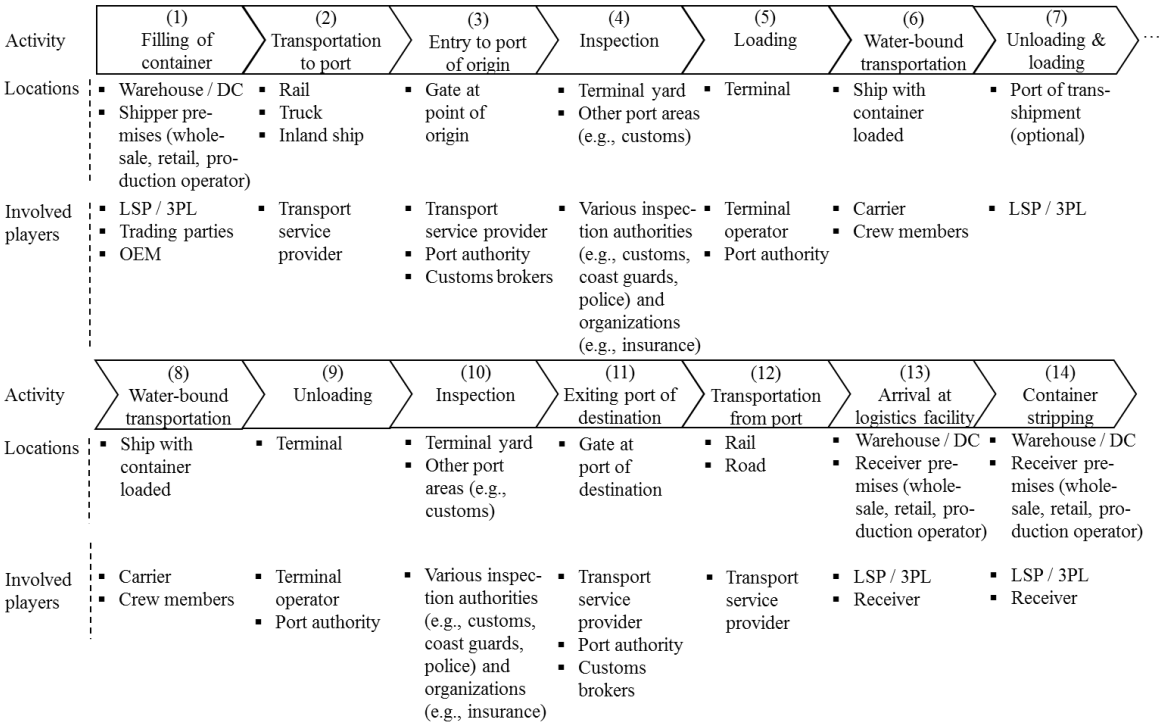

Figure 1 – Idealized chain of operational activities in typical maritime containerized transportation process (own conceptualization)

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Do past safety violation experiences reduce future violation behaviors?

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Abstract

The recurrence of safety violation indicates that firm's operational improvements via corrective actions based on violation experiences may be limited. We argue that an adaptive corrective response to the violations might in turn hinder a system-wide improvement. Thus, the improvement from correcting one type of violation may not be effective in reducing other types of violations. We conducted panel data analyses on 2,965 listed firms with 4,474 violation records in the U.S. Our results indicate that past violation experiences are negatively associated with subsequent repeat violations (of the same clause), but positively associated with non-repeat violations (of a different clause).

Keywords: Occupational Health and Safety, Safety Violations, Policy and Operations

Introduction

Governments, media, and consumers nowadays are increasingly concerned about sustainable operations of firms. One of the important dimensions of sustainable operations relates to Occupational Health and Safety (OHS) (Kleindorfer et al., 2005). OHS problems can incur substantial social costs. In the United States (U.S.), on average, there are more than 12 workers losing their lives on their job everyday (BLS Census of Fatal Occupational Injuries, 2016). In addition, firm's reputation, image, cash flow and productivity would be undermined (Fan et al., 2014; Lo et al., 2014). An improved OHS

performance can reduce operational risks (Wolf, 2001), improved product quality (Das et al., 2008) and increased revenue and profitability (Lo et al., 2014). Previous literature substantially explores factors for OHS performance improvement, including manager's attitudes (Pagell and Gobeli, 2009; de Koster et al, 2011), OHS management systems (Lo et al., 2014), linearized and decoupled operations (Wolf, 2001; Wiengarten et al., 2017).

In spite of the above empirical evidence for improved firm performance resulting from OHS system implementation, whether violating firms will limit their future transgressions on safety violations, which is the core objective of OHS, has remained uncertain. Ironically, past research documented a low management commitment level of OHS in the industries (Pagell and Gobeli, 2009). In particular, when the operations managers are under productivity pressures, the safety practices may be compromised to meet urgent production goals (Brown et al., 2000; Wiengarten et al., 2017). Drifting away from safe practices often occurs in the firm because of poorly committed managers. This could cause damage, injury and fatality. Since the internal volition is often absent, government enforcement is expected to be the gatekeeper of safe operations. However, the effectiveness of government enforcement in improving safety performance of firms has not been widely examined. Our study aims to fill this gap.

In the U.S., mandatory correction actions are required for safety violation. Corrective actions are monitored by the Occupational Safety and Health Administration (OSHA) as an important element of experimental learning and safety improvement process (Hofmann and Stetzer, 1998; Christian et al., 2009; Catino and Patriotta, 2013). The purpose of levying such government enforcement includes retribution, deterrence, rehabilitation, restoration and incapacitation (Meyer and Grant, 2003). Also, the enforcements are expected to be followed at an organization-wide level, such that not only the violating department but also the other members in the organization will learn from the punitive sanctions (Braithwaite and Petitti, 1992).

Although the mandated corrective action seems to be an effective means to prevent firms from making the same mistake, the scope of improvement might be just at the level of a specific issue and not directed towards making organization-wide improvement, beyond the immediate point of correction. It has been observed that firms violate a variety of safety regulations on a continual basis. For example, Manke Lumber was fined US$ 87 thousand in 2015 for eleven violations, which had caused its workers' severe injuries and fatalities (OH&S, 2015). Similar cases of violations occurred even in some highly reputable firms, such as Disney and Home Depot, resulting in US$ 21,000 and US$ 150,000 fines respectively (ISHN, 2013). It is therefore unclear whether the lessons learned from the past violation experiences do extend to a more comprehensive improvement, or such regulatory violations are inherent in the systems. Are the improvement practices just *Quick Fixes*—taken only to respond to the immediate correction action, impeding wider improvements in all kinds of safety compliances?

If the problem of safety violations, like other chronic management issues, is inherent within organizational systems and cultures, it is unlikely that firms would be able to improve extensively, or simply take corrective actions dictated by the government authority (Haunschild and Rhee, 2004). Even if follow-up actions are required after a safety violation, organizations might only resort to an adaptive response to mechanically comply with rules (Fiol and Lyles, 1985; Perrow, 1984). That is, organizations could only fix the specific failure without fundamentally transforming the current organizational systems and cultures underlying the failure. In fact, real organization-wide improvements in OHS require changing current organizational routines, systems and cultures, which are

unlikely to be accomplished by simply taking the required corrective actions. Firms need to proactively identify potentially critical incidents and develop an "early warning system" (Cope, 2005). Such a wider level of improvement, in turn, may require stronger enforcement forces and the interactions of other institutional pressures as an agency for change (Haunschild and Rhee, 2004). External institutional pressures drive organizations to deviate resolutely from their current organizational routines and take actions addressing the root cause(s) of any violations.

In this study, we explore the effectiveness of government enforcement in operational improvement of firms. Specifically, we investigate if safety violation experiences can deter subsequent violating behaviors of the same and different clauses. In addition, we explore the moderating roles of institutional pressures on a firm's operational improvement, subsequent to OHS violations. Adopting DiMaggio and Powell's (1983) categorization of institutional pillars, we examine the strength of enforcement as a coercive institutional pressure that is approximated by the amount of penalty, and normative and mimetic pressures approximated by voluntary OHS certification and relative industrial performance.

Drawing on neo-institutionalism (DiMaggio & Powell, 1883), we conceptualize a safety violation order issued by the government as a mandate for safety improvement. We first postulate that a firm's past violation experience is *negatively* related to subsequent *repeat safety violations* (to the *same* clauses), which indicates the improvement on a specific clause where the hazards were exposed. In addition, drawing on the notions of safety culture and organizational myopia (Staw et al., 1981; Levinthal and March, 1993), we postulate that a firm's past violation experience is *positively* related to subsequent *non-repeat safety violations* (with respect to *different* clauses), indicating the absence of systematic and wider organizational improvement. We offer evidence to show that the inefficiency of government enforcement reduces subsequent violating behaviors of firms.

Theoretical background and hypothesis development

Coercive pressure of OSHA enforcement

The essential premise of neo-institutionalism is that organizations in an institutional environment are becoming similar or "isomorphic" in nature (DiMaggio and Powell, 1983). Firms become isomorphic because they have to obtain legitimacy for survival (DiMaggio and Powell, 1983; Suchman, 1995). Coercive, normative and mimetic pressures are three primary pressures that make organizations conform to an established institutional environment (i.e., the prevailing organizational structures and practices) (DiMaggio and Powell, 1983; Scott, 2013). In other words, these external institutional forces serve to facilitate the diffusion of operations management practices such as total quality management (Yeung et al., 2006), radio frequency identification (Barratt and Choi, 2007; Whitaker and Mithas, 2007) and shape the standards in an organizational field, including safety requirements in industries (Lo et al., 2014).

Coercive pressure stems from political influence and government mandate (Zukin and DiMaggio, 1990). Organizations are penalized when they do not conform to the coercive pressure (Scott, 2013). The coercive pressures (e.g., government intervention) drive organizations to adopt managerial and technological innovations for environmental and safety enhancements (Gray, 1983). Thus, a firm's sustainable practices are primarily affected by the role of *government-as-coercer* (Scholz and Gray, 1997).

From an economic perspective, the market participants often pursue the most economically efficient way to produce goods. Pursuing productivity goal may undermine worker's safety (known as productivity-safety trade-off) and increase social costs (Lo et al., 2014). The government, as a coercer, aims to correct such market imperfections, which could cause adverse environmental and social outcomes (Scholz and Gray, 1997). Government regulations and enforcements, thus, play an important role in pushing sustainable operations (Tang and Zhou, 2012) by setting minimal environmental and safety requirements that all firms must follow. The fine and penalty of enforcement increase the costs of non-compliance and shape firms' behaviors (Scholz and Gray, 1997). Therefore, law enforcement imposes a deterrent effect of preventing employers putting worker's health and safety at risk.

To the violating firms, failure incidents such as safety violation records force to challenge the status quo, initiating necessary changes. A safety violation signals that the safety performance of the firm is in an undesirable state, putting pressure on them to search for new methods, which can improve the current status (Cyert and March, 1963; Madsen and Desai, 2010). The mandated corrective actions following a violation can be viewed as an adaptive approach in response to the OSHA's enforcement, as the specific actions are laid down according to the hazards exposed in the inspection. These actions provide firms with explicit roadmaps as to what knowledge and alternative methods have to be searched, and allow firms to make the necessary changes and corrections. In addition, improvements are likely to take place because the violating firms are targeted for scrutiny by the authority and other stakeholders (e.g., the public). Firms that fail to respond and commit repeat violations will be penalized more seriously in the future (Desai, 2011; Zavyalova et al., 2012). Therefore, even though the violating firms may not be fully committed to comply with the safety regulations, they are mandated, or coerced, to correct any specific violation or neglect identified during inspection. We thus postulate:

Hypothesis 1a: The higher the number of past safety violations recorded, the lower is the number of subsequent repeat violation (to the same clauses) incidents.

Despite the fact that law enforcement may improve firms' operational systems, Haunschild and Rhee (2004) find that the firms' lessons learnt from previous mandated product recall experiences can be shallow and symbolic, leading to no fundamental improvement on the firm's product safety routine and practices. Therefore, it is possible that the mandated improvements set by the government authority can be simply adaptive and reactive in nature, within a limited scope (Scholz and Gray, 1997). It is unlikely that these will lead to a system-wide improvement. If a firm aims to achieve a more fundamental improvement after the corrective action to the specific hazard exposed by the OSHA, the firm needs to proactively seek a deeper understanding of causality between behavior and outcome, and challenge the norms and status quo of the organization (Appelbaum and Goransson, 1997; Argyris and Schon, 1997). Although the adaptive corrective actions might bring immediate performance improvement, it could lead to organizational myopia, making firms overlook the big picture and other potential failures (Levinthal and March, 1993). This is especially the case when the improvements to be adapted are mandated by external parties (Haunschild and Rhee, 2004).

In the context of safety violations, the recurrence of safety violation records might indicate that safety problems of the firm are deep-rooted in its organizational systems and

culture, thus hindering proactive organizational learning for improvements. Reason (2017) pointed out that a safety violation record is often the "sharp-end" of a poor safety management culture. If a poor management culture is entrenched in a firm, although they are willing (coerced) to correct any exposed hazards in an inspection, it is difficult for the firms to proactively introduce organization-wide safety improvements. Previous studies have suggested that recurring safety violations are rooted in enduring organizational schema that hinders correct attribution of failure (Hofmann and Stetzer 1998; Reason, 2017).

From an economic perspective, if the expected penalties are smaller than the investment to explore potential hazards, the deterrent effect of violation would be insufficient to motivate a proactive improvement (Greve et al., 2010). In addition, the inhibited improvement efforts can be caused by a simple correction mechanism after a safety violation (Levinthal and March, 1993). The failure experience could narrow the organization's focus on the domain of the problem. A firm that consistently resorts to adaptive improvement in response to safety violations is unlikely to take further actions to explore other hazards. First, the simplified correction mechanism narrows the firms' focus on the specific hazard exposed, making them unable to explore other underlying hazards (Levinthal and March, 1993). In addition, for long, the public and scholars have criticized the penalties from OSHA for being too low (U.S. Government Printing Office, 2008; Viscusi, 1979). Firms may rely overly on government inspections to identify the hazards, rather than investing in an early warning system to proactively explore the safety flaws in the operations system.

Further, a safety violation is an adversity that can damage the firm's reputation (Lo et al., 2014). In responding to such a threat, the firm's information processing will be restricted thus increasing its reliance on organizational schema (Ocasio, 1993). The firm may simply refer to the previous method used to cope with the violation. Thus, the cumulative use of adaptive mindset for safety violation increases the firm's rigidity to undertake comprehensive corrective actions. The lesson learned from the past violation is unlikely to be extended to various other units in the firm, thus inhibiting the spillover effects of corrective behaviors in the entire organizations. Therefore, we postulate that the past safety violations should positively associate with the subsequent non-repeat violations, which leads to an increased number of overall violations.

Hypothesis 1b: The higher the number of past safety violation records, the greater is the number of subsequent non-repeat violation (to the different clauses) incidents.

Hypothesis 1c: The higher the number of past safety violations records, the greater is the number of subsequent violation incidents.

Method

Samples

We sampled a large number of U.S. listed manufacturing firms and developed a firm-year panel data set to examine our hypotheses. The use of panel data has advantages in mitigating endogeneity concerns (Ketokivi and McIntosh, 2017) (see detailed discussion in the robustness check section). Panel data analysis was also used in the previous study whose dependent variable is corporate malfeasances (e.g., Mishina et al., 2010;

Haunschild and Rhee, 2004). Safety violation data were collected from OSHA's violation database (OSHA, 2017) while other financial data were collected from COMPUSTAT database. The data collection process started with obtaining the name list of 8,953 manufacturing firms (SIC 20 - 39) from COMPUSTAT database. Next we searched for these firm names in OSHA's violation database for their violation records. From each violation record we were able to obtain the violating firm's name and address, the violation date, type and other related information. We summed up all the violations of a firm in one year to create the variable of annual number of safety violations as the dependent variable. If a firm was not engaged in any violation in that year, then the observation was coded as "0". As our analysis involved the comparison with the industry peers, we excluded an industry (at 4-digit SIC) that did not have any violation history within our research window.

We collected the OHSAS 18001 certification data from each firm's official website, annual report and media report. At the time of data collection, the window of violation database was from 1988 to 2014 at the time of data collection while the OHSAS 18001 was developed in 1999. Thus, we used the violation data between 2000 and 2014 as our dependent variables. We used the one-year lag between dependent variables for independent variables, so our independent list covered the period 1999 to 2013. In the event, we generated a panel data set consisting of 25,273 observations drawn from 2,965 firms. In the data set, 694 firms had at least one violation. In total, 4,474 violations were reported. The remaining firms with no violation record are used as control firms. Adding these control firms may bring a large amount of "0" in our dependent variable. However, Cramer et al. (1999) report that the parameter estimations are robust in samples involving large percentages of "0" observations. In addition, Bayus (2013) argues that it is more difficult to find statistical support with a large number of "0" observations. This suggests that adding firms without violations made the hypotheses testing more conservative.

Variables

We use subsequent safety violations rate as a proxy for firms' safety performance as our dependent variable (Pagell and Gobeli, 2009; Lo et al., 2014; Wiengarten et al., 2017). This was measured by the firm's annual number of violations to OSHA's regulations scaled by the number of employees ('0000) at year *t*. The violation database categorized the violations under serious, repeat, willful and other violations. We focused on the number of repeat violations (*repeat violation rate*) for hypothesis 1a to capture a specific safety improvement related to the past violations. Repeat violation is issued when the firm had been cited for the same safety regulation clauses in the past. For example, Metalico Rochester Inc. was cited in 2011 with violations for failing to develop proper safety procedures, which leads to the death of an employee. These are classified as repeat violations by OSHA because Metalico Rochester Inc. was cited for the same violation in 2010. For hypothesis 1b, we excluded repeat violations from our measurement of dependent variable, as our objective here is to test if past violation experiences are related to a higher number of subsequent non-repeat violation (to the different clauses) incidents. For H1c, we considered both repeat and non-repeat violations to examine the impact on overall violation number. We treated all other types as equal while calculating the number of violations, as the classification was not mutually exclusive (i.e., a violation can belong to many types at the same time). For example, a violation can be serious and willful at the same time. This treatment is consistent with previous studies (e.g., Pagell and Gobeli, 2009; Lo et al., 2014; Wiengarten et al., 2017). In our sample, nearly 99% of OSHA visits

were without advance notice, so the firms could not have indulged in last-minute cover-ups before the visits. Accordingly, spot-check inspections should more accurately reflect the safety performances of firms.

With H1a, H1b and H1c, we hypothesized the relationship between past safety *violation experiences* and subsequent safety violation incidents. The variable, *Violation Experiences*, was measured by the total number of violations a firm committed in all the years before a certain year (year *t*). This measurement was consistent with the studies of *organizational learning from failure* (e.g., Haunschild and Rhee, 2004; Yiu et al., 2014). This measurement captures the total past experiences in all years before the safety violation incident in year *t*. In our sensitivity analysis, we replaced this variable by the number of safety violations committed by a firm in one year (instead of all years) before year *t* (i.e., at year *t*-1; see robustness checks section).

We included a number of control variables in the models to ensure their robustness. We first included the natural logarithm for transformed number of employees to control for *firm size*, the return-on-assets (*ROA*) and operating income per employee ratio (*Productivity*) to control for firm performance because a larger and profitable firm is likely to have abundant resources to invest on safety practices. We included *firm age* because older firms may cumulate more violation experiences. We also included the financial slacks of the firm because resource abundant firms have higher capability to invest in safety precautions. Financial slacks are multi-dimensional and include *unabsorbed slack* measured by quick ratio [1], *absorbed slack* measured by selling, administration and general expenses scaled by sales and *unborrowed* slack measured by financial leverage (debt/equity) (Wiengarten et al., 2017). Firms may face higher safety risks when their operations are complex. We included *labour intensity* (total assets per employee) to control for process complexity in the operations (Lo et al., 2014). We included research and development *(R&D) intensity* (R&D expenses per employee) to control for the absorptive capacity because learning is more effective in highly absorptive capacity firms (Tsai, 2001). We also included *annual number of inspections* of the firm to control for some firms being targeted by authorities. The size of violation penalty relates to the violation types: willful and repeated violations are penalized more vigorously by the OSHA. Thus, we included the percentage of past willful and repeat violations to the total violations to control for the *types of violation experiences*. We also controlled for the average *penalty* the firm received in the past, whether the firms were *OHSAS 18001* certified and the *number of violations of the industry* (four-digit SIC)

Finally, we included the dummy variables of *year*, *industry* and *state* of the firm's headquarters to control for fixed effects. Except otherwise stated, the independent variables have at least one-year lag, *t-1*, to the dependent variable, *t*, to exclude the alternative explanation of reversed causality.

Results

Table 1 presents the results from the OLS analysis with robust standard errors. The maximum variance inflation factor (VIF) of the independent variables is 2.437, indicating that multicollinearity is not a serious concern.

Model 1 examines H1a with the dependent variable as *repeat violation rate*. We excluded the control firms with no violation records throughout the whole research

[1] Quick ratio was calculated by current assets minus inventory then scaled by current liabilities.

window, because these firms do not possibly have repeat violations. We also conducted a separate analysis by including all sample and control firms, the results are largely similar to our main analysis. In Model 1 of Table 1, the coefficient for past *violation experiences* is significantly negative (-0.0024, $p < 0.05$), which supports H1a. With one more past violation experience, the firm's subsequent repeat violation would reduce by 0.0024 per ten thousand employees, given that the average repeat violation rate is 0.034 and the decrease is 7%.

Model 2 examines H1b with the dependent variable as *non-repeat violation rate*. The coefficient for past *violation experiences* is significantly positive (0.0293, $p < 0.01$), which supports H1b. With one more past violation experience, the firm's subsequent non-repeat violation would increase to 0.0293 per ten thousand employees. Given that the average non-repeat violation rate to be 1.0992, the increase is 3%

Model 3 includes both repeat and non-repeat violations in the dependent variable in order to examine H1c. The coefficient for past *violation experiences* is significantly positive (0.0265, $p < 0.01$). Given that the average total violation rate is 1.1332, with one more past violation experience, it increases the total violation rate by 2%. This result supports H1c, which suggests that the present violation experience associates with a higher overall violation rate in the future.

Table 1: Regression analysis of safety violations

	Model 1 (N=8294)		Model 2 (N=25273)		Model 3 (N=25273)	
	DV: Repeat violation rate (to the same clauses)		DV: Non-repeat violation rate (to the different clauses)		DV: Total violation rate	
Independent variables	**Coef.**	***p***	**Coef.**	***p***	**Coef.**	***p***
Violation experiences (H1)	-0.0024	0.043	2.9302	0.000	2.6501	0.000
F-test	1.2500	0.000	7.4500	0.000	8.2700	0.000
Note: two-tailed tests; the control variables includes operations experience, number of inspection, R&D intensity, ROA, productivity, Absorbed slack, unabsorbed slack, labour intensity, firm size, violation type of past violations, industry violations, OHSAS 18001 and penalty in the previous violations; The dummy variable of year, industry and state were included; 0.0000 indicates <0.0001;Violation rate = number of violation per 10 thousand employees						

Conclusion

This study has explored the relations between the past safety violation experiences and subsequent repeat, non-repeat and overall safety violations. It has presented an analysis of a sample set of 2,965 U.S. listed firms with 4,474 violations issued by Occupational Safety and Health Administration from 2000 to 2014. We find that past violation experience associates negatively with the subsequent repeat violation incidents, which show a certain level of improvement after a firm was cited and the corrective action was conducted. However, the past violation experience associates positively with the subsequent non-repeat violation and overall violation incidents.

The results have shown that firms do not necessarily reduce their safety violations as they accumulate more safety violation experiences. The literature has already captured superior improvement effects from the additional experiences of errors (e.g. Edmondson, 1996; Catino and Patriotta, 2013) and accidents (e.g. Hofmann and Stetzer, 1998; Haunschild and Sullivan, 2002). However, consistent with the notion related to organizational myopia (Levinthal and March, 1993) and the shallow learning effect in mandated product recall (Haunschild and Rhee, 2004), our results show that the adaptive corrective actions to past violations hinders proactive exploration of other hidden hazards in the system. Table 1 shows that adding one violation per (‘0000) employees to the mean of *violation experiences* (from 3.2898 to 4.2898), the mean violation rate per year is seen to increase by 2.6501. These result findings call for future research to investigate how to motivate firm to better utilize the violation experience and conduct more proactive learning process, which to improve the OHS performance in the industries.

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Introducing a holistic supply chain sustainability approach to emerging economies: challenges for theory and practice

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Abstract

This paper aims to extend the current theory and enhances the practice of supply chain sustainability in emerging economies, where contextual elements are extremely relevant, especially in supply chains predominantly operated by micro and small enterprises (MSEs). A qualitative research approach was employed using team interviews with different members of stakeholder groups of the cashew supply chain in Ceará, Northern Brazil. The findings indicate that supply chain members have different comprehension about the practice of sustainability. In turn, third party actors (e.g. Sebrae, Embrapa) are recognised as central players to spread the practice of sustainability through the cashew supply chain. This paper contributes in advancing the supply chain sustainability literature and show empirical evidences that already well established frameworks developed in the North may not be as relevant to all contexts.

Keywords: Supply chain sustainability, Micro and small enterprises (MSEs), Emerging economy.

Introduction

The literature on supply chain sustainability are increasing in the last years and has been considered a fruitful research field (Ansari and Kant, 2017). Currently, it is urgent the need for empirical research that demonstrate the characteristics of sustainability approaches through supply chains. According to Pagell and Wu (2009, p. 38), "when we discuss sustainable supply chain management we are referring to managerial decisions and/or behaviors", which demonstrate that it is necessary to understand how direct supply chain relationships introduce sustainability advancing the current knowledge based more on the focal company point of view.

By challenging the comprehension of the concept of supply chain sustainability, we believe that there are contextual elements from emerging economies that might affect

most supply chains, but the European and North American perspectives have not covered (Gold and Schleper, 2017). Fritz and Silva (2018) and Jia et al. (2018) corroborate with this idea by arguing that the literature does not adequately deal with the specific issues of SCS in emerging economies. There is a pressing need to stimulate companies to have increased supply chain collaboration in different contexts and that the supply chain complexity should be taken into account. The supply chain sustainability only is possible if a learning process happens and the sector context is effectively observed (Silvestre, 2015).

Thus, according to Cagliano et al. (2016) to have truly food supply chain sustainability (FSCS) it is necessary to align strategies and practices, which is related to innovation. In the current debate, FSCS emerge from practices performed among companies in a multitier level. The levels should encompass all actors involved in the process toward sustainability at the strategic, structural and process levels of the supply chain (Beske and Seuring, 2014). By assuming these comprehension and need for changes in how to apply sustainability in supply chains worldwide, this paper aims to extend the current theory and enhances the practice of supply chain sustainability in emerging economies.

Therefore, this research aims to apply Beske and Seuring's (2014) framework to explore sustainability issues within the cashew supply chain in Northern Brazil. This research adopts a learning perspective to supply chain sustainability in an emerging economy and aims to understand how applicable this framework would be to different supply chains, especially the ones with predominantly micro and small enterprises (MSEs) within developing settings. There are several gaps that need to be covered by studying contexts such as Latin America (Fritz and Silva, 2018). Aiming to contribute with theory and practice this paper is structured in different sections that challenge the current understanding and meaning on the research topic.

Supply Chain Sustainability

Discussions about sustainability and SCM have been increasing in the past years precisely because the study of these topics is both timely and significant (Golicic & Smith, 2013). As presented by Ashby et al. (2012), the initial discussions under this perspective point out to the year 2003, but only in 2008 a wider range of articles was being published about the topic. According to Ahi and Searcy (2013), there is at least twelve "definitions" on the perspective published along this decade, however not a theoretical evolution about Sustainable Supply Chain Management, which is the more widespread expression on the topic. From this discussion, it is clear that more than creating new concepts and/or definitions; it is necessary to evolve the field through a new approach that carries both theoretical and methodological consistence.

Focusing on SCS, the organisations "need to satisfy various contradicting objectives such as profit maximization while reducing environmental impacts and maximizing social responsibility" to reach sustainability practices (Ansari and Kant, 2017, p. 874). Therefore, to challenge the current literature is an important step to advance in the comprehension on how to practice sustainability in emerging economies. Within this

debate it is important to highlight the need for more clear comprehension about what is sustainability. According to Fritz and Silva (2018), the Triple Bottom Line (TBL) is not enough to understand sustainability, which could be clearly observed by discussing the sustainable development goals (SDGs). Since other elements are involved with what companies do what they do, it is relevant to demonstrate their comprehension and interactions created to better performance its practices.

In addition to this point of view, it is necessary to understand what is currently presented in the literature. According to Ansari and Kant (2017), there are several framework that represent the topic, some of them following a narrow perspective. This occur aside other reasons, because sustainability has been used in a instrumental and normative perspective (Gold and Schleper, 2017). Although this point of view, other elements (including SDGs) should be used to better capture the complexity of applying sustainability in supply chains. In order to advance in the comprehension of new conceptualization of SCS, Figure 1 illustrate how is possible to observe differences.

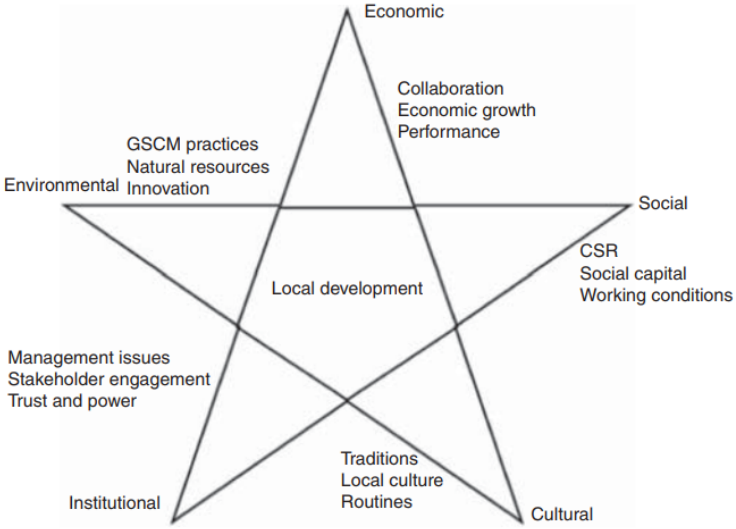

Figure 1: Origami framework for sustainability in supply chains.
Source: Fritz and Silva (2018)

The figure show a set of folder considering elements around sustainability and it allows scholars to recognise that sustainability is more complex than observed following the triple bottom line perspective. Fritz and Silva (2018) state that the origami metaphor consider the need of change in the design, because it is not a star, but it can assume different formats. In the SCS literature, there are calls for new ways to analyse true sustainability, which can be delivered by creating another logic of analysis (Montabon et al., 2016). According to Touboulic and Walker (2015, p.21), "future research efforts could seek to develop our understanding of the implementation process of SSCM by framing it as transformation/change in organisational practice". For this paper we debate about other elements that are around the SCS practice.

According to Beske and Seuring (2014), to understand supply chain sustainability it is necessary to consider a broader discussion using some categories and practices that

can facilitate the analysis of SSCM. According to these authors, this is possible in three hierarchical levels: Strategic values, Structure, and Process (Figure 2). Each of these levels guide how supply chain may introduce sustainability as well as how it is possible to design a sequence of practices contributing in that way.

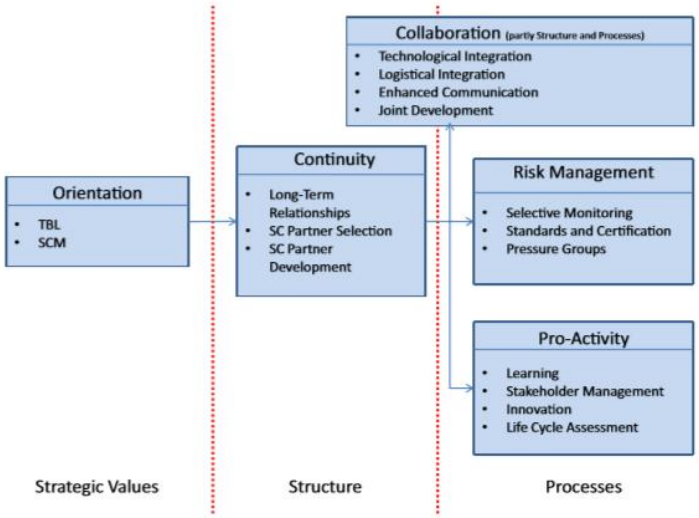

Figure 2: Sustainable supply chain categories and practices
Source: Beske and Seuring (2014)

As presented in the Figure, there is a unique way to introduce elements toward SCS, which not consider other elements such as contingency factors. Tachizawa and Wong (2014) demonstrate that in a multitier supply chain there are several influences beyond what is directly consider in the literature. However, as presented by Mena et al. (2013) and other authors in SSCM, when considering the sustainability in supply chains the economic dimension of sustainability have a little relevance when social and environmental dimension are more difficult to be observed. This paper aims to observe Beske and Seuring's (2014) framework and its relation with the emerging economies contexts and perspectives.

Research Method

A qualitative research was developed using interviews with different members of the cashew supply chain in Ceará, Northern Brazil. The research focus is on cashew production, considering its economic relevance as well as that it is the most exported product in Ceará state, which is the first position in Brazil regarding export cashew nut. To enable a rich and multi-faceted view of the local business practices, ten interviews were conducted with representatives of different stakeholder groups: four farmers, four processing firms (e.g. cashew nut, Cajuina), and two third party members (i.e. Embrapa and Sebrae).

Since our focus is on MSEs, direct supply relations has been identified to ensure evidence of practices that are accessible to these firms. Data gathering was developed

between June and August of 2018. The interviews were conducted in Portuguese, recorded, transcribed and translated to English by both authors to ensure the reliability of the study. The analysis was conducted based on five main categories of Beske and Seuring (2014), namely (1) Orientation; (2) Continuity; (3) Collaboration; (4) Risk Management, and (5) Pro-activity management. Additionally, contingency factors were analysed to better support the argumentation and findings. For that, a content analysis was used in order to understand better the meanings and understandings.

Findings

The cashew supply chain in Ceará is exported-oriented mainly operated by four medium companies. Small and micro operations have been emerging locally in the last decades as an alternative for enhancing community engagement and maintaining the cashew production, an economic activity that has long history and is a regional heritage, i.e., it is part of the local culture and background. The findings indicate that supply chain members have different comprehension about the practice of sustainability (Table 1). For example, farmers believe that their production are sustainable in nature (simply because it's an agricultural product, with no consideration to pesticide/herbicide usage, water consumption, land management or working conditions) while the processing firms do not recognise themselves as the ones responsible for the implementation of sustainability practices since they have small business.

In turn, third party actors (e.g. Sebrae, Embrapa) are recognised as central players to spread the practice of sustainability through the cashew supply chain. Though the findings was clear that to introduce sustainability, mostly considering the MSEs characteristics, it is necessary to have someone not economically included in the supply chain to have clear practices. Additionally, it was not found elements that demonstrate a clear relation with collaboration, which is a key aspect for Cagliano et al. (2016). There are also a lack of elements that demonstrate pro-activity as an operational level for SCS. It was found that this elements could be better related to orientation, which change the structure of levels presented by Beske and Seuring (2014).

Table 1: Representative's point of view

Category	Key quotes
Orientation	As I said, we are a small property, so we have settled everything here in the same region. They are people, small traders that we pass on, what we can get through. (P2) Nowadays there is the company X that try to have a sustainable production. Thus, its employees are having all job rights respected (OA1)
Continuity	No, not really. I did not know if the companies that were providing me were adopting sustainability practices. (Agro 2) There is an interaction between the members mainly with the rural producers and the representatives of organs like the embrapa and

	sebrae the interaction with the industries is more commercial. (P3)
Collaboration	The sector chamber at ADECE meet once a month discusses price, quality, technologies (OA1) Yes, and often we have a cashew meeting, there is the Northeast cashew that brings this information and it has the Farmers' Union, and we always get together and we are exchanging some experience. (P1)
Risk management	We face an abnormality, a prolonged drought, which is the risk. Of those six years of drought, the chain was already reaching its limit, a little more and we were going to start a serious problem. (Agro 1)
Pro-activity	Not found

As presented in the table, by applying the Beske and Seuring's (2014) framework, it was possible to identify some alignments, but more importantly some key inconsistencies that require a broader perspective that would include the specific contextual elements from MSE dominant supply chains in emerging economies to fill the existing gap in the mainstream publications. For example, the category orientation is stressed as totally aligned and necessary when it comes to supply chain sustainability in such a context. The empirical study shows that supply chain members do not feel themselves as part of a supply chain as a system, neither the processing firms have this feeling of being part of a broader system.

This result ratifies the need for awareness and dedication to the TBL principles, which create an opportunity to talk about other dimensions as presented by Fritz and Silva (2018). The continuity category is mostly absent locally due to the fact that relationships are very volatile and no long-standing relationships were identify. Collaboration is based on personal connections and trust in that specific person, as opposed to trust more embedded in the supply chain relationships, which makes it more difficult to involve a broader set of actors and enhance collaboration outcomes. The risk management category is clear for farmers and is influenced by contingency factors.

In a complementary way, contingency factors were identified as relevant by interviewees to understand the local context such as: low productivity (Bloom et al. 2010), business informality (Silvestre, 2015), lack of government incentives and support (Azzi da Silva and da Rocha, 2001) and the extremely dry period facing the region in the last years (Silva et al. 2018). Although these challenging factors were identified, it was found that currently the role of third party is deemed as essential to develop supply chain activities, especially the integration of sustainability business practices to MSEs. The findings also demonstrate that the Beske and Seuring's (2014) framework requires adaptations since the influence of contingency factors impact directly in how firms manage and practice supply chain sustainability.

Conclusions

From the empirical results, it is clear that the framework do not fits directly with the emerging context of Brazil. The findings demonstrate that contingency factors and third party practices are necessary to reach supply chain sustainability. These elements demonstrate that to discuss about hierarchical levels it is necessary to understand before what is around the relationship analysed as well as how the supply chain members perceive themselves in the process. Research on SCS need to assume a more behavioural point of view instead of assume everything as static and without influence from the context where the relationship are.

By analysing the cashew supply chain in Ceará, there are two main contributions: (1) theoretically, by providing a critical stance to the mainstream supply chain sustainability literature. It also proposes a framework that extends theory and enhances the practice of supply chain sustainability in emerging economies, where contextual elements are extremely relevant, especially in supply chains predominantly operated by MSEs, and (2) for practitioners there is the indication to understand better what they are doing and making to have sustainability as a truly practices and logic regarding their strategies and operations in the market.

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The role of water resource accounting in supply chain: a conceptual framework

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Abstract

Due to growing pressures on global resources such as water, interest in supply chain water use has grown considerably. Water resource accounting is an established method for measuring supply chain water use, but what drives organisations to engage in these accounting activities is unknown. Similarly, what hinders engagement with accounting activities is not known. The research aims are twofold, firstly we review supply chain management and water resource accounting. Secondly, we develop a framework of drivers and barriers to supply chain engagement with water resource accounting. Following this we highlight key future research opportunities.

Keywords: water resource, supply chain management, conceptual framework

Introduction

As populations increase and the world is faced with issues such as climate change, and increased resource pressure, business' and their supply chains face an important challenge in ensuring the sustainability of our world. Water is one resource that has received growing attention over the last half decade, reports of droughts and increased water needs for communities across the globe have become increasingly more frequent (Masante et al., 2018). The World Economic Forum's Global Risk Report (GRR) has listed water crises among the top-five risks in terms of impact for eight consecutive years. Therefore, the practise of quantifying water use is an increasingly popular topic within academia. The idea of quantifying water use has also made its way into mainstream media with online calculators enabling consumers to calculate a water footprint of their diet, of their daily routine in the home and other situations (EasyCalculation, n.d.; GRACE Communications Foundation, 2017).

A water footprint uses the idea established concept of virtual trade water and has been described as a quantitative indicator of the water used to create a product or conduct a process (Allan, 1992; Hoekstra et al, 2011). Whilst individual water footprints are of importance it is argued that the global water footprint of a supply chain is more important due to the increase in magnitude of the water footprint (Christ & Burritt, 2017). Additionally, water related risks can be present at any one stage of a supply chain. Therefore, efforts must be taken by businesses to evaluate, monitor and manage their water use across not only their own activities but also those of the supply chain. Corporate water accounting exists as a methodology to assist in the evaluation of business water use making use of tools such as the water footprint.

Whilst initiatives such as CDP Water (Carbon Disclosure Project, 2017) and the CEO water mandate (United Nations Global Compact, 2011) exist to encourage organisations in the disclosure of their organisational water related risks, it is not widely understood to what extent companies engage or do not engage with water accounting of one form or another. Also it is not clear that what are the barriers that companies face wishing to engage or begin engaging with water accounting activities. This research aims to provide a framework to understand this gap through review of the relevant literature.

Research methodology

The purpose of this research is to explore a new research area and to conceptualise a framework for the understanding of the research area. The literature review process has been described as the process of collecting and analysis research in order to produce new ideas (Seuring & Müller, 2008). Depending on the purpose of the literature review, the research process of collecting and analysing research can follow a structured approach or an unstructured approach (Arksey & O'Malley, 2005). The purpose of this research involves collection and evaluation of relevant material and therefore follows a structured approach.

In order to collect relevant material for this research the first part to material collection involves a scoping study to outline the key concepts behind this research. Following the scoping study several observations can be made. In order to ensure the research is relevant to the water resource accounting within the supply chain context, the term "supply chain" should be included in any search terms. Evident from the scoping study, it is necessary to include one of either "water resource accounting", "water footprint" and "water

evaluation". In terms of identifying whether research pertains to the drivers and barriers of engagement with water resource accounting is somewhat less easy to describe in words and is therefore validated by a group of researchers. The next stage in material collection is to implement the search in relevant databases including Google Scholar, Scopus and Web of Science. There also exists a large amount of public research in this area and to capture this, Google was also used. The findings of the literature search are presented in the following section.

Literature review

Water resource accounting is an overarching term that refers to practices that enable organisations to quantify and account for their water use, focusing on the collection of relevant data the aim of water resource accounting is to assist decision makers in improving aspects such as water efficiency, total water use, and waste water (Christ & Burritt, 2017). One tool that exists and has been widely applied in many cases of water accounting is a Water footprint. There are differing methodologies for the quantification of a water footprint and this is currently beyond the scope of this research. In this case we simply refer to the volumetric footprint that is an indicator of the water required to produce a product or conduct a process (Hoekstra, 2010).

Both public and academic research have investigated the drivers, barriers and benefits of water resource accounting. In academia, Antonelli & Ruini (2015) focus on understanding the benefits realised by a single company through their engagement in water resource accounting. They show that by using the water footprint as a measure of water use the company is able to improve water use efficiency across a portfolio of products, they also show how this enabled the company to identify opportunities to expand into new product markets. Public research carried out in line with The CEO Water Mandate (Morrison & Schulte, 2010) evaluates the different methodologies available to companies when undertaking water accounting activities. They also outline several drivers for doing so, they outline hotspot analysis as a key driving force as well as potential for operational efficiency improvements and increased communication with stakeholders as well as supply chain partners.

Many barriers have also been identified with regards to water resource accounting, and a large proportion of these challenges focus on methodological challenges. Berger & Finkbeiner (2010) discuss the growing number of approaches available for use in water footprint methods, and how this potentially causes confusion for the decision maker. In further research Berger & Finkbeiner (2013) evaluate the different approaches based on the different nature of data collection and the data requirements. Furthermore, Chenoweth et al (2014) provide a review of all standalone water use indicators and the methodological challenges presented by each indicator. They discuss the inconsistency in terminology between methodologies and raise the issue of correctly identifying water components for analysis.

Beginnings of a conceptual framework

This work is the first step towards theory building and conceptualisation of the research field. Therefore, this work will be iterative and the authors predict the framework will

undergo many iterative changes before completion. The framework, as seen in Figure one, will be presented in three parts which are;

- Drivers of engagement with water resource accounting
- Barriers of engagement with water resource accounting
- Benefits of corporate water resource accounting

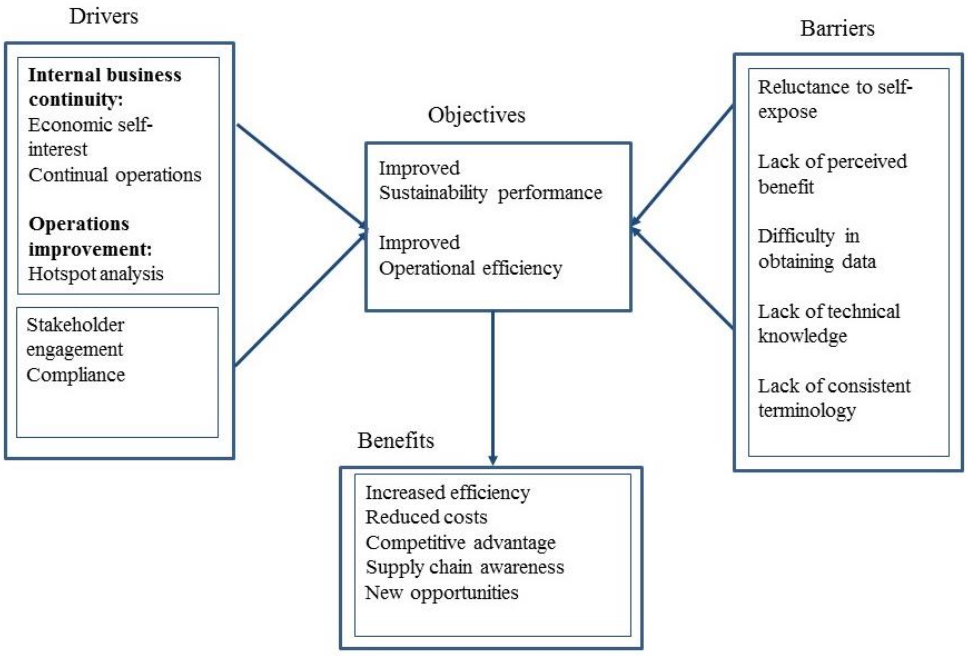

Figure 1- Conceptual framework

Drivers of engagement with water resource accounting

The first element of the research framework focuses on the factors that drive companies to engage with water resource accounting. Through careful review of the literature several different themes emerged, these themes are then explained in the following subsections.

Economic self interest

In the cases when water consumption and withdrawal are two factors directly related to operational costs organisations will hold a clear desire to reduce their water consumption, and withdrawal, to ultimately lower the costs of operations.

Continual operations

Where the organisations activities are subject to water risk an element of water risk assessment is necessary to ensure risks are adequately assessed and mitigation or contingency plans are appropriately developed and implemented. Water resource accounting exists as a measure to assist in the identification of supply chain water related risks.

Hotspot analysis

Water resource accounting can provide specific hotspot analysis which can be beneficial in several ways; where the identified "hotspot" indicates to the organisation that water use in a particular activity is somewhat large in comparison to the water use of the whole supply chain this analysis can prompt organisations to evaluate the water use at the identified activity level. This evaluation could prompt several actions whether they be supplier evaluation or technological evaluation.

Tools to identify opportunities for innovation and change

Either as a result of hotspot analysis or independently, water resource accounting can act as a tool to identify opportunities for innovation and change within the supply chain. That is to say that through engagement with corporate water resource accounting organisations may review specific activities or processes within the supply chain with respect to water use and identify opportunities to redesign a process or product resulting in improved water use.

Stakeholder engagement

When discussing stakeholder engagement, stakeholder is an encompassing description for the groups with interest in an organisations engagement with corporate water resources. Firstly, shareholders will have their own beliefs and drivers for interest in this topic, these individual drivers are not the focus of this work. However, their collective belief that organisations should engage with corporate water resource accounting is itself a driver to organisational engagement with corporate water resource accounting. Customers form the second body of stakeholders, with their purchasing behaviours they are able to demonstrate their power in encouraging organisational strategy. With the increase in conscious consumers acting in the best interest of planetary resources the change in buying pattern ultimately impacts organisational consideration for water resources.

Barriers

The framework also aims to explore and identify the barriers that organisations and their supply chains may face when they are attempting to engage in water resource accounting activities. Again, through evaluation of the literature several themes of barriers are identified and explained in the following subsections.

Reluctance to self-expose

In some cases, the exercise of fully disclosing supply chain water evaluation may expose risks within the supply chain. Furthermore, when the organisation does not have the capability to manage the risk this can have detrimental effects on the performance of the organisation and the supply chain.

Lack of perceived benefit

Dependent on several ideas including the organisations position within the supply chain, the organisational internal knowledge and the inter supply chain relationships there can be limited perceived benefit for engaging in supply chain water use evaluation. In the instance where the organisation plays a role with limited expose to water use there is no obvious reason as to why the organisation would engage with water accounting and no perceived benefit of doing so. Secondly, if the internal knowledge surrounding the

importance of supply chain water use is lacking limited understanding of the benefits of water accounting will also hinder the organisational engagement.

Difficulty in obtaining data
In many cases the resources required to collect and analyse the water use of an organisation and the entire supply exceeds the available resources. When the data is not already held by the organisation and the extra resources required to collect the data can be perceived as too difficult or not worth the extra cost so data is not collected.

Lack of required technical knowledge
In comparison to the case where the data is perceived too difficult to collect, another barrier may be the technical knowledge and skills of the organisation. In instances where the data is held by the organisation but the knowledge required to make sense of the data is not present it can be the unfortunate result that no analysis of the data is carried out.

Lack of consistent terminology
This barrier focuses more on the shortcomings of the existing methodologies and tools in place rather that the shortcomings of the organisation or supply chain. Several tools exist to measure water use, and different methodologies employ different terminology which can cause confusion to users and hinder the understanding of the methodology itself and therefore limit the application of the methodology.

Benefits of engaging with water resource accounting
The third segment of the framework focuses on the benefits of water resource accounting. Identification of the potential benefits to engaging is important in establishing the business case for do so, in cases where benefits are well understood and clearly communicated organisations have succeeded in bring water resource accounting to the attention of the organisation and supply chain. On the other hand, when benefits are unclear and unexplored it can be difficult to make the case for engagement in such activities. By outlining key benefits, organisations who have experienced difficulty in making the business case for water resource accounting are provided with key points that may help develop the case further.

Increased efficiency
As a result of analysing water use throughout organisational processes organisations may identify opportunities to redesign or reengineer processes such that the efficiency of the process is increased. This can of course lead to overall operational efficiency improvements both to the focal organisation and to the wider supply chain which potentially lead to greater production capacity, reduced lead times and reduced material requirements.

Reduced costs
In many cases the objective of reducing supply chain costs is present, water resource accounting can assist in the realisation of this objective by identifying processes that are unnecessarily costly due to their inefficiencies. Given that inefficiencies are addressed the supply chain can experience cost reductions.

Competitive advantage

Aware consumers are increasingly turning their attention to supply chains to understand the water used in producing products and services. So much so that when an organisation can clearly communicate their water intensive activities and the strategies in place to reduce this intensity the organisation holds competitive advantage over the competitors that cannot do so.

Supply chain awareness

The nature of water resource accounting requires in depth evaluation of organisational activities and supply chain activities. In doing so, supply chain weaknesses are identified prompting action resulting in a strengthened supply chain. Additionally, complete supply chain evaluation requires communication throughout different entities in the supply chain, where positive relationships already exists these can be strengthened and provide further communication between supply chain entities. On the other hand, where negative relationships exist this opens up opportunities for change in exchanges between entities.

New opportunities

Through the process of reviewing supply chain water use, organisations may identify hidden opportunities for product development or redevelopment. With the desire to reduce water use organisations may look to the inclusion of new technologies that can assist in redefining current products or to develop novel products.

Conclusion

In this research, we have presented the first thoughts of a framework for supply chain engagement with water resource accounting. This research has practical implications for both practitioners and academics, for those within industry we have highlighted some of the potential benefits of engaging with water resource accounting that may serve as a starting point for internal communications around this issue. For academics, we have developed a starting point for understanding the business environment of engagement with water resource accounting. This provides a solid starting point to further refine and develop this framework.

Furthermore, in this first exploratory study of the role of water resource accounting we have explored the drivers and barriers companies face when engaging with corporate water resource activities. We have shown those companies who do engage do so for several reasons, whether it is as a result of indirect or direct pressure from stakeholders or from internal desires to analyse and improve organisational water use.

This study possesses several methodological shortcomings, in order to collect the data, the review process has been conducted by a small team of researchers and in order to increase the validity of the research further researchers should be involved to determine the search terms. Similarly, further input from alternative researchers when determining the corresponding categories for drivers and barriers identified from the literature would only refine the research.

One of the next steps in this research is to involve industry leaders who have shown themselves to be proactive in engagement with water resource accounting to firstly verify the framework developed in this research and secondly, to build a richer picture of the business benefits to water resource accounting.

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Sustainable water management strategies in corporate supply chain management

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Abstract

This paper focuses specifically on water resource challenges and examines, via corporate social responsibility disclosures, the emerging resource development and management strategies undertaken by FTSE 100 companies oriented towards their suppliers with regards to water within their supply chains. Findings from 50 multi-national companies listed on the FTSE 100 reveals that it is the consumer facing industries have taken the biggest steps towards demonstrating their development of resources to address sustainability challenges and engaged closer with their supply chain when addressing water challenges in order to generate wider shared benefits across multiple organizations and community regions.

Keywords: Supply chain management, water sustainability, sustainability reporting

Introduction

At an organizational level supply chain manager are placed in a key role in ensuring continued access to critical resources whilst orienting business and suppliers towards building up levels of social, environmental and economic capital. This is a critical strategy as companies are now expected to compete on a sustainable supply chain vs sustainable supply chain basis (Sarkis et al., 2011). Effective governance of sustainability within corporate supply chains requires understanding the roles of different stakeholders (Akhavan and Beckmann, 2017) and how effective organizational collaboration can be utilized to provide the support functions to create shared value from engaging in pro-sustainability operations (Porter and Kramer, 2011). In this context, supply chain managers in large companies find themselves in a position of a unique vantage point and are involved in every aspect of operational activities from logistics through to strategic planning, finance, marketing, and communication which can create positive or negative effects for the company and its stakeholders and simply imposing rules and regulations from above may not generate the required sustainability management practices at the supply chain (Schnittfeld and Busch, 2016), and would still require effective measurement and monitoring processes. Previous research in the field

has attempted to integrate concepts concerned with measuring and monitoring sustainable practices and performances within the supply chain, including the integration of social, environmental, technological, political and economic performance issues (Schaltegger and Burrit, 2014), the efficient use of resources (Koh et al., 2016), or environmental hot spots emerging from certain processes (Acquaye et al., 2017).

The focus on supply chain management is a crucial one as companies are increasingly being held to account for the actions of their suppliers (Hassini et al., 2012). Ensuring sustainability practices in the supply chain is crucial given the popular view of contemporary organizational trends sees the shifting of production networks towards regions where labour costs and environmental standards may be lower, or where legislation is less strictly enforced and therefore seen as a 'race to the bottom' (Guenther et al., 2012). The challenge of examining sustainable development across corporate supply chains is vast and this paper therefore narrows the focus to water resources. This is justified on the basis that water pulls together traditional environmental-centric views of sustainability regarding pollution and resource exhaustion. The use of water as a "case" resource fits with a number of the United Nations Sustainable Development Goals such as Goal 6: Clean Water and Sanitation concerning water availability as well as Goal 12: Responsible Consumption and Production which considers indirect focus on the sustainable use of water sources. These goals set out targets by 2030 for: improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials; halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally the expansion of international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programs; sustainable management and efficient use of natural resources; and for companies, "especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle" (UN, 2019). At a policy level there is increased pressure on companies to engage in sustainability practices and demonstrate successes. For example the Commission of the European Union references the integration of water resource consumption to consider the 'efficient' use of abstracted water as part of its 'A Resource Efficient Europe' agenda (Commission of the European Union, 2011, 2012). While this is a start, a draw-back of this approach is that it focuses only on blue water (water that has been sourced from surface or groundwater) and does not consider the green and grey water which can play a prominent role in water resource consumption in many industries and opens up the debate on water sustainability away from a water efficiency perspective, but to also include measures of quantity, quality and re-use (through direct re-use and treated waste water). Here there exists the opportunity to integrate product water footprint, and the virtual water (the water embedded into global trade flows) into corporate management and reporting (Antonelli and Sartori, 2015; Hoekstra, 2017)

This research explores the challenges facing supply chain managers with regards to measuring and monitoring their water consumption. In order to gain an overview on the water challenges presented, this paper takes the case study of 50 large corporates listed on the FTSE100 and examine the reported water challenges from supply chain managers against traditional purchasing and supply chain management criteria. The focus on water is justified in the current research environment, where the role of water in an environmental management strategy is relatively under-developed in comparison to

other sustainability challenges such as carbon emissions and pollution prevention. Focus on large corporations is a suitable starting point as their size and position within global value chains gives them the ability to enforce standards in water consumption and waste water processes in order to create a larger market of potential suppliers and distributors, who in turn are forced to attach greater priority towards environmental performance (Fiorino and Bhan, 2016). The following sections of this paper set out the concepts of sustainable supply chain management with a resource dependency focus. The paper then continues to outline the methodological process of content analysis of corporate water sustainability disclosures. The final sections present the results and discuss the institutional and governance implications for water sustainability management within the supply chain.

Supply Chain Management and Resource Dependency

In focusing on water as a natural resource, this paper considers how water can become both a serious constraint for business operations, as well as a resource which can be exploited for sustainable competitive advantage. Water in this sense can be framed as a resource dependency issue, where under resource dependence theory - RDT (Pfeffer and Salanick, 1978) it is theorized that as a company becomes more dependent on a greater number of organizations in its supply chain, it can become more exposed to negative and unintended consequences (Ellram et al., 2013). Under this theoretical perspective, companies will attempt to utilize their power within the supply chain to manage and align their stakeholder interests to meet their own interests, and satisfy the interests of local community groups. These dependence relations on resources such as water give greater strength to the need to engage, manage and collaborate with their suppliers in order to maintain access to physical resources as well as knowledge capabilities, societal connections, and raw materials (Wieland, 2014). Asymmetries in information, knowledge and resource access can magnify power imbalances between the firm and stakeholders, as well as the extent which bounded-rational managers fail to consider stakeholders' interests to the firm. More powerful organizations are able to exploit their power to suppress their partner organizations, but this also offers the opportunity for a well-made contract structure to negate organizational weakness. RDT has implications regarding the optimal configuration and divisional structure of organizations and their stakeholders in supply chains with the basic arguments of resource dependence theory based along ideas that organizations depend on resource, resources originate form an organizational operational environment, resources required by one organization are often controlled or owned by other organizations, resources are the basis of power and this power and resource dependence are directly linked, and legally independent organizations can therefore depend on each other, such as during the structuring and organization of supply chain relations. The resource dependence concept can be understood through the evaluation of buyer-supplier relationships and these can be uncovered through reviewing Corporate Social Responsibility (CSR) strategies and communications specific to a firm's water consumption and management.

Effective sustainability supply chain management is closely linked with the leadership activities of firms managing suppliers and weighing up the managerial practices which have a direct link between sustainability and supply chain management outcomes (Beske et al., 2014). Examining CSR reports enables an overview of the firm-stakeholder-

supplier relations, where firm operations, through their supply chain interact with local communities, becoming dependent on local infrastructure, tax and political arrangements and access to water resources. This can be a visible symbol of the relationship between firm and natural resources. These substantive measures can be contrasted with legitimacy-based pro-environmental behavior disclosures, which can be driven by environmental leadership (Bansal and Roth, 2000) and legislative requirements (Hamann et al., 2017). If there is a lack of governmental legislation and governance action taken in addressing water stresses and as result it is left to private companies to develop mechanisms to deal with corporate supply chain water stresses (Hoekstra, 2017). Formal Government backing and indicators are required as CSR disclosures alone lacks the substantive credibility. For example, there is a need for businesses to take a lead role in managing the global water stresses worldwide by considering how concepts such as virtual water is embedded within their supply chain.

Materials and Methods

Examining corporate company disclosures as a mechanism to study their water resource dependence can be a useful technique to evaluate what challenges and relations are presented as important enough to be declared in corporate CSR strategies and communications. Relationships existent between resource management can be identified through communication releases from the company. These types of disclosures reflect the governance processes of the firm (i.e. the leadership and monitoring of resource management), as well as reflecting traditional supply chain management strategies such as supplier screening (i.e. monitoring strategies for environmental performance); supplier development (i.e. collaboration with suppliers to generate mutual benefits between the central firm and its suppliers) and external influences from agencies (Akhavan and Beckmann, 2017). Where this research differs from traditional supply chain management is the specific focus on water resources and the attempts to reconcile traditional supply chain management perspectives with methods and techniques such as virtual water and water foot printing.

Data Sources

The data sources used in this research are focused on the corporate reporting of 50 companies that were continuously listed on the FTSE 100 stock-exchange between 2007 and 2014 inclusive, giving a continuous sample of companies to investigate over an 8-year period. The FTSE 100 was chosen due to the relatively strong pro-environmental culture of the companies listed, the diversity of sectors represented and the global reach of the companies registered on the exchange (Okereke, 2007; Helfaya and Moussa, 2017). Industrial sectors and companies represented are shown in Table 1. The justification of using formal reports is the acceptance of documents as part of CSR strategies and use by wider stakeholders. This offers advantages over databases such as Asset4 and CDP which are less accessible and often require a financial contribution for access. Annual reports were downloaded from company websites and reports containing information relating to sustainability performance (termed ‘CSR report’, ‘sustainability report’, ‘environmental report’, and other such variations) were obtained, referred to as ‘CSR report’ in this paper.

Table 1 Companies in the Study and Sectoral Classification

SECTOR	NUMBER	COMPANIES
Energy	3	BG Group, BP, Royal Dutch Shell
Financials	13	Aviva, Barclays, British Land Co, HSBC Holdings, Land Securities Group, Legal & General Group, Lloyds Banking Group, Old Mutual, Prudential, Royal Dutch Shell, Schroders, Standard Chartered, Standard Life
Consumer Staples	8	Associated British Foods, British American Tobacco, Diageo, Imperial Tobacco Group, Reckitt Benckiser, SAB Miller, Tesco, Unilever
Health Care	4	Astra Zeneca, GlaxoSmithKline, Smith & Nephew, Shire
Communications	4	BT Group, Sky, Vodafone, WPP Group
Utilities	3	Centrica, National Grid, SSE
Materials	3	Anglo American, BHP Billiton, Rio Tinto
Consumer Discretionary	7	Capita, Carnival, Compass Group, Kingfisher, Marks & Spencer, Next, Whitbread
Industrials	3	BAE Systems, Rolls Royce, Wolseley
Technology	2	Experian, RELX

These texts were analyzed and disclosures relating to water in the supply chain were extracted and classified according the concept of Sustainable sourcing and supply chain management (SustSSM) framework (Akhavan and Beckmann, 2017). This framework served as an initial starting point to identify the potential resource dependencies under the following categorites:

- Internal integration and governance –the commitment of senior management within companies towards sustainability activities. This can be through use of internal codes of conduct, guidelines and policies relating to operations and supply chains and can include goal setting, action plans, management systems and provisions of incentives and rewards for company members
- Supplier screening with focus on water issues –the demands placed on supply chain partners, ranging from explicit definition of minimum requirements and standards to become approved suppliers through to formal assessments and strategies as well as enforcing consequences for non-compliance.
- Supplier development with focus on water issues – moving beyond supplier screening toward situations where the firm takes an active role in collaborating with supply chain partners and develop joint programs for sustainability. These types of activities include training, education and supplier incentives. Other actions include sharing knowledge resources and capabilities to build resources and assets and be mutually beneficial for both buyer and supplier.
- External governance, inter-organizational collaboration and collective initiatives involves macro-level management of sustainability issues such as collaboration with NGOs and collective industry initiatives to develop and enhance knowledge, financial, and capability resources to address water sustainability issues.

Descriptive statistics were developed to identify the dominant classifications of disclosures of supply chain water management. Chi Square analysis was run to assess the variations in these disclosures across different industrial sectors which may hint at sectoral institutional variations in the nature of supply chain water management and inform the development of future typologies of water sustainability supply chain management strategies.

Results

From 800 reports surveyed only 283 references to water sustainability in the supply chain were made and these were concentrated to 59 annual reports and 224 CSR reports across just 20 companies. Comparing across the industrial sectors, consumer staples make up the bulk of the companies disclosing against this criterion with only reports from companies in the Consumer Discretionary and Technology sectors recording multiple supply chain water sustainability disclosures for any one year. The results of the Chi-Square analysis (see Table.2) gives a Pearson Chi-Square statistic of $\chi 2(283) = 54.77$, $p<0.001$, and therefore there is a statistically significant association between industrial sector and purchasing and supply chain management strategy. It is also shown that Consumer Staples accounts for over 50% of the total supply chain disclosures, and accounts for higher than expected disclosures in Internal Integration and Governance; Supplier Development; and External Governance categories. Sectors with higher than expected disclosures relating to supplier screening comprise of the Health Care, Consumer Discretionary and Technology Sectors, accounting for 51.3% of the typology disclosures, whilst supplier development is largely dominated by the Consumer Staples sector, accounting for 66.7% of the disclosures.

Table 2 Cross-Tabulation and Chi Square Statistics (Sector by Type of Disclosure)

		Sector									
		E	F	CS	H	Co	M	CD	I	T	Total
Internal Integration	Count (Expected)	0(1)	2(4)	59(60)	14(13)	4(3)	8(6)	8(12)	0(0)	19(14)	114
	%within Category	0	2	52	12	3.5	7%	7%	0%	17	
	%within Sector	0	22	40	44	50	53%	28%	0%	51	40
Supplier Screening	Count (Expected)	1(1)	4(3)	29(42)	16(9)	3(2)	2(4)	13(8)	0(0)	12(10)	80
	%within Category	1	5	36	20	4	3	16	0	15	
	%within Sector	33	44	20	50	38	13	45	0	32	28
Supplier Development	Count (Expected)	2(1)	3(2)	46(36)	2(8)	1(2)	4(4)	8(7)	0(0)	3(9)	69
	%within Category	3	4	67	3	1	6	12	0	4	
	%within Sector	67	33	31	6	13	27	27	0	8	24
External Governance	Count (Expected)	0(0)	0(1)	15(11)	0(2)	0(1)	1(1)	0(2)	1(0)	3(3)	20
	%within Category	0	0	75	0	0	5	0	5	15	
	%within Sector	0	0	10	0	0	7	0	100	8	7
Total		3	9	149	32	8	15	29	1	37	283

	Value	df
Pearson Chi-Square	54.77	283
N of Valid Cases	283	

E= Energy; F= Finance; CS= Consumer Staples; H= Health; Co= Communications, M= Materials; CD= Consumer Discretion; I= Industry; T= Technology

Reporting solely on the numbers of CSR disclosures against particular purchasing and supply chain management practices does not reveal the quality and focus of the

dependencies and asymmetries which persist in driving supply chain management practices. As Table 2 indicates, the most common disclosure relating to supply chain water sustainability management is covered by the category of internal integration and governance (accounting for 40% of all disclosures). These disclosures are generally split between how to design and implement water efficiency strategies (and subsequently measure and monitor their effectiveness) and an internal justification for why such strategies are taken. Given that the effects of water impacts are more likely to be felt locally, as opposed to the carbon agenda where impacts are not necessarily felt at the point of operational output, different strategies to deal with these processes and engagement with suppliers are required.

External Certification and Signaling

External certification and signaling strategies are associated with external governance, inter-organizational collaboration and collective initiatives in supply chain management, pursued by companies often to gain a degree of legitimacy through involvement in NGOs and international collaborations. These types of disclosure are often symbolic in nature and the substantive element of addressing sustainability challenges are less important than the ability to disclose membership of groups or sustainability awards. The engineering firm BAE systems (Annual Report 2010, p52) discuss the awarding of a certifying seal awarded to companies that 'demonstrate a continuous commitment to sustainability' with the rationale that this 'helps the pubic to identify businesses that promote sustainability…evaluated against criteria relating to the economy, society and environment'. Whilst these types of activities may appear to be purely symbolic in nature, membership of multi-company initiatives and external prizes can help focus corporate activity and re-organize the power relations between companies and suppliers. Externally accredited stakeholder and supplier forums are highlighted as important activities for bringing sustainability challenges beyond focus on internal operations. The importance of water in these types of forums is highlighted by SAB Miller (Sustainability Report 2009, p15) who state: 'Water is one of our top three global sustainable development priorities. As a founding signatory of the United Nations CEO Water Mandate, we recognize our duty to promote responsible water use throughout our operations and to encourage our suppliers to do the same'. This type of action can help diffuse pro-sustainable water practices through corporate operations and into wider supply chain management strategies.

Resource Efficiency in the Supply Chain

Internal operations management can guide the supplier screening and development practices which firms engage with their suppliers, either directly or indirectly. In this sense, managing water challenges can be achieved through embedding standards, expectations and skills on water efficiency across the full supply chain. From a resource dependence perspective there is evidence of the development of institutional frameworks to begin to converge and align the interests of stakeholders with those of the focal firm via monitoring and measuring systems. An example of this can be found in the brewing sector. Diageo (Sustainability & Responsibility Report 2013) highlight the importance of a collaborative approach to develop supply-chain wide resource efficiency, stating: "we are increasingly looking at impacts from our supply chain. For example, we are

assessing the way our ingredients are grown in terms of the implications for water use" (p31). Supplier screening is also utilized in retail, for example Tesco (Corporate Responsibility Review Report 2012) comment that "Although water used in our supply chain far outweighs that in our direct operations, we believe it's important to manage our resources carefully and this year we carried out surveys of water use across the Group' (p19) whilst British American Tobacco take this further, stating in their 2010 Sustainability Summary report (p15): 'As a business with an agricultural supply chain, we depend heavily on natural resources and ecosystems. We therefore recognize the need for a clear, strategic approach to managing our environmental footprint. It not only makes good economic and environmental sense for us to use raw materials, energy and water efficiency, it is our responsibility'. These are good aspirational settings but require greater collaboration with suppliers to gain full acceptance and implementation.

Managing Power Relations

Sustainable supply chain management strategies ultimately are concerned with managing power relations between actors within the supply chain and here, through the lens of water resources exist evidence of how companies attempt to minimize information asymmetries and misaligned principal-agent challenges. This can be through developing strict codes of conduct and practice, for example by the British Retailer Marks and Spencer (2010), who provide guidance to agricultural suppliers in their 'How We Do Business Report', emphasizing the need to perform these supplier assessment strategies. Despite these guidelines and frameworks, there exists little evidence of how these are applied to supplier development strategies. Diageo's collaborative approach introduced in the previous sector centers around company-centric commitments to reduce water wasted in water stressed areas (Sustainability & Responsibility Report 2013), seemingly as an attempt to manage power relations by enforcing standards onto suppliers with little consideration of formal dialogue or collaboration which might facilitate a two-way discussion between supplier and purchaser. Anglo American (Sustainability Report, 2010, p65) provide an example of weaker symbolic disclosures, stating "we believe that engaging key suppliers on opportunities such as water, energy, carbon, occupation health and safety will lead to new strategic initiatives being implemented in partnership with them". GSK (Corporate Responsibility Report 2010, p170) discuss formalizing and quantifying supply chain water management, referring to 'virtual water' which "represents a major part of our water footprint" and the steps to engage "with suppliers to assess their awareness of, exposure to and plans for mitigating water risks" with plans to use this information to grade suppliers and drive improvement. This is a crucial step to deliver benefits to wider society both environmentally and socially, and highlights the importance of firms acting in a co-operating and interdependent manner to tackle these crucial resource issues (Schnittfeld and Busch, 2016). These types of disclosures and activities are typical of those firms involved in agricultural produce, tobacco manufacture and alcohol production. By integrating supply chain environmental and social sustainability impacts into the formal reporting mechanisms of the firm, and holding the firm account through assessing the extent to which the focal firm collaborates with its supply chain partners to build up product stewardship and sustainable development resources. This type of collaboration also reveals the extent to which the focal firm is vulnerable to supply chain

disruptions concerning the availability of water resources.

Discussions and Conclusions

This paper presents an analysis of the water sustainability disclosures from a supply chain management perspective of 50 FTSE 100 firms. From this analysis we suggest that although there is a recognition of the importance for water management in the supply chain for large corporations, this appears to be limited to companies operating in the consumer staples industry. This is likely as a result of the close interaction between the consumer and firm which adds additional consumer legitimacy pressures when arranging supply chains and developing purchasing and sourcing strategies. Additionally, there is also a need to consider the visible supply chains which extend into agricultural communities. Both aspects can have implications for the sustainable strategic competitive advantages. We see that there is currently little evidence of standardization on reporting on water issues specifically in the supply chain and from a resource dependency perspective this leads to persistent information asymmetry problems, where firms become dependent on their suppliers for information regarding the availability and access to water resources. However, the embeddedness of water sustainability disclosures within the supply chain of FTSE 100 firms remains limited and outside of the Consumer Staples sector there is little evidence to suggest that this topic is emerging as a widespread reporting priority in CSR reporting. For consumer staples, producers these companies often exhibit more visible supply chains and are more susceptible to direct consumer pressures, additionally associated with negative health and wider social impacts (in the examples of alcohol and tobacco consumption) which may account for the pressures which result in the push towards greater scrutiny of their suppliers and internal operations, as well as the need to engage with external institutions. Despite the academic literature moving towards conceptualizing competition along a supply chain v supply chain basis, the reflections of water resources remain limited to internal company operations and there is subsequently little written in CSR and Annual Reports of FTSE 100 companies about the water resources within the supply chain.

Future work should address wider reporting on water sustainability, drawing on widely available databases of corporate disclosures and work towards developing tools that can aid in company decision-making. A virtual water management framework could be developed for companies to formally integrate into their supplier screening and development strategies and help alleviate the pressures on water resources and provide the tools for supply chain managers to implement. Our findings have direct implications for governmental policy and business strategy. Governments have the ability to influence and improve the reporting environment. National Governments, Supra-National Organizations and NGOs can work together to influence and improve the reporting environment, set regulations and foster the harmonization of expected standards. This working would aid the development of water supply chain management in SMEs which lack the resources of the larger corporations to implement and shape water resources management within their supply chains.

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Towards sustainable and resilient production systems: a resource orchestration perspective

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Abstract

Research orchestration (RO) perspective argues that resource orchestration actions are needed to develop unique set of capabilities to effectively implement strategies at different hierarchies. This study sets out to provide a resource orchestration perspective to provide capabilities-based explanation as to why firms having "similar" resources could differ in obtaining competitive performance based on existing empirical studies. The initial part of the study with review of literature indicates that: (i) RO provides a relevant view to explain relationship of resilience and sustainability in manufacturing, and (ii) creating fit rather than linear benefit, should be the aim of resource investments.

Keywords: sustainability, dynamic capabilities, competitive advantage

Introduction

Fulfilling customer expectations amid uncertain global business context with minimum environmental impact is high in the research and managerial agenda today. Having relevant assets and development of suitable capabilities are needed for generating competitive advantages. Such capabilities are required to sustain operations performance upon disruption (Dabhilkar et al., 2016) and may also help to improve sustainability of manufacturing facilities (e.g. Wong et al., 2018). On the other hand, a more stringent action than ever before is needed to address the burden put on the planet and society due to manufacturing activities; therefore, manufacturers have to devise strategies to make their production sustainable and resilient. There are some studies on the issue of resilience and sustainability in production systems. However, it seems that such discussions are often done without a clear perspective on coordination and alignment of assets and capabilities.

Research orchestration (RO) is a perspective that argues that resource orchestration actions are needed to develop unique set of capabilities to effectively implement strategies at different hierarchies (Sirmon et al., 2011). The emphasis of RO is on actions that effectively structure, bundle and leverage firm resources (e.g. skills and knowledge, routines/practices, finance, information and technologies). The resources could be owned by the firm, suppliers, customers or other partners - and accessible by the firm (Raddats et al., 2017).

The purpose of this paper is to discuss how RO could help explain the aspirations of building resilient and sustainable production systems that are able to render greater value to stakeholders and the society in general. It also intends to perform systematic analysis

of empirical studies to understand why manufacturers with access to a great deal of resources differ in their sustainable performance and resilience against disruptions.

Approach

This paper builds on systematic review of extant literature within the supply chain and operations management (SC&OM) domain. Recent guidelines for systematic review (e.g. Seuring and Gold, 2012) and example papers following such methodology (e.g. Golicic and Smith, 2013) have been used in the process.

In the first stage of the study, papers published in years 2011-2018 in SC&OM bearing ROP as theoretical lens have been reviewed. Sirmon et al., (2011) is considered a starting point as it is (one of) the early works and top cited papers describing the theory. The review in this stage dealt with identification of: (i) empirical evidence to validate or extend the theory (e.g. Carnes et al., 2017), and (ii) implications for practical operationalisation of the theory in the domain of interest. The focus of the second stage (ongoing) has been to perform synthesis from empirical studies addressing resilience and sustainability in manufacturing firms.

As a result of the literature search query with "resource orchestration" in topic of papers in ISI Web of Knowledge® database. A total of 145 records were obtained (as of 10 April 2019). Out of these, 85 were journal articles, which were the focus of the review in this paper. The top five journal bearing the most articles were: Strategic Entrepreneurship Journal (5), Journal of Supply Chain Management (4), Journal of Business Research (3), Journal of Operations Management (3) and R&D Management (3). The publication year distribution of the identified papers is shown in Figure 1. The number of publications discussing RO has been increasing over the years since 2012.

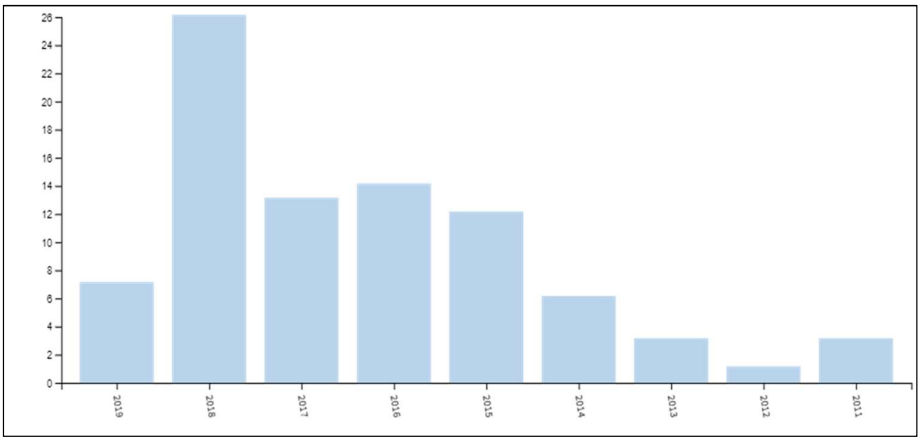

Figure 1. Identified literature by publication year

Findings

Preliminary findings suggest that RO has been quickly picked up well by researchers to discuss different operations management related phenomena involving utilisation of capabilities suited for prevailing circumstances. Some relevant ways of developing and renewing capabilities have been noted from reviewed papers such as (i) interactively developing such capabilities with partner firms (Raddats et al., 2017), and (ii) leveraging of resources embedded somewhere in the supply chain or owned by other actors. The orchestration role played by top management as well as the engagement by other management hierarchies appears to be very important according to the reviewed studies;

they are vital to drive competitive advantages from such resources accessible to a firm.

A sample of the reviewed literature is given in Table 1. From these sample studies, some interesting implications are obtained that could be extended in discussing the relationship between resilience and sustainability. For example, it is implied in the reviewed research that RO could lead to better utilisation of resources (Wong et al., 2018). And these resources do not have to be owned by the focal firm to be utilised with orchestration actions; they can be embedded somewhere in the network of actors that the focal firm has access and some form of control over (Raddats et al., 2017). Similar arguments can be found for resilience as a set of dynamic capabilities (e.g. Birkie et al., 2017).

Extension of this would direct to the argument that firms could alter partnership arrangements in their supply chains (Gong et al., 2018) to create better alignment for development of evolving capabilities (Fainshmidt et al., 2017), possibly using interactive means (Raddats et al., 2017).

While the second stage of the study is still ongoing, the observations from stage one of the systematic review suggest that: (i) RO provides a relevant view to explain relationship of resilience and sustainability in manufacturing, and (ii) creating fit rather than linear benefit, should be the aim of resource investments (e.g. Liu et al., 2016). Another preliminary observation is that RO implies views traversing organisational boundaries could enhance synergistic potential of diverse resources (Wong et al., 2018).

Table 2 provides some arguments about the possible relationships of resilience and sustainability within supply chain and operations management context. It also relates this relationship with different tenets of RO. Some of the arguments are taken directly from the respective papers while others are inferred from a combination of studies. The idea behind this table is to provide an initial ground of how these arguments could be addressed using RO perspective.

Table 1 Implications from a sample of reviewed papers

Reference	Methodology used	Key findings	Implications
(Wong et al., 2018)	Survey of 203 Thai manufacturers using multiple measurement items for constructs	Financial performance was achieved through cost reduction; internal, supplier and customer sustainable development positively affected each other, and by acting together they made firms lean, green and profitable	The orchestration of capabilities and resources seems to foster achievement of better synergies among relevant performance indicators
(Gong et al., 2018)	Exploratory multiple case study	Multinational corporations tend to orchestrate in breadth by internally setting up new functional departments and externally working with third parties, and orchestrate in depth working directly with their extreme upstream suppliers adopting varied governance mechanisms on lower-tier suppliers along the project lifecycle	Structural changes in supply chain result from the orchestration
(Carnes et al., 2017)	Empirical analysis using primary data collected from 189 managers	Discussion of integrating resource orchestration with contingency theory to theorise how managers differentially orchestrate their firm's resource portfolio and capabilities to develop innovation based on the firm's life-cycle stage	Approach from this paper could be used to discuss innovation-based solutions encompassed in sustainability and resilience development
(Chadwick et al., 2015)	Data collected from 190 firms in South Korea	Emphasis the importance of middle managers in implementing top management's strategic emphasis, lending empirical support to a fundamental tenet of RO arguments	Top management has key role in RO but several management levels take their role to it in regenerating/reconfiguring new and existing capabilities
(Cui and Pan, 2015)	Case research methodology with exemplary coding procedure	Generate a process model to explain RO in the successful adoption of e-commerce by manufacturers; the predominant competitive environment of each phase gives rise to a specific focal capability that is developed through resource-focused actions	RO based on change in environment can give rise to development of newer suitable capabilities

Reference	Methodology used	Key findings	Implications
(Fainshmidt et al., 2017)	Survey of 854 multinational firms	Performance during crisis is associated with the pre-crisis development of asset management capabilities, or the capacity of managers to orchestrate assets so as to extract more value from the firm's resource pool	Dynamic managerial capabilities evolve as a response to a firm's task environment; Dynamism in the business environments affect development of the capabilities
(Epstein and Roy, 2001)	Conceptual framework development	Presents a framework that describes the drivers of corporate social performance, the actions that managers can take to affect that performance, and the consequences of those actions on both corporate social and financial performance	Implies that RO actions could be consciously decided to foster better economic and social performance at multiple levels
(Hughes et al., 2018)	Analysis on, data from COMPUSTAT database on financial variables of 1559 US firms	Long-term investment in the (pension and retirement) employee-base of the firm has long-term performance implications. Through orchestration, new combinations of existing resources in strategy, manufacturers and specifically their operations managers can enhance profitability	Further research is needed to explore and expand on the important role of RO for manufacturers' performance
(Liu et al., 2016)	A questionnaire survey was conducted in 196 firms in China to test hypotheses	IT competency strengthens the relationship that supply chain integration (SCI) has with operational and financial performance; The more similar the IT competency configurations are to those of the top performers in the high-level SCI group, the higher their operational and financial performance are	According to RO theory, what matters is not SCI or IT competency but the fit or alignment of these two interdependent variables.
(Miao et al., 2017)	Meta-analytic structural equation modelling	Entrepreneurial orientation (EO) mediates the human and social capital - firm performance relationships; social capital is positively associated with human capital; social capital - firm performance relation is mediated by human capital and EO	EO and human capital helps in mobilising resources to influence firm performance
(Raddats et al., 2017)	Exploratory study consisting of seven dyadic relationships in five sectors with case study design	An additional dimension of capabilities should be recognised: whether they are developed independently or interactively (with another actor). Examples of interactively developed capabilities are identified	Manufacturers need to understand how to develop capabilities (also) interactively to create competitive advantage; and identify actors to develop these capabilities with

Table 2. A few arguments about resilience-sustainability link and how RO could explain them

Arguments about resilience-sustainability relationship	RO perspective: enhancements
• There is limited region resilience-sustainability synergistic optimisation (Ivanov, 2018)	• Consideration of different hierarchy levels could provide more detailed understanding
• Resilience capabilities upstream supply chain are more effective than those downstream (e.g. Trucco et al., 2018); resources lost downstream imply dependent losses upstream (Kleindorfer et al., 2005)	• Interactively developing capabilities with multiple actors from relevant actors could be an additional way to further discuss the argument
• Hybrid consideration of sustainability initiatives and resilience strategies provides considerable (production) cost savings (Jabbarzadeh et al., 2018);	• Effectiveness of capabilities could depend on portfolio of possible uses and targets of the same
• Big data predictive analytics capabilities are significantly related to economic, social and environmental sustainability performance (Jeble et al., 2018); proactive resilience practices help to reduce performance degrading influences from disruptions (Dabhilkar et al., 2016)	• Creation of fit between IT and other related capabilities with production or business strategies could lead to better performance and (longer lasting) competitive advantages; this is a subject of further research need
• Disruption orientation can lead to resilience capabilities to better mitigate disruption (Ambulkar et al., 2015); companies need to consider their suppliers' sustainability measures to avoid customer setbacks (Veit et al., 2018)	• RO actions that are based on change in the relevant environment can give rise to development of newer and suitable capabilities
• Actual development of sustainable systems remains challenging; designing inherently resilient systems is an alternative (Fiksel, 2003)	• Strategic investment in human capital as key elements in production (industrial) systems shall be part of contest-focused effective RO actions
• Opportunities for shared value creation should be identified in sustainable value chain development (Fearne et al., 2012); cooperative and communicative relations (among supply chain actors) has positive effect on resilience, which in turn can increase customer value (Wieland and Wallenburg, 2013)	• Performance and competitive advantage could be different at different levels and hierarchies. Looking at beyond just one level (or company) is necessary; the business context could change continuously

Discussion

Many papers discussing resilience capabilities and managing unanticipated disruptions do not seem to have considered the potential implication of firm life cycle stage on the accumulation of capabilities. One may argue that companies considered in many of such (especially large scale) studies are well established and often publicly traded. This may exclude startup stage of company life cycle stage. However, it does not enable us to understand if differences of disruption mitigation capabilities existed between firms at mature and declining stages.

Epstein and Roy (2001) imply that companies could consciously develop RO actions to improve economic and social performance at different levels. This implication can be taken to address multiple dimensions of sustainability. The question still remains as to how this can be practically achieved. This one of the areas suggested for future research (Hughes et al., 2018). The relevance of human capital in mobilising resources (Miao et al., 2017), and alignment of supply chain integration needs with competencies in areas like IT (Liu et al., 2016) are regarded as important in RO.

An aspect of even higher important but missing from resilience and sustainability literature (with operations and supply chain management lens) is the role of managers in different hierarchy levels in enhancing RO actions (Chadwick et al., 2015). Clearly top management commitment is key for resilience capability development (e.g. Dabhilkar et al., 2016). The same is true in fostering sustainability initiatives (e.g. Giunipero et al., 2012). However, barely any paper has so far discussed how strategic directions about resilience capabilities or sustainability policies are reflected and operationalised by middle and font line managers. Many such papers in fact do not differentiate between capabilities that may reside within the role of the top management, or those traversing multiple hierarchies in the organisation. This could be a point of extension that could help elaborate on how seemingly similar set of capabilities could result in different level of achievement in post-disruption performance or sustainability objective achievement; the managerial actions (at different hierarchies) in orchestrating resources for better effectiveness.

Considering supply chain network level, we have noted that similar resilience capabilities located upstream the chain are generally more effective in disruption mitigation than when located downstream (e.g. Trucco et al., 2018). The effectiveness of resilience capabilities also depends on static supply chain complexity factors (Birkie et al., 2017). However, in those and other similar studies, it is not discussed how effectiveness of capabilities may vary as the composition of the capability set changes, or as the business context (e.g. disruption) drifts, or if the capabilities were dominantly enacted by middle or top management hierarchies. A similar pattern of investigation could be done with sustainability as well.

While the scale of change is different, both management of unanticipated disruptions with resilience capabilities as well as reducing environmental and social impact for better sustainability require adjusting to changing conditions. RO based in prevailing changes in the business environment is suggested to result in new capabilities suited for the context (Cui and Pan, 2015; Fainshmidt et al., 2017). This argument implies that future research in the domain of interest (resilience-sustainability) could investigate if and how this can be explained.

The discussion of making production systems sustainable and resilient is getting a lot of attention recently. However, the practical achievement and what it means in reality is much more sophisticated than the concept appears. Using RO perspective gives an opportunity to discuss what this could mean when taken to ground. For example, if we

are discussing about development of new production systems with sustainability as a core, then the starting point is that the system to be developed (of the company as a whole if it is to be developed for a new one) can be considered to be at startup phase of the firm lifecycle stage. The underlying mechanisms of orchestration for a firm at this stage could be different from the ones used by a mature firm therefore managers would emphasis on different forms of capabilities suited for the stage their firm is at (Carnes et al., 2017). This .has different important and interconnected implications with regard to, for example, which actors they chose to jointly invest for capabilities development, which forms of IT and other collaborative platforms they need to decide on and so on. Those decisions surely will have an impact how the business model is formulated for a future production system.

As we have many old production system that will probably continue to operate for some years while advanced and dominantly autonomous production systems start to fully operate, the strategies to be followed in operating those old systems in a new manufacturing business setting will most likely require a different set of capabilities and RO actions that many researchers and managers currently may think of. And the extent of interactive capabilities developed spanning multiple business and economic system boundaries could be the requirement. The overall proposition of this paper, once again is that as researchers, we could use RO to create a way of understanding more details about creating and running more sustainable and resilient production systems.

Conclusion

Several empirical studies on resilience, sustainability in operations management concepts do not address issues of resource orchestration with respect to scope, maturity stage, and hierarchy level of firms. This study sets out to provide a resource orchestration perspective to provide capabilities-based explanation as to why firms having "similar" resources could differ in obtaining competitive performance based on existing empirical studies. The findings of the study could inform operationalisation of strategies and empirical research with RO as overarching lens. It is to be noted however that this study is ongoing and the findings stated herein are only preliminary. For this reason, findings in relation to operationalisation of the different RO dimensions to explain the phenomenon of resilience capabilities and sustainability actions has not been discussed in detail.

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LPI: An Expanded Analysis of Countries' Logistic Efficiency

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Abstract
The objective of this research was to identify factors not covered in the Logistics Perfomance Index (LPI), and their impact the logistic performance of the countries. For this, a correlation analysis was performed on the LPI dimensions and related variables in the literature, involving social aspects, national infrastructure, and institutional policies seeking to identify these characteristics and their impact in the measurement of logistic efficiency. Results indicate that technological readiness, government effectiveness, and economic freedom have a high correlation with the logistic performance of the countries. The main contributions relate to widen logistic efficiency knowledge and guide policymakers actions.

Keywords: logistic performance; institutional environment; LPI.

Introduction

Studies and research have shown that the quality of the logistics system, both at the level of organizations and global supply chains, is related to interest rates, taxation and costs (Farahani et al., 2009), with the reduction of barriers and commercial intensity (Hoekman & Nicita, 2008); with the level of export (Dennis & Shepherd, 2011) and with economic growth and development (Limão & Venables, 2001, Portugal-Perez & Wilson 2010, Arvis et al., 2012; Bakar et al., 2014). Cross-border trade and economic competitiveness act as an engine in the search for efficiency and logistics efficiency, making monitoring and measurement fundamental.

Despite the importance of measuring countries' logistic performance, until the early 2000s, there was no general pattern for measuring it. Given the need for a logistic performance measurement model, the World Bank has constructed an index, the LPI - Logistic Performance Index, which allows for global comparison of countries. This indicator is considered an international benchmarking tool, which focuses specifically on measuring the ease and friendliness of trade and transportation in the countries, allowing them to identify the challenges and logistical opportunities encountered (Arvis et al., 2007).

Although it is considered a comprehensive measure to evaluate logistic performance, the LPI presents limitations and has fostered several studies (Guner & Coskun, 2012; Markovits-Somogyi & Bokor, 2014; Andrejić & Kilibarda, 2016; Yu and Hsiao, 2016; to 2017, Rezaei et al., 2018, Wang & Tang, 2018), or to an economic bloc or limited number of countries (Guner & Coskun, 2012). It should also note that the strategic choices of global supply chains in terms of structure, resources and capabilities are affected and dependent on regulations, culture, and values associated with the institutional structures of different

countries (Makino et al., 2004; Richey et al., 2005; Scott, 2008; Miemczyk, 2008). Thus, it is assumed that differences in countries' logistic performance are also explained by political and institutional factors that characterize them (Hausman et al., 2005).
In order to understand the factors that determine the countries' logistical efficiency, how they interrelate and how they affect such efficiency, the following question was posed: "What are the socioeconomic, environmental, and political factors that influence logistics performance and which the impact of the insertion of these factors in the measurement of the logistics efficiency of the countries? "

This article is part of a more extensive survey that seeks to answer the survey question raised. Based on the assumption that socioeconomic, political and environmental factors considered in the measurement of logistics performance, the main objective of this article is to identify those factors that influence the logistics efficiency of the countries. For this, we performed a correlation analysis. We justified this research by the need to expand the frontier of knowledge about the logistics efficiency of the countries, pointing out essential aspects that affect this efficiency. Besides, the practical contribution is to provide policymakers with a guide on how much each of the inputs or outputs needs to be worked on for efficiency.

Theoretical Background

Fugate et al. (2010), define the logistic performance as the degree of efficiency, effectiveness, and differentiation associated with the accomplishment of activities. For Chow et al. (1994), logistic performance is a derivative of organizational performance and may be related to "hard" or objective measures, such as net profit, transport cost, labor cost, number of shipments, order cycle time , and "soft" measures based on qualitative data such as expert ratings and customer satisfaction.

Efficacy is related to production, without considering the resources consumed in the process. That is, it refers to the output of a desired effect or result, in how the outputs combine the desired results (Goldman & Sparks, 1996). Langley and Holcomb (1992) extended the definition of logistics effectiveness, relating it to the capacity to create value for the customer through the exclusivity and differentiation of services.

Efficiency, in turn, refers to the ability to reach a target with minimal effort or wastage (Goldman & Sparks, 1996). According to Andrejić and Kilibarda (2016, p.773) "Efficiency is a significant indicator of operations analysis and is one of the most commonly used basic performances. Measuring, monitoring and improving efficiency are the key tasks for companies in the 21st century. " Min and Joo (2006) also recognized the importance of measuring logistics efficiency.

Given the importance of measuring countries' logistical performance, the World Bank has built an index, the LPI - Logistic Performance Index, which allows a global comparison of countries. Since the first publication of the index, inserted in the "Connecting to Compete" report in 2007, new versions published in 2010, 2012, 2014, 2016 and more recently in 2018. The first report included 150 countries, the 2010 reports and 2012 ranked 155 countries, and the two most recent versions cover around 160 countries. Each release contains a ranking with all countries participating in the survey.

The indicator comes from information collected in a questionnaire made to logistics professionals of the leading companies responsible for the movement of goods around the world. The first part of the questionnaire provides information on international logistic performance, where respondents express their opinion on the eight major markets with which they most trade (Arvis et al., 2016). The second part of the questionnaire refers to internal logistic performance and is called the domestic portion of the index.

The LPI survey, therefore, offers two different perspectives on logistic performance. Qualitative assessments in relation to countries, so that they can compare to their competitors

and analyze the costs of poor logistic performance, and a domestic analysis, which provides assessments both as well as qualitative and quantitative data from the countries, which provides details on the environment and logistics processes, institutions, and time and cost performance data (Arvis, et al., 2010).

The LPI has been a benchmark for ranking countries based on the performance of their logistics costs (Mustra, 2011). However, measuring the logistics efficiency of a country requires greater attention because the supply chains are complex, their performance depends mostly on the characteristics of the country, especially the infrastructure and institutions that logistics needs to function well, such as imports, regulations, procedures, and behaviors (Arvis et al., 2018).

Hausman et al. (2005) already pointed out that differences in countries' logistic performance were the result of their different political and institutional structures linked to enforcement or regulation. Lee and Wyk (2015) have found that institutional constructs related to political risk, financial risk, economic freedom, political freedom, and competitiveness directly or indirectly influence logistic performance. Similar results also found Dani, Santos, and Hein (2017), when they studied the correlation between logistic performance and the economic freedom index. More recently, Wong and Tang (2018) sought to identify and understand the main determinants of logistic performance and found among them the level of corruption, as well as better technology, labor, and education infrastructure. Since the first edition of Connecting to Compete in 2007, other methods have been used to measure the logistics efficiency of the countries. However, these researches have been restricted to LPI components (Yu and Hsiao, 2016, Marti et al. 2017), or an economic bloc or the limited number of countries (Guner & Coskun, 2012; Markovits-Somogyi & Bokor, 2014, Andrejić & Kilibarda, 2016).

Therefore, the need to analyze the logistical efficiency of the countries by a more robust methodology and that includes aspects disregarded in previous research. The methodological construction used in the complete research to measure logistics efficiency will be the Data Envelopment Analysis - DEA. Although initially designed to measure a company's performance in a production economy context, the DEA has widely applied in the study of real policy scenarios in different fields such as education, health, transportation, agriculture, energy, among others.

Methods

The present research has a quantitative approach and uses statistical tools for the treatment and analysis of the data. The research method is bibliographical and documentary, with secondary data, collected from the databases: Logistic Performance Index, Global Governance Indicators, Global Competitiveness Index, World Economic Forum, and other bases such as International Transparency, Fraser Institute, and Heritage Foundation.
The sample includes the countries classified in the LPI and the sampling period goes from 2010 to 2018, with biannual data. Therefore, there are 155 countries in the years 2010 and 2012, 160 countries in 2014 and 2016 and 167 countries in 2018.

The variables selected for the measurement of the logistic efficiency, next step of the research, will be those that present a correlation, greater or equal to 60%, with the LPI index and its components. We can test some variables in aggregate forms, such as the index of international trade freedom, or its components, alternatively, in the search for the best arrangement of these variables.

The LPI components and the indicator itself will use as inputs and outputs in the structures proposed by the model. Besides the six variables that make up the LPI, variables

that represent socioeconomic, political and environmental aspects of the countries will test. Table 1 presents a summary of the variables used..

Table 1 – Variable used in the model

	Variable	Definition	Related Studies and Source
Variables identified in the literature and widely accepted.	LPI index and components (customs, infra-structure, services quality, tracking and tracing, timeliness, international shipments)	Indicates the countries' logistical performance based on the efficiency of customs clearance and border management, the quality of the trade and transport infrastructure, the quality and competence of the logistics service, the tracking and tracing capacity of shipments, the frequency with which shipments reach consignees on schedule and on the ease of organizing international shipments at competitive prices.	Arvis et al. (2007, 2010, 2012, 14, 2016, 2018), Andrejić & Kilibarda (2016), Marti et al (2014), Lee and Wyk (2015), Marti et al (2017) Source: World Bank database
Economic Variables	GDP per capta	GDP per capita is the gross domestic product divided by the population in the middle of the year. GDP is the sum of the gross value added by all resident producers in the economy plus any taxes on products and minus any subsidies not included in the value of the products. It calculates without deducting depreciation of manufactured goods or amortization of natural resources. Data are in current US dollars (Version 20180226).	Markovits-Somogyi & Bokor; (2014); Marti, et al (2014); Lee and Wyk (2015,) Source: World Bank database (2018)
	GDP_PPP	It is the gross domestic product converted into international dollars using purchasing power parity rates, based on the round of 2011. GDP at purchaser prices is the sum of the gross value added of all resident producers in the economy plus any taxes on products and less any subsidies not included in the value of the products. It calculates without deducting depreciation of manufactured goods or amortization of natural resources.	Markovits-Somogyi & Bokor; (2014); Marti et al (2014); Lee and Wyk (2015,) Source: World Bank database (2018)
	Size of market (Size_Mkt; Size_Mkt_Dom; Size_Mkt_Ext)	Variations (size of the domestic market, external market, and overall market size) were used, represented by the sum of GDP plus the value of imports of goods and services, minus the value of exports of products and services. The data are present on a scale of 1 to 7, where 1 (worst) and 7 (best)	Source: The Global Competitiveness Index. Base dados World Economic Forum
Social Variables	Higher education and training (EDU):	Ranking of the country's quality and quantity of higher education, and quality and availability of on-the-job training, on a scale of from 1 (worst) to 7 (best).	Guner & Coskun (2012) and Wong & Tang (2018) Source: The Global Competitiveness Index. Dataset: World Economic Forum
	Supply of Labour (LAB):	Ranking of the country's labour market efficiency and flexibility, and efficient use of talent on a scale of from 1 (worst) to 7 (best).	Wong & Tang (2018) Source: The Global Competitiveness Index. Dataset: World Economic Forum

	Technological readiness (TECH)	Ranking of the country's technological adoption and ICT use in businesses and individuals, on a scale 1 (worst) to 7 (best).	Wong & Tang (2018) Source: The Global Competitiveness Index. Dataset: World Economic Forum
Variáveis Políticas e Ambientais	Economic Freedom (ECN_FRD)	It is an index that measures the degree to which the institutions and policies of countries are consistent with economic freedom.	Source: Heritage Foundation
	Political Risk (POL_RISK)	Countries are scored between 0 and 1; 0 is worst and 1 is best. Dimensions of political risk are; voice and accountability (VA), political stability and absence of violence (PV), government effectiveness (GE), regulatory quality (RQ), rule of law (RL) and control of corruption (CC).	Source: Worldwilde Governance Indicators (World Bank)
	Legal System and Property Rights (LEG_SYS)	It reflects aspects of government protection of a country. It is an indicator composed of nine sub-indicators: judicial independence, impartiality of the courts, security of property rights, military interference in the rule of law and politics, the integrity of the legal system, enforcement of contracts, regulatory costs of real estate sales, costs of the criminal business, police reliability	Source: Fraser Institute
	Freedom to Trade Internationally (FTI)	Index with information on tariffs practiced, non-tariff barriers, trade regulators, and cost of compliance. Presented on a scale of 0 to 10, it reflects the distribution of the underlying data.	Source: Fraser Institute
	Tariffs Barriers (TARIFF)	It reflects the tariffs and costs that limit international trade. Presented on a scale of 0 to 10, it indicates the distribution of the underlying data.	Source: Fraser Institute
	Non Tariffs Barriers (NON_TARIFF)	It reflects the inefficiency of the administrative system and compliance costs in import and export. Presented on a scale of 0 to 10, which indicates the distribution of the underlying data	Source: Fraser Institute

Once the variables were defined, the Kolmogorov-Smirnov and Shapiro-Wilk tests were applied to verify if the data presented normal distribution. Then, the correlation analysis of the variables was performed, according to Guner and Coskun (2012), to establish the relationship of such variables with the logistic performance of the countries. We chose the Spearman correlation because the data were not standard by the Kolmogorov-Smirnov test (Stevenson, 1981). We used the SPSS software for these analyses.

Kozak et al. (2012) states that correlation is a method used to measure the association or consistency between two variables, pointing out the direction and intensity of the linear relationship between them, without involving a cause and effect relationship. The correlation coefficient (r) varies between -1 and 1 and the signal indicates the direction (positive / negative) of the relationship between the variables, whereas the value indicates the strength of the same relation. Regarding the intensity of the correlations, the variables have a strong (direct) positive linear correlation when "r" is close to 1, and a strong negative (inverse) linear

correlation when it is close to -1, even if there is no linear correlation or a weak linear correlation, r is close to zero (Figueiredo Filho & Silva Junior, 2009).

Preliminary Results and Analysis

As already mentioned, the primary intention of the research is to obtain an index that represents the "logistical efficiency" construct of the countries, through the DEA technique. One of the requirements of the DEA model is that inputs and outputs are positively correlated (Chen & Chen, 2009). Thus, we expected a high correlation between input and output variables.

Before performing the analysis of the correlation between the variables, tests applied indicates the form of distribution of the data. Table 2 shows the Kolmogorov-Smirnov and Shapiro-Wilk normality test results for LPI components.

Table 2 - LPI components normality test

	Kolmogorov-Smirnov[a]		Shapiro-Wilk	
	Statistic	*P-Value*	Statistic	*P-Value*
LPI	0.107	0.000	0.952	0.000
CSTM	0.105	0.000	0.949	0.000
INFR	0.116	0.000	0.940	0.000
IRCP	0.051	0.000	0.987	0.000
QLT	0.096	0.000	0.950	0.000
TRAC	0.080	0.000	0.969	0.000
TIME	0.061	0.000	0.984	0.000

Legend: LPI – Logistic Performance Index; CSTM – Customs; INFR – Infrastructure; IRCP – Competitive prices on International Shipments; QLT – Logistics quality and competence; TRAC – Tracking and Tracing; TIME – Timeliness.
a. Lilliefors Significance Correction; df = 879
Source: Research data.

As can be seen from both the Shapiro-Wilk test and the Kolmogorov-Smirnov test, the LPI variables show a non-normal distribution. Therefore, the appropriate correlation analysis, in this case, is obtained by the Spearman Correlation test (Stevenson, 1981). Table 3 shows the correlations between the input and output variables, used in the different structures to be tested later, in the DEA technique.

Table 3 - Spearman correlation coefficients between input and output variables

	TRAC	TIME	IRCP	LPI	
CSTM	0.86**	0.81**	0.83**	0.92**	Correlation Coefficient
	.000	.000	.000	0.000	Sig. (2-tailed)
	790	790	790	789	N
INFR	0.89**	0.84**	0.85**	0.94**	Correlation Coefficient
	.000	.000	.000	0.000	Sig. (2-tailed)
	790	790	790	789	N
QLT	0.91**	0.87**	0.87**	0.95**	Correlation Coefficient
	0.000	0.000	0.000	0.000	Sig. (2-tailed)
	790	790	790	789	N
DOM_SZ	0.63**	0.60**	0.60**	0.63**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	640	640	640	641	N
FOR_SZ	0.74**	0.72**	0.71**	0.74**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)

	640	640	640	641	N
MKT_SZ	0.66**	0.64**	0.63**	0.66**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	640	640	640	641	N
EDUC	0.77**	0.74**	0.71**	0.77**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	640	640	640	641	N
LABOR	0.43**	0.43**	0.40**	0.44**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	640	640	640	641	N
TECH	0.79**	0.77**	0.75**	0.81**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	640	640	640	641	N
ECN_FRD	0.66**	0.65**	0.64**	0.70**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	761	761	761	762	N
GDP_PPP	0.72**	0.70**	0.68**	0.73**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	607	607	607	609	N
GDP_PCP	0.73**	0.70**	0.68**	0.74**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	616	616	616	618	N
POL_STB	0.50**	0.49**	0.49**	0.52**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	780	780	780	781	N
POL_RISK	0.73**	0.70**	0.71**	0.76**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	630	630	630	632	N
GOV_EFF	0.77**	0.74**	0.76**	0.80**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	630	630	630	632	N
FTI	0.57**	0.56**	0.56**	0.59**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	780	780	780	781	N
LEG_SYS	0.66**	0.64**	0.64**	0.67**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	569	569	569	571	N
TARIFF	0.30**	0.30**	0.30**	0.30**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	567	567	567	569	N
NON_TARIFF	0.62**	0.64**	0.62**	0.65**	Correlation Coefficient
	.000	.000	.000	.000	Sig. (2-tailed)
	568	568	568	570	N

Legend: CSTM – Customs; INFR – Infrastructure; QLT – Logistics quality and competence; TRAC – Tracking and Tracing; TIME – Timeliness; IRCP – Competitive prices on International Shipments; DOM_SZ – Domestic Market Size; FOR_SZ – Forein Market Size; MKT_SZ – Market Size; EDUC – Higher education and training; LABOR - Supply of Labor; TECH – Technological readness; ECN_FRD – Economic Freedom; GDP_PPP – GDP per capta with purchasing power parity; GDP-PCP – GDP per capta (current US$); POL_STB – Political Stability; POL_RISK - Political Risk; FTI – Freedom to Trade Internationally; LEG_SYS – Legal System and Property Rights; TARIF - as tarifas e custos; NON_TARIFF – Non-Tariffs Barriers .
All coefficients presented significance at the 1% level.
Source: Research data.

The results of Table 3 indicate that there is a high correlation between the LPI and its components (above 0.80). This result indicates the assertiveness of the world bank in choosing these variables to compose the LPI. When analyzing the relation of the LPI and its components to the size of the market, it is observed that the relationship is more expressive

with respect to the size of the foreign market (0.74), which makes sense, since the LPI is measured based on perceptions of large freight forwarders over other countries with whom they transact.

Regarding social aspects, the highest correlation occurred with the EDUC variable (0.77), indicating that the quality and quantity of higher education and quality training can play an important role in logistics performance. In turn, supply labor did not present a sufficient correlation to insert in the logistic efficiency measurement model. The result for technological readiness (0.81) is consistent with the empirical literature, which shows that technology has increased supply chain efficiency and logistic performance (Will and Blecker 2012, Wong, Soh and Goh 2015, Wong & Tang 2018), placing it at the same level as the LPI components.

For the economic aspects, the results here differ from those of Guner and Coskun (2012), when they analyzed the member countries of the OECD. Guner and Coskun (2012) found a low correlation (0.407) between GDP and LPI. Our results indicate a much higher correlation (0.73 and .074) for GDP_PPP and GDP_PCP, respectively, at a significance level of 1%. This difference, however, can be caused by the sample analyzed or even by the variable used. The fact that variables related to GDP show a high correlation with the LPI components may indicate the need for this variable to appear in the efficiency measurement model, although in the form of a control variable. The GDP is also an indicator of the size of the economy, which we can use as a parameter for clustering the sample, which should occur when analyzing the efficiency by the DEA.

Regarding institutional aspects, we can see that the LPI has a significant correlation with both the economic freedom index (0.70) and the political risk index (0.76). We highlight the importance of considering the institutional aspects in the measurement of the logistic efficiency of the countries, corroborating the understanding of Hausman et al. (2005). Separately from the political risk index, government effectiveness also showed a high correlation with LPI (0.80). Although they showed less correlation with the LPI and its components, the variables LEG_SYS and NON_TARIFF (0.67 and 0.67, respectively) will be included and tested in the search for the best DEA arrangement.

Contrary to expectations, tariff barriers, freedom of foreign trade and political stability showed a lower correlation with the LPI (0.30, 0.59 and 0.52, respectively). We noted that these variables are composite indicators and that their components can individually correlate with LPI.

Conclusion

This article is part of more comprehensive research where it is sought to identify and understand the factors that influence the measurement of the logistics efficiency of the countries and the impacts of these factors in the classification of efficient countries, based on an expanded analysis of the LPI using the DEA technique. Thus, this part of the research focused on the analysis of the correlation between the LPI (and its indicators) and some variables, indicated in the literature as determinants of logistic performance, seeking to identify those that will later compose the logistic efficiency analysis of the countries.

The results indicate that, given the high correlation with the LPI, considering those with a coefficient of more than 60%, should be included the indicator of logistic efficiency of the countries. Variables related to higher education and training and the level of technological domain (social aspects) variables that characterize the institutional environment of countries such as the index of economic freedom and the political risk index, legal system and non-tariff barriers.

In this aspect this research has proved to be relevant, since it expands the knowledge frontier on the logistic efficiency of the countries, pointing out the essential elements that

affect this efficiency. Also, the final result of the comprehensive research can make a practical contribution by offering policymakers a guide on how much work each input or output needs to do to achieve the countries' logistical efficiency.

Although this research represents a breakthrough in proposing a global logistic efficiency index from the LPI, we found some limitations. The first of these is the lack of available data from other variables to improve the model, such as the level of CO2 emission, available only up to the year 2014. The second limitation is that the countries analyzed were chosen based on the available data, which may have influenced some of the analyzes.

Finally, correlation tests are essential exploratory techniques for the investigation of the association among the behavior of the variables groups. The simple identification of a significant correlation between two or more variables should interpret with caution. Since such analysis does not provide evidence of the direct dependence or the causality among the variables, but they also tend to vary jointly. What brings security to this research is the fact that the analysis of the correlation favors the elaboration of hypothetical models, which should confirm after, through other tests performed after the development of the research.

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When do 3PLs initiate low carbon supply chain integration?

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Abstract

As a response to global climate change, decarbonizing supply chains has gained increasing attention from academia and industry. Motivated by the evolving role of third-party logistics providers (3PLs) from a service provider to a resource integrator in supply chains, this paper investigates when 3PLs initiate supply chain integration in order to decarbonize their supply chains. Drawing upon three theoretical lenses, i.e. social network theory, institutional theory and resource-based view of the firm (RBV), this paper develops a theoretical framework and tests it using survey data from 348 Chinese 3PLs. The findings have implications for both researchers and managers.

Keywords: 3PLs, Supply chain integration, Low carbon supply chain

Introduction

With growing pressure on reducing carbon emissions from supply chain management (SCM), decarbonizing supply chains has gained increasing attention from academia and industry. Given the critical role of third-party logistics providers (3PLs) in supply chains, previous research has examined the operational importance of 3PLs in decarbonizing supply chains (Das, 2018). However, the strategic role of 3PLs in decarbonizing supply chains has not received enough attention, although many researchers show that 3PLs have now taken on a more proactive manner for customers by organizing networks, sharing information, managing assets, and reducing inventory (Zacharia *et al.*, 2011).

Further, despite the substantial amount of research on supply chain integration (Flynn *et al.*, 2010; Huo *et al.*, 2017), the majority of these research focuses on manufacturer-initiated SCI, and there is a dearth of research on the antecedents and effectiveness of SCI from the perspective of 3PLs, let alone in LCSC research. To fill the gap of low carbon supply chain integration (LCSCI) from the perspective of 3PLs, this paper focuses on 3PL-initiated LCSCI, namely a customer integration initiated by 3PLs to achieve LCSCs, and investigates the drivers and outcomes of 3PL-initiated LCSCI.

Based on the social network theory (Choi and Kim, 2008), institutional theory

(DiMaggio and Powell, 1983), and the resource-based view of the firm (Barney, 1991), we propose a theoretical framework of the antecedents and consequences of 3PL-initiated LCSCI, including customers' outsourcing scope, government (environmental) regulation, 3PLs' decarbonisation capabilities and 3PLs' financial performance.

The remainder of this article is structured as follows. The subsequent two sections review the literature and develop research propositions. This is followed by a description of research method, in which the sampling method and measures are illustrated. Next, analysis and results are presented and discussed. The conclusion is then put forward.

Literature review

Low carbon supply chain management (LCSCM)

Low-carbon supply chain management (LCSCM) is considered as the combination of low-carbon operations management and supply chain management in response to climate change, focusing on activities that reduce carbon footprint in supply chains (Damert *et al.*, 2018). Although some researchers argue that the drivers, barriers and performance outcomes of LCSCM should be similar to those of green supply chain management (GSCM), the empirical findings on the determinants and effectiveness of LCSCM have been inconclusive (Rivera, 2004; Zhang and Wang, 2014).

Low carbon supply chain integration

Supply chain integration (SCI) refers to "the degree to which a manufacturer strategically collaborates with its supply chain partners and collaboratively manages intra- and inter-organization processes" (Flynn *et al.*, 2010, p. 59), where the inter-organization (or external) SCI includes collaboration that takes place between a focal firm and its suppliers and customers. With the evolving importance of LSPs in supply chains, there is a rapidly growing research on the effectiveness of SCI between a focal firm and its LSPs on firm performance (Huo *et al.*, 2017). The common feature of these research is that they all take the perspective of the focal manufacturing firm; the amount of research on SCI from the perspective of LSPs is limited.

Vachon and Klassen (2006) are among the first who link supply chain integration and the green supply chain practices. Mao *et al.* (2017) show that manufacturing firms' low-carbon supply chain integration (LCSCI) have positive effects on their environmental and financial performances. Nevertheless, there has been no research on LCSCI from the perspective of 3PLs, and it remains unclear about the drivers and outcomes of 3PL-initiated LCSCI. To fill the research gap, this research takes the perspective of 3PLs and focuses on their LCSCI. In particular, we define 3PL-initiated LCSCI as a customer integration initiated by the 3PLs to achieve LCSCs.

Theoretical foundations and hypothesis development

Relationship between outsourcing scope and 3PL-initiated LCSCI

The social network theory (SNT) has conceptualized the supply chain as a functional social network between companies consisting of nodes and links (Carter *et al.*, 2015). Embeddedness is one of the core ideas at the heart of organizational social network theory and is defined as "the extent to which a firm relies on a supply network and perceives the influence of the network" in the context of SCM (Kim, 2014, p.220). Usually, the structural and relational embeddedness are adopted to measure the social capital within supply networks (Choi and Kim, 2008).

The impact of outsourcing scope on the supply network as well as 3PL-initiated

LCSCI can be understood from the perspectives of the relational embeddedness, which refers to the quality or the strength of a relationship (Moran, 2005). Since a wide outsourcing scope is usually associated with increased mutual dependence, commitment and interactions, it gives rise to the strong tie. As the relationship between firms becomes stronger, environmental collaboration in supply chains is more likely to occur (Tate *et al.*, 2013).

Therefore, an increase in the outsourcing scope can lead to an increased level of relational embeddedness of 3PLs, which is positively associated with 3PL-initiated supply chain integration and environmental collaboration. Hence, we propose that the outsourcing scope of 3PL services may have a positive relationship with 3PL-initiated LCSCI.

H1: Outsourcing scope has a positive relationship with 3PL-initiated LCSCI.

Relationship between environmental regulations and LCSCI

Institutional theory identifies three dimensions of isomorphic drivers as institutional pressures that influence firms to adopt organizational competitive environmental alignment, namely coercive, normative, and mimetic drivers (DiMaggio and Powell, 1983), where coercive pressure refers to pressure exerted by those in power, such as the government environmental regulations (Sarkis *et al.*, 2011). To conform to the environmental regulations by the government, 3PLs are motivated to form environmental collaborations in the supply chain (Vachon and Klassen, 2006), and build the strategic supply chain relationship and dependence with their customers (Huo *et al.*, 2017), and thereby leading to 3PL-initiated LCSCI. Thus, we propose the following hypothesis:

H2: Government regulation has a positive relationship with 3PL-initiated LCSCI.

The role of 3PLs' decabonisation capabilities

Decarbonisation capabilities refers to firm-specific capabilities to decarbonize the supply chain. Previous research has indicated that the lack of firm-specific capabilities is one of the most common obstacles to GSCM practices (Wu *et al.*, 2012). According to the resource-based view (RBV), firm-specific decarbonisation capabilities are rare, valuable, non-substitutable, and difficult-to-imitate resources in LCSCM.

We argue that these organization-specific capabilities and resources contribute to the collaborative relationship between the 3PLs and their customers, since the decarbonisation capabilities enable 3PLs to circulate their professional knowledge and resources efficiently to their customers, which is helpful for building strong ties with dependency and trust, thereby increasing the 3PLs' relational embeddedness (Choi and Kim, 2008). Therefore, we propose that the effect of outsourcing scope on 3PL-initiated LCSCI can be stronger if the 3PLs have higher decarbonisation capabilities.

H3: Decarbonisation capabilities play a positive moderating role in the relationship between outsourcing scope and 3PL-initiated LCSCI.

Although 3PLs with higher decarbonisation capabilities can be more able and willing to initiate LCSCI proactively rather than responsively, they may become more self-motivated and less motivated by coercive pressures, such that the effectiveness of government environmental regulations on motivating 3PL-initiated LCSCI could be stronger for the 3PLs with lower decarbonisation capabilities than on their higher capabilities counterparts. Therefore, we propose that 3PLs' decarbonisation capabilities may weaken the effect of government environmental regulation on 3PL-initiated LCSCI.

H4: Decarbonisation capabilities play a negative moderating role in the relationship

between government environmental regulation and 3PL-initiated LCSCI.

Relationship between 3PL-initiated LCSCI and 3PL's financial performance

3PL-initiated LCSCI is related to interaction and collaboration in the social networks. As 3PLs build tense and strong ties in their networks through frequent interaction and intense collaboration with their customers, operational efficiency and economic performance will follow, as long as they are not embedded too much (Uzzi, 1997). Also, the relational capabilities gained from increased level of embeddedness will ultimately enable them to combine cross-organizational complementary resources in unique ways and realize sustainable advantage over their competitors (Paulray, 2011). Therefore, we propose a positive relationship between 3PL-initiated LCSCI and 3PL's financial performance.

H5: 3PL-initiated LCSCI has a positive relationship with 3PLs' financial performance

The theoretical framework in this study as well as the proposed hypotheses are shown in Figure 1.

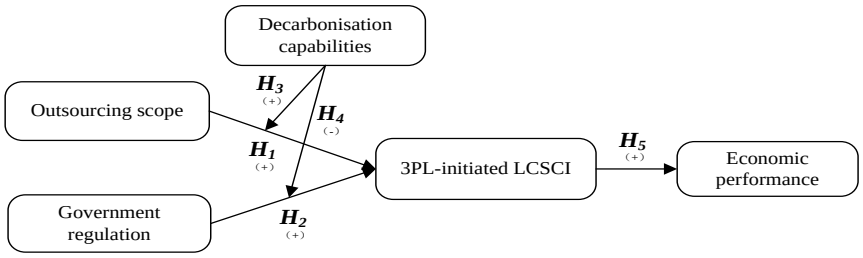

Figure 1 - Theoretical framework

Research method

Data collection and sample profile

The sample was derived from 3PLs located in Guangdong province, China. As one of the earliest regions to open up in China, Guangdong province enjoys advanced economic development; its logistics industry grows rapidly. To collect the data, we collaborated with logistics and SCM organizations in Guangdong province, inviting them to participate in an online questionnaire survey. A total of 1300 3PLs took part in the survey, which was distributed in two rounds. After screening out invalid responses such as blank and incomplete questionnaires, we identified 191 and 157 valid responses for the first and second rounds, respectively, resulting in 348 in total. Thus, the response rate was 26.7%. Table 1 outlines the profile of the sample in line with four characteristics: business origin, ownership, the number of employees, and firm size.

Construct measurement

The constructs measured in this study were derived from the existing literature. Since the empirical investigation was carried out in China, we employed back-translation in order to ensure conceptual equivalence (Cai *et al.*, 2010). The measurement scales were first translated into Chinese and further amended by two research assistants. The initial questionnaire was developed and then examined by using a random selection of 60 samples to conduct validity analysis, exploratory factor analysis (EFA), and correlation analysis using SPSS software. After this, three SCM professors were invited to verify the questionnaire, and the final version of the survey used for delivery was confirmed.

The items in the questionnaire were measured using a five-point Likert scale, with a score of 1 indicating 'strongly disagree', 2 indicating 'disagree', 3 indicating 'uncertain', 4 indicating 'agree', and 5 indicating 'strongly agree'.

Table 1- Survey sample profile

Variables	Total Responses	First-wave frequency	Second-wave frequency	Chi-square test
Business origin				
Transportation-based 3PLs	116	60	56	$\chi2$=2.162 df=2 p=0.339
Warehouse-based 3PLs	100	61	39	
Integrated 3PLs	132	70	62	
Ownership				
Private company	86	55	31	$\chi2$=4.707 df=3 p=0.195
State-owned	165	89	76	
Foreign-funded	81	40	41	
Joint-venture	16	7	9	
Number of employees				
<100	97	51	46	$\chi2$=0.851 df=3 p=0.837
100-200	111	63	48	
200-500	71	37	34	
>500	69	40	29	
Firm size				
<5	55	25	30	$\chi2$=9.149 df=5 p=0.103
5-10	98	61	37	
10-20	77	37	40	
20-50	51	27	24	
50-100	26	18	7	
>100	41	22	19	

Non-response bias and common method bias

We used the method recommended by Armstrong and Overton (1977) to compare the two samples. As shown in Table 1, a Chi-Square test for the firm characteristics variables indicated that there was no statistical difference between the two rounds, thus confirming that both rounds of samples were unbiased.

Since the data investigated was derived from a single source, common method bias was likely (Podsakoff *et al.*, 2003). Therefore, we implemented Harman's single factor test, whereby we conducted an unrotated principal component analysis, yielding 5 eigenvalues greater than 1 after extraction. The first factor explained 38.203% (lower than 40%). In addition, we conducted a confirmatory factor analysis (CFA) for Harman's single factor model (Sanchez and Brock, 1996). Compared to the measured model, the indicators of the tested model were poor ($\chi2$/df=3.297, GFI=0.635, AGFI=0.539, IFI=0.595, TLI=0.551, RMR=0.077, and RMSEA=0.081. This showed that overall, common method bias was not a problem in the data.

Reliability and validity analysis

The results of the reliability and validity tests are shown in Table 2. Internal consistency was measured using Cronbach's coefficient. The Cronbach coefficients of all the constructs ranged from 0.808 to 0.898 (above 0.7). This confirmed that the constructs had psychometric properties. An examination of the CFA of all the constructs showed that all the indicators of the measurement model, such as $\chi2$/df, GFI, AGFI, IFI, TLI,

RMR, RMSEA, were ideal, and therefore that the constructs were unidimensional (Bentler and Bonett, 1980). In addition, as suggested by Fornell and Larcker (1981), we measured convergent validity. The results showed that all the standard factor loadings were above 0.7, and the t-values were above 10 for all but two items (0.67 and 0.692). Thus, convergent validity was confirmed. Composite reliability and AVE can be used to measure the reliability of constructs (Hair *et al.*, 2006). When CR and AVE are above 0.7 and 0.5 respectively, it indicates a high degree of internal consistency, and that the consistency between the constructs/traits is higher than that of the errors (Hair *et al.*, 2006). As shown in Table 2, the composite validity values of the constructs ranged from 0.807 to 0.873 (above the threshold value of 0.7), and the AVE values ranged from 0.527 to 0.635 (above the threshold value of 0.5). Table 3 presents the arithmetic square roots and correlation coefficients of the constructs. The results showed that the arithmetic square roots were larger than the correlation coefficients of the construct and the correlated construct, thus confirming that the measurement scale of the constructs had sufficient discriminant validity, as suggested by Fornell and Larcker (1981).

Table 2 - Construct measurement

Scale	Factor loading	S.E.	t-value
Outsourcing scope			
1. The function of low-carbon logistics service expands	0.717	--	--
2. The content of low-carbon logistics service increases	0.728	0.081	12.286
3. The number of users of low-carbon logistics service increases	0.732	0.083	12.52
4. The low-carbon logistics service industry increases	0.722	0.08	12.692
5. The geographic coverage of low-carbon logistics service increases	0.742	0.088	11.875
Government regulation			
1. Policy law promulgated by the government for low-carbon business environments	0.736	--	--
2. Policies and regulation issued by local governments for local business environments	0.675	0.094	10.678
3.Policies issued by the government for low-carbon logistics services	0.701	0.095	11.287
4. Carbon auditing assigned by the government	0.75	0.098	11.669
Decarbonization capabilities			
1. Possess the ability to design low-carbon logistics services	0.796	--	--
2. Possess carbon-reduction technique	0.743	0.074	14.018
3. Possess low-carbon facilities	0.716	0.07	13.765
4. Possess low-carbon coordination capability	0.73	0.068	14.33
5. Possess carbon-reduction capability	0.781	0.069	15.28
6. Possess the capability for improving low-carbon logistics services	0.73	0.072	13.229
3PL-initated LCSCI			
1. help customers and their supply chains to make plans for low-carbon logistics integration	0.726	--	--
2. help customers and their supply chains to achieve low-carbon logistics coordination	0.778	0.085	13.097
3. help customers and their supply chains to achieve technical support for low-carbon integration	0.704	0.088	11.685
4. help customers and their supply chains to achieve environmental goals regarding low-carbon logistics service integration	0.738	0.088	12.272
5. build up strategic alliance with customers for low-carbon logistics integration	0.692	0.091	11.475
Economic performance			
1. market competitive position increase	0.778	--	--
2. logistics cost reduction	0.670	0.072	12.553
3. ROI increase	0.905	0.069	17.037
4. customer satisfaction increase	0.816	0.061	16.205

*Standardized factor loading

Table 3 - Discriminant validity

	Mean value	S.D.	Outsourcing scope	Government regulation	*Decarbonization* capabilities	3PL-initiated LCSCI	Economic performance
Outsourcing scope	3.92	0.69	0.728				
Government regulation	3.97	0.65	0.365**	0.716			
Decarbonization capability	3.87	0.89	0.724**	0.330**	0.751		
3PL-initated LCSCI	3.96	0.65	0.657**	0.433**	0.658**	0.726	
Economic performance	3.79	0.76	0.415**	0.516**	0.401**	0.326**	0.797

Note：** P<0.01；the values on the left-hand side of the diagonal line are correlation coefficients; and the values at the diagonal line are arithmetic square roots.

Results

Using SPSS 20.0 software, we set two explanatory variables (‘government regulation’ and ‘outsourcing scope’) and moderating variables, and multiplied them to obtain interaction items. Next, we set ‘3PL-initiated LCSCI’ and ‘economic performance’ as dependent variables and used stepwise regression to perform a hypothesis test. As shown in Table 4, Models 1-3 set ‘3PL-initiated LCSCI’ as the dependent variable, and Models 4-5 set ‘economic performance’ as the dependent variable. The tolerance of all the models was above 0.15, indicating that multicollinearity was not a problem. In Model 2, the regression coefficients of ‘outsourcing range’ and ‘government regulation’ were 0.579 (t=13.503, p<0.001) and 0.233 (t=5.550, p<0.001). This result indicated that these two factors had a positive impact on ‘3PL-intiated LCSCI’, and therefore that H1 and H2 were verified. In Model 5, the regression coefficient of ‘3PL-initiated LCSCI’ was 0.323 (t=0.323, p<0.001), indicating that ‘3PL-initiated LCSCI’ had a positive impact; hence, H5 was verified. Model 3 tested the moderating role of ‘decarbonization capabilities’. With this model, the regression coefficient of ‘outsourcing scope’ was 0.236 (t=3.778, p<0.001), indicating that ‘decarbonization capabilities’ positively moderated the relationship between ‘outsourcing scope’ and ‘3PL-initiated LCSCI’, and therefore that H3 was confirmed. The regression coefficient of ‘government regulation’ and ‘decarbonization capabilities’ was 0.362, indicating that ‘decarbonization capabilities’ negatively impacted the relationship between ‘government regulation’ and ‘3PL-initiated LCSCI’; hence, H4 was verified.

Table 4 - Stepwise regression results

Variables	Dependent variable：3PL-initiated LCSCI			Dependent variable：Economic performance	
	Model 1	Model 2	Model 3	Model 4	Model 5
Number of employees	0.064	-0.03	-0.061	0.144†	0.124†
Firm size	0.065	0.083	0.105*	-.066	-0.087
Transportation-based 3PLs	-0.027	0.035	0.024	-.018	-0.009
Warehouse-based 3PLs	-0.064	0.029	0.009	.007	0.027
SOEs	-0.227†	-0.068	-0.025	-.108	-0.034
Private owners	-0.161	0.053	0.076	-.155	-0.104
Joint ventures	-0.126	-0.014	-0.13	-.050	-0.010
Outsourcing scope		0.579***	0.295***		
Government regulation		0.233***	0.139***		

Decarbonization capabilities			0.397***		
Outsourcing scope *Decarbonization capabilities			0.236***		
Government regulation *Decarbonization capabilities			-0.362***		
3PL-initiated LCSCI					0.323***
Tolerance	⩾0.16	⩾0.2	⩾0.15	⩾0.16	⩾0.16
R^2	0.035	0.492	0.595	0.025	0.126
Adjusted R^2	0.015	0.479	0.581	0.005	0.105
R Square Change		0.458	0.096		0.101
F Change		152.266	28.38		38.978
Sig. F Change		0.000	0.000		0.000

Notes: 1. Coefficients are standardized; 2. *** *P<0.001; ** P<0.01; * P<0.1*.

In order to reveal the moderating role of the variables, we set the average of 'decarbonization capabilities' as standard, dividing the sample into two groups: high level of decarbonization capabilities (high level) and low level of decarbonization capabilities (low level) in order to conduct a regression analysis of '3PL-initiated LCSCI'. Figure 2 shows that in the low-level group, the regression coefficients of 'outsourcing scope' and 'government regulation' were 0.409 (t=6.619, p<0.001) and 0.378 (t=5.7890, p<0.001), revealing a significant positive impact on '3PL-initiated LCSCI'. In the high-level group, the regression coefficient of 'outsourcing scope' was 0.526 (t=7.946, p<0.001), indicating that this variable also had a significant positive impact on '3PL-initiated LCSCI', but the degree of impact was larger than in the low-level group. In addition, the regression coefficient of 'government regulation' was 0.058 (t=0.89, p>10%), showing that the impact of this variable on '3PL-initiated LCSCI' was smaller than in the low-level group, and was not statistically significant. This analysis further verified H3 and H4.

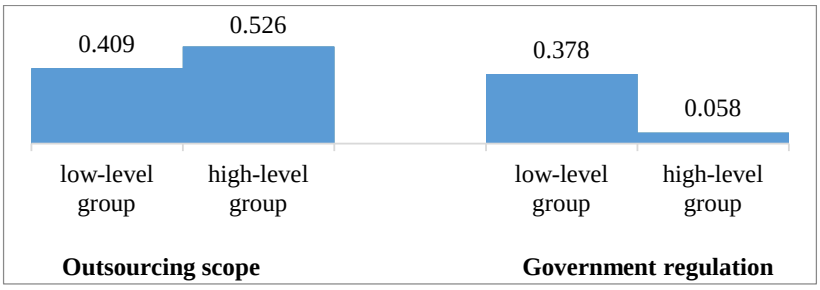

Figure 2- The moderating role of decarbonisation capabilities

Conclusion and future research

Drawing upon three theoretical lenses - social network theory, institutional theory and RBV - this study develops a research framework for 3PL-initiated LCSCI, the constructs of which were verified by the empirical investigation conducted in China. The research results highlights the positive impact of 3PL-initiated LCSCI on corporate performance. It appears that, with the advent of decarbonized economies and societies, logistics service provision has been given greater environmental focus, distinct from traditional logistics functions. The emergence of 3PL-initiated LCSCI, to a large extent,

echoes Bowersox's (1998) prediction that "the logistical mission of yesterday is being replaced by a broader concept driven by social responsibility" (p.2). This study shows that, as a strategic action, 3PL-initiated LCSCI is developed in response to a low-carbon economy. The findings of the current study provided evidence of 3PLs as supply chain orchestrators in decarbonized economies and their strategic benefits. Differing from many previous studies that focused on green SCI and 3PLs, this study provides a new perspective on 3PL-initiated LCSCI in consideration of the role of 3PLs as low-carbon supply chain orchestrators. Thus, the research results can contribute to knowledge development not only for SCI but also 3PLs. The present study also identified practical benefits for 3PLs in becoming supply chain orchestrators in a decarbonized economy and society. It suggests that, although the increasing pressure to outsource low-carbon services from both customers and government regulation, 3PLs be aware of their ability to initiate LCSCI, particularly their decarbonization capabilities. In order to gain the most from this initiative, 3PLs should optimize all their related processes, such as developing low-carbon logistics service design, techniques, and coordination capacity.

The empirical investigation can also provide scope for further exploration. Firstly, in relation to the factors that influence 3PLs to initiate LCSCI. This study assumed the degree of 3PL development to be at the same level. Given the negative role of decarbonization capabilities identified regarding the impact of government regulation on 3PL-initiated LCSCI, future research could examine the impact of these two factors on 3PL-initiated LCSCI in 3PLs at different stages. For example, when 3PL possess mature decarbonizing offerings, what is the impact of government regulation? Secondly, the empirical study was conducted in China; therefore, future research could investigate the differences between LCSCI initiated by 3PLs in cross-culture settings. Finally, the sample used in this study was relatively narrow, as data was only collected from one region. Future studies could expand the geographic coverage of the data.

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Managing supplier sustainability risk: A behavioral perspective

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Abstract

Buying organizations are increasingly exposed to supplier sustainability risk that arises from negative sustainability-related conditions or potential events in their supply base that might provoke harmful stakeholder reactions. Drawing on the behavioral theory of the firm, we develop a conceptual model to explain how three key contextual factors (buyer's slack resources, buyer's perceived sustainability risk, and supplier's dependence on the buyer) may influence the buyer's choice among four risk management strategies: do nothing, monitoring, collaboration, and phase-out. A vignette-based experiment with supply managers is conducted to test the model and its associated hypotheses.

Keywords: Supplier Sustainability Risk; Behavioral Theory of the Firm, Vignette-Based Experiment

Introduction

A growing number of buying organizations (termed "*buyers*") are experiencing greater exposure to different types of risk within their global supply chains, and these risks need to be proactively managed to protect them against financial loss and reputational damage. A particularly important topic is *supplier sustainability risk* (SSR), which originates from the use of poor environmental or social practices by a supplier, or the reasonable likelihood of a negative sustainability-related event within the buyer's supply base – either of which might provoke negative stakeholder reactions.

Anecdotal evidence suggests that buyers manage SSR in different ways and multiple supplier sustainability risk management strategies (termed "*SSR strategies*") have been conceptualized (Hajmohammad and Vachon 2016). Beyond identifying potential SSR strategies, further theorizing based on a synthesis of the supply chain risk management and sustainable supply chain management literatures points to multiple distinguishing factors that tend to favor one strategy over another: *degree of proactivity*, temporal framing (*pace* and *temporal focus*), and *onus of action*. Moreover, the behavioral theory of the firm (BTF) links these strategies to explain three major underlying factors that shape the buyers' diverse responses: degree to which the buyer has slack resources,

level of buyer's perceived risk, and level of supplier dependence on the buyer. A vignette-based experiment offered the means to empirically test and validate hypothesized relationships in the conceptual model.

Managing Supplier Sustainability Risk (SSR)

In this study, we focus on an emerging type of supply chain risk, namely, supplier sustainability risk, which is broadly defined as "*[a sustainability-related] condition or a potentially occurring event*", located within a focal firm's supply base, that "*may provoke harmful stakeholder reactions*" (Hofmann et al. 2014).

Factors influencing risk management

Risk management strategies that focus on activities in the supply chain before an event has occurred, i.e., pre-event strategies, have been classified into three primary categories: risk acceptance, avoidance, and mitigation (Ritchie and Brindley 2007). We synthesized three important underlying conceptual dimensions from the literature to parsimoniously characterize SSR strategies:

Proactivity: The degree of proactivity of SSR strategies varies along a passive–pre-emptive continuum based on the degree to which the strategy attempts to anticipate, rather than react to, the materialization of risk. In short, pre-emptive strategies focus on prevention rather than correction of supplier misconducts, mishaps, or mistakes.

Temporal framing: Temporality is multi-faceted, and the focus here is to emphasize two dimensions that characterize strategic actions: pace and temporal focus (Kunisch et al. 2017). Pace refers to how fast a strategy can be initiated and implemented (Lee et al. 2014). At the risk of oversimplifying, temporal focus denotes the extent to which a strategy's focus is on short- or long-term goals and outcomes. Consequently, the temporal framing of the SSR strategies may range along slow – fast and short-term – long-term continuums.

Onus of action: SSR is an inter-organizational phenomenon between a buyer and a specific supplier in its supply chain. Therefore, managing the risk may involve either or both parties (Hallikas and Lintukangas 2016). By definition, the strategy's onus of action refers to the degree to which both parties initiate actions, bear the burden for resources, and take responsibility for pushing implementation forward.

Toward a typology of SSR strategies

Four general SSR strategies highlight key theoretical differences yet remain parsimonious: do nothing, supplier monitoring, supplier collaboration, and supplier phase-out (Hajmohammad and Vachon 2016). The 'do nothing' strategy is primarily passive and fast-paced in nature with a focus on short-term demonstrable outcomes, such as limited commitment of financial resources. Moreover, by definition, neither the buyer nor supplier must shoulder the onus of action, limiting (at least in the short term) the potential for conflicts prompted by the efforts to improve. Management of SSR using supplier monitoring is less passive than the 'do nothing' strategy and, depending on the standard employed, also relatively fast paced. The focus clearly is on short-term outcomes that demonstrate passable performance, which potentially might prompt unethical behavior by either the supplier or the auditor. Of particular note, the onus of action is shared to some degree, although often predominantly placed on the supplier. Specifically, while the buyer might initiate a monitoring strategy, either the buyer or supplier might be required to commit resources to monitor achievement of the required sustainability behaviors or performance. Moreover, the supplier might be required to take corrective actions and make significant investments to improve its operating

processes and products to mitigate SSR, further shifting the burden to the supplier. Supplier collaboration strategy is more pre-emptive and aims at mitigating SSR by improving the suppliers' environmental and social performance through jointly-developed solutions. The temporal focus is a combination of short-term compliance and long-term improvement. Rather than forcing the supplier to improve, the buyer might look for a better supplier and then terminate the existing supplier relationship (Hajmohammad and Vachon 2016). While this fourth strategy represents a modestly proactive means to mitigate risk, the onus of action now falls entirely on the buyer to bear switching costs. Pacing is also likely to be moderately fast, and the relatively short-term temporal focus is simple: dramatically reduce risk, but with financial costs and disruption of integrating a new supplier into an established supply chain.

Predictors of SSR Strategy

The behavioral theory of the firm (Cyert and March 1963) views firms as coalitions of internal and external actors and suggests that boundedly-rational and satisficing managers take strategic decisions primarily based on two different measures: performance level they aspire to (aspirations) and the present conditions (internal and external) of their organization . Organizational aspirations are the desired performance levels in specific organizational outcomes . The BTF suggests that failure in meeting an aspiration level prompts problemistic search (or search for solutions) that results in organizational change. In other words, if the performance is higher than the aspiration level, decision makers will make no changes and continue the status quo as they consider that the firm is performing well, whereas if the performance falls below the aspiration level, the gap creates a sense of crisis and calls for a change, i.e., new strategies, techniques, or procedures to improve the situation (Bromiley 1991; Audia and Greve 2006). Thus, supplier sustainability risk within a buyer's supply chain threatens to deliver performance below a reasonable aspiration level (i.e., a failure), and needs to be addressed. The BTF's key concepts of problemistic search and coalitional structure of the firm (Gavetti et al. 2012) suggest at least three notable factors that might account for different firm responses to the SSR: degree to which the buyer has slack resources, buyer's perception of risk attributable to a supplier, and supplier's dependence on the buyer. These influential factors and their theoretical foundations are discussed in detail in this section.

Slack resources: Unabsorbed slack

Organizational slack is defined as the cushion of actual or potential resources that are not consumed by the necessity of the firm's continued daily operations. These slack resources allow the firm to successfully adapt to the internal or external pressures and to initiate changes in strategy with respect to the external business setting (Bourgeois 1981). Slack resources can take two forms : absorbed slack and unabsorbed slack. As a starting point, we focus on unabsorbed financial slack resources that are available to buyers to direct toward SSR strategies and adjustments that flow from these strategies and identified risks. In BTF's problemistic search model, slack acts as a buffer to absorb business shocks, to facilitate experimentation that generates new ideas and strategies, and to increase managerial discretion to refine established norms, relationships, and processes (Bradley et al. 2011). More importantly, slack significantly influences managerial risk-taking behavior (March and Shapira 1992): when slack resources available to managers decline, they become more passive and open to accepting the risk (Wiseman and Bromiley 1996). Conversely, high levels of slack lower managerial acceptance of the risk: managers will be inclined to increase the scope of their

information acquisition about the supply market and to explore new ways to mitigate or avoid the risk they perceive (Sidhu et al. 2004). As such, slack resources are essential for proactive management of the risk. Greater unabsorbed financial slack resources also tend to insulate a firm from pressure to solely focus on short-term performance and reduce its vulnerability to failure by providing a liquidity buffer in the event of loss (Bromiley 1991). With such a buffer in place, management can extend the time horizons of the firm's investments and can invest in initiatives with positive performance implications that do not have an immediate pay-off (Martin et al. 2016). Hence,

H1a: If a buyer has a low degree of slack resources, the management of SSR favors less proactive and shorter-term oriented strategies (i.e., do nothing or supplier monitoring).

H1b: Conversely, if a buyer has a high degree of slack resources, the management of SSR favors more proactive and longer-term oriented strategies (i.e., supplier collaboration or supplier phase-out).

Buyer's perception of risk

The *shifting-focus model* by March & Shapira (1992) ─ an extension of the problemistic search model ─ suggests that decision makers evaluate performance not only relative to an aspiration level (i.e., an acceptable or desired level of performance) but also relative to a survival point (i.e., performance is so low that the firm might fail). This relative evaluation influences the decision maker's inclination to be risk-averse or risk-tolerant in their decisions. Focusing on a survival point might induce decision makers to be more risk averse because they interpret low performance as a step toward failure. In contrast, their risk aversion might decrease if decision makers assess the firm's low performance relative to an aspiration level and interpret any gaps as repairable. Yet, even the reference point might change as decision makers potentially shift attention between the two (i.e., survival vs. aspiration) depending on which is perceived to be closer to actual performance (Audia and Greve 2006). By extension, when buyers perceive a high level of risk, for example, a serious threat to their firm's reputation and image that might greatly hurt the firm's survivability, the tendency is to become both more proactive and risk averse. Options include phasing out the problematic supplier or initiating collaborative actions to improve supplier performance, respectively. Collaboration also potentially reduces the information asymmetry and helps the buyer to more accurately assess supplier-related risks; however, when the buyer perceives a low level of risk, firm survival is less of a concern. As a result, the firm can afford to be more passive and willing to accept the risk by doing nothing or monitoring the supplier.

H2a: If the buyer's perception of a supplier's risk is low, the management of SSR favors less proactive strategies (i.e., do nothing and supplier monitoring).

H2b: If the buyer's perception of a supplier's risk is high, the management of SSR favors more proactive strategies (i.e., supplier phase-out and supplier collaboration).

When faced with problems, however, the viable solutions available to managers are limited in firms with low degree of slack resources (Yasai-Ardekani 1989). Without slack resources, carrying out the strategies that require a high onus for buyer action would be very challenging, if not impossible (e.g., when buyer needs to make sizeable investments to have a collaborative relationship with their suppliers or switch from one supplier to another) since these strategies require changes to the scope and/or volume of their supplier management processes and activities. In other words, the strategic actions taken by managers are well limited by the degree of resources at their disposal . Hence,

H2c: The hypothesized relationships between perception of risk and choice of SSR

strategy are moderated by the degree of slack resources. More specifically, with lower degree of slack resources, the management of SSR favors strategies with lower onus for buyer action. Thus, do nothing is favored for lower levels of the buyer's perception of supplier risk, and supplier phase-out is favoured for higher levels.

Supplier dependence

Organizations are not self-sufficient and their survival would ultimately depend on their ability to properly manage their external and internal coalitions (Pfeffer and Salancik 2003). When the performance falls short of the aspiration level, the problemistic search might lead to changes in structure, procedures, or routines of an external coalition rather than an internal one. For these changes to be implemented, organizations must negotiate and use their bargaining power to make proper adjustments. The organizations' ability to implement such changes depends on the level and nature of the dependence they develop and the relative power of all players (Pulles et al. 2014). By extension, the level of supplier dependence on the buyer influences which firm is more likely to bear the costs of either controlling or improving environmental and social performance. In practical terms, the onus of action is likely to fall to the firm with higher dependency, i.e., less power, in this buyer-supplier relationship. As supplier dependence increases, the buyer's relative power increases in the buyer-supplier relationship, enabling the buyer to more strongly influence the actions and behaviors of the supplier (Bastl et al. 2013). Particularly, supplier dependence enhances the buyers' ability to effectively monitor the supplier or push the supplier toward a more collaborative relationship whereby new practices are introduced at the supplier's facilities beyond the buyer's direct control (Hoejmose et al. 2013). In contrast, when the supplier has low dependence on the buyer, the buyer has limited influence and is in a poor bargaining position, thereby limiting the buyer's ability to either impose monitoring or encourage collaboration (Parmigiani et al. 2011). Therefore,

H3a: If a supplier has a high degree of dependency on the buyer, the management of SSR favors strategies with a higher onus for supplier action (i.e., supplier monitoring or supplier collaboration).

H3b: If a supplier has a low degree of dependency on the buyer, the management of SSR favors strategies with a lower onus for supplier action (i.e., do nothing or supplier phase-out).

H3c: The hypothesized relationships between supplier's dependency and favored SSR strategy are moderated by the degree of slack resources. More specifically, with lower degree of slack resources, the management of SSR favors the lowest cost approach. Thus, supplier monitoring is favored if a supplier has a high degree of dependency on the buyer, and do nothing is favored if a supplier has a low degree of dependency.

Methodology

We used a vignette-based experiment to examine the factors affecting the buyer's choice of SSR strategy (Rungtusanatham et al. 2011). Drawing from supplier sustainability risk events reported in the media, we developed two scenarios about fictitious mid-sized multinational companies. In each scenario, participants were asked to adopt the role of Procurement and Supply Management Director, review the profile of one supplier, and then indicate what actions, if any, they would take regarding the safety or environmental issues at that supplier's facilities. Eight vignettes for each scenario were carefully designed to allow the manipulation of all three independent variables at two levels: degree to which the buyer has slack resources (high and low,

i.e., S+ and S-), the buyer's perception of risk attributable to a supplier (high and low, i.e., R+ and R-), and a supplier's dependence on the buyer (high and low, i.e., D+ and D-). This resulted in a 2x2x2 full-factorial design, with other descriptive elements of the scenarios unchanged. Full-time supply managers currently working for medium or large companies (i.e., more than 100 employees) in the U.S. were targeted, and our sample was drawn from an internet panel recruited by Qualtrics. Data collection was open for two weeks, after which our targeted sample size of 200 complete responses was achieved. Two responses were discarded because of their poor response patterns (straight-lining), yielding 198 completed responses (396 vignettes).

Data Analysis and Results

Moderated multinomial logistic regression model (Jaccard 2001) allowed us to assess the effect of slack resources, perceived risk, and supplier dependence on supply managers' specific choice of SSR strategy. With multinomial logistic regression, the log-odds of the outcome categories are modeled as a linear combination of the predictor variables. The two levels of each three predictor variable were modeled as a dichotomous variable, with the reference group being a buyer with a high degree of slack resources (S+), a buyer with a low perception of risk attributable to the supplier (R-), and a supplier with a low degree of dependence on the buyer (D-). The logistic regression model describing the relationship between $logit(y_{kl})$ (the log-odds that the strategy *k* is selected compared to the reference strategy *l*) and our set of predictors is:

$$logit(y_{kl}) = B_0 + B_{1kl}S + B_{2kl}R + B_{3kl}D + B_{4kl}RD + B_{5kl}RS + B_{6kl}DS + B_{7kl}RDS \quad \text{(Eq. 1)}$$

We ran three multinomial logistic regressions using 'do nothing', supplier monitoring, and supplier collaboration as the reference group to complete the comparison. Table 1 summarizes the regression analysis results, including the models' goodness of fit information, regression coefficients, relative odds ratios, and their significance level. As indicated in the table, the fit statistic (-2 Log Likelihood (-2LL)) improved significantly when the main effects and full factorial interaction effects were added to the intercept-only models (significant chi-square tests at $p<0.001$), confirming that the complete interaction models most accurately predict manager's choice of SSR strategy. In addition, the Pseudo Nagelkerke R2 (48.3) for the complete interaction models indicates that the predictors and their interactions account for almost 50% of the variance in the respondent's choice among the four strategies.

In the main effect models (Table 1, Panels A-I~VI), the exponent of the logistic coefficient (i.e., Exp(Bi)) for each predictor variable is equal to the odds of the specific strategy being selected compared to the reference strategy within group 1 of the predictor variable divided by the same in its reference group, holding constant all other predictor variables in the equation. The significant main effect of slack resources in Panels A-II and A-III that compared to collaboration and phase-out strategies, the 'do nothing' strategy was significantly more likely to be selected in case of low slack resources (B=-2.018; B=-1.484, $p<0.001$, respectively). Similarly, monitoring strategy was significantly more likely to be selected compared to collaboration and phase-out strategies in a low slack situation (Panels A-IV and A-V; B=-1.275, $p<0.001$; B=-0.741, $p<0.05$, respectively). Together, these results provide support for H1a and H1b, suggesting that pre-emptive and long-term oriented strategies are preferred in high slack situations, whereas passive and short-term oriented strategies are favored when slack resources are low. In addition, perceived risk negatively influenced the likelihood of the 'do nothing' and supplier monitoring strategies being selected compared to

collaboration and phase-out strategies. Particularly, collaboration and phase-out strategies were 18.29 and 10.63 times more likely to be selected in high risk situations compared to the 'do nothing' strategy (Panels A-II and A-III), and 5.1 and 2.96 times more likely compared to monitoring strategy (Panels A-IV and A-V). Together, these results provide strong support for H2a and H2b, suggesting that managers prefer pre-emptive strategies to passive ones when they deal with high supplier sustainability risk. Lastly, the results supported H3a and H3b, demonstrating that the monitoring and collaboration strategies were significantly more likely to be selected compared to 'do nothing' (Panels A-I and A-II; B=2.101, p<0.001; B=1.908, p<0.001) and phase-out (Panels A-V and A-VI; B=-2.11, p<0.001; B=-1.918, p<0.001) strategies when the supplier was highly dependent on the buyer. However, supplier dependence did not have a significant effect on the preference between phase-out and 'do nothing' strategies (Panel A-III; B=-0.009, p>0.1) and between collaboration and monitoring strategies (Panel A-IV; B=0.193, p>0.1).

The complete interactive logistic models (Table 1, Panels B-I~VI) include the product terms in addition to the main effects. In these models, the main effect coefficients for each factor are conditioned to the reference groups of two other factors. In addition, the exponent of the logistic coefficients for the product terms will be "the ratio of predicted odds ratios" (Jaccard 2001). To better appreciate the results of the interactive logistic models, we used Equation 1 and the coefficients reported in Panel B to calculate the predicted $\text{logit}(y_{kl})$ for each cell of the 2x2x2 factorial design. We then converted these log-odds to relative odds of strategies by calculating the exponent of each (Figure 1). As demonstrated in Figure 1, the odds ratio of collaboration strategy compared to the monitoring reduced from 0.38 in S+ R- D+ to 0.16 in the S- R- D+ situation (Cell II vs. Cell II') and from 5.14 in S+ R+ D+ to 0.27 in the S- R+ D+ situation (Cell IV vs. Cell IV'). In fact, the monitoring strategy was the most favorable to the buyers for highly dependent suppliers in low slack condition. In addition, the insignificant logistic coefficients for slack resources (S) effect in Panel B of Table 1 indicate that in R- D- situations, managers' preference amongst the four strategies does not change based on degree of slack resources (i.e., S+ vs. S-). Particularly, low degree of slack does not increase the likelihood of the 'do nothing' strategy, which has lower onus for buyer action compared to the phase-out strategy when buyers deal with low-risk independent suppliers. However, the 'do nothing' strategy remained the most preferred strategy in S- R- D- similar to S+ R- D- cases (Fig. 2, Cell I' and Cell I). Besides, although the odds ratio of phase-out strategy compared to the 'do nothing' strategy decreased significantly from 27.99 in S+ R+ D- to 1.13 in the S- R+ D- situation (Fig. 2; Cell III vs. Cell III'), the 'do nothing' and phase-out strategies were almost equally likely to be selected in the S- R+ D- case (Fig. 2; Cell III'). Hence, the results only partially support H3c. Finally, the likelihood of phase-out compared to the collaboration strategy significantly increased from 0.17 in S+ R+ D+ to 0.78 in the S- R+ D+ situation (Fig. 2; Cell IV vs. Cell IV') and, surprisingly, decreased from 2.33 in S+ R+ D- to 1.54 in the S- R+ D- situation (Fig. 2; Cell III vs. Cell III'). Besides, the monitoring strategy turned out to be the most preferred strategy in S- R+ D+ (Fig. 2; Cell IV') and the 'do nothing' and phase-out strategies were almost equally likely to be selected in the S- R+ D- case (Fig. 2; Cell III'). Therefore, our results provide only partial support for H2c.

Discussion and Conclusion

The theoretical development and empirical results of this paper extend the literature to date in six important ways. First, our findings call for more scholarly attention to the

crucial effect of slack resources on the strategic decisions made by middle managers, in this case, supply managers. In short, the decision outcome of "which risk management strategy to use" varies depending on if a desired strategy is deemed to be affordable. Second, this study extended the behavioral theory of the firm to explain the decision making within inter-organizational buyer-supplier dyads rather than intra-firm contexts. Also, additional empirical support is provided for the problemistic search model and firm's coalitional structure. Third, our study contributes to the literatures that speak to risk management in supply chains by providing theoretical foundations to differentiate among the four SSR strategies often discussed in the literature. Particularly, a synthesis of theory established that, in addition to their fundamental differences in how they target the risk (avoid, mitigate, or accept), four distinct strategies also differ in their level of proactivity, temporal framing (pace and temporal focus), and onus of action. Fourth, the results of this study provide additional support for the resource dependence theory from a risk management perspective. Fifth, our findings add depth to the literature on sustainable supply chain management by extending a risk-based framework and empirically examining the concept of SSR strategies and specific predictors. Finally, from an empirical standpoint, the vignette-based experiment methodology allowed for more controlled examination of the causal relationships with a sample of practicing supply managers.

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Figure 1. Relative odds of SSR strategies given contextual conditions

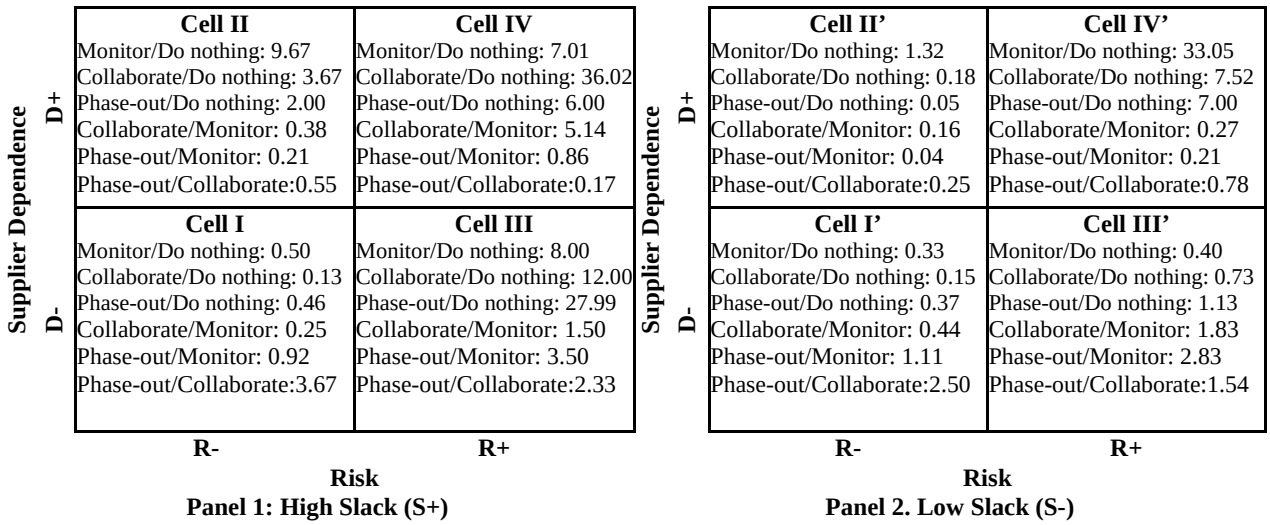

Table 1. Multinomial logistic regressions - Direct effect (A) and complete interaction (B) models

		Panel A (Direct Effect Models)			Panel B (Complete Interaction Models)		
		B (SE)	Wald	Exp(B)	B (SE)	Wald	Exp(B)
Regression Model 1 Ref.: Do Nothing	***I: Choice of Supplier Monitoring***						
	S[a]	-0.743 (0.322)*	5.33	0.48	-0.405 (0.523)	0.60	0.67
	R[a]	1.278 (0.350)***	13.35	3.59	2.773 (1.118)*	6.15	16.00
	D[a]	2.101 (0.322)***	42.50	8.18	2.962 (0.702)***	17.80	19.33
	R x D				-3.095 (1.662)[I]	3.47	0.04
	R x S				-2.590 (1.277)*	4.11	0.07
	D x S				-1.589 (0.857)[I]	3.44	0.20
	R x D x S				6.135 (2.065)**	8.82	461.8
	Intercept	-0.613 (0.298)*	4.24		-0.693 (0.354)*	3.84	
	II: Choice of Supplier Collaboration						
	S	-2.018 (0.375)***	28.90	0.13	0.170 (0.814)	0.04	1.19
	R	2.906 (0.402)***	52.29	18.29	4.564 (1.208)***	14.29	96.00
	D	1.908 (0.377)***	25.68	6.74	3.379 (0.894)***	14.28	29.33
	R x D				-2.280 (1.706)	1.79	0.10
	R x S				-2.965 (1.379)*	4.62	0.05
	D x S				-3.207 (1.179)*	6.60	0.05
	R x D x S				4.436 (2.184)*	4.13	84.44
	Intercept	-1.249 (0.355)***	12.38		-2.079 (0.612)**	11.53	
	III: Choice of Supplier Phase-out						
	S	-1.484 (0.351)***	17.86	0.23	-0.213 (0.519)	0.17	0.81
	R	2.364 (0.371)***	40.58	10.63	4.112 (1.081)***	14.47	61.09
	D	-0.009 (0.380)	0.001	0.99	1.473(0.795)[I]	3.43	4.36
	R x D				-3.014 (1.684)[I]	3.20	0.05
	R x S				-2.994 (1.196)*	6.26	0.05
	D x S				-3.424 (1.350)*	6.44	0.03
	R x D x S				6.786 (2.301)**	8.70	885.09
	Intercept	-0.250 (0.292)	0.734		-0.780 (0.364)*	4.59	
Regression Model 2 Ref.: Monitoring	***IV: Choice of Supplier Collaboration***						
	S	-1.275 (0.309)***	17.06	0.28	0.575 (0.882)	0.43	1.78
	R	1.629 (0.318)***	26.19	5.10	1.792 (0.791)*	5.14	6.00
	D	-0.193 (0.319)	0.37	0.82	0.417 (0.736)	0.32	1.52
	R x D				0.815 (0.960)	0.72	2.2
	R x S				-0.375 (1.115)	0.11	0.69
	D x S				-1.439 (1.092)	1.73	0.24
	R x D x S				-1.699 (1.404)	1.46	0.18
	Intercept	-0.636 (0.346)[I]	3.38		-1.386 (0.645)*	4.61	
	V: Choice of Supplier Phase-out						
	S	-0.741 (0.317)*	5.47	0.48	0.192 (0.621)	0.10	1.21
	R	1.086 (0.324)**	11.26	2.96	1.340 (0.579)*	5.36	3.82
	D	-2.11 (0.330)***	40.87	0.12	-1.489 (0.613)*	5.90	0.23
	R x D				0.082 (0.920)	0.01	1.08
	R x S				-0.404 (0.878)	0.21	0.67
	D x S				-1.836 (1.275)	2.07	0.16
	R x D x S				0.651 (1.580)	0.17	1.92
	Intercept	0.363 (0.304)	1.43		-0.087 (0.417)	0.04	
Regression Model 3 Ref.: Collaboration	***VI: Choice of Supplier Phase-out***						
	S	0.533 (0.340)	2.47	1.70	-0.383 (0.880)	0.19	0.68
	R	-0.543 (0.360)	2.27	0.58	-0.452 (0.737)	0.38	0.64
	D	-1.918 (0.343)***	31.28	0.15	-1.905 (0.826)*	5.32	0.15
	R x D				-0.734 (0.998)	0.54	0.48
	R x S				-0.029 (1.021)	0.001	0.97
	D x S				-0.397 (1.511)	0.07	0.67
	R x D x S				2.35 (1.732)	1.84	10.48
	Intercept	0.999 (0.353)**	8.01		1.299 (0.651)*	3.98	

a. S: Slack resources (ref. = S+); R: Risk perception (ref. = R-); and D: Supplier dependence (ref. = D-).

*b. *** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05; [I] p-value < 0.1*

c. Goodness of fit:

Direct Effect Models	***Complete Interaction Models***
-2 Log Likelihood (intercept only): 319.076	*-2 Log Likelihood (intercept only): 319.076*
-2 Log Likelihood (full model): 120.465	*-2 Log Likelihood (full model): 81.193*
*Chi Square (df): 198.611 (9)****	*Chi Square (df): 237.883 (21)****
Nagelkerke R^2: 0.422	*Nagelkerke R^2: 0.483*

Digitalization and environmental sustainability: What are the opportunities?

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Abstract

This paper provides an explorative study on digitalization and sustainability from the angle of industrial firms. The paper presents case studies on application of the Triple Layered Business Model Canvas, which allowed for relevant insight into the field. The findings in this study show that companies do not capture sufficient sustainability data along their supply chain in order to conduct an overall sustainability assessment. The opportunities lies in adaptation of new technologies, which allow collecting data along each phase of life cycle of a product. Four Sustainable Development Goals by United Nations that are aligned to Industry 4.0 are addressed.

Keywords: Sustainability, manufacturing, clusters, digitalization

Introduction

Digitalization and sustainability are two terms that have gained increased attention the recent years since they are representing potential transforming forces of businesses and society. Sustainability has moved from being regulative pressure from the surroundings and a corporate buzzword, to becoming an encompassing concept that businesses has to relate to and implement in their activities. Sustainability is "a radical transformation towards a sustainable society" (Grin et al., 2010, Joyce and Paquin, 2016).

The fourth industrial revolution is envisioned based on innovations in technologies, smart materials and manufacturing operations. The revolution includes initiatives termed Industry 4.0, the Industrial Internet, Factories of The Future, and Cyber Physical Systems. A driving force for this development is the accelerated use of Internet of Things (IoT)-technologies (Porter and Heppelmann, 2015, IEC, 2015). Companies have common needs across sectors for optimizing operations, for managing parts and raw materials, in production, assembly, packing and dispatching. Digitalization can play a vital role in

providing valuable data to help making businesses more efficient and sustainable (EMF, 2016). A relevant perspective of a sustainable development adopting digital technologies should adhere to the 17 Sustainable Development Goals (SDGs) by the United Nations (UN, 2016b, UN, 2016c). How these goals are aligned to Industry 4.0 in practice among industrial actors are still unclear (Bonilla et al., 2018). Bonilla et al. (2018) have identified four of the goals of particular relevance for Industry 4.0: Goal 7 Affordable and clean energy, Goal 9 Industry, innovation and infrastructure, Goal 12 Responsible consumption and production, and Goal 13 Climate actions. Each goal is complemented by a set of sustainability-targets and indicators to measure and drive performance towards meeting the goals (UN, 2016a).

In order to transform companies to become sustainable, a new theoretical basis is needed. Digitalization of global value chains and sustainability are however, representing separate fields of research within operation management. This paper aims at exploring the territory represented by the intersection between digitalization and sustainability, and propose a set of potential research directions.

Sustainability measurement as whole requires comprehensive data and information. However, the evidence of some studies is that part of the firms are at the stage where they are not capturing the entire data and information on their business processes. This paper aims at exploring how industries approach the expectations and needs to become more sustainable, and how digitalization may solve the challenges in this context. The study is based on in-depth studies of two companies in the maritime and marine sector in Norway (Klymenko and Nerger, 2018). In these case studies the Triple Layered Business Model Canvas (TLBCM) (Joyce and Paquin, 2016) is applied to test this tools applicability, as well as mapping the challenges for using such framework in the companies' development towards sustainability. Based on this, we discuss how digital technologies may solve some of these challenges.

Digitalization and Industry 4.0

The term digitalization has grown fast within operation management in industry as well as in academia in the past decades. Digitalization addresses the transformation of information flows and data through usage of new technologies and tools, that is, reconstruction of business processes towards more efficient. The term "Industrie 4.0" which concern digitalization in the manufacturing industry, was coined at the Hannover Fair in 2011, describing how digital technologies will revolutionize the organization of global value chains (Schwab, 2016). The term originates from a governmental high-tech strategy in Germany, promoting the computerization of manufacturing (Zuehlke, 2010). Industry 4.0 encompasses a broad range of technologies and concepts. In the context of manufacturing, Industry 4.0 focuses on intelligent products and production processes (Brettel et al., 2014). In the envisioned factory of the future, or smart factory, cyber physical systems will enable communication between machines, products and humans, vertically as well as horizontally. The products are intelligent and customized, to accommodate for the increased need for rapid product development, flexible production and increasingly complex environments (Vyatkin et al., 2007). Brettel et al. (2014) point out that the concept of Industry 4.0 is being used in different contexts, but is lacking an explicit definition. Based on a literature review, Hermann, Pentek, and Otto (2015) provide the following definition of Industry 4.0:

> *Industry 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each*

other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain." (Hermann et al., 2015, p. 242)

This definition itself contains several terms and concepts, as IoT, CPS and IoS. However, the core of this definition is that items, systems and humans communicate with each other over the Internet in real time. This implies that everything is connected. The second main aspect is the development of services based on this connectedness. According to World Economic Forum, the fourth industrial revolution is being driven by extreme automation and extreme connectivity in combination with artificial intelligence (UBS, 2016). The extreme connectivity enables global and instant communication enabling new business models, which is second aspect of the fourth industrial revolution. The development of new business models is also made possible by the advances in data processing capacity enabling the analytics of "Big Data". Hence, the fourth industrial revolution encompasses a variety of enabling technologies, as CPS, IoT, Big Data, RFID, cloud computing 3D printing and blockchain (Bonilla et al., 2018).

Digitalization, sustainability and business models (BM) for sustainability

Digital technologies provide the information needed to create iterative and restorative systems enabling the companies to move towards sustainable operations and products.

Coupling IoT-enabled innovation with sustainability principles can help companies identify new business models. Some examples of areas where the ongoing digitalization have been used to move towards more sustainable operations are optimization of capacity utilization, implementation of predictive maintenance, and automation of sales and inventory management. Digitalization is seen to enable sustainable business models several areas, including (EMF, 2016):

- Knowledge of the location of assets (products, production resources, humans). Tracking to determine the location is an enabler of sharing models, and it contributes to bring down the costs of operations. This allows improved resource utilization, rapid redeploying of resources, and keeping assets in service over an extended period of time. Tracking also facilitate auditing and consolidation of records in an efficient manner reducing the costs.
- Knowledge of the condition of an asset. Sensor data can monitor environmental conditions to keep track of the performance of an asset and its use patters providing data for sustainability indicators driving their operations towards their sustainability goals.
- Knowledge of the availability of an asset. The availability data supports increased sharing of assets and development of new more sustainable business models. It promotes the shift towards a more service-oriented economy, for example in energy systems, data about usage and demand of energy at a given location and a given point in time enable more efficient usage of the energy.

Digitalization can be identified as one of the enablers of sustainability in terms of improving resource efficiency, manufacturing performance and as an opportunity to establish accessible data system and obtain flexible and smart use of data through application of information technology. Another contribution of digitalization is strengthening firms' ability to respond on internal and external uncertainties and changes (Gürdür et al., 2019).

There is a growing literature exploring how Industry 4.0 related technologies could contribute to achieving the sustainable goals. According to de Sousa Jabbour et al. (2018), Industry 4.0-associated technologies have the unique potential to unlock environmentally-sustainable manufacturing, however there are few emerging works

providing insights into these two fields. Stock et al. (2018) have recently published a relevant study addressing this issue. Based on a literature review and expert interview, Stock et al. (2018) qualitatively assess "the potential of industrial value creation in Industry 4.0 in terms of it contribution to the shift towards sustainable value creation for sustainable value creation" (p. 255). The point of the departure for this study is the United Nations' 17 SDGs and the characteristics of Industry 4.0, which in this paper are referred to as Cyber Physical Systems (CPS), Cloud Computing, and Digital Twin & Digital Shadow. The study assesses the macro and micro potential. The macro potential encompasses business models and value creation network and product life cycle. The micro potential covers quantity of materials used, shared of reused, remanufactured and recycled materials total amount of waste, energy consumption, use of renewables, energy efficiency, greenhouse gas emissions, water use emissions of pollutants and noise, working conditions, information and transparency, and utilization of data. For some of these indicators, specific technologies are given, as RFID and 3D-printing. The above study gives some relevant suggestions of how Industry 4.0 related technologies may facilitate sustainability. However, little attention is devoted of what are the main challenges of the industry, and how technology may accommodate these. In order to shed light on this, we need to introduce a tool that companies can use in the process to address sustainability goals, called the Tripe-Layered Business Model Canvas.

The Triple-Layered Business Model Canvas

The literature suggests a vast number of frameworks and methodologies on sustainability. Some scholars propose various business models, for instance business models for sustainability, circular business models (Schaltegger et al., 2012, Bocken et al., 2014, Joyce and Paquin, 2016). The TLBMC, first introduced in 2016, belongs to the field of sustainable business model. A business model (BM) is a conceptual model that integrates coherence of processes and information necessary for value creation of a firm (Teece, 2010), and the TLBMC tool integrates business model innovation with sustainable business model development. The TLBMC integrates sustainability as part of their business models across three layers: economic layer based on the original business model canvas, environmental layer based on a life cycle approach and social layer based on a stakeholder view. It designed to address three dimensions of sustainability based on the original business model Canvas (Osterwalder et al., 2005).

The TLBMC describes how the company generates economic, environmental and social values. The template of the Environmental layer is presented at the Figure 1. According to Joyce and Paquin (2016), there are horizontal and vertical coherences between each layer. In horizontal coherence of TLBMC, each of three layers is being examined separately, while the vertical coherence combines the value creation of the three canvas layers (Lozano, 2008).

The Economic layer is directed to assessment of nine interdependent components, such as customer value proposition, segments, customer relationship, channels, key resources, key activities, partners, cost and revenues.

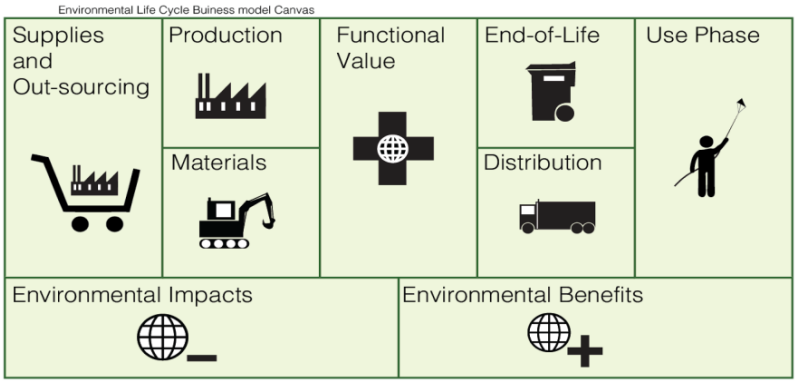

Figure 1. The Environmental layer of the TLBMC (Joyce and Paquine, 2016)

According to the framework, the Environmental layer is based on a life cycle perspective of environmental impact. The layer assesses environmental benefits and environmental impacts of the company. Moreover; as business model canvas evaluates how revenues outweigh costs, the Environmental layer aims to assess where the company's highest environmental impacts compared to environmental benefits that can be a potential area for implementation of sustainability-oriented innovations (Joyce and Paquin, 2016). Due to this approach, organizations might search for environmentally oriented solutions, especially when its environmental impacts are large. The TLBMC does not use the entire approach of the LCA. However, it provides a perspective of the LCA while integrating it to the environmental phase of the business model. The Environmental layer consists of nine components, which together give the holistic view on environmental performance of the company.

The Social layer explores the social impact of an organization on its stakeholders. The stakeholders may include employees, shareholders, customers, suppliers, community, government, interest groups, media, etc. The template is based on the original business model canvas with a stakeholder approach.

Similar baseline can be drawn at the perspective of UN SGDs. The seventeen SDGs as well as TLBMC are based on the Triple bottom line concept (Elkington, 1997). These are directed to enhance economic, social and environmental value creation. However, the framework of SDGs is broader in scope and can be relevant for different groups of stakeholders (private households, businesses, cities, industries).

Design/methodology/Approach

The issues addressed in this paper are explorative in their nature, and hence call for an open and explorative approach. Initially, we address the evidence for sustainability measurement and the role of digitalization from industrial perspective by presenting the case study of two Norwegian firms. Furthermore, the UN SDGs are presented with relevance to digitalization and Industry 4.0. Finally, the discussion of findings provides the overview of current extent and solutions for data availability and information flow issues along the value chains with respect to sustainability assessment.

The companies of the case study

The methodology of the TLBMC was applied on two companies from marine and maritime industries (Klymenko and Nerger, 2018). The companies were selected based on their practices and focus towards sustainability. Company A is a maritime mechanical equipment suppliers and it is one of the leading firms in Western Norway. The company holds control over the whole value chain that involves various activities starting from

design, manufacturing, marketing and after-sales service for maintenance and repair. The production facilities are located in the region. From a sustainability angle, the firm focuses on providing maintenance, upgrade service for the equipment in order to extend the lifetime of equipment. The product range includes environmentally friendly products with lower energy consumption, low noise and vibration.

Company B is a fishing company that provide catching, processing and delivery of fish fillets. It uses a eco-friendly factory trawlers with hybrid propulsion and low NOx emissions. The company focuses on sustainable harvesting techniques that minimizes emissions and utilize 100% of the fish and aims to provide a high degree of transparency as all fish caught are traceable. Both companies are categorized as small and medium-sized companies representing two different and important industries in Norway. Consequently, the selection of companies provides for comparison, and for in-depth insight into different types of companies.

Findings of the study

The studies of the two companies show that the economic layer of the original business model canvas were proven sufficient for both cases (Klymenko and Nerger, 2018). Not surprisingly, most information related to economy, consisted of straightforward facts that can quickly be revised by managers. Unlike the economic layer, the data collected for the social and environmental parts did not completely fulfill these two corresponding layers. Some components of the social layer were difficult to define and measure, for instance, social value, scale of outreach and social impacts. The study of Joyce and Paquin (2016) suggests limited and brief description of the elements of the layers. Thus, some additional sources were applied in order to develop the insight of the components and indicators, for instance, Guidelines for social life cycle assessment of products (Life Cycle Initiative at UNEP, United Nations Environment Programme, 2009). Finally, the data and information for the environmental layer provided a generalized understanding of the impact. The study revealed, however, that there is a lack of data on greenhouse gas (GHG) emission for distribution, energy requirements during the operation, etc.

The case of company A emphasize the differences regarding product types, as this have impact on the following manufacturing, energy consumption for product use, and finally the environmental impact. Unlike the study described by Joyce and Paquin (2016) where the TLBMC framework was applied on Nespresso capsules, the products in company A was very complex. The complexity led to challenges in applying the TLMBC framework. Nevertheless, company A produces several kinds of product units and some of them identified as environmentally friendly products, that have lower energy consumption, low noise and vibration. The interviews revealed that company A does not have a single storage of data and information. The data is distributed according to the organizational structure of the firm and separate pieces of data belong to specific department or to responsible of those employees. Consequently, there is a lack of a systematic approach to information storage, where the data can be organized in accessible and structured way. Sustainability from the perspective of the TLBMC, is directed towards detailed review of all business processes, starting from raw materials delivery by suppliers, along the manufacturing, logistics, warehousing, towards customer use, and finally finishes at the end of use stage. The challenge with availability and easy access to data and information made it difficult to map the different elements in the TLBMC, which is a key to complete sustainability evaluation.

The case of Company B differs in terms of shorter value chain, which is integrated in one vessel. According to Ziegler et al. (2016), fuel use is the main driver to greenhouse gasses (GHGs), eutrophication or depletion of abiotic resources. The fishing phase

consumes most fuel and contributes 75% - 79% of GHGs. In this case, fishing is one of the central activities of the company. However, information about fuel consumption and emission NOx were not available at the company. General information about consumption level came from the ship building company in Spain. Hence, the data collection time was significantly longer than initially planned. To apply life cycle approach to the environmental layer, it is imperative to take a broader view on the entire life cycle. For fishing companies, suppliers include firms who provide packaging material, processing factory manufacturers, fuel providers, and vessel maintenance companies among others. In this case, the conduction of a more comprehensive sustainability assessment was limited due to the absence of necessary information about suppliers that are part of the product's life cycle and hence are contributors to the emission level of the product. Generally, where the company has control over its value chain, it was possible to obtain sufficient data and information to conduct the sustainability assessment, however, when it comes to suppliers and distributors less relevant data was available. As a result, a more thorough sustainability assessment would require more time and information from distributors and suppliers.

To visualize the understanding of data and information availability from the case study across the layers, the summary of information received is presented in Table 1.

Table 1. Data and information collected for the Environmental Layer for companies A and B

	Data available
	Partly available data
	No data

Environmental layer	Company A	Company B
Supplies and Outsourcing		
Production	Energy consumption Waste for recycling, hazardous waste	Estimated fuel consumption
Materials		Information about reduction of pollutants from supplier
Functional Value	One type of mechanical system	1 kg fresh frozen fish
End-of-Life		
Distribution		
Use Phase		
Environmental Impacts	Electricity use in production facilities Data on noise and vibration Hazardous waste	NO_x production Disposal of packing material
Environmental Benefits	ISO 14001 Three environmentally friendly products Waste for recycling and further processing	Reduction of NO_x (2016-2017) 100% use of fish Modern trawler prevents catching of small fish which secure future stock

Exploring the interrelations between digitalization and sustainability measurement, the findings reveal on high data requirements especially for the environmental layer of the TLBMC. Based on the case study example, the information collected partly fulfill the requirements for production phase analysis for both companies A and B. For company A

data on energy consumption in production facilities for 2012-2017 was received. The analysis showed a reduction in energy use in the last years. However, the cause for this decrease is not quite clear. According to the findings in company B, the resulting data consisted information on fuel used for catching, processing, freezing on the vessel, and storage/freezing after taken from the vessel per 1 kg of fish. The information for material phase for company B provides particular insight on packaging materials. Although, the first common issue for those companies is absence of the information from the suppliers, for instance, environmental impact from raw materials supply and logistics. Furthermore, customer use and end of life stages are not at the main scope of the businesses. As a result, the responsibility for the product impact often ends when the supplier role finishes. At the same time, the information flow on business activities generally are not completely shared between supplier firms across the value chain.

Hence, based on the data and information collected during the interviews and secondary data assessment, the environmental impacts and benefits are not addressing the entire impacts and benefits of the activities of the companies A and B. Consequently, the result estimated in the study provides limited findings.

The result shows that important data and information are not available or even not accessible for the companies. Firstly, there is a lack of supplier materials information. Both case companies receive general data and information about resources and materials they supply. However, there is no complete information flow from supplier to buyer firm. Bonilla et al (2018) underlines the principle of Industry 4.0 to promote real-time shared information through supply chain tiers that can help companies to understand patterns of consumption and increase transparency of a product information. Another essential phase for sustainability assessment is use phase and end of life of a product, which also defined as lacking of data. Industry 4.0 fundamental technologies can help in resolving this gap. First is cyber-physical systems (CPS), which establishes connective and communicative solutions that allows sufficient information exchange and control between humans, machines and products (Bonilla et al., 2018). According to Bonilla et al., (2018), the second is Internet of Things (IoT), which is essential for data mining and recording, and directed to information exchange from physical things to Internet. The collection of data and information is carried out through installed sensors, actuators and communication technologies. In fact, digitalization and novel emerging technology solutions are crucial for industrial sustainability, which is directed to redesign for value creation in sustainable production and consumption.

Digitalization and the SDGs

Drawing on the study of Bonilla et al (2018) and the findings from the case study above, we address the collaborative linkage between Industry 4.0 components and SDGs. The SDG 7 Affordable and clean energy is directed to ensuring access to affordable, reliable energy and particularly improvement of industrial energy efficiency (UN, 2016 b). As an illustration, the case studies of companies A and B reveal on importance of assessing energy consumption along the whole life cycle of a product. Technology for monitoring and data collection is crucial for further adjustments in energy efficiency of a product. In the same way, the SDG 9, which aims to enhance innovation and sustainable industrialization, can be flourished by digitalization in order to define weak and potential stages for sustainability improvements. The case study underlines the lack of tools for systematic data and information collection at the stage of supply materials, production and material phases, thus, it lead to the lack of complete sustainability assessment. Finally, the SDG 12 Responsible consumption and production, which requires data and information from use phase of a product as well as manufacturing phase in order to make

further improvements. The actions towards contribution to SDG 13 Climate actions, aims to assess COx, NOx emissions, hazardous waste and other chemicals that have negative impact on environment and climate change overall. Thus, the initial stage towards sustainable development is in reliable technologies for critical assessment of today's impact, followed by further sustainability-oriented decisions.

Discussion

The concept of sustainability is a transdisciplinary field by nature. Whether it is sustainability evaluation through variety of tools such as sustainable business models, or whether it is assessment through indicators of SDGs, one and the other requires accurate and detailed data and information. According to the study findings, the example of case study of the TLBMC application underlines that sustainability is a data- and information-demanding area. The study indicates that examined companies are at the stage where they are not capturing entire data and information along the supply chain. Consequently, it is more difficult to conduct overall sustainability assessment.

However, gathering data is not enough for holistic pictures of sustainability measurement. It follows that the data should be processed and transformed into information and knowledge categories. When evaluating some of the SDGs indicators, the process relies on available data, preferably in time-series, accessible and timely updated (Bastianoni et al., 2019). Schaffartzik et al. (2015) propose that the data and information in form of macro- and micro-economic aggregates are historically easier to report and it is more sufficient than the information and data reported in physics-based units, as most of the environmental dimension data is.

High data requirements for sustainability measurement underlines how important the focus on digitalization of the businesses is. Digitalization from the perspective of business model for sustainability can be defined as a procedure to create a common system for storage of data and information, its processing and structuring, and approach to the effective interpretation of data crucial for business model redesign and sustainability assessment. An important contribution of the study is that it through these case studies show the importance of data availability is for both sustainability measurement in general and for application of the TLBMC in particular.

Conclusion

The paper presented an explorative study on digitalization and sustainability from the angle of industrial firms, and a case study on application of the TLBMC for two companies. The results show that the companies do not capture enough sustainability data along their supply chain in order to conduct an overall sustainability assessment. Thus, this also indicates that the companies do not have enough information on their operations to manage their processes in a way that enable them to move towards their sustainability goals. The opportunities lies in adaptation of new technologies, which allow collecting data along each phase of life cycle of a product. Industry 4.0 has brought beneficial changes towards digitalized infrastructure and essential for sustainability assessment.

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Current state of digitalization in the European Electronic Components and Systems Industry: A multiple-case study analysis

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Abstract

Our paper highlights the various consequences of implementing information technology in sustainable supply and value chains of industries. With a particular focus on studying the digital transformation of the European Components and Systems (ECS) industry, our research examines the progress made by industry practitioners in implementing new, digital technologies and the impact achieved. We conducted an exploratory multiple-case study that included a qualitative content analysis of four selected industrial cases from a major European innovation project. The results contribute to the theory of how value chain process improvement can be assessed after innovative technical adaptations have been made in factories.

Keywords: Digital Transformation, Case Study Research, Impact Assessment

Introduction

The trend towards an increasingly digitalized manufacturing environment is an emerging topic for researchers and practitioners of different fields (Hannola et al. 2018, Richter et al. 2018). Various European manufacturing industries have invested into a rising number of activities to develop and explore the potential of digital technologies to remain competitive within an era of a digitally transformed world. The integration of intelligent and smart systems, digital technology adoptions and new management approaches in the context of Industry 4.0 becomes increasingly important due to improved value chain management. Other new technologies may include innovative applications such as real time monitoring, controlling systems or advanced process digitalisation (e.g. visualization methods along the horizontal and vertical supply chain). The implementation of digital technologies may affect different issues of core business processes such as production processes, product development, organizational structures and supply chain management (Sjödin et al. 2018). To ensure the improvement of such processes, it is of high interest to measure the impact of digitalisation activities. Therefore, a company must identify the relevant performance indicators while implementing new technologies or sustainable programs and compare the results to the desired performance change.

Hence, one objective of our research is to present novel holistic insights of conducted digitalization efforts within a large-scale European innovation project in the European Electronic Components and Systems (ECS) domain. The focus is put on impact assessment of developed and (partially) implemented digital technologies. We intend to measure the dynamic interaction among the various dimensions i.e. the effect of digital transformation projects on production workers, organizations, fabs, internal supply chains, and the society (Felsberger and Reiner, 2018). Another objective of our paper is to make the organizational, economic and social impacts of digital advances within the ECS industry more visible and thus better explainable to decision makers, using the Triple Bottom Line (TBL) approach (Elkington, 1998). Impact evaluation is amongst others crucial to justify future investments into Industry 4.0 under consideration of management implications as well as research and development activities. Our research contributes to improving performance evaluation of smart factory technologies and theory development. Furthermore, it closes the gap in the scientific literature concerning the properness and comprehensiveness in evaluating the impact of digital technologies. Our objectives lead to the following research question: *What are the main impacts and benefits of digitalized operations with respect to sustainable value creation in selected areas of the European ECS industry?*

This paper is structured as follows: First, we review the existing literature that relates to the core of our paper . We then focus on introducing into our methodology, case study research, including case descriptions and research structure. Finally, we present the comprehensive results of our multiple-case study on the achieved impacts of conducted digitalization projects, give a conclusion and an outlook.

Related work

Manufacturing performance is a much-discussed topic in operations management research for which there is no uniform definition, model or measurement system. Past research has for example focused on manufacturing metrics based on quality and output

(Leachman et al., 2005), the overall equipment effectiveness (OEE) measure (Jonsson, 1999, Schwab et al. 2017), or mapped the area of operational decisions during a growth period to the three performance dimensions of the Triple Bottom Line (TBL), economic, social, and environmental. However, an explicit focus on assessing the impact of digitalisation projects on manufacturing performance has not received sufficient attention. Hence, approaches must be identified to make the impact of digitalisation initiatives – i.e. the impact of current ICT phenomena – visible and measurable. However, digitalisation is changing the landscape in manufacturing as enterprises begin to use internet of things to connect manufacturing assets, big data analytics to monitor plants, and artificial intelligence to support decision making processes. Therefore, manufacturing operations has become smarter by slowly adopting ICT approaches and technologies (Kusiak, 2017) and merging them with production and process technologies on the threshold of a fourth industrial revolution affecting different industries. Electronics components and systems (ECS) are widely understood as enablers for multi-layered innovation in various industries, from automotive to healthcare. According to the European Industrial Strategic Roadmap, the European Components and Systems (ECS) industry employs about 250.000 people, while more than 800.000 people work on the integration of components to systems and further 2.500.000 are employed in the components value chain. Therefore, research into how the ECS industry itself will benefit from digitalisation is of great importance.

Methodology

Instrument development and case selection

To answer the underlying research question of our paper, we apply a multiple-case study approach, including four different industrial cases of digitalization in the production environments of European ECS companies. All four cases outline different digital solution approaches – related to topics including cyber-security for legacy systems, agile manufacturing maintenance, or machine learning for improved decision-making. From a methodological point of view, case study research is an appropriate technique for describing a phenomenon within its real-life context – here the digitalization of manufacturing environments (Yin, 2003, Voss et al., 2002, McCutcheon and Meredith, 1993). Our study uses primary data from expert interviews and assessments with people in charge of digitalization projects in the case companies. We assess the current situations and challenges leading to digital transformation projects, the implementation of digital technologies to solve these challenges, and the achieved impacts. A qualitative content analysis is applied to gain valuable information and investigate the impacts of digitalization efforts in the ECS domain referring to our four individual cases. The approach enables us to retain the holistic and meaningful characteristics of real-life events such as individual life cycles, small group behavior, organizational and managerial processes, international relations, and the maturation of industries (Yin, 2009). To structure our multiple-case study research, we followed the concept by Stuart et al. (2002). Therefore, we used their five-stage approach. The first stage of this research model handles the development of the research questions, followed by the second stage “instrument development” which deals with the selection of representative cases including their description and the development of the research instrument, that serves as a written guide to conduct further investigation. The third stage is concerned with the collection of required data by means of open, unstructured, semi-structured and structured expert interviews, focus-group discussions, analysis of documents and questionnaires.

The data collected is examined in the next step by using qualitative content analysis for extracting relevant information (e.g. deducing categories). Finally, our investigation is concluded with the documentation and dissemination of the results and the subsequent testing of internal, external validity, and reliability (Stuart et al., 2002).

Introducing the cases

In this subsection, we outline the characteristics and background information of the case study sample (Table 1). The presented case description is based on the original documentation of four selected cases. The industrial partners of the European project SemI40 (semiconductor manufacturer, (Case A) component supplier of ECS industry (Case B), PCB assembler (Case C) and semiconductor manufacturer (Case D)) are responsible for the case description. Here, we introduce each case by describing the industrial challenge and the envisaged solution. Afterwards, we set the focus on the case analyses to explore the expected impact behind the single cases.

Table 1. Case descriptions

Case	*Description*
A	Secure production networks are a central prerequisite for implementing Industry 4.0 applications in real production environments. In today's production plants, many different machines communicate intensively over the network. Compared to an office IT network, the communication behavior of nodes in a Machine-to-Machine (M2M) communication network is generally relatively stable. A human intervention (from outside) in this communication violates this stability. The use of Intrusion Detection Systems (IDS) is a way to detect such deviations from normal behavior in the production network. However, classical IDSs require the definition of rules for the execution of applications on a host machine or the communication behavior in the network. These rules are manually defined by experts based on their understanding about the known signatures of the running applications on a host or the traffic exchanged over the network. If one of these rules is violated, an alarm is triggered, and analysis can be started to identify the possible causes. For large systems such as production networks, however, such rule-based IDSs are very complex to configure and maintain, requiring extensive domain knowledge to map the entire production network and its acceptable behavior and to keep these rules or signatures updated.
B	The production of sputtering targets is a powder metallurgical process that involves many critical production steps and tight requirements. The sputtering targets are treated in production lots of up to 10 pieces. No or only a few process parameters are recorded along the supply chain, but the combination of this data with the production lots was either impossible or only possible by hand. The main production step - hot deformation - was planned by hand and the heating times are determined on the basis assumptions. The challenge is to integrate single piece traceability into the entire production chain and to optimize and more accurately design the main production process step. Single piece tracking is achieved by a unified unit number, which will be implemented in the ERP/MES and on each single material ingot. With new tailored process models and advanced model-based control tools, the production step deformation will be controlled more efficiently and accurately. In the final production steps, single piece production is installed together with almost paperless production.
C	Embedded components directly in the printed circuit board (PCB) increase the complexity of PCB production, especially the process steps copper plating and photo (etching) process. The general trend in the electronics industry is towards smaller, more compact and more powerful devices. To meet the new requirements, the case company developed and patented its technology several years ago. The aim was to integrate the active and passive components attached to the outside of printed circuit boards inside the boards in order to reduce the overall size and protect the components. The current quality control of the copper plate thickness is performed after each individual copper process. The complete production process for a lot size of 30 working panels can be traced on the collected data based on manual operator input into Excel documents. These Excel documents are not standardized for all users and process steps and are stored on local storage devices.
D	In addition to cost and time, effective quality assurance is one of the most relevant parameters for efficient manufacturing in the semiconductor industry. Up to now, the detection and classification of quality issues has mostly been carried out by skilled employees. Over the last years, the increasing level of fab automation requires enhanced and fully automated quality controlling methods with extensive measuring instruments and tools. The implementation of automatic control serves to overcome the limits of the human operator’s performance to detect defects. A central IT platform must capture and process quality data from a highly automated semiconductor manufacturing process in real time. Based on this data, especially trained employees will only have to inspect wafers that are marked as defective.

Data gathering

In total 22 different digitalisation projects were carried out under the umbrella of this large-scale project and have been fully documented. They describe different digital solution approaches related to the topics cyber-security for legacy systems, agile manufacturing maintenance, machine learning for improved decision-making and fab digitalization and virtualization. In our study, we selected four of these 22 specific cases that represent all four areas and have achieved and documented the most meaningful

results. At the suggestion of case study researchers such as Senger and Österle (2002), who have requirements from business engineering for a generic case structure, we have developed a template to achieve a structured description of the digitalisation cases in a first step. This template was completed by all industrial case owners supported by us to ensure a high-quality case documentation. As a result, all 22 case studies were documented in a unified structure: describing current situation and challenge to be solved, digital solution approach to be implemented, the target situation to be achieved, and the expected impact to be generated in a first step within the first 18 months of the project. In the last six months of the three-year innovation project, an impact assessment was carried out by the case owners using a template developed by us, which was also the basis for the analysis in this paper. This impact assessment template consisted of two separate sections: In the first section, all case owners had to update the status of their cases with respect to the degree of implementation, while in the second section, case owners had to answer specific questions about the concrete impacts of the implemented digital solution. However, the core of the impact assessment form consists of a broad listing of KPIs that help case owners evaluate the technical impact in the three dimensions of the TBL-model. The KPIs they had to consider included, *IT/information security in manufacturing environment, production flexibility, transparency, traceability, availability, reliability, dependability, data and information quality, process quality, product quality, expandability, OEE, material resource efficiency, workforce satisfaction, satisfaction of the internal customer, satisfaction of the external customer, innovation and problem-solving skills, knowledge development and gain, operating costs, process lead time, productivity, and energy consumptio*n. The effect of the digitalisation project on each impact aspect had to be quantified by the case owner on a 5-point scale. In addition, the case owner had to describe in the prose how an impact was achieved and what the strengths and weaknesses as well and what the threats and weaknesses of this impact were. All completed impact assessment forms were reviewed by us to high quality documentation, followed by one requested for content elaboration by case owners.

Data analysis

This section gives an overview on how our results have been gained. We apply the method of qualitative content analysis for extracting relevant information e.g. impact on defined performance measures, from the impact self-assessments and documented case descriptions. Data was analyzed in the text coding program NVIVO 12, and we conducted a cross-case analysis (Seawright and Gerring, 2008). Finally, our investigation is concluded with the documentation and dissemination of the results and the subsequent testing of internal validity, external validity and reliability (Stuart et al., 2002). To increase the rigor of the content analysis process, we asked the case owners to check the results of the filtered descriptions for incorrect formulations and wrong interpretation of their formulations. We developed a case analysis table in which the four cases are coded and filtered. The results were divided into three categories: The first category describes the economic impact of the process, method, application or tool. The second category deals with the social dimension and its impact on workforce satisfaction and/or problem-solving skills. The third category illustrates the impact of the individual cases on environmental performance indicators such as energy efficiency and material efficiency (Felsberger and Reiner, 2018). The last step of the analysis comprises the documentation of the achieved impact. We adhered to the TBL evaluation framework and evaluated the individual cases according to their impact on the most relevant KPIs mentioned by the case owners.

Findings

Already an informal analysis of the cases before the content analysis has shown the disruptive impact of digitalization on manufacturing environments in the ECS industry. In addition, an overview of different impacts is developed from the results of the individual impact assessments. Selected findings show that digitalization efforts in manufacturing environments positively affect the performance of production processes, sustainable value chain management and overall supply chain productivity. In this regard, digitalized operations offer the potentials to decrease defects, reduce costs and increase the overall company's sustainability. Our results are partially congruent with the findings of Ron (1998), as flexibility, material handling and life cycle performance are important aspects for assessing a company's sustainability performance. We make the current challenges of the European ECS industry more visible, discuss the consequent digitalization projects addressing these challenges, and discuss the achieved impacts.

Assessed case-specific impacts and benefits of digitalized operations

Case A – Semiconductor manufacturer

The benefits of exploiting an anomaly detection system in an Industry 4.0 production network is threefold: First, it helps to detect any suspicious network traffic that can be caused either by a legitimate user (due to misuse) or by a malicious attacker (e.g., due to attempted sabotage, intellectual property theft, or product quality degradation). Unlike commercial solutions, which rely on a priori known signatures of knows threats, network anomaly detection systems rely on machine learning or statistical algorithms to learn regular communication patterns exchanged between different equipment and machines. Any significant deviation from regular patterns (normal behaviour) is flagged as an anomaly. An interesting property of these systems is that they are able to detect any new attack even if their signatures do not exist in the data base (i.e., detecting zero-day attacks). Second, detecting abnormal behaviour at an early stage can allow the security department to take proper countermeasures to neutralise potential attacks or minimise their risk, which can have a positive impact on systems availability, reliability and dependability. Third, detecting and preventing any malicious network activity can ensure that the production processes cannot be touched by an attacker or a competitor to compromise the product quality. It is also worth mentioning that the collected data for this case from a real production network and the designed algorithms for anomaly detection can be exploited as a baseline for any project related to cybersecurity in Industry 4.0 CPPSs.

Case B – Supplier of the ECS industry

First, there has been an increase in quality improvement: focusing on a zero-defect strategy requires the operator's cooperation and a corresponding focus on quality. For this purpose, the optimization algorithm should give the operator recommendations as to (1) how, (2) when and (3) where products are to be manufactured. There was also a significant increase of energy efficiency: Since the heating of the ovens is the main energy factor, the optimal use of heated ovens and the potential decommissioning of unused ovens contribute greatly to energy efficiency. The optimization of oven usage has been added as a goal in the optimization algorithm in order to avoid the heating of material without subsequent rolling. Furthermore, the throughput was increased by 3-5%. Besides, the implemented traceability of single pieces along the whole internal supply chain

increased data quality, speed of complaint handling and product and process development. The implementation of MES solution in the first production step of powder pressing and sintering further improved the interface between supply chain and shop floor and thus the speed of order handling. Finally, paperless production in the final production step, the mechanical processing of sputtering targets, reduced costs of operating supplies (paper and palettes) and reduced the likelihood of confusion in order handling.

Case C – PCB assembler

The successful completion of the digital traceability project will allow the case company to fully trace produced cards and embedded components. This will improve product quality, customer satisfaction and employee satisfaction, by reducing the time spent on analysis and searching for errors. In short, the traceability project is running at the case company as planned, with a larger scope and a longer schedule than expected in the beginning. The experience gained so far greatly supports the future implementation of machine learning for traceability and quality improvement as a following project. The target is to have full unit traceability, which is also a customer requirement. The exact technical solution cannot be described due to confidentiality reasons, but it will allow the case company to ensure knowledge about which PCB was produced when, on which machine, by whom and with what components from which supplier and lot.

Case D – Semiconductor manufacturer

Due to the camera system implemented, no human intervention is required anymore to fully track all data and monitor production processes. Better and more reliable KPIs now enable more effective decisions, gaining more control of the production processes, increasing flexibility, reducing costs and increasing quality. It is also possible to optimize maintenance scheduling by detecting machine weaknesses at an early stage. The process is continuously monitored while the system is in operation. The process quality is more stable by increased reliability regarding standardized errors. The new process provides the permanent quality of process controlling and product quality control. The scrap rate is drastically reduced. The camera system provides 100% quality control through algorithms. Therefore, quality inspection is no longer subject to the errors made by human operators, and a consistent quality level is ensured.

Cross-case analysis: Aggregating case-specific impacts on performance dimensions

The qualitative analysis of the collected case data led to the identification of different impacts and improvements identified by the case partners during the impact self-assessment. Based on the impact rating (scale from no impact “1” to very high impact “5”) of the case owners, we identified four main KPI categories with the highest ranking at a rate of 4-5 on the scale (very high impact). These KPIs are listed in the table below: the impacts and increases in the *level of automation*, the impact on *process quality* such as quality assurance processes that lead to higher productivity and reduction of operating costs, the improvement of *traceability* and, finally, most cases ensure an increased *transparency* within the system or fab.

Table 2. Overview about the impact on performance dimensions

	Case A	*Case B*	*Case C*	*Case D*
Level of Automation	• Proposed detection system does not require any manual update of attack signatures. • It learns the normal traffic behavior by observing the benign traffic crossing the network.	• Case increase traceability along the supply chain and set up systems/models help the operator with decision making. • Give optimized recommendations and model-based process times.	• Interconnection of two separate process steps on a data exchange level provides the enabling baseline for further automation of processes.	• Solution will increase the automation for the manual control from 0 to 100 % .
Process quality	• Adopting an IDS can help detect any attack to manipulate the production processes. • By analyzing the network traffic commanding physical processes, rather than relying only on checking the HMI system.	• Temperature and format based inline reheating time calculations will improve the quality of the sputtering targets. • Especially the microstructure which plays a crucial role for material performance at the customer.	• Process quality is improved by the possibility to fully trace back all steps, recipes and settings. • Knowledge was generated through testing within the project. • Gained knowledge is actively used and already led to improved process steps. • Standardized processes • Easier knowledge transfer • PQEs have time to further improve process.	• Process is continuously monitored as long as the system is up and running. • Process quality is more stable due to an increase of reliability related to standardized errors. • Camera system provides 100% quality control through algorithms • Quality inspection is no longer at risk by mistakes by human operators. • Stable quality level is ensured • Several sub use cases were implemented.
Traceability	• Early detection of an anomalous network traffic can support to trace any changes in processes or harm induced by cyberattacks.	• Each product can be traced through single piece tracking along the production chain, ERP and on the shop floor by implementing marking via engraving machines.	• Enable full unit traceability this will in turn enable further opportunities to enhance processes and quicker pinpoint and tackle problems. • Traceability allows full accountability in production. • Data is no longer transferred manually (transfer happens directly from one equipment to a data base and the MES). • No human interaction or transfer required, no change of data, 100% data integrity. • High knowledge about used products and process steps. • Easy identification of faulty parts. • Complaint handling. • Fulfilment of customer wishes. • Improved process data collection.	• All data can be tracked using the new solution. • Data is automatically stored in the database (no more lack of data traceability).
Transparency	• Implementing an IDS can help improve the transparency of industrial communication systems by timely detecting any irregularity that may happen due to cyberattacks or misuses.	• Every employee has access to the relevant context he/she needs for the work through installing SD4 terminals, part of the MES, directly on the shop floor. • Detailed planning boards are available on every workplace via the SD4 terminals. • Each production group has a screen where workers can see actual planning status and availability of the equipment.	• Full unit traceability will allow perfect accountability for all parts and increase transparency of all production processes internally as well as externally. • Constant monitoring of the processes by collecting data in a timely manner and higher sample sizes. • Its correlation to product quality data will logically lead to more stable processes and higher product yields.	• System is very transparent (all data available on server systems). • Operator has direct access and visibility to all relevant data.

Cross-case analysis: Impact on TBL dimensions

Economic dimension

Most of the cases deal with production process improvements. As a result, we have identified some overlaps in the economic impact when comparing cases. When assessing the operational level of a case organization, several impacts of individual process improvements are evident. Not only internal but also external improvements can occur. For example, the IDS of Case A will detect any suspicious activity within the information network supporting the production environment, caused either by an insider (misuse) or by an outsider (attacker). This will help make Industry 4.0's production environments more resilient to potential cybersecurity attacks. Employing a network anomaly detection system can prevent any cyberattack to compromise production quality. Furthermore, increasing traceability along the supply chain and establishing systems/models that help the operator in decision making by providing optimized recommendations and model-based process times are fundamental impacts of the proposed solutions. Automated early and precise detection of faulty items lead to a more reliable inspection rate and thus to a reduction in variability within control processes. This allows operating departments to increase throughput. This also has an impact on costs. A company can reduce operating and production costs by improving overall product and process quality (Felsberger and Reiner, 2018).

Social dimension

Digitalisation is leading to an increase in know-how and skills. The implementation of further visualization tools and the increase of transparency and traceability of products and production systems leads to improved usability and acceptance among the employees. An increase in knowledge of individuals leads to a higher qualification and a better understanding, thus raising employee satisfaction and the general knowledge level in the departments. The better qualified the employees are, the better a product can be delivered on time. The digitalization efforts lead to higher process knowledge of employees. A fundamental insight is also the fear of losing one's job – a general fear of "Industry 4.0" and related topics is noticeable in the workforce. The case companies expect significant knowledge development and gain, especially for specific process experts. The developed digital solutions are very innovative, using different hardware and software components. Therefore, employees develop improved problem-solving and innovation skills. Companies benefit from these developments. In a highly automated fab, no human resources are available for non-value adding jobs e.g. manual quality inspection. Quality inspection is a very monotonous and exhausting task, which is rationalized in the future factory. The operator can therefore be used for performing much more important tasks, which also increases workforce satisfaction (Felsberger and Reiner 2018).

Environmental dimension

The optimization of production processes makes it possible to shut down machines based on the capacity requirement forecast and thus save energy costs. For example, case B deals with the reduction of heating times, based on online temperature measurements, leading to a reduced energy consumption reflected in less electric energy and pure hydrogen. Furthermore, high potentials can be identified to reduce electrical power. Production costs can be reduced by using more energy-efficient manufacturing systems. This leads to price advantages over competitors and strengthens the competitiveness of European ECS companies. Modern production equipment and optimally operated machines will emit fewer pollutants and use limited resources more sparingly in order to protect the environment. The very high impact of energy and resource savings could be demonstrated by an excellent energy data management concept. The improved data quality and the link between the different process steps will lead to fewer sample parts being produced, which slightly reduces the usage of material leading into an increase in resource and material efficiency. With improved process stability, product quality will also improve, further resulting in a reduced scrap rate. Europe's resource dependency on other countries is a problem regarding the competitive advantage for the future development (Marre et al., 2015; Felsberger and Reiner 2018).

Conclusion and outlook

The results of our multiple-case study contribute to the evaluation of process improvement through the implementation of digital technologies. Our investigation underlines the concrete benefits of digitalization efforts in the European ECS industry. The impact assessment aims to rigorously analyze the added value gained through the implemented technologies in the case companies. In order to analyze the impact of technology adoption on various levels in a company, the TBL-model is used, which differentiates between the social, economic and environmental dimensions. The results of our study support industrial decision makers in assessing the relevance to invest into digitalization. Consequently, this may lead to a further increase in operational

performance and competitiveness of manufacturing companies in Europe. In particular, we wanted to show the influence of digitalisation efforts and new technological solutions (algorithms/sensors) in the production sector (cases A-D). Furthermore, our insights regarding the effect of learning from data over time offer decisive potentials and opportunities for future developments related to Industry 4.0 projects. In a follow-up paper, we will also include impact assessment data from the remaining cases.

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Is 3D printing a myth and hype to achieve sustainability? An evidence from Chinese Manufacturing firms

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Abstract

3D Printing (3DP) is a new technology with the ability to provide companies or industries with an additional competitive edge. We aim to explore how 3DP complement conventional manufacturing process by improve sustainability in Chinese manufacturing firms under the lens of actor network theory. Through ten semi structured interviews with different manufacturing enterprises from different industry who has adopted 3DP, we discovered that 3DP is undeniably perceived as a tool to facilitate design to prototyping in manufacturing process, however, the sustainability performance of this adopting 3DP is limited by the technology own's bottleneck.

Keywords: 3DP, sustainability, Chinese manufacturing firms

Introduction

3D Printing (hereinafter 3DP), also known as additive manufacturing or rapid prototyping with first appearance in the 1980s, is a disruptive and innovative technology with the ability to provide companies or industries with an additional edge in the current era (Phaal et al., 2011; Chan et al., 2018). The 3DP industry is expected to rise to $13 billion by 2019 and $49 billion by 2025 globally (Wohler Report, 2018). Currently, 60% of this skyrocketing growth of 3DP applications has penetrated the United States' manufacturing processes (Faludi, 2015). It is a revolutionary technology in which an abstract digital computer-aided design (CAD) design file can be transformed into physical object as long as it is paired with a 3D printer. This trend of 3DP will reconfigure enterprise' existing supply chain, because it breaks existing performance trade-offs in two fundamental ways. First, 3DP reduces the capital required to achieve economies of scale. It has lowered entry barrier to manufacturing. Second, it increases flexibility and reduces the capital required to achieve scope. Economies of scope decide what and how a product can be manufacture. Flexibility of 3DP is able to offer enterprises with more customized product with lower unit cost than conventional manufacturing technology. The leverage between *capital and scale* has the potential to impact how supply chain is re-configured; while the leverage between capital and scope has impact on how a product is design or manufacture. And both reconfigurations will influence an enterprise on the decision of which level of deployment of 3DP in their business model.

This simplification of the supply chain process benefits the quantification of material flow throughout the supply chain. Under this observable phenomenon, we applied the lens of Actor Network Theory (Latour, 1996) to explain the study. The core concept of ANT presenting an idea of how human (actors) and non-human elements (actants) are linked, interact and associated with different elements to generate a socially constructed phenomenon. Actor is nothing more than whatever it modifies, transform or creates (Latour, 1999). Base on this concept, we explore the operation of 3DP involves a series of interactions between human and technology. In order to stay focus in the study, we narrowed our lens to study how does 3DP improve manufacturing process and achieve sustainability in Chinese manufacturing firms.

The rest of the paper is organised as follows. Section 2 reviews related studies. Section 3 presents the research method employed in this study, including the data collection and analysis procedures. Section 4 summarises and discusses the results from the interviews and Section 5 concludes this paper.

Literature Review

The complement of 3DP in current traditional supply chain

Supply chain, with term's first use in 1982, indicate it's meaning of a linear process. The development of linear manufacturing method under the boost of globalized supply chain, third world country's labor inputs, advance manufacturing technologies has grown the global GDP for 20 times in last decade. However, the characteristic of linear manufacturing method which is one-way track that is without planning in "after-sale" phase such as reuse, recycle (Ashby *et al.*, 2012) has led to enormous wastage that harm the economic, societal and environment. In this "take-make-dispose" traditional manufacturing method, approximately 80% of the materials resources are ended up in landfill, wastage, incinerator, when the economic value is not being fully exploit. For instance, the input of powder-like materials that pass through the printer's extruder is equal to the final product, while pre-stock materials meet almost exactly the company's customer demand. In other words, the quantification of materials is accurately reflecting in the beginning of production stage base on the design of the product. Hence, the 3D printable design file at the forefront of 3DP ecosystem is critical, in the sense that it possess direct causal effect to the supply chain performance.

On the other hand, the advocate of Industrial 4.0 in Germany, and Made in China 2015 has indicated the rise of governmental level to emphasize in adoption and implementation of advance manufacturing technologies such as 3D Printing in manufacturing industry to improve the linkage of value stakeholder through supply chain with the objective to achieve sustainability.

From Design to Manufacturing in ANT Lens

The core concept of ANT theory is *translations* which is the processes that generates consequential effects, i.e. formation of actor network, such as devices, agents, institutions organisation (Law and Hassard 1992). Translation of actors and actants always follow by transformation that making two elements equivalents. For example, design stage is the forefront of the product manufacturing cycle, based on ANT, besides produce an object with particular function, design could include specific meaning and social implication through this objects and technology.

The interaction of 3DP in the ecosystem is seen as a patterned network consisting of heterogeneous materials with multiple actor and actants. The process of penetration through availability of 3D printable design file are formation of human agency (designer) to non-human objects (3DP technology). Base on ANT, beyond creating objects with particular function,

design adds specific meaning and social implication to objects (Harman, 2015). In the process of constructing non-human actors (3DP ecosystem), designers hold an ethical responsibility for the impacts of their work, as the design work will interact with other elements and evolve to new network. In particular, it is argued that 3DP ecosystem in China can be understood as an outcome of negotiations among diverse actors when each attempt to extend the network.

3DP and Sustainability

Extant literature on how 3DP technology leads to sustainability remains at the conceptual stage from a management perspective. 3DP, a data-driven technology, possesses fast visualisation that enables the realisation of complex freeform products (Gebler et al. 2014) and contributes to the transition of current economic structure to a knowledge-based economy, which has been described by Anderson (2013) as a 'new industrial revolution'. However, it is not a type of technology that is applicable to all industries; hence, the adoption of 3DP in different industries will lead to various types of business models. A few researchers have studied the application of 3DP in achieving a circular economy (Despeisse et al. 2017) and closed-loop supply chain and identified that 3DP is promising for sustainability and circular economy. Orientation towards sustainability and 3DP operating skills limit firms' realisation of the ability of new technology to achieve the merit of sustainability.

3DP with the fancy characteristic of fast visualisation and customisation, customer dominance at product development stage, decentralised supply chain that promise for a more agile(Mohr and Khan, 2015), lean(Ghobadian et.al, 2018), responsiveness(Laolume et.al, 2016), cost effectiveness (Choonara et.al, 2016) that indicate the sustainability performance. The upmost characteristic we discussed in the study is the offering of 3D printable design that work as foremost of 3DP value chain, is an important penetration actor that promise for innovation activities in the manufacturing process, as it holds an ethical responsibility for the impacts of work because it will continue evolve with other new heterogeneous network and get new identity subscribe to it. This is the research gaps we identified after a thorough literature review in 3DP application and sustainability context. 3DP technology made local enterprises easier access to achieve product and process innovation with sustainability implication, but the low entry barrier of technology can also be seen as a two edge sword, it can be considered as a friendly technology to facilitate knowledge creation or a loss intellectual property monitoring system where right of creator are bypass and being used abusively.

Research Design and Method

Based on the findings of the literature review, one research question is formulated: How does 3DP in manufacturing process improve sustainability in Chinese manufacturing firms. Because these questions are open-ended in nature and no prior studies have proposed a research model or theory to address them, it is necessary to explore the responses to these questions. In order to fully capture insights in addressing the above research question in an explanatory manner, an empirical qualitative approach is adopted. We conducted 10 semi-structured interviews with companies from different industries that have already established 3DP technology in their business model.

The overall interview process and interview data analysis are described as below. First of all, we identified and contacted local 3DP enterprises and asked the counterpart to assign representatives whom are familiar with the operation of business. The interviewees of this study are either founder, CEO or engineers. All interviews were conducted in Mandarin, and the recorded interviews were transcribed. The transcripts were then translated, and the authors cross checked the interview data to make sure original meaning of the English translations are accordance with Mandarin interviews. The interview data are extracted following the standard content analysis procedures based on seven themes, which are 3DP application process,

economic, society, environment, sustainability to reflect the research question. The question includes of the origin of the design files, how does 3DP complement current business model, the perception of how 3DP improve firm's environment, economic and societal performance and so on. The findings are summarised in Findings and Discussion.

Findings and Discussions

According to Williams and Kent (1993), the authors perceived that technology is "a design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome". The outcome of interviews reveals that 3DP is an important driver to innovation that facilitate process efficiency throughout the supply chain to achieve sustainability. However, we argued that the application of 3DP itself does not constitute to improvement in sustainability. As suggested by actor network theory, where actor (3D printable design file) is nothing more than whatever it modifies, transforms or creates, the source of 3D printable design file which are origin from open source from the internet is difficulty to guarantee the genuine of the heterogeneity network. As open source allows anyone to modify, to remove an actor from a network as they wish, by constant injecting or creates multiple untraceable actor to the network, it is not a new network that each contributor should carry the responsibility on the work. Hence, the responsibility that hold to the masterpiece itself become vague.

In the analysis of 3DP impacts in economic dimension, some interviewees suggest that the fast visualization that 3DP offers shorten the lead time of product design and prototyping process. For instance, a spare part company manager expressed that spare part that required huge dedication as the structure of the spare part is very complex. By implementing 3DP in their production, it helps the firms to save human resources costs that initially assigned to designer, as the computer-aid-design tools will improve the task deliverable time and hereby shorten the overall work time allocate to the design. On the other hand, our findings demonstrate that 3DP is a novel technology to the healthcare industry, where 3D-printed prostheses are customisable which allow users, especially children, with fragile bone structure to easily upgrade or replace the prosthetics according to age and bone development. With the combination from 3D scanner, the 3D-printed prosthetic permits the patients to obtain 3D-printed prosthetic devices with higher precision and greater comfort.

Lastly, it is remaining controversial if 3DP is an environment friendly tool or even harmful to the environment (Hsiao, 2013). Although a few interviewees support that the concept of 3DP which transform materials-powder to a final product which lead to shorter journey of logistics that eventually benefits the environment with lower carbon footprint. However, the bottleneck where in current stage, 3D printers accepts solely certain type of materials. Hence, if a production of a product required formation of different type of materials, it does not have significant difference compare with conventional manufacturing process, besides the fancy of one-off printing 3DP could offer. Meanwhile, we should not underestimate the impact of emission of artificial powder materials to the environment.

Conclusion

Indeed, the development of 3DP, in which all items' input and output waste are calculated through back-flow product-processing decision support, is critical for the manufacturing sector because the post-sale stage is not visible, and the waste impact is currently unquantifiable at current stage. But, regardless the hype of how 3DP could recast the current supply chain and achieve sustainability, what remain priority is manufacturers should still hold a conservative attitude on fully replace of technologies on traditional manufacturing process, especially at high production volumes (Petrick et.al, 2013). 3DP is undeniably perceived as a tool to facilitate design to prototyping process, the firms which is failed to reap the benefit at this stage

finds it is difficult to realise economic benefit of 3DP; Vice versa, our investigation show that firms will continue to achieve environmental and societal sustainability after they reap economic benefit at design to prototyping stage.

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Grocery retail and food security in urban neighbourhoods: a case study of South Africa

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Abstract

Food security is a complex issue, encompassing both societal and household level factors, but has not been deeply researched in the context of urban areas. This study explores grocery shopping dynamics of poor urban residents and the effect of those dynamics on food security. This study was conducted as a single case study comprising of 49 semi-structured interviews with residents of a South African township. The findings highlight the importance of micro retailers and issues with food quality. This study presents opportunities for further interdisciplinary work to investigate purchasing and consumption behaviour towards certain staple foods that make up a majority of current diets.

Keywords: Urban neighbourhoods, food security, grocery retail

Introduction

This paper represents the first in a series of empirical investigations into urban poor neighbourhood grocery retail dynamics and how it impacts food security in those areas. It builds on a literature review (Tuomala, 2019), which highlights the interdisciplinary nature of urban food security research and brings forward avenues for empirical research. This paper explores the specific dynamics of poor urban dwellers' grocery shopping habits as well as the importance of micro retailers in urban communities.

The data was gathered in a small urban neighbourhood, referred to as a township, in the Western Cape, South Africa. Semi-structured interviews were conducted with 49 people living in the township, 25 of whom were beneficiaries of an NGO that assists the families of malnourished children with different livelihood programmes and food parcels. All the beneficiaries were unemployed women. The remaining 24 were ordinary residents of the township. The assistance of the NGO was invaluable due to security concerns and their knowledge of the township and its residents.

This paper first presents a short literature review on urban food security and sustainable supply chain management (SSCM), followed by the research design. The findings from the empirical data are presented in the subsequent section, and further divided into subsections on urban food retail, hampers and specials and quantity versus

quality. The conclusions sum up the paper and present the main takeaways and future research avenues.

This paper contributes to a research gap in urban food security and empirical research from a supply chain management and food retail perspective. As urban dwellers are mostly net food buyers, this point of view brings an important angle into the whole food security discourse.

Literature

The FAO (2009) has defined food security to include all people having 'physical, social and economic access to sufficient, safe and nutritious food to maintain a healthy and active life'. As over half the global population resides in cities, the urban population should be prominently featured in food security discourse. However, in an overview of both international and specifically African food security agendas, Crush and Frayne (2011) found little reference to the urban context. While the FAO definition specifically mentions *access* to food in its definition, food security agendas mostly focus on ensuring fundamental availability through increased agricultural production rather than e.g. strengthening distribution networks (Battersby and Crush, 2014). South Africa for example produces enough food to feed all its citizens but has high levels of household food insecurity (Mushunje et al., 2015).

Household food insecurity often stems from financial or spatial constraints (Battersby and Crush, 2014). Financial constraints refer to inadequate entitlements, as brought forward by Sen (1981). According to his essay *Poverty and Famines,* a majority of malnourishment is not caused by insufficient availability but rather a lack of the means to acquire food. Spatial constraints are linked to financial prowess as limited entitlements can force people to live in marginalised neighbourhoods, characterized by e.g. precarious housing structures, inadequate access to basic services and overcrowding (Fox, 2014). As the global urban population continues to grow, so do the poor and informal neighbourhoods in cities. South Africa is already 66% percent urbanised and the global urban population is estimated to reach a similar figure by 2030 (United Nations, 2018).

Marginalised neighbourhoods and urban food insecurity are a result of urban inequality and poverty. A useful theoretical framework for examining these phenomena is urban political ecology (UPE). UPE considers the city to be made up of socio-economic processes, which mediate natural resources and their distribution (Swyngedouw and Heynen, 2003). UPE lends itself well as a lens to specifically examine urban food security for several reasons (Agyeman and McEntee, 2014). The main benefit is that it can analyse the hybrid relationships between physical, social and economic factors that result in the production of the urban environment. Food requires such tools, as it intertwines the physical and the social. Power relations are an example of such factors, as neoliberal market forces ensure food security is not an issue for everyone in a given city. Placing these processes into a physical location functions well in urban food security research, as spatialization is one of the material conditions and affects the relationships that determine who is food insecure and why (Agyeman and McEntee, 2014; Swyngedouw and Heynen, 2003).

Urban inhabitants regardless of social status are net food buyers. Market dependency results in financial capacity limiting choices in terms of where and what to purchase. Supermarkets are often located in wealthier areas, where business is expected to be profitable. In an analysis of supermarkets in Cape Town, Battersby & Peyton (2014) found that there are eight times as many supermarkets in richer areas of town as in the poorer areas, where population density was much higher. The few stores that were easily accessible to poorer consumers, such as those near transport hubs, did not stock a lot of

fresh produce, thereby limiting nutritious options. Consumption of fresh and nutritious food is driven by both supply and demand, but as posited by Weatherspoon et al. (2015), the causality is not always apparent, as can be observed from 'food deserts'. A food desert in an area where fresh and healthy food is unavailable for purchase for residents, due to either spatial or financial restrictions (Myers and Sbicca, 2015). The difficult question is whether these areas form because residents do not demand fresh food or because they would not buy if it were available (Weatherspoon et al., 2015). Underlying these questions are classist and racist connotations as well as power relations relating to decisions on what who eats. The food desert concept is useful here, as it spatializes food insecurity. However, it does not always grasp the complexity of the underlying factors regarding supply and demand (Battersby and Crush, 2014; Weatherspoon et al., 2015).

The complexity of the global food system further exacerbates the notions of power in urban food retail (Tuomala, 2019). Supply chains are becoming increasingly centralised due to global large retailers (GLR) dominating the market (Maertens, Minten, and Swinnen, 2012). GLRs are generally managed in a Western country and therefore the subtleties of different contexts may be bypassed. SSCM literature is widening its focus to better include external stakeholder pressure, diverse contexts and social issues in addition to economic and environmental sustainability (Touboulic and Walker, 2015). Nonetheless, social issues still remain under researched in SSCM as identified by Yawar & Seuring (2017). They specify several social issues that have appeared in SSCM literature, for example, excluding marginalised populations from supply chains. Marginalisation derives from many factors, but in the case of South Africa, poverty and race dominate. Employing a predominately Western and MNC perspective on sustainability ignores the different nuances of e.g. supply chain dynamics in marginalised neighbourhoods in emerging countries (Pagell and Shevchenko, 2009; Touboulic and Ejodame, 2016).

GLRs have been able to penetrate the emerging markets largely due to foreign direct investment (FDI) and liberalization of trade in these countries (Nguyen, Wood, and Wrigley, 2013). However, failing to adapt to local grocery shopping habits and dynamics can lead to business failure, and has done for many chains (e.g. Amine and Tanfous, 2012). The informal sector and micro retailers are a relevant part of grocery shopping in emerging countries and poor urban neighbourhoods (Nandonde and Kuada, 2016). Micro retailers are located within easy reach, provide a social backdrop for purchasing with e.g. credit systems and enable people to purchase food in smaller quantities than formal supermarkets might (Minten, Reardon, and Sutradhar, 2010; Nandonde and Kuada, 2016). Empirical research into the shopping habits of urban poor and informal neighbourhoods is needed to further explore the specific dynamics, and this paper contributes to this research gap.

Research design

The data for this paper was collected in a township located in the Western Cape in South Africa, about an hour outside of Cape Town. The township is small, especially compared to others in the same area, such as Khayelitsha or Mitchell's Plain. This single case study (Ellram, 1996) is the first in a series of research endeavours around this subject. Urban food security is context specific and suffers from a lack of interdisciplinary data (Nguyen et al., 2013). Single case studies are useful, as they provide a starting point for future comparative studies.

The interviewees are divided into two distinct groups: beneficiaries of the NGO and township residents with monthly income. The data was collected in cooperation with an NGO working in the area. The beneficiaries of the NGO are unemployed women, whose

children have been deemed malnourished in an annual check-up the NGO conducts at schools in the township. The remaining 24 residents were people living in the township who have some form of income, through either a salary or entrepreneurial activities. Their ages ranged from 18 to 60+ and out of the 49 total residents interviewed, only three were male. Table 1 summarises the interviewees and the acronyms used in the findings section of the paper.

Table 1 Summary of interviewees

Interviewee group	N	Acronym	Characteristics
Beneficiaries of NGO	25	BEN 1-25	Unemployed women
Residents of township	24	RES 1-24	Living in township with income
Total interviews	**49**		

Most of the beneficiaries were originally from the Eastern Cape (EC) or Zimbabwe. The residents were all South African nationals. Especially for the beneficiaries, being an immigrant poses some additional challenges as they are not eligible for government grants and finding employment can be difficult without the proper documentation, such as refugee status. Many of the Zimbabwean beneficiaries were especially dependant on the NGO and their monthly food parcel for this reason.

The interviews were conducted either at the NGO offices or around the community. Working with the NGO was highly valuable, as moving around the neighbourhood would have been impossible without local knowledge and guidance. Security issues had to be considered carefully, as townships often have high crime rates and it would have been dangerous for an outside researcher to walk unaccompanied around the neighbourhood. Language was another issue. Many of the interviewees spoke Xhosa and very limited English. There was always a translator present if English was a challenge. The interviews were always recorded and transcribed in their entirety and any Xhosa segments were translated later. It would have been difficult for the researcher to approach the residents, asking for interviews regardless of whether or not they spoke English, so this was always done by the NGO staff. A lot of the residents interviewed were chance encounters on the streets, which adds diversity to the interviews. The township was a challenging backdrop for an outside researcher to gather data in, not just because of language issues but also due to cultural differences and the racial tensions in South Africa. While interviews are one of the most common ways to gather qualitative data, it is important to reflect upon the interview as a complex social encounter with biases and preconceptions on both sides (Alvesson, 2003).

The interviews were conducted over a period of two months. Questions were arranged in a semi-structured manner, with basic information about interviewees asked first, followed by more specific questions about groceries. Basic information included the name and occupation of the interviewee, whether their household depended on the grants or if there was a salary involved, and how much of whatever income they had was spent on food. The more specific questions about grocery shopping habits asked whether a majority of the household shopping was done in supermarkets or small tuck shops in the community, locally referred to as *spaza* shops, how often and what kind of things were bought. Meat and vegetables were asked about specifically, as fresh food or lack thereof is a good indicator of food security (Weatherspoon et al., 2015). The transcripts of the interviews were coded in Nvivo, using codes such as ‘supermarket’, ‘meat’, ‘hamper’ and ‘transport’.

Findings

Food retail outlets

The grocery market in South Africa is strongly divided among the LSMs (Living Standards Measurement), which is a unique market research tool in the country. Residents of townships are largely found in the lower LSMs (1-4 out of 10). However, in terms of how much of their income is spent on food, there are apparent differences even between the two different groups of township dwellers. This can be observed from Figure 1.

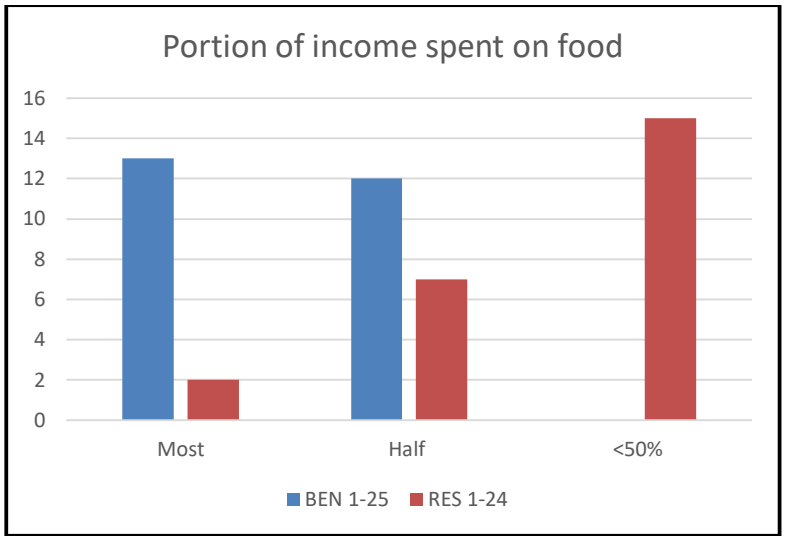

Figure 1 Portion of income spent on food among beneficiaries and township residents

Out of the NGO beneficiaries, i.e. unemployed women who receive government grants or help from family members, all spent at least half of their monthly income on food, with the majority claiming that most of their money goes towards groceries. The residents, who have some form of salary, are more likely to spend less than half of their income on groceries. This difference is not apparent in what people buy and when. Monthly groceries were bought with similar patterns across both groups. Both *spaza* shops and supermarkets are utilized by most respondents, with only a few exceptions who exclusively use one or the other. A common monthly grocery shopping pattern is buying a 'hamper' or a 'combo' of staple products in the *spaza* shop and topping it up with vegetables, meat and canned goods from the supermarket or a specialty shop, such as a butcher. *"What we do from the spaza shops there's this hamper that has 10kg* [packages] *of groceries so we only buy that hamper and then the other small necessities we buy from the supermarket*" (BEN8). The hampers will be discussed in more detail in the next subsection.

Supermarkets are used by a majority of respondents and relied upon for consistency of quality and product availability. "*I prefer shopping in town because they are never short of anything like in spaza shops where you would try buying something and find that they do not have it*" (BEN16). The township itself has a small shopping centre along the main road close to the train station. Many respondents use the small supermarket there as one of the main sources of groceries, but also the larger supermarkets in the nearby town centre were used. A few respondents also said they prefer to use a certain supermarket chain in town because they collect loyalty points and are able to get discounts. For some people, especially those living in the further edge of the township the distance to the local supermarket was an issue. "*The thing is I love to buy and support the spazas around us but the thing is the food that they were selling is not good for us. So I would like to take*

the shops that we are using [like the local supermarket] *to be closer to us because they are selling fresh food*" (RES7). Others were concerned about product availability claiming that some of the brands or products they like to use were unavailable at the local supermarket, and therefore prefer to shop in the bigger stores in town.

Spaza shops were unanimously deemed convenient because of their location in the neighbourhood, within walking distance in even the furthest edges of the township. All respondents were nonetheless also of one mind about the shortcomings of the *spaza* shops, mainly regarding their product quality and hygiene. *Spaza* shops are generally informal and unregulated, private businesses run mostly by immigrants from e.g. Somalia. In fact, respondents would often refer to buying from a *spaza* shop as "*buying from the Somalians*" or "*from the foreign shops*". *Spaza* owning Somalians are mostly refugees, but they are both generally (Battersby, Marshak, and Mngqibisa, 2016) and among the respondents viewed as stealing livelihoods from domestic entrepreneurs. This xenophobic atmosphere was likely the reason why no foreign *spaza* owner was willing to participate in this study. Despite the negative connotations around the foreign shops, people were willing to use them because of their cheap prices.

Keeping the prices down does however affect product quality in the *spaza* shops. Most respondents had experienced purchasing expired or faulty goods but did say that it is usually not a problem to return and exchange them. Respondents said they are very diligent about checking expiry dates and how the product is looking before making the purchasing decision. What makes this slightly challenging is that customers do not choose their own products at *spaza* shops, as they are operated through a window that the customer stands outside of requests the products from the sellers. However, it was said that *spaza* owners do take advantage of e.g. children by short changing them or selling them faulty products on purpose.

Respondents used several different types of outlets to buy meat. The monthly shopping patterns for meat also varied more than the other types of products. In purchasing meat is where the income differences became the most apparent, both in how often it was bought and where. A common pattern among the residents was to buy a 5-10kg bag of chicken and keep it in the fridge to be eaten throughout the month. Many of the beneficiaries of the NGO were unable to do this, as they did not have electricity at their dwelling, so were unable to store perishable food such as meat. If this was the case, they would buy meat in smaller portions at the *spaza* or butcher shop on the day it was to be eaten and cook it immediately.

Questions of meat quality were discussed during the interviews as well. Many residents were able to make the choice of not buying meat at the spaza shops because of the bad quality and hygiene. "*One time I buy a chicken, the one in plastic bags… the chicken was bad smelling with a lot of flies around the pot and I just took it off… I don't buy chicken here anymore*" (RES14). If the beneficiaries wanted to buy meat, many of them felt they had no alternative except to buy at the *spazas* because of price and occasionally distance to the other outlets. The butcher shop was located near the local supermarket, so spatially there was no difference between the supermarket and butcher. The selection was deemed better at the butcher's and it was possible to also buy smaller portions, compared to the supermarket. Meat and other protein sources, such as baked beans, are also bought in cans. Canned fish and corned beef were mentioned by several interviewees and were also included in the food parcel given to the beneficiaries by the NGO. Protein sources are scarce in the staple diet of township dwellers, especially those of lower income who cannot afford it. As RES1 put it, "*we use lots of starch in Africa*".

Hampers and specials

The prevalence of starch in the staple diet is very apparent in the contents of the 'hamper'. A 'hamper' or 'combo' is bought once a month at a fixed price either on payday or the day government grants arrive, depending on the interviewee.

People generally bought two different types of combos, one containing dry goods and cooking oil and one of vegetables. The contents of the dry goods hamper varied slightly between respondents, though not in the amount of starch. A common combination was 10kg or 5kg packages of flour, mealie (corn) meal, sugar and two litres of oil. Some of them had rice as well and occasionally also beans and samp, a coarser version of the mealie meal. They were generally purchased at the *spaza* shops in the community, where people had the chance to price compare between the sellers. When buying packages as large as 10kg, location of the outlet is an important factor, but price is still the deciding one. "*Because the spaza shops have hampers* [they are cheaper]. *The prices are not the same but when you buy in town you find that they also have hampers, but you also have to consider the transport costs*" (BEN6). If there are several shops within a convenient distance, respondents chose the cheapest hamper. They might also buy the hamper in a different shop from month to month, depending on special offers or other price fluctuations. Hampers were usually purchased by households with four or more people. If for example the children from a household were staying with family elsewhere, there was no need for a hamper during that time.

The vegetable hampers included long shelf life vegetables such as 7 kg of potatoes, 3 kg each of onions, carrots and pumpkin. This hamper had to be purchased in a specific supermarket in the nearby town centre, but the transport cost was worth it as the hamper is priced so well. It is only sold for a short period each month, around payday and when the government grants arrive. "*If you go let's say on the 25th, there are people getting paid on the 25th, on the 15th on the 31st. If you go let's say 1 o'clock in the middle of the day, you can't get it because it's finished*" (RES10).

Grocery shopping among the respondents was extremely systematic and diligent. The dates of the grants and payday are important not only among the township residents but also among the retailers, as the vegetable hamper demonstrates. Respondents follow advertisements for specials through pamphlets, window ads and online. A lot of time and effort is put into price comparison, as even a R10 (0,60€) saving is valuable. "*What I normally do, I make sure I have a lot of time when I am doing shopping because I collect all the pamphlets so if I see maybe one of the supermarkets I can save R10 on rice, I go for it.*" (RES18).

Quantity versus quality

In terms of food security, for most interviewees it is not so much the quantity or availability of food that is an issue but access to higher quality food. From the interviews, it is evident that spatial and financial constraints brought forward by Battersby & Crush (2014) are indeed legitimate concerns for the township inhabitants.

Healthy protein sources and sufficient fresh vegetables are beyond the reach of most respondents, and sugar consumption is extremely high. For example, monthly hampers bought at informal traders contain no protein, and usually a large bag of sugar. When asked what the interviewees would like to eat if they could eat anything they wanted, the most common answer was fresh vegetables and meat. For many of the respondents, especially the beneficiaries, the only food source is the hamper and the food parcel received at the NGO. Compared to the hamper, the food parcel is slightly healthier. In addition to similar items such as rice and mealie meal, the food parcel also has oats, beans, canned fish, peanut butter and a soup mix which all contain protein. The parcel has been put together by a dietician, however with respect to donor wishes and product availability.

Many interviewees admitted to health issues such as high blood pressure and weight problems, which are linked to diet. Measuring food security in urban areas is increasingly leaning towards malnourishment and dietary diversity, rather than merely the more traditional undernourishment (Carletto, Zezza, and Banerjee, 2013; McCordic and Frayne, 2018). It is not uncommon to refer to the 'triple burden of malnutrition', which encompasses undernourishment, micronutrient deficiencies and obesity (Gómez et al., 2013). Due to the high starch, low protein diet of most interviewees, the latter two are more relevant in their case. As demonstrated by their wish to eat more vegetables and meat, there is some awareness about the lack of dietary diversity but little opportunity for action.

Battersby and Crush (2014) suggest that the food desert concept be moulded to fit the modern African city perspective. As opposed to the more Western perspective of a food desert where complete lack of outlets is assumed for the definition to be met, in an African context the concept needs to be a lot more fluid. The data collected here supports this notion. There are plenty of outlets, but the entitlements of the inhabitants are lacking as well as the quality of products available. Due to its size and proximity to the nearby town, this township also has good connections to major supermarkets in wealthy areas. Financially many of the respondents were however unable to shop in those outlets, because even the R10 (0,60€) bus fare was a factor in their monthly spending.

The *spaza* shops therefore play a significant role in the urban food security discourse. For the lowest income demographic, their low prices ensure that they are at least able to get something to eat and they purchase perishable items in small quantities, so they do not require storage. The proximity to where people actually live was a pertinent factor for the residents with incomes as well. *Spaza* shops were used at an almost daily basis for small top ups of both groceries such as salt, milk and stock cubes as well as for other necessary items e.g. mobile phone data, paraffin and cigarettes. Because the *spaza* shops are unregulated and informal, there is no official accountability for the quality of the food. It was possible to exchange expired or otherwise faulty goods, but this was done on a case-by-case basis: there is no official stance and *spaza* shop owners can refuse to do so. As Nandonde and Kuada (2016) posit, and is evident from this research, micro retailers are the key to retail in Africa. This has opportunities for both large grocery (and other) chains, as well as private entrepreneurs. Price remains a deciding factor, but quality is also important.

The hampers could potentially provide an avenue to improve the quality of the food people eat. The contents of the hamper, i.e. the starchy staples of the South African diet are very ingrained in the societal psyche of the people that live in townships. There are deep historical roots as to why this is the case; the legacy of apartheid is particularly evident in township issues. Urban planning and the spatial inequalities that derive from it in terms of e.g. supermarket location are still heavily influenced by the segregation enforced by apartheid politics (Haysom, 2015). The food eaten in townships is also a vestige of what life was like for Africans during that time. Starchy staples were all that was available and culturally it remains the standard a quarter of a century later. To elicit change into this mind set would require a cultural overhaul and thus would also require extensive empirical research on hampers and the staples of the South African diet.

Conclusions

Underlying factors to food security in townships are varied and complex. While food is readily available, access to it requires a financial stability not many residents in townships have. The government grant system assists those with the least means, such as single unemployed parents, but the grants are meagre and many, such as immigrants, do not

qualify. Further, issues stemming from larger societal structures, such as the legacy of apartheid, have significant effect on the food security of people living in townships.

Access to more nutritious food is a serious issue in a township setting. Staple foods that make up the majority of a common township dweller's diet are predominately carbohydrates and very little protein or fresh vegetables. Many of the respondents recognize the deficiencies in their diet, but also the restrictions they have on doing something about it. Improving retail in and around townships is an important step in increasing food and nutrition security in these areas. The *spaza* shops and other micro retailers have an important role to play, as their business models fit into the dynamics of townships better than large supermarkets. The hampers of staples that people buy regularly are also an interesting potential avenue for improving nutritional value in diets. In this paper the focus was on township dwellers and their particular grocery dynamics, but empirical data from the retailer side would provide a more holistic picture of the current situation. Unfortunately, data from the spaza shops is unavailable, as the shopkeepers are very hesitant to talk to outsiders about their businesses, likely due to the apprehensive and xenophobic treatment they have received in South Africa.

The main contributions and suggestions for expanding this research are the following:

1. The shopping habits of the township dwellers are systematic and diligent. People spend a lot of time planning and comparing prices through specials and hampers. Making nutritious options more available and visible could improve food and nutritional security.
2. Lack of outlets is not an issue in the township as much as the quality of the produce available and the lack of storage opportunities in people's homes. Vegetables and protein sources are difficult to come by in the township and for some people the larger supermarkets are too far to frequent regularly. Regulation of the *spaza* shops, e.g. requiring them to have proper storage for fresh produce and banning them from selling expired goods is a potential course of action.
3. More interdisciplinary empirical research in contexts such as townships is needed. SCM, development studies and urban geography are examples of disciplines where urban food security research should be prominent, as well as fields such as public health and nutritional studies.

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Stakeholder management in sustainable supply chains: The case of Chile

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Abstract

The purpose of this paper is to analyze how stakeholder can contribute to create more sustainable biomass-to-energy supply chains (SC) in emerging countries by conducting a case study in Chile. The data sample consists of a total of 39 semi-structured interviews with internal and external stakeholders of biomass-to-energy-SCs. The results indicate that stakeholder can pressure a focal firm to adopt sustainable practices to mitigate further reputational losses. Moreover, stakeholder can facilitate the awareness for sustainability frauds in SCs by addressing possible concerns before they start to pressure SC members. Furthermore, collaborations with non-traditional SC stakeholders can help to solve sustainability issue.

Keywords: Supply Chain Management, Stakeholder Management, Sustainability

Purpose

Biomass has significant potential to overcome the shortcomings of fossil fuels and works as a substitute to heat, power as well as chemical production (Peters et al., 2015; Dale et al., 2018). Besides alternative energy sources like nuclear (4.9%), hydro (2.5%) or other renewables, solar PV, wind, solar thermal or geothermal, (2%) (International Energy Agency, 2018), biomass provides with 10% a remarkable contribution to the global energy production. Because of declining stocks of fossil fuels, the worldwide energy production will be shifting more towards renewable energy. Hence, it is to be expected that bioenergy, as a renewable energy, will still play a significant role for the future energy mix (Dale et al., 2018; La Fuente et al., 2017).

While well designed bioenergy systems promise several benefits and solutions (Hong et al., 2016; Dale et al., 2018), different social, environmental and economic issues communicated by stakeholders along the supply chain (SC) can be identified (Gold and Seuring, 2011; Dale et al., 2018). Despite the competing land use between biomass production for food, material and energy, multiple studies point out a crucial role to the (sufficient) supply of biomass (e.g. Lautala et al., 2015; Hong et al., 2016). Moreover, air emissions or noise pollution because of the transportation are problems to be considered

(Sharma et al., 2013). Since those issues affect stakeholders, they put pressure on the companies. For example, the society has forced energy companies to a nuclear phase-out in Germany (Rehner and McCauley, 2016). Another example is that communities and NGOs have protested together against hydropower projects in South America which has led to a redesign of the future energy mix (by the government) (Siegel, 2016). To address these challenges, using a sustainable supply chain management (SSCM) perspective might be fruitful because it takes into account stakeholder sustainability concerns.
Therefore, stakeholder theory as well as SSCM are taken as the theoretical starting points for the research, where a particular contribution has been made by the framework put forward by Gold (2011) for biomass-to-energy SCs.

Taking this as a theoretical starting point, the following research questions can be derived:

- Which stakeholder groups and sustainability issues are evident?
- How can stakeholder management contribute to realize a more sustainable biomass-to-bioenergy supply chain?

Analysing biomass for bioenergy SC in Chile is relevant for two main reasons. First, Chile provides an interesting and diverse setting to analyse stakeholder management in bioenergy SC because of existing challenges (e.g. negative perception of or long transportation distances for biomass) and opportunities (e.g. unused local biomass or job creation). Second, sustainable SC issues are normally discussed against a Western perspective and empirical data, also from South America, is still scarce in the current discourse (Jia et al., 2018).

Literature review

Stakeholder issues in biomass-to-energy SCs

From a risk-based perspective (Gold and Schleper, 2017), external pressures can lead to e.g. reputation losses and sanctions by the government (Seuring and Müller, 2008; Meixell and Luoma, 2015). For avoiding these risks, stakeholder management is of strategic relevance in sustainability management (Hörisch et al., 2014). This also holds for the successful implementation of SSCM for biomass-to-energy (e.g. Hörisch et al., 2014; Dale et al., 2018) which is also concerned with economic, environmental and social issues in order to "[…] *meet stakeholder requirements and improve the profitability, competitiveness, and resilience of the organization"* (Ahi and Searcy, 2013, p.339). While there has been a growing interest in SSCM in the last years (Beske and Seuring, 2014), the literature on stakeholder and SSCM for biomass-to-energy is still scarce. The most comprehensive framework has been proposed by Gold (2011). This framework is selected and modified to narrow the current study because this conceptual framework covers most frequently described stakeholders as well as challenges and benefits of biomass-to-energy-SCs.

Freeman (2010) defines a stakeholder as "*any group or individual who can affect or is affected by the achievement of the organization's objectives*" (2010, p.25). Therefore, governmental bodies, NGOs, associations, residents, consumers or citizens are possible stakeholders for biomass-to-energy SCs (Gold, 2011). To supply the power plant with sufficient biomass, for instance, causes increasing truck traffic, emissions and dust which impact the residents near the streets (Dale et al., 2018). Additionally, biomass power plants can produce odor by chemical reaction and emissions due to combusting biomass. Despite the challenges, biomass-to-energy SC operations produce also local jobs, they invest in the infrastructure or provide an extra income by using / adding a value to unused resources (Dale et al., 2018; Peters et al., 2015)

In contrast to the challenges or benefits, governmental bodies influence directly biomass-for-energy SCs by determining the legal framework. They can impose new regulations, tax the CO2 emissions, offer subsidies for attracting new biomass-projects or provide standards and certification for the bioenergy systems to reduce social or environmental impacts (Gold, 2011; Beske and Seuring, 2014). Moreover, NGOs can launch campaigns against biomass producers when being aware of negative sustainability issues such as erosion or loss of biodiversity due to monoculture.

While most studies cluster stakeholders against generic classes such as NGOs, citizens or employees (Dale et al., 2018; Freeman, 2010), other researchers criticize this because a generic classification results in fuzzy and unclear groups (e.g. Perrault, 2017). For instance, one individual might be part of different classes at the same time by being employed as well as a customer. Furthermore, one issue can be addressed by different stakeholder groups and stakeholder groups can have different concerns regarding a SC. This interconnection of a broad set of stakeholders and issues leads to a complex nexus of stakeholders. To overcome this issue, Mitchell et al. (1997) present one of the most used decision models to focus on the most important stakeholders and their claims by structuring them against the attributes power, legitimacy and urgency. However, Busse et al. (2017) pointed out that even a stakeholder group with initially one attribute (e.g. legitimacy of the issue) can get the support by another stakeholder with enough power to pressure the firm.

Stakeholder management in SSCM

Because the framework of Gold focuses more on the management of internal and external relationships rather than how to make a biomass-for-energy SC more sustainable, we extend its framework with SSCM practices from Beske and Seuring (2014). The set of possible practices are helpful to deal with sustainability issues of stakeholders. However, stakeholders can occupy different roles to contribute to a more sustainable SC. They can (1) put pressure on a focal firm to adopt sustainable practices (e.g. Meixell and Luoma, 2015; Maas et al., 2018) , (2) they can facilitate the awareness of a fraud (e.g. Busse et al., 2017) and (3) they can help to solve the risk (e.g. Beske and Seuring, 2014).

(1) Stakeholders might directly pressure a firm to adopt certain sustainable practices. For instance, when residents or citizens are impacted by emissions from a bioenergy power plant (La Fuente et al., 2017), they might communicate their concerns via letters or mails. However, when there is no willingness to pay attention to the issues, they also start to protest against the business activities – even with violent demonstrations. For fulfilling the claim, possible practices are technology integration or SC partner development for improving the production process of the SC (Beske and Seuring, 2014), e.g. by implementing a new filter system into the power plant.

However, (2) stakeholders are also helpful, e.g. in the case of low SC visibility, to facilitate the awareness of risks or frauds in the upstream or downstream part of the SC. Since SCs become more complex and intercontinental, focal firms are more often confronted by low supply chain visibility. Busse et al. (2017) pointed out, that most focal firms are just aware of the first or maybe second tier of their SC. However, if the focal company has no chance to make spontaneous audits or to visit their supplier, it’s likely that it is unaware of risks such as inadequate protection equipment for the working staff of the biomass supplier. Cooperation with third parties (e.g. NGOs) can be a way to control the working conditions and address potential risks. This would also enhance the transparency of the SC activities which would ultimately lead to risk reduction and more legitimacy by stakeholders.

Furthermore, (3) different stakeholders can support the focal firm to mitigate or solve a risk when the issue is known but there is a lack of knowledge how to deal with it. Regarding Dale et al. (2018), forest areas might face an increased erosion of the ground or less nutrition in the soil. The cooperation with third parties such as research institutes or universities with a broad knowledge about different topics are a common way to solve a complex issue.

The different roles of stakeholders and their specific issues regarding biomass-for-energy SCs by Gold (2011) frame the further research process. The findings are then used to derive recommendations how stakeholder management can contribute to a more sustainable SC.

Methodology

This research project was embedded in a multi case study with the aim of theory elaboration (Ketokivi and Choi, 2014). Compared to large-sample theory testing methods, case studies have the advantage of getting close to a theoretical item and to enlighten underlying causal relationships (Siggelkow, 2007). Furthermore, the evidence of the case study value regarding the analysis of bioenergy-SCs can be clearly seen in other research projects such as Ahl et al. (2018) or Dale et al. (2018) where the authors interviewed stakeholders and experts. Furthermore, our comparative analyses between the empirical results and the theory allow us to provide theoretical propositions. According to Eisenhardt and Graebner (2007), a case study needs a clear research process. We followed the suggestion by Stuart et al. (2002) to define the research question, determine the research instruments and field, gather and analyze the data and finally disseminate the entire process.

Description case study / case selection

The research is based on extensive field work in Chile from November 2016 to July 2017. The unit of analysis were supply chains of the Chilean pulp and paper industry which produce energy as by-product. The industry considered as apt because of two reasons: first, using second generation biomass embraces the advantage of avoiding the trade-off of the land use for the food or biomass production and the use of the biomass for wood products or combustion (Awudu and Zhang, 2012). Second, the use of production residues generates further income by adding a value to the unused biomass (Cambero and Sowlati, 2014).

While Chile has arguably only two big companies in the pulp and paper sector (when comparing turnover and owned forest area in ha), we focused the data generation mainly on their SCs and the surrounding stakeholder environment. For having a further possibility to contrast the findings, we included one smaller company and their suppliers. To get a deeper understanding of the (implemented) SSCM approach, we collected data from more than one firm in each SC, as suggested by Pagell and Wu (2009). While the main data source were semi-structured interviews, we used site visits, workshops and secondary information of the companies to triangulate the information from the interviews. The basic structure of the interview guideline was the modified framework of Gold (2011). In order to ensure that the questionnaire provided the expected richness of information, multiple drafting stages had been held before the questionnaire was rolled out in Chile and slight modifications were made, based on the first experiences. The main objective was to interview representatives holding management positions and other powerful decision-makers in the bioenergy field. As proposed by Wolf (2011), newspapers and business magazines were used to identify possible interview partners in the context of bioenergy SCs. Additionally, institutions such as the German Chamber of

Commerce Abroad (Deutsche Außenhandelskammer) in Santiago de Chile, universities or local researcher were helpful to acquire information and contacts.

Every interview was carried out face-to-face by one researcher and subsequently audiotaped. A total of 39 interviews were conducted with all actors of the biomass SCs as well as related stakeholders (see Table 1).

Table 1: Overview of the main actors and their distribution

Actor	Number of interviews
Producer of energy (P)	13
Biomass supplier (B)	6
University (U)	8
Government (G)	3
Association (A)	2
Consulting (CS)	4
Community (C)	3
	Total 39

To gain / ensure a better understanding of the business operations and processes, side and field visits took place as well as secondary data from each interviewed company was obtained. Moreover, we organized three stakeholder workshops to discuss the abstracted findings with the involved actors.

Reliability and validity

Further internal validity is ensured by returning summaries of the interviews to the interviewees. The qualitative content analysis is used to evaluate the conducted interview material. Kassarjian (1977) stated that a content analysis should follow a clear and expedient operational structure. Therefore, a six-step content analysis based on the suggestions by Mayring (2015) is applied. Due to abductive reasoning (Locke et al., 2008), the main frame of the coding system is derived from existing theoretical frameworks, which contributes to external validity, and secondly further (sub-) categories and/or items are later added. This yields a certain transparency for third parties and allows them to verify and replicate the analysis.

Findings

Based on the first research question, the results of the case study can be divided into the three dimensions of sustainability: (1) economical, (2) ecological and (3) social.

At the economic dimension, the two most present challenges are the cost of biomass and transportation – both challenge the success of bioenergy business operations as well as are interdependent and influenced by the petroleum price. While mainly the supplier of the biomass is facing these challenges, the focal firm starts to cooperate with a non-traditional SC-member – the main competitor. By exchanging the rights to harvest forest areas which are located closer to the plants of the other one (e.g. P8A or P8B), the cooperation has cut down transportation distance and therefore reduced emissions and improved the competitiveness.

Regarding the ecological dimension, the two main challenges are emissions and a decrease of biodiversity. In relation to the latter, the case study shows that several stakeholders have the concern that the current forest management causes a loss of biodiversity. As one stakeholder said: "*a monoculture of pine, of eucalyptus, is a symbol*

for a loss of biodiversity (U6C: par.: 69). While multiple stakeholders are aware of this issue, no focal firm is dealing with the topic.

The results indicate that the issue of emissions can be divided into emissions stemming from (1) the burning of forest or production residues, (2) the power plants and (3) transportation.

(1) By burning biomass such as forest or production residues, GHG emissions are produced. "*There is still a lot of biomass*, […] *which they burn in the field* […] *and therefore produces a huge contamination and the energy is lost, it kills the bacterial flora of the soil, as well."* (U6A: par. 21). Due to top-management and employee engagement, the win-win cooperation between a focal firm and sawmill have been established. The saw dust provides a sufficient feedstock supply for the focal firm. Therefore, they could reduce emissions as well as the energy costs and generate an extra income (for the sawmill).

(2) Further emissions are emitted by the power plant itself. As one interviewee pointed out, their energy facility emitted emissions and a bad odor which affected the near community – which consists to 25% of the own employees. For answering the pressure due do demonstrations and strikes, the company installed a high class filtration system (well above the minimum requirements). As a result, the emissions and the odor are minimized.

(3) The transportation of the biomass from the forest to the power plant leads to further emissions, "[…] *because all the trucks are running with diesel*" (P1B). As the company is aware of the issue and willing to find a solution, they cooperate with third parties (e.g. consulting companies or universities) to improve the current technology and to identify new operations models or strategies which could cut down the emissions and costs.

At the social dimension, missing knowledge or education about the technology behind bioenergy, a common view amongst interviewees, leads to misinterpretations and, therefore, rejection of bioenergy projects by citizens. "*But the society does not have an idea about this technology and how they would benefit*. (U6A: par. 59). For instance, the steam coming out of the energy plant was put on a level with emissions such as smoke. Consequently, *two-way communication* and *knowledge transfer* are in use to invite communities to an open house day to demonstrate the process of generating bioenergy and to create a discourse on new bioenergy plants.

The case study reveals also that citizens or indigenous have a negative perception of forest industry because they see no direct / personal (economic) benefit. This causes demonstrations and rejection of bioenergy projects. To overcome the issues, linkage developments are in place to get more legitimacy for the business operations. For instance, one company uses their waste heat of their production process to feed the local heat grit and to offer affordable energy to the citizens.

Furthermore, the trucks loaded with biomass damage the local infrastructure and produce dust which impacts the human aspiration system. As an answer, one focal company demanded that their supplier adds an irrigation system and phone number to each truck. Additionally, they invested in the infrastructure after each harvesting season. Therefore, the residents are less impacted by dust, have a repaired infrastructure and an option for direct denunciation of future issues.

Discussion and Conclusion

The case study shows that stakeholders in their possible role as a pressure group as a facilitator or a solver can contribute to a more sustainable SC and their issues need to be managed right.

In line with Seuring and Müller (2008) or La Fuente et al. (2017), stakeholders, for instance when citizens are affected by emissions from a bioenergy power plant, are willing to pressure a focal firm to adopt SSCM practices. In both cases, the origin of the issue was localized in the SC and modernization could directly abolish the issues and avoided a further reputation loss.

Hence a focal firm can also lose reputation by a general negative perception, for instance, no visible economic benefit or a feeling of unfair treatment by the forest industry, the development of common wealth projects can stop a further loss of legitimacy. Sauer and Seuring (2017) have revealed similar practices and labeled them as linkage development. Therefore, we propose that:

> **Proposition 1a:** Because of sustainability issues, stakeholders are willing to pressure a focal firm to implement sustainability practices (such as modernization).
>
> **Proposition 1b:** When a focal firm is already facing pressure, the company can just be reactive and seek to stop the reputation loss – like acting as a firefighter.

However, sometimes missing knowledge or misinterpretation can also lead to reputation loss. In line with literature (e.g. Beske and Seuring, 2014; Gold, 2011), the case study shows that active two-way communication or knowledge transfer are possible ways to deal with the issue and yields the opportunity to change a pressure group to a future facilitator. By exchanging possible concerns with stakeholders, their issues can be recognized even before they start to pressure a SC.

As outlined by Busse et al. (2017), stakeholders are aware of issues, for instance, the loss of biodiversity, and could act as a facilitator for the focal firm. An ongoing discourse with stakeholders about possible issues as well as benefits such as job creation or decreasing of erosion might be a way to overcome a reputation loss (e.g. Gold, 2011). As a result, we propose:

> **Proposition 2:** Using a stakeholder as facilitator leads to the awareness of sustainability issues and enables the possibility to avoid possible pressure groups (and the loss of reputation).

In two cases, issues are known, for instance, the problem of transportation, and are solved by cooperation with non-traditional SC-members such as competitors (Beske and Seuring, 2014). As a result, the transport emissions and costs are decreased as well as the competitiveness is increased.

In the best case, stakeholders reveal an issue and support the focal firm to solve the challenge. Stakeholders are aware of issues, for instance, production residues can be a valuable resource, and they are an instrument to solve it, for example, by launching a cooperation. Therefore, the emissions and energy costs are decreased and an extra income is created (Dale et al., 2018) – an improvement of the environmental and economic performance. Therefore, we suggest that:

> **Proposition 3:** Stakeholder are a helpful “instrument” to identify and solve sustainability issues in a proactive way.

Limitations and research quality

The contribution of this paper is an extended explorative analysis in the setting of an emerging country. First, this research comes up with a refinement of previous theoretical

ideas to the still under-researched intersection between stakeholder management and SSCM.

Second, to the best of our knowledge, this is the first empirical validation of the theoretical constructs of the framework by Gold as well as our investigation has provided evidence on stakeholder issues and how they might be solved in the context of biomass SC, as demanded by Mafakheri and Nasiri (2014).

Third, while the current SSCM discourse is clearly dominated by a western perspective (Jia et al., 2018; Gold, 2011), this piece of research work is one further step to fill the gap by being based on an emerging country setting. However, this refinement of the framework extends the understanding how stakeholders might contribute to a more sustainable SC, for instance, by acting as a pressure group, a facilitator or a solver.

Nevertheless, the empirical qualitative study has its limitations both on the theoretical as well as on the empirical side (Eisenhardt and Graebner, 2007). Therefore, three mayor limitations can be identified. (1) While we grounded our research on the conceptual framework of Gold, a more reflective approach on stakeholder management as well as SSCM might yield additional insights. (2) even though we based our research on a framework and the data analyzing process followed strict rules (e.g. Mayring, 2015), the subjectivity of the researcher in the analyzing process could not be avoided. Because the more the researcher had to interpret the data, the more the results and the propositions were influenced by his subjective opinion. (3) The data, restricted to one industry in one country, might cause a limited generalizability of these results.

However, the limitations of our study causes future research opportunities. The empirical propositions of our study should be anchored in a more comprehensive way in the existing body of literature. Here, a literature review applied in the field of SSCM and stakeholder management might validate or reject our propositions. While the generalizability is currently restricted, further empirical studies in a diverse setting, for instance, another industry in an industrialized country can extend it (Eisenhardt and Graebner, 2007). This would also provide further empirical evidence as requested by Meixell and Luoma (2015).

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Diffusion of green innovation in complex supply networks

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Abstract

Ecological concerns such as global warming have become crucial for global business. Accordingly, green supply chain management has received tremendous attention; but we are still witnessing a series of firm's green-related scandals caused by suppliers. In this study, we argue that this chronic problem might be due to the limited diffusion of process and product green innovation across the complex supply network. Building on a complex adaptive system perspective, this study conducts an empirical study on why and how the diffusion of green innovation is limited, and on how possible it is to amplify the limited diffusion within the network.

Keywords: green innovation, multiple supply networks, complex adaptive systems

Introduction

Over the decades, ecological concerns such as global warming, climate change, and air/water pollution have become critical for global business. Many executives now aware that the challenge of 'green' will largely affect the way they do business, and even determines their survival in the market (Lubin and Esty, 2010). The rising interests greening an entire supply chain have reshaped existing practices in supply chain management. Accordingly, green supply chain management (GSCM) has received tremendous attention (e.g., Zhu and Sarkis, 2004; Srivastava, 2007; Lee et al., 2014; Dai et al., 2015) with regard to "the integration of green concerns along the supply chain embedded in inter- and intra-organizational practices" (Schmidt et al., 2017, p. 4). This study regards GSCM as a form of green innovation within the supply chain.

Despite the recognized importance of GSCM, and the resulting efforts being made by many stakeholder groups including academics and practitioners, we are still witnessing a series of corporate green-related scandals caused by suppliers. One of the infamous cases would be Sony. In 2001, 1.3 million game consoles were blocked by Dutch officials due to high amounts of cadmium detected in the console's cables, manufactured by one of

Sony's suppliers. Recently, toxic food scandals grew in China, where the quality of the product materials supplied to major brands such as McDonald's was called into question (VOA News, 2014). We observed that supplier-induced scandals are not just confined to green products; more oftentimes, they are also associated with green processes such as pouring toxic metals into rivers around the factory (for Nike, Adidas, Puma, H&M, and Apple cases, see Foster, 2011; Mozur, 2013).

In this study, we argue that such a chronic problem might be due to the limited diffusion of process and product green innovation across the complex supply network. We are not alone in this opinion; extant studies argue that in many cases, GSCM innovation works up to the tier-one level, and thus lower-tier (i.e., tier-two and -three) suppliers remain the weak link for environmental sustainability (Mena et al., 2013; Tachizawa and Wong, 2014; Wilhelm et al., 2016a; 2016b). In general, lower-tier suppliers are small in size, and thus less (or no) visible to the public in the country of buyers. They are also mostly located in third world countries where green regulations are very loose. Consequently, they tend to take a passive (wait-and-see) approach, i.e., not managing green issues properly until their customers get punished by stakeholders (Villena and Gioia, 2018).

Recently, very few studies have demonstrated how risky these supplier-driven issues are, and how much damaging this is to dominant buying firms. For instance, Kim et al. (2019) found that buying firms that are caught in such scandals face an abnormal reduction in shareholder value of 1.00%. Focusing on green issues, Lo et al. (2018) also revealed that environmental incidents caused by Chinese suppliers are associated with a decrease in shareholder value of 1.13%. Given that such "supplier sustainability risks" (Foerstl et al., 2010) are caused by not only tier-one, but more often lower-tier suppliers (Plambeck, 2012; Tachizawa and Wong, 2014; Grimm et al., 2016; Wilhelm et al., 2016b), buying firms should extend their attention to inter-organizational green practices, particularly to ones with lower-tier partners in the complex supply network.

Meanwhile, supply chain scholars have argued that supply networks should be understood as a complex adaptive system (CAS) that emerges, rather than under the control of focal buying firms (Choi et al., 2001; Surana et al., 2005; Pathak et al., 2007; Nair et al., 2009; Carter et al., 2015). This profit-focused view is now applied to another pillar of sustainability: green. For example, Nair et al. (2016) were first to bring the CAS perspective to GSCM, suggesting that "[green] innovations that originate in the dominant buying firm continue to develop beyond that firm's boundaries" (p. 67). Similarly, Touboulic et al. (2018) argued that the pressure imposed by the central controller on green initiatives could not be successful without understanding its emergent nature in the supply network. Indeed, green innovation emerges in supply networks, rather than being controlled by focal buying firms; but more evidence is needed (for conflicting results, see Villena and Gioia, 2018).

In this study, we extend the existing studies by conducting an empirical investigation on the following research questions (RQs): (1) *why and how the diffusion of green innovation is limited across a complex supply network*? (2) *how is possible to amplify the limited diffusion of green innovation within the network*? To this end, we focus on the role of customer pressure and supplier capabilities, and the balance of them. Specifically, we use the CAS perspective as our theoretical lens, which is useful for this study given that green ideas are not only simply forced by a focal controller (i.e., customer pressure), but also emerge (i.e., supplier capabilities) in a complex supply network. On top of that, following prior studies (e.g., Gilley et al., 2000), we examine green innovation across the supply network based on the process versus product distinction. This approach would allow the authors to arrive at deeper insights into the literature.

Literature review

Innovation is a means to generate and sustain competitive advantage and ultimately leads to firm performance (Ahuja and Katila, 2001; Jansen et al., 2006; Laursen and Salter, 2006). In a sustainability context, green innovation is understood as the application of various resources in novel ways using unique capabilities to a product or process with intent to reduce environmental impact (Srivastava, 2007; Vachon and Klassen, 2006). Research indicates green practices to generally foster both firm sustainability and financial performance (Ateş et al., 2012; Ketchen and Hult, 2007; Zhu and Sarkis, 2004).

As many practical and academic examples show (see Choi & Lin, 2009; Hora et al., 2011), firms are increasingly held accountable for environmental misconduct in lower tiers of their supply chain, termed supply chain liability, which can generate various negative consequences (Hartmann and Moeller, 2014; Schmidt et al., 2017). Consequently, firms are starting to take responsibility for their supply chain and actively propagate green innovation to suppliers and customers (Hajmohammad and Vachon, 2016). Research has identified several drivers of the adoption and propagation of green practices along different tiers in the supply chain (Lo, 2013; Mitra and Datta, 2014; Paulraj et al., 2015), most prominently stakeholder pressure and firm green capabilities. While diffusion of green innovation to low-tier supply chain partners is increasingly gaining attention, as earlier discussed, the most severe environmental breaches still happen in the upstream supply chain, beyond the first-tier level (Foerstl et al., 2015; Wilhelm et al., 2016). Thus, research must identify the contingencies affecting the diffusion of green innovation across complex and globally distributed multi-tier supply chains.

Green innovation can take various forms, mainly product innovation and processes innovation (Azadegan and Dooley, 2010; Swink, 2006). Scannell et al. (2000) define product innovation as "the ability to develop new products and/or technologies in anticipation of, or in response to, customer requirements" (p. 32). Green product innovation relates to new product development aiming to reduce energy consumption, pollution and waste by the means of product design and material use (Nidumolu et al., 2009; Parmigiani et al., 2011). Subsequently, Scannell et al. (2000) define process innovation as "the ability to develop new processes using the latest technologies in anticipation of, or in response to, customer requirements" (p. 32). Green process innovation is concerned with all firm operational processes, including manufacturing, logistics, and lifecycle management, in order to reduce impact on the environment (Srivastava, 2007).

Several studies explore the differences and complementarities between product and process innovation in a sustainability context. In a buyer-supplier setting, for example, Wagner and Bode (2014) were among the first to explicitly distinguish between both types of innovation when the success of exploring push and pull innovation strategies. Focusing on purchasing sustainability, Foerstl et al. (2015) show that both process-related and product-related factors drive high-tier supplier green innovation implementation. While there are some notable exceptions, many previous studies have taken on an integrated view of product and process innovation. However, we argue that a more nuanced perspective is needed to derive new insights into green innovation diffusion and contingent factors.

Theory and hypotheses

Supply network as CASs

A supply network can be defined as "a network of firms that exist upstream to any one firm in the whole value system" (Choi et al., 2001, p. 352). In general, the network is nonlinear and complex. It is also difficult to predict, manage and control. Thus, the focal buying firm's visibility toward upstream suppliers is inevitably limited. This nature of

complexity makes it difficult for the buying firm to fully control their supply networks. In this sense, the supply network should not be treated as a system that results from purposeful design. Rather, it should be more recognized as a CAS that "emerges over time into a coherent form, and adapts and organizes itself without any singular entity deliberately managing or controlling it" (Choi et al., 2001, p. 352).

Since the seminal work by Choi et al. (2001), there have been many studies that examine the CAS view within the supply chain domain. Among them, Surana et al. (2005) and Pathak et al. (2007) provide a concise overview of supply network as a CAS, saying that a CAS (1) consists of agents (e.g., suppliers or OEMs) that possess schema (i.e., norms, beliefs, etc.), (2) is self-organizing with respect to behavior of the individual agents, (3) exhibits nonlinear dynamism that affects the system, (4) exists in a state of quasi-equilibrium (stability versus change), and (5) evolves over long length and timescales. All these properties are summarized into the Choi et al.'s (2001) three foci: internal mechanisms (agents, self-organization & emergence, connectivity, and dimensionality), environment (dynamism, and rugged landscape), and co-evolution (quasi-equilibrium & state change, nonlinear changes, and non-random future) (for a review, see Nair and Reed-Tsochas, 2019).

Given the above-mentioned properties of CAS, it is important for buying firms to find out a balance of control versus emergence (Pathak et al., 2007; Nair et al., 2009; Carter et al., 2015). Here, controls such as rules and policies may act as a form of reducing degrees of autonomy. Thus, exerting too much control might detract from innovation generated by suppliers within the network. In contrast, emergence can be understood as self-organization that allows that the appearance of supply network beyond the scope of control. Thus, like controls, too much emergence can be problematic as it might lead buying firms to lose the leadership (Choi and Linton, 2011). Indeed, "when managing supply networks, managers must appropriately balance how much to control and how much to let emerge" (Choi et al., 2001, p. 351).

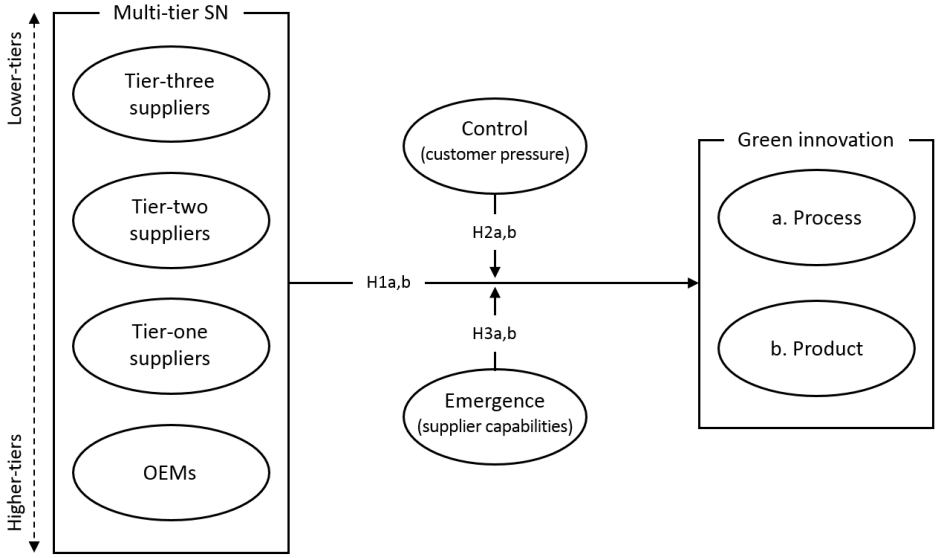

Figure 1 – Conceptual framework

Hypothesis development

In this section, we first discuss why and how the diffusion of green innovation is limited in a complex supply network. We then describe how possible it is to amplify the limited diffusion of green innovation in the supply network. For our purpose, we introduce

customer (green) pressure and supplier (green) capabilities as proxies for the control and emergence of green innovation. Our premise is that buying firms may try to control suppliers through, e.g., contractual terms (i.e., control); however, these suppliers are also able to make their own decisions when it comes to developing green capabilities (i.e., emergence). Figure 1 depicts our conceptual framework.

Limited diffusion of green innovation. In complex supply networks, green innovations are usually initiated by focal buying firms. These large, oftentimes brand-owning firms are so visible that they draw greater attention from the general public, and thus are easily coming under increased legal exposure and stakeholder scrutiny. Indeed, based on a longitudinal case study, Nair et al. (2016) found that green innovations emerge from a focal buying firm sensing the environmental stimuli, which then spread in the entire supply network. But, once in the supply network, diffusion of green innovation was found to be no longer under the control of the buying firm; rather it is an emergent phenomenon. This finding is further supported by a recent carbon reduction study in a food supply network (Touboulic et al., 2018).

However, as earlier noted, the current consensus is that the diffusion of process and product green innovation is limited mostly to tier-one suppliers, and thus lower-tier (i.e., tier-two and tier-three) suppliers remain the riskier members of the network (Tachizawa and Wong, 2014; Villena and Gioia, 2018). This might be simply because of high costs of development, and/or a lack of financial resources. That is, in general, focal buying firms have only limited information about distant suppliers (Choi and Hong, 2002), and subsequently, it is costly and time consuming to exert direct control over the entire supply network (Ciliberti et al., 2008; Grim et al., 2014; Foerstl et al., 2015; Wilhelm et al., 2016b). This often leads the buying firm to manage their supplier sustainability indirectly (Meinlschmidt et al., 2018; Villena, 2018); e.g., setting requirements for direct (i.e., tier-one) suppliers, so that they propagate the buyer's green innovation vision in their own supply network.

The problem of this so-called "mandated fashion" (Brockhaus et al., 2013) is that there would be always a lack of consistency across the supply network. That is, the level of requirements set by focal buying firms does not necessarily spread to the entire supply network at the same level. Some evidence supports this statement. For example, using a sample of 172 Chinese suppliers, Christmann and Taylor (2006) found that the level of compliance differs depending on the level of customer involvement. Moreover, based on data from multiple sources, Villena and Gioia (2018) revealed that buying firms monitor their direct suppliers' green compliance; but oftentimes, these suppliers do not demand the same level of compliance from their own (lower tier) suppliers.

There are arguably two reasons for this limited diffusion of green innovation in a complex supply network. First, compared to higher-tier firms (tier-one and OEM), lower-tier suppliers typically have more limited resources and consequently, lack of expertise in managing the green requirements (Lee and Klassen, 2008; Ayuso et al., 2013; Grimm et al., 2014; Lee et al., 2014). Therefore, suppliers with limited resources may likely face greater difficulty in allocating their efforts to the green initiatives originally initiated by the focal buying firms. Second, as earlier discussed, lower-tier suppliers are less visible to the general public, and thus perceive a lower risk of being penalized by the market for not addressing green issues (Tachizawa and Wong, 2014; Villena and Gioia, 2018). In this regard, there is no reason for them not to take a passive approach, which may cause the limited diffusion of green innovation. Given the discussion, we posit the following hypothesis:

Hypothesis 1 (a-b). *In multi-tier supply networks, lower-tier firms are less likely to adopt (a) process and (b) product green innovation, compared to higher-tier firms.*

The role of customer pressure. Customer has been perceived as an important group of stakeholders for GSCM (Kim and Lee, 2012). Accordingly, a myriad of studies show how pressure from customers affects suppliers' environmental strategy. Jira and Toffel (2013) found that suppliers who face the pressure from their buyers are more likely to engage in climate change mitigation actions. Gualandris and Kalchschmidt (2014) also revealed that customer pressure has a positive impact on suppliers' sustainable (process) initiatives. Chavez et al. (2016) verified the causal relationship between customer pressure and suppliers' GSCM practices. These studies all highlight the importance of customer pressure for initiating suppliers' green practices. However, their scopes are limited largely to top-tier (i.e., tier-one) suppliers, which may be not enough to cover the green issues driven by lower-tier suppliers.

Extending the literature on the role of customer pressure in GSCM, we argue in this study that such buyer's attention to environmental-related issues is a catalyst even for the adoption of green innovation by lower-tier suppliers. Unlike dominant buying firms, lower-tier suppliers are less visible to stakeholders outside the supply network (e.g., NGOs), and thus may take a passive approach for green initiatives. However, looking inside the network, even such passive suppliers are by nature sensitive to customer demands. Their decision making might thus be influenced inevitably by requests from customers, especially from their direct customers.

Recently, Villena and Gioia (2018) find that lower-tier suppliers do not likely prioritize green initiatives unless they are pressured by customers to do so. That is, when the level of customer pressure is high, such suppliers may likely become more proactive, increasing their level of commitment toward the required green innovation (also cf. Christmann and Taylor, 2006). In a similar vein, when faced with high customer pressure, even resource-poor suppliers may likely dedicate part of their resources to comply with customer's green requirements. Indeed, not to mention higher-tier firms, customer pressure changes the behavior of the passive suppliers. Given the abovementioned discussion, we posit the following hypothesis:

Hypothesis 2 (a-b). *The higher the level of green pressure a firm experiences from customers, the larger the adoption of (a) process and (b) product green innovation by the firm.*

The role of supplier capabilities. Likewise, supplier capabilities have been discussed as an important source of buyers' GSCM. As observed by many studies, suppliers can choose to develop GSCM practices, independent of buyer influence (Lee and Klassen, 2008; Tate et al., 2011; Huq et al., 2016; Nair et al., 2016; Touboulic et al., 2018). In fact, such "environmental championing" (Lee and Klassen, 2008), or "supplier innovation capabilities" (Huq et al., 2016) are likely to be motivated by the opportunity, they identify or anticipate, to leverage green initiatives in their process and product innovation (Wagner and Bode, 2014; Foerstl et al., 2015). These capabilities then facilitate cooperation and partnership relationships with buying firms, thereby enhancing the network's ability to better manage environmental issues.

It is intuitive that such capabilities would be less likely among lower-tier suppliers. As earlier discussed, lower-tier suppliers are rather passive, acting only in response to customers' green demands. Indeed, in their qualitative sample, Villena and Gioia (2018) found almost no lower-tier suppliers that are willing to develop their own GSCM

initiatives. Consequently, the adoption of green innovation is more likely among suppliers that are larger, and that have more slack resources, or specialized assets (Delmas and Montier, 2009; Jira and Toffel, 2013). That is, the development of own green capabilities might tend to decrease as they go further up in the supply network.

However, it is not quite like that. Consider the lower-tier suppliers observed in Huq et al.'s (2016) study. These suppliers are located in Bangladesh, a country far from the Western markets. They may be visible to the local public but not likely to those in the county of buying firms. Nevertheless, they choose to go beyond the passive approach, developing own social capabilities. Even smaller suppliers (19–239 employees) take this path; Lee and Klassen (2008) found that few of the lower-tier suppliers appear to improve GSCM practices even though they perceive little or no pressure from customers. In this study, we argue that such supplier capabilities generate "spillover benefits" (Busse, 2016) that enhance the buying firms' green ability. This means that when the level of supplier capabilities is high, buying firms may be able to deal with environmental issues more effectively. Hence, we posit the following hypothesis:

Hypothesis 3 (a-b). *The higher the level of green capabilities a frim benefits from its suppliers, the larger the adoption of (a) process and (b) product green innovation by the firm*.

Research methodology

Sample

A total of 693 randomly selected companies from German-speaking Europe (Germany, Austria and Switzerland) were contacted via e-mail and invited to participate in an online survey. Overall 284 usable responses were obtained, resulting in an effective response rate of 40.98%. Non-response bias was assessed by comparing the answers of early (n =168) and late respondents (n =116) for one item randomly selected from our green innovation constructs (Armstrong and Overton, 1977). Responses of these two samples did not significantly differ at the 5% significance level.

The sampling population included executives, directors, supervisors, and managers as firm informants on business unit level across different industries. We selected the German-speaking because the German business environment has been exposed to green management practices and green supply chain management some time further ruling out the impact of recency effects on our results (Ehrgott et al., 2011). Moreover, German consumers and businesses are recognized for their green awareness and demand for corporate citizenship (Brown and Dacin, 1997; Maignan and Ferrell, 2003), thus promising theoretically interesting and practically insightful findings.

Measures

The variable assessing green process and product innovation was measured based on a nine-item scale adopted from Sarkis et al. (2010). Each scale captures the extent to which the participants' employing company invests in each environmental improvements initiative on a five-point Likert-type scale (1 = not at all to 5 = a very great extent). For a more detailed analysis the nine items were split into green product and green process innovation practices. Customer pressure and supplier capabilities were estimated using the scale of prior studies (e.g., Vachon and Klassen, 2006; Ateş et al., 2012). In addition informants were asked to choose their firm's position within the supply chain on a four option ordinal scale of end customer proximity/distance: the differentiation into (1) raw material supplier, (2) component supplier, (3) system supplier, and (4) manufacturer was adopted from Wynstra et al. (2010). By using these categories, we account for the cross-

industry nature of our study and different supply chain complexities. Our non-tabulated test results support their reliability and validity.

Due to the significance of the supply chain position item, our subjects' supply chain position assessment was cross-validated based on secondary data. Two authors independently categorized each company to one supply chain position based on the 3-digit SIC code in combination with the descriptions of their core business activity provided in the Hoppenstedt firm database. Moreover, information obtainable on the company website was used for further triangulation. Further, firms were seen on a business unit level. This enabled us to have multiple recipients from different business units within on big company. Therefore, supply chain position can be assessed more precisely avoiding the problem of big multinational companies operating at various stages of the supply chain at least to a certain extend. Table 1 presents descriptive statistics and correlation results of the measures used in this study.

Table 1 – Descriptive statistics and correlation results

	Mean	SD	1	2	3	4
1. Process	3.33	0.88				
2. Product	3.01	0.92	0.73			
3. MtSN[a]	2.72	0.89	0.20	0.15		
4. CuPr[b]	3.00	0.91	0.51	0.51	0.04	
5. SuCa[c]	3.03	0.85	0.63	0.56	0.08	0.67

Note: n = 284; [a]multi-tier supply networks; [b]customer pressure; [c]supplier capabilities; Coefficient values more than 0.20 are statistically significant at $p < 0.01$.

Results and discussion

To test our first hypothesis (limited diffusion of green innovation), we conduct an analysis of variance (ANOVA) and the Scheffe method. As shown in Table 2, we found that tier-one suppliers have the highest level of green innovation for both process and product categories. Going by mean values, OEM seems to adopt green innovation more than tier-two suppliers. However, as the Scheffe test shows, there is no significant difference in the adoption of green innovation between the groups. For the product category, the level of adoption by tier-two suppliers is similar to even that by tier-one suppliers. But, unlike tier-two ones, we found that the level of green innovation adopted by tier-three suppliers is significantly lower than that of all customers (for both process/product). These findings support H1a, but partially support H1b.

Table 2 – ANOVA for green innovation by SN members

	Tier-three (a)	Tier-two (b)	Tier-one (c)	OEM (d)	F
Process	$2.59^{(b,c,d)}$	$3.20^{(a,c)}$	$3.61^{(a,b)}$	$3.34^{(a)}$	10.05^{***}
	(1.08)	(0.87)	(0.79)	(0.79)	
Product	$2.24^{(b,c,d)}$	$2.97^{(a)}$	$3.23^{(a)}$	$2.98^{(a)}$	7.53^{***}
	(0.99)	(0.83)	(0.94)	(0.85)	
No. of cases	22	99	100	63	

Note: n = 284; the numbers in parentheses are standard deviations; the numbers in the superscripted parentheses indicate Sheffe pairwise test with significant level of $p < 0.05$; $^{***}p < 0.001$.

Our findings suggest that tier-one suppliers seem to lead both process and product green innovation in its supply network. This is followed by OEMs, albeit not statistically significant between the groups. Indeed, tier-one suppliers to OEMs are responsible for ensuring green sustainability throughout the network (Brockhaus et al., 2013; Grimm et al., 2014; Foerstl et al., 2015). Contrary to expectations, yet, tier-two was found to adopt the level of green innovation similar to those of tier-one and OEMs. This is an interesting result given that

most of the prior GSCM studies argue that green-related scandals are generated by lower-tier suppliers (e.g., Tachizawa and Wong, 2014; Wilhelm et al., 2016a; 2016b; Villena and Gioia, 2018). But, it should be noted that this is only for the product category, not for the process one. Finally, as expected, we found that tier-three suppliers are weak links for network sustainability.

To test our hypotheses 2-3 (the roles of control and emergence), we conduct a 4 (tier-three, tier-two, tier-one, and OEM) × 2 (high versus low customer pressure, by mean split) × 2 (high versus low supplier capabilities, by mean split) factorial ANOVA. This analysis has been widely used for comparison, not only in supply chain research (e.g., Frohlich and Westbrook, 2002; Shin and Benton, 2004; Koh and Saad, 2006; White et al., 2011), but also in other fields such as marketing (e.g., Gong et al., 2013), information systems (e.g., Sengupta et al., 2018), organizational behavior (e.g., Hepburn and Barling, 2001), etc. Following prior studies (e.g., Shin and Benton, 2004), for succinctness, we omit the higher-order interactions of the variables.

Table 3 – Full-factorial ANOVA on green innovation

Source	Process (R^2 = 0.34)			Product (R^2 = 0.25)		
	SS	df	*F*	SS	df	*F*
Corrected model	77.02	14	10.13***	62.23	14	6.58***
Intercept	1481.94	1	2728.89***	1159.92	1	1746.97***
MtSN[a]	10.03	3	6.15***	9.90	3	4.97**
CuPr[b]	1.72	1	3.18+	0.87	1	1.31
SuCa[c]	16.51	1	30.41***	12.62	1	19.01***
MtSN × CuPr	3.02	3	1.85	4.41	3	2.21+
MtSN × SuCa	3.85	3	2.36+	2.04	3	1.02
Error	146.08	269		178.60	269	
Total	3383.11	284		2817.88	284	
Corrected total	223.11	283		239.84	283	

Note: Higher interactions are omitted for succinctness; [a]multi-tier supply networks; [b]customer pressure; [c]supplier capabilities $^{+}p < 0.10$; $^{**}p < 0.01$; $^{***}p < 0.001$.

As Table 3 demonstrates, for using process green innovation as dependent variable, we found a marginally significant interaction between multi-tier supply networks (MtSN) and supplier capabilities (SuCa). Looking at the individual effects, we found a statistically significant difference in the adoption of process green innovation between each network member, and also between high and low supplier capabilities. On the other hand, for using product green innovation as dependent variable, a marginally significant interaction was also revealed, but this time between multi-tier supply networks (MtSN) and customer pressure (CuPr). Likewise, as the individual effects, we found a statistically significant difference in the adoption of product green innovation between each network member, but not between high and low customer pressure.

To provide additional evidence for our hypotheses 2-3, we conduct regression analysis for each group. As shown in Table 4, control (customer pressure) has a positive impact on the adoption of process green innovation by tier-two, and of product green innovation by tier-two and tier-one. For the others in the network, contrary to our expectations, the control approach was found to be ineffective. In contrast, we found a relatively extensive impact of emergence (supplier capabilities) for each tier's green adoption. The results shown in Table 4 reveal the significant positive impact of supplier capabilities on the adoption of green innovation by all tier members (tier-three to OEM), for both process and product categories. This means that supplier capabilities indeed increase the adoption of green innovation by buying firms.

Table 4 – Regression estimation of green innovation

Multi-tier SNs	Process				Product			
	Tier-3	Tier-2	Tier-1	OEM	Tier-3	Tier-2	Tier-1	OEM
Constant	0.03	0.30	0.69^{+}	1.34*	0.33	0.51	–0.02	1.20*
	(0.45)	(0.29)	(0.36)	(0.50)	(0.60)	(0.32)	(0.45)	(0.54)
Control (CuPr[a])	–0.09	0.31**	0.10	0.02	0.13	0.35***	0.27*	–0.02
	(0.19)	(0.09)	(0.09)	(0.13)	(0.24)	(0.10)	(0.11)	(0.14)
Emergence (SuCa[b])	0.76**	0.45***	0.50***	0.38**	0.54^{+}	0.26*	0.41***	0.49**
	(0.22)	(0.09)	(0.10)	(0.14)	(0.29)	(0.10)	(0.12)	(0.15)
Firm size	0.00	0.09***	0.07**	0.02	–0.00	0.04	0.07*	0.04
	(0.07)	(0.02)	(0.02)	(0.03)	(0.09)	(0.02)	(0.02)	(0.03)
Industry diversity	0.23	0.07	0.20*	0.19	0.03	0.11	0.23*	0.04
	(0.16)	(0.07)	(0.07)	(0.13)	(0.20)	(0.08)	(0.09)	(0.14)
Observations	22	99	100	63	22	99	100	63
F for the model	12.6***	31.0***	24.1***	5.05***	4.11*	17.3***	19.7***	4.59**
R^2 (%)	74.80	56.92	50.45	25.85	49.22	42.44	45.43	25.85
Adjusted R^2 (%)	68.87	55.09	48.36	20.74	37.27	39.99	43.13	20.74

Note: The highest VIF for all the variables in each model is 3.27, with almost all scores falling between 1 and 2; [a]customer pressure; [b]supplier capabilities; standard errors are shown in parentheses; $^{+}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Finally, based on the results, we discuss the issue of control versus emergence for the diffusion of green innovation across complex supply networks. As summarized in Table 5, our findings suggest that control is not a panacea for network's green innovation. More importantly, this study suggests that for each network member, different approaches need to be considered, a point that has been largely ignored. Therefore, the results of this study provide new insights (e.g., fine granularity) into the CAS/GSCM literature, where the empirical evidence remains conflicting (see Nair et al., 2016; Touboulic et al., 2018; Villen and Gioia, 2018).

Table 5 Control versus emergence for green innovation across multiple SNs

Multi-tier SNs	Process-driven			Product-driven		
	CuPr[a]	SuCa[b]	Ctrl. – Emerg.	CuPr[a]	SuCa[b]	Ctrl. – Emerg.
Tier-three suppliers	N	S	Emergence	N	M	Emergence
Tier-two suppliers	S	S	Balance	S	S	Balance
Tier-one suppliers	N	S	Emergence	S	S	Balance
OEMs	N	S	Emergence	N	S	Emergence

Note: The diffusion impacts of [a]customer pressure and [b]supplier capabilities are: S = significant ($p < 0.05$), M = marginally significant ($p < 0.10$), and N = none significant.

Conclusion

The results of this study make several contributions. First, we uncover who is the riskiest of the risky in the supply network. Despite scholarly efforts, it is still unclear exactly which member of the supply network is leading green innovation, and which member is a 'troublemaker.' Second, we shed light on the issue of control versus emergence for the diffusion of green innovation. This issue has been recognized as an important agenda when managing a multiple, complex supply network (Choi et al., 2001; Pathak et al., 2007; Carter et al., 2015), so it does for the diffusion of green innovation within the network (Nair et al., 2016). Third, we respond to the call for research on sustainability in multi-tier supply chains (Wilhelm et al., 2016a; 2016b; Villena and Gioia, 2018). Results from this study provide additional insights into the theory of GSCM, where most of the studies are limited in scope to buying firms or tier-one suppliers.

References are available from the authors

Blockchain-sustainability affair in the Fashion Industry

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Abstract
Sustainability is becoming a key aspect to compete in nowadays fashion market since customers, NGOs and governments are pressuring companies to become more sustainable. Having full knowledge of all actors and activities carried out along the supply chain is therefore becoming an essential factor for the fashion industry to ensure adequate levels of sustainability. In this context this study aims at investigating the issue of supply chain traceability. Secondary sources were analyzed to deepen the adoption of traceability, in particular by analysis the blockchain technologies, along fashion supply chain in order to support sustainability purposes.

Keywords: Sustainability, Traceability, Blockchain, Fashion

Introduction

Sustainability has become more and more a fundamental driver to the competitive success of fashion firms. In recent times, due to environmental and social scandals, as mistreating of animals, application of unequal working and payment conditions to employees, and the creation of eco-unfriendly collections based on polluting industry, we have witnessed the creation of a profound furrow in customers minds, dividing clearly companies which behave in a sustainable way and which are worth to be taken into account, form those which do not.
Literature maintains Supply Chains (SC) in Fashion Industry are tightly chained with the question of contributing to business sustainability (Caniato et al., 2012, Li et al., 2014). Many activities related to the production of fashion products are affected by critical environmental and social issues indeed, as the use of chemical reagents to obtain precise aesthetic features (e.g. tanning activities, Masilamani et al., 2017), or the lack of regulations for employees. Consequently, achieving a high degree of sustainability performances in SC has become strategically crucial for competing in the fashion markets. A review on the issue has showed how scholars evaluate diverse viewpoints on how to pinpoint the right SC strategy to reinforce the responsibility of company towards the environment and society. One of them is enhancing the visibility level along SC by mean

of a traceability system (Macchion et al. 2018; Moretto et al. 2018), to identify the sources of contamination, or defects or critical nodes, or to assure trust among the peers of the SC network (Marucheck et al., 2011), and to make decisions in a consistent manner with the own values.
In this perspective, the digital era has been providing companies with many opportunities offered by technology advancements to be exploited in operations. One example is blockchain technology (Casey & Wong, 2017; Tapscott & Tapscott, 2017), but how it can be practically useful for trace objects and elements along the fashion SCs is still missing in literature.
Based on these gaps, this paper aims at investigating the adoption of traceability practices along fashion supply chain in order to support sustainability objectives. In particular the blockchain will be investigated based on cases of application of this technology within the fashion supply chains.
This goal is tackled through the analysis of secondary sources, specialized in the fashion context, which describe examples of companies that have adopted, or are adopting, blockchain technologies to track their internal processes and supply chain for sustainability objectives.

Literature review

Sustainability in the fashion industry
The recent environmental and social scandals emerged across the world and the growing pressures by non-governmental organizations (NGOs) have brought under the public spotlight the topic of sustainability as an urgent issue to be addressed (Ageron et al., 2012).
Companies in several industrial contexts, therefore, have become always more sensitive to such challenge and started working on the internal processes and on the products/services they deliver. However, this is not enough, as the public community realized that managing environmental and social issues is not only confined to the boundaries of focal companies, but must be extended to the supply network (Krause et al, 2009) and through the distribution channels as well (Zhu et al., 2005). It follows that companies have now moved to address the emerging issue related to the challenge of sustainable supply chain management, which is defined as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements" (Seuring and Müller, 2008).
The extension of these virtuous behaviours from focal companies through their supply networks might not be easy to accomplish and could rely on different strategies. For instance, some players, in several industrial contexts, have decided to abolish those current suppliers that are not proactive on sustainability, in favor of new ones more sustainable; in some other cases, the focal companies themselves developed sustainable capabilities to be forcedly extended to suppliers. In some other situations, the focal companies developed green and social capabilities, but in partnership with current suppliers; finally, there are also cases in which companies cooperate with competitors in order to develop sustainable standards and grow sufficient levers to exert such behavior to suppliers (Zhu et al., 2010). Notwithstanding such strategies, the extension of sustainability practices to an entire supply chain represents one of the most complex business challenges of the moment, as the globalization has brought to a fragmented scenario, in which suppliers are dislocated in different parts of the world, below different environmental and social regulations (Sarkis, 2012).
These issues are more than relevant for the fashion industry (de Brito et al., 2008), whose entire business model has been mainly built on the use of fragmented suppliers - often located in low-labour cost countries and where environmental and social regulations are not strict - and on

production processes highly polluting and consuming (Lo et al., 2013). The fashion industry, in fact, is now acknowledged as a business in which there is a high level of pressure on costs and prices, leading several fashion producers, in order to meet such requirements, to offset their workers' rights and environmental emissions. This has attracted the attention of several NGOs, which have considerably raised their attention to such industrial context, starting numerous initiatives (such as the known Detox Campaign by Greenpeace) which aim is to inform the public opinion about the unpleasant aspects behind this industry.

Traceability and blockchain in the fashion industry

Notwithstanding the recent interest by academics on the issue of sustainability in the fashion industry, tracing all the actors in the supply chain still remains a discussion point.

In the fashion market, in which the identification of suppliers collaborating in the production is becoming a weapon of success, giving evidence (and therefore tracing) of the origin of supply chains is assuming a key role. However the development of traceability for the network remains an open challenge due to the difficulty of structuring traceability practices cross national boundaries to identify suppliers located internationally (Macchion et al., 2017).

In structuring traceability systems companies must define tools and mechanisms to transmit information, by focusing not only in their internal processes but on the development of a complete inter-organizational traceability that could align different actors of the supply chains and ensure the data exchange in a standardized way.

The development of traceability practices should be supported by proper tags, labels, barcodes, microchips or RFID, applied directly to each product or batch, but nowadays new tracking technologies are developing in the market thanks to the growing possibilities offered by new digital technologies: the blockchain.

The early blockchain concept was proposed by a developer hiding behind the pseudonym Satoshi Nakamoto, which has been fully validated through the bitcoin system implementations since 2009. Even if the blockchain was born for bitcoin contexts, paradoxically, it could also save the fate of fashion market, that increasingly requires the most complete traceability of garments and production, to guarantee both social and green supply chain sustainability. The blockchain, in fact, allows to check the history of the product along the supply chain, as well as the prevention, or at least the reduction, of the phenomenon of counterfeits, by leaving the final consumer the possibility to verify this information.

As stated by Fu et al. (2018) "The blockchain entries could represent transactions, contracts, assets, identities, or practically anything else that can be digitally expressed using smart devices. New versions of blockchain technology implementation offer support for the implementation of smart contracts encoded in ledger's blocks, which implements different business rules that need to be verified and agreed upon by all peer nodes from the network. When a transaction arrives, each node updates its state based on the results obtained after running the smart contract. Such replication process offers a great potential for control decentralization". Based on this structure composed of nodes, it represents a weapon to protect the consumer on one side, and the brand itself on the other side, considering the possibility that some stocks end up in the so-called Gray market (i.e. the parallel sales market outside official circuits of the brand). Moreover, its development could be supported by greater consumer demand for tracked products. According to a recent Pwc report, customers would be willing to pay 5 to 10% more than the list price to buy traced products.

Research aim and research methodology

This paper revolves around the role of technology advancements to achieve higher level of sustainability within supply chains, by understanding to which extent they could be catalysts of a progress in the sustainability performance of SCs. In light of this consideration, the following research question is formulated:

RQ: How advanced Digital Technologies, such as Blockchain, might improve SC sustainability?

In pursuance of our aim, for the exploratory nature of the topic under investigation this paper is based on a secondary data qualitative analysis methodology on five different companies. This methodology provides the opportunity to understand complex phenomena in their whole facets by examining companies' documents and code of conducts, newspaper reports and sustainability and CSR reports available on the company's website and represents an important source for empirical studies (Harris, 2001). In fact, in order to plan how to select and invest on technologies to address the sustainability journey at a SC level, a profound understanding of all the practices undertaken in the field is needed. Thus, to explore our research question we embraced a supply chain perspective, and we selected five important firms consistent with the following eligibility criteria:

1. The selected company is the focal firm of each SC and is large size brand owner. Hence, it has sufficient levers to structure and influence its entire supply chain;
2. The selected company delivers products at the international level; therefore, the whole supply chain has to be compliant with different national and international sustainability regulations.
3. The selected company must have begun the path of digitalization and sustainability to study sustainability implications due to technological changes over the years.
4. The selected company must publish available information related to their commitment to sustainability and digitalization also in their online site as evidence of their sustainable path.

In order to collect data, we focused on gathering two diverse type of information consistently to the researched field. First, the different digitalization practices and projects to assess and measure the digital maturity of companies, and in particular of their SCs (Plomp, 2010; Schumacher, et al., 2016; Bienhaus and Haddud, 2018). Second, the environmental and social strategies and practices adopted by the companies during the considered years. All the collected practices of digital transformation and sustainability have been catalogued in a spreadsheet and they have been analyzed. The whole analysis has been conducted during the years 2018 and 2019 and information were collected starting from the first implementation of digital transformation and sustainability principles and practices within the supply chains. As specified, the research was conducted on a group of 5 international companies belonging to different SC networks and market segments. The selected firms all belong to the fashion industry; they are positioned in different market segments; they are homogeneous in terms of size (i.e. more than 1bn revenue), brand longstanding existence (i.e. 150 to 50 years); they show a high level of world-class operational and organizational practices; they state to pay attention to sustainability (i.e., mentioned as a competitive priority); and they are at diverse stage in the approach to digital transformation, showing to have conducted explorations on the chance offered by technology to digitalize their SCs.
Moreover, the selected companies are heterogeneous per type of products (i.e., clothes, accessories and jewelry) to cover the variety of products of the fashion industry and per country of origin of the headquarter, to understand the impact of country of origin in the approach to digitalization and sustainability.
Table X summarizes the profiles of the chosen companies.

Name of the company	Revenue (€)	Year of foundation	Headquarter's country	Main Products	Main Market Segment	Use of Blockchain

LVMH	42,8 bn (2018)	1987; Louis Vuitton: 1854	France	Clothes, Wine	Luxury	Product Traceability System
De Beers	6,1 bn (2016)	1888	South Africa	Diamonds	Luxury	Product Traceability System
Alrosa	4,09 bn (2018)	1954	Russia	Diamonds	Luxury	Product Traceability System
Levi Strauss	5,5 bn (2018)	1871	US	Clothes	General Purpose Clothing	Workforce condition Traceability System
Hugo Boss	2,7 (2018)	1924	Germany	Clothes	General Purpose Clothing	-

The selected companies

- LVMH is a French luxury company founded in 1987 as result of the merger between Louis Vuitton and Moët Hennessy. Over the years, it has progressed by acquisition, adding to its portfolio more than 60 brands such as Bulgari, Céline, Christian Dior, Givenchy, Loro Piana or Sephora. LVMH group has produced 46.8 bn € revenue in 2018 (+10% on 2017) and it counts 150.000 employees. Besides the fashion industry which amount to 40% of the revenues, its business comprises also selective retailing, wine, cosmetics, and jewelry. (LVMH, 2019).
  LVMH in 2017 has created a blockchain-dedicated team to develop MVP of a blockchain-based traceability system. The platform AURA leverages on Quorum by JP Morgan, an industrial adapted version of Ethereum. Within the network of companies, Louis Vuitton and Parfums Christian Dior have been elected to test the MVP with the purpose to scale-up the solution to the entire company. The strategical idea at the bottom is to co-opt inside this network not just the entire SCs but also the competitors as well. However, the project is still in its infancy and it has not been officially confirmed by LVMH. (Coindesk, 2019)

- De Beers and Alrosa are two leaders of the diamonds industry. Their business owns the entire Supply chain: form the exploration in search mineral deposits, to the mining process, and to the production and B2C selling of jewelry.
  Since its foundation in 1888, De Beers has been based in South Africa. Its business spreads toward 35 different countries with a revenue of 6.1bn € in 2016 and more than 20.000 employees. (De Beers, 2019). The Russian Alrosa, founded in 1954, follows De Beers as the second largest player of the sector, with revenues audited around 4,09 bn € in 2018 (300bn Rub) (Alrosa, 2019).
  De Beer and Alorsa have joined their forces on the development of a traceability system to combat the illegal diamond trafficking and forgery. From their union rose Tracr, a blockchain system with the purpose of tracking the gems status form the mining process to the customer ownership. Ensuring the quality and the history of a diamond is important also to safeguard the overall value of the market. Indeed, incumbent as De Beer or Alorsa are continuously threatened by innovation in chemistry like the synthetic diamonds, or changes in customers priorities. (Trackr, 2019)

- With 5,5 bn€ revenue divided between more than 110 countries, Levis Strauss is a US global general-purpose clothing producer and seller. Its brand is worldwild recognized mainly for its historical leadership in jeanswear. The origins of the company date back in the 1853's California, and to date the company comprises more than 15.000 employees. Recently, the firm has signed a partnership with

Harvard University to investigate how blockchain may be used to reinforce the workforce welfare. The project pilot has gained the sponsorship of the U.S. Department of State, and it aims at monitoring the workers' condition within the entire Supply Chain (Coindesk, 2019).

- Hugo Boss Group is one of the world market leaders in the premium segment of the apparel market that accounts almost 14000 employees and in the fiscal year 2018 it achieved net sales of 2,7 billion euro. The actions of the company are guided by the vision of being the most desirable fashion and lifestyle brand in the premium segment, and by the believes that the desirability of its brands will be the most important factor in the group's long-term success. Hugo Boss's management has claimed in diverse occasion to foresee Blockchain as a disruptive technology, which potential need to be explored. In particular, it is currently studying how to leverage on a blockchain-based system to track products along their Supply Chian (SCF Briefing, 2019).

Results and discussion

Thanks to the analysis of secondary data from companies listed above, the potential contribution of visibility and traceability through blockchain for sustainability was hinted.

The term Digital Supply Chain (DSC) refers to the data exchanges between actors involved within a supply chain. As stated by Büyüközkan and Göçer (2018), DSC is about "how supply chain processes are managed with a wide variety of innovative technologies", as IoT, Big Data Analytics, cloud computing and blockchain itself.

This great volume data shared between actors in a supply chain is increasingly growing and offers a wide range of opportunities for enhancing the chain efficiency and effectiveness, yet creating complexities, unclearness and issues in data management. Moreover, many supply chains still suffer from lack of integration between parties, many documents are still paper-based, and a lack of visibility on processes is still evident. Businesses are therefore trying to focus on integrating processes and transactions, which generates a huge challenge. According to Santos and Eisenhardt (2005), supply chain integration constitutes a key driver for minimization of network's governance costs, in particular the costs associated to information exchanges with other actors in the ecosystem. Scholars agrees in recognising that integration between participants in a supply chain builds supply chain efficiency.

The key area in which supply chain digitalization can provide benefits is integration between actors, in complex supply chains.

Blockchain technology can create a support towards supply chain integration. According to Korpela, et al. (2017), blockchain can address DSC limitations thanks to the following features:

- A distributed ledger of transactions replicated to every node of the blockchain network. As already discussed, the distributed ledger is open to all nodes (which may have restrictions depending on the permission level). Transactions create new blocks that are chained to the previous, and everyone who has read permissions can verify the validity of transactions (for instance, the seller can notify the buyer about a transaction, and verify the existence directly from the ledger).
- The possibility to develop smart contracts, for automating business transactions and document exchanges between parties within the supply chain. Smart contracts are

developed on blockchains and can be used to "automate DSC transactions at a very detailed level" (Korpela, et al., 2017). As an instance, smart contracts could enable automated transactions in dependence of pre-determined agreements between parties.
- The use of public key cryptography (PKC), to encrypt and decrypt a transaction. This feature ensures a high security level, as well as sustaining the whole architecture.

As a result, blockchain could enable a quick, reliable and efficient execution of transactions and document exchanges, in a secure way and at low cost (Korpela, et al., 2017).

According to evidences provided by secondary case studies, blockchain adoption in business transactions is not supposed to replace enterprise systems, but to be integrated with them in order to receive and store data in ERP's relational databases, while leveraging distributed ledgers properties to provide trust and accountability to business processes.

An insight on some benefits that can be achieved by integrating enterprise applications with blockchain is provided by Banerjee (2017).

- ERP store information about purchase, storage, production or shipment of a product. Integrating with blockchain can provide a copy of this information into the network, which is indelible, immutable and trackable at any time.
- ERP generate financial transactions. Integrating with blockchain can make transaction transparent and reliable.
- ERP holds procurement information, like purchase order and purchase agreements. These can be registered in digital formats in a blockchain and made available only to the intended parties through their private key. This would harshly reduce the need for emails or other means of communication.
- Integrating ERP with blockchain can reduce disputes over invoices. From the results of an IBM survey (Guarini, 2016), over 100 million of dollars of invoices worldwide are subject of disputes. According to IBM estimations, blockchain could avoid this kind of disputes in 90-95% of cases.
- Integrating ERP with blockchain can replace Electronic Data Interchange protocols (EDI). Messages can be transferred across members via blockchain nodes, with confidential data stored and accessible with a private key.

Pandey (2019) proposes a framework for implementing blockchain in company's ERP databases, with the purpose of solving the issue of inconsistencies in data flows. The solution is proposed in the case of two actors (a buyer and a seller), within a generic interaction based on contract, order, payment and delivery. If records are correctly uploaded on a blockchain platform, this becomes a single source of truth, and both actors can access to relevant information in real time. This approach can be followed also at a full supply chain perspective, with more actors involved. In the same way, blockchain provides a ledger where to keep record of all transaction and information exchanges.

Cases have also allowed to identify where blockchain could play a stronger role to increase transparency within companies' processes and along the supply chain. The main potential benefits are the following:

- ***Transparency and auditability***: The distributed ledger is replicated to every active node, capable of communicating with ERPs. The ledger is immutable, and each

member of a transaction channel can have access, read or write according to their permissions. Moreover, auditability is made easy thanks to data integrity: for instance, financial audits are immediate and certain.

- ***Transaction processes***: The most important information transactions occurring between actors are automated thanks to smart contracts, making the process smoother, more efficient and less subject to errors.
- ***Visibility:*** Data about the status of purchase orders are constantly updated, and information is available almost in real time.
- ***Trust:*** The adoption of smart contracts and of a shared ledger provides the highest possible level of trust between parties. Data are shared and immutable, and each involved party has access to the same version of truth. For this reason, it is expected to reduce disputes on orders or invoices.
- ***Multi-party collaboration***: Actors can easily exchange digital information and access to shared data uploaded on blockchain.
- ***Document exchange***: Paper flows are replaced with digital data exchanges, which can easily synchronize data that were previously spread across systems. Moreover, documents can be digitally stored in dedicated databases and are fully auditable.
- ***Failures identification***: Thanks to the increase in visibility on flows, and the reduction of information asymmetry, detection of issues is easier and faster.
- ***Lead time***: Increase in visibility and data sharing efficiency could reduce downtimes due to slow exchanges of information. However, no evidences that time savings are expected to be significant, if compared to the overall process lead time, can be obtained.
- ***Cost***: Increase in process efficiency is expected to reduce time required by operators in repetitive tasks, which can be dedicated to more value-adding activities. However, due to the high costs implied by the blockchain service provision, these cost savings are not relevant.

Thanks to the preliminary analysis of secondary case studies, we were also able to link benefits of blockchain listed above with sustainability practices, to understand for which practices blockchain could also become an enabler of sustainability practices.

Sustainability practice	**Details**	**Role of blockchain technology**
Adoption of recognized sustainability standards	• Life Cycle Assessment (LCA) • EU Eco-Management and Audit Scheme EMAS • UNGC • ILO • Guidelines for Multinational Enterprises • ISO 26000	Transparency and auditability Transaction processes Trust Document exchange
Certifications	• LEED • ISO 14000 • ISO 50000 • SA 8000 • EPD • GOTS (Global Organic Textile Standard) • Other (such as certified cottons and fibres)	Transparency and auditability Transaction processes Visibility Trust Document exchange
Purchase of sustainable material	• Eco-friendly / certified materials • Recycle raw materials • Eco-friendly packaging and shopping bag	Transaction processes Visibility Trust

Suppliers selection	• Selection according to
	  o environmental and social indexes
	  o certifications obtained by suppliers
	  o geographical location
	• Request of adoption of
	  o Restricted Substances List – RSL
	  o Manufacturing Restricted Substance List - MRSL
		Transaction processes
		Visibility
		Trust
		Document exchange

Suppliers monitoring	• Supplier audit • Self-certification • Sanctions • Extension of code of conduct to suppliers	Transparency and auditability Transaction processes Trust Document exchange Failures identification Lead time
Supplier collaboration	• Supplier training • Knowledge sharing with suppliers and actors of the SC • New processes and technologies development with suppliers and actors of the SC • Joint development of projects oriented to improvement of sustainability practices • Financial support to suppliers	Trust Multi-party collaboration Lead time Cost
Evaluation and consumption mapping	• Mechanical and/or chemical analysis on final product • Internal energy, water consuming, air pollution audit	Transaction processes Document exchange Lead time Cost
Eco-friendly production processes and machines	• New clean technology for water saving and air pollution minimization • Energy efficiency programs • Manufacturing machinery renewal	Lead time Cost

Conclusions and future developments

This paper investigates the topic of traceability for supply chain sustainability, with a main focus on the contribution that blockchain technology could play to foster these benefits. Whether the relevance of sustainability for the fashion industry is well recognized by both practitioners and scholars, companies are still struggling in identifying methods to enable and foster sustainability at the supply chain level. Literature presents visibility and transparency as key drivers to push sustainability, and blockchain technology appears as one of the most promising tools to enhance transparency. Through the analysis of secondary data from leading fashion companies, this paper identifies the main potential benefits of blockchain technology and makes a possible link between these benefits and the main supply chain sustainability practices.

This paper is just a preliminary step of a broader research project, oriented to investigate how blockchain technology could enable the achievement of sustainability in the supply chain. Further steps have the purpose to make direct interviews with selected companies, to triangulate data collected through secondary resources. Moreover, future research aims at assessing the potential contribution of blockchain, selecting cases that already implemented the technology to compare the ex ante and the ex post performance in terms of sustainability and the consequent level of implementation of practices.

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The Impact of Organizational Health Management on Organizational Performance
A Meta-Analysis and Meta-Regression

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Abstract

Demographic change is a challenge for organizations. One consequence is the change in organizational age structures. Organizations need to motivate their employees for longer durations of work. One possibility to meet these challenges is to promote their employees' health through Organizational Health Management (OHM). Despite possible positive effects, OHM has been extensively implemented in a few organizations. This is due to the unknown effect of an OHM. By using meta-analyses and metaregressions, this paper answers the question of the link between OHM and organizational performance and moderating influences. Recommendations for organizations as well as implications for further research are given.

Keywords: Organizational Health Management, Organizational Performance, Meta-Analysis

Introduction

Demographic change is a challenge for organizations. One consequence of this is the change in organizational age structures. As a result, organizations need to motivate their employees for longer durations of work and maintain their capacity to maintain competitiveness despite aging workforces (Lück et al., 2008). One way for organizations to meet these challenges is to promote their employees' long-term health and work capacity through Organizational Health Management (OHM). Numerous studies have shown that, despite possible positive effects (e.g. such as reduced absenteeism), OHM has so far only been extensively implemented in a few organizations. This is due to a lack of resources and to the unknown effect of an OHM on organizational performance, which must be shown to organizations. The following research question arises: What influence does the implementation of an Organizational Health Management (OHM) have on the organizational performance? Based on previous empirical studies, it is not possible to derive any unambiguous statements on the effect on organizational performance measures (Bechmann et al., 2011). The claim to research is growing to prove the suspected effects of an OHM on organizational performance. Special attention is given to the term "evidence-based". The goal of the evidence base is to create a basis for decision-making based on a compilation of the currently best available evidence. So far, such compiled information is missing in the form of a meta-analysis, from which even insufficient recommendations for the implementation of an OHM can be derived. Precise research questions arise:

- What effect on organizational performance does the implementation of an OHM have?
- What influence do moderating factors have on the effect of an OHM?
- How generalizable are the results of the effects of an OHM?
- What are the recommended courses of action for organizations, which implications for further research?

Theoretical Background and Hypothesis

Operationalization of Variables

Organizational Health Management (OHM) is a management task of an organization whose primary objective is to maintain and promote employee health at the organizational level. The OHM thus comprises the planning, control, and monitoring of specific measures that serve to prevent occupational accidents and work-related health hazards and therefore relate to risk factors and their avoidance (pathogenetic OHM measures) as well as measures to promote health resources (salutogenetic OHM measures). In order to maintain and promote employee health, the OHM is intended to promote the health-specific further development of existing conditions, work processes, structures and systems. An OHM consists of operational policy elements (e.g. policy document), organizational elements (e.g. health committee), the core process (OHM measures) as well as a continuous improvement process (in the sense of a control loop).

There are numerous approaches to how the success (organizational performance) of an organization can be categorized or operationalized. At Nagel (1997), the subdivision is found in social and economic success. Social success refers to changes in material and immaterial working conditions, as well as behavioral changes and relationships between employees. Economic success is understood to mean changed values of monetary quantities (e.g., profit, turnover) and non-monetary quantities (e.g., product quality, market share). In the context of this research project, the focus is on non-monetary economic variables which have a proven relation to the health situation in the organization (e.g., sickness absenteeism, productivity).

Conceptual Framework and Hypothesis

Draw on the resource-based view (Barney, 1991) and health-specific models (e.g. Edington, 1983), a conceptual framework was derived (see figure 1). It explains how an OHM can affect organizational performance. According to the resource-based view, material and immaterial resources must be combined to generate superior resources. The OHM measures can be interpreted as material resources. The employees with their characteristics affected by the OHM measures can be interpreted as immaterial resources. The combination of material and immaterial resources results in superior resources, which have an effect on organizational performance. The superior resources represent a mediator of the relationship of an OHM and the organizational performance. Accordingly, mediators include all effects of an OHM on employees and their social relationships as well as the associated changes in attitudes, behavior or abilities and their effects on health-specific aspects (Edington, 1983) and (Badura et al., 2008). In spite of the impact of OHM on organizational performance via mediators described above, primary studies will be considered that report relevant statistic on the direct link. The conceptual framework of this research project integrates the results of all selected primary studies.

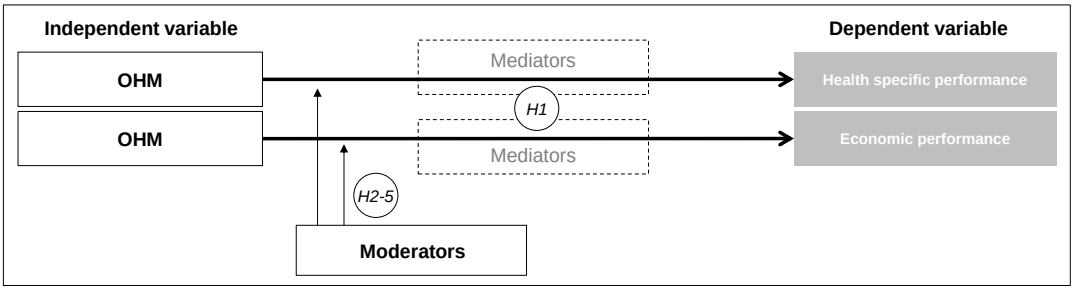

Figure 1: Visualization of the conceptual framework

The focus here is on the question of an impact-oriented design from a management perspective, which is discussed on the basis of the moderator analysis. Basically, moderators (see figure 2) are variables that can affect the direction and strength of the relationship between an independent and a dependent variable. The hypotheses H2-5 refer to the moderators.

Moderator	Description of Coding
Non-systematic OHM vs. systematic OHM	The dummy variable is encoded with 1 if it is a systematic OHM, otherwise 0.
Purely pathogenetic approach of OHM vs. salutogenetic approach of an OHM	The dummy variable is encoded with 1 if it is a salutogenetic approach of an OHM, otherwise 0.
Uncertified OHM Vs. certified OHM	The dummy variable is encoded with 1 if it is a certified OHM, otherwise 0.
Newly implemented OHM vs. existing OHM	The dummy variable is encoded with 1 if the effect of an existing OHM is measured, otherwise 0.

Figure 2: Coding scheme

An OHM has the primary objective to promote employee health. The OHM measures can be interpreted as material resources (e.g. imparting knowledge to managers for health-oriented leadership). The employees with their characteristics affected by the OHM measures can be interpreted as immaterial resources (e.g. coping strategies of the employees). The combination of them results in superior resources (e.g. reduced sensitivity to stress, psychological and physical well-being), which have an effect on the organizational performance (e.g. less absenteeism). H1.1: OHM improves health-specific organizational performance. An OHM also affects the social capital in the organization and thus the satisfaction. This leads to increased productivity (Badura and Hehlmann, 2003). H1.2: OHM improves economic organizational performance.

An OHM can be very different and differs in the amount and intensity of implemented OHM elements. Various descriptions can be found in the literature (e.g. maturity levels (Zwetsloot, 2000). An OHM with all kinds of elements rather represents a complete management process. This gives the OHM its systematic character. An underlying complete management process ensures continuous improvement. H2.1: A systematic OHM has a stronger effect on health-specific organizational performance than non-systematic OHM. H2.2: A systematic OHM has a stronger impact on economic organizational performance than a non-systematic OHM.

In the purely pathogenetic OHM approach (only with pathogenetic OHM measures), the focus is on the identification of existing diseases and risks as well as prevention in the sense of avoiding such procedural and physical risks. In the salutogenetic OHM approach (pathogenetic and salutogenetic OHM measures), the focus is also on strengthening health resources. Since the salutogenetic OHM approach represents a supplementation of the

pathogenetic, a stronger effect is to be expected from the former. H3.1: A purely pathogenetic OHM approach has a weaker effect on health-specific organizational performance than a salutogenetic OHM approach. H3.2: A purely pathogenetic OHM approach has a weaker effect on economic organizational performance than a salutogenetic OHM approach.

Health and safety certifications (e.g., OHSAS 18001 or DIN SPEC 91020) are based on management systems of other domains (e.g., quality) and therefore provide a systematic implementation. By contrast, non-certified OHMs cannot be systematically available, so that a stronger effect of the certified OHM can generally be assumed. H4.1: A certified OHM has a stronger effect on health-specific organizational performance than a non-certified OHM. H4.2: A certified OHM has a stronger effect on economic organizational performance than a non-certified OHM.

For existing OHMs, there is the opportunity to profit more from the process of continuous improvement. Through learning effects and experiences, both the OHM itself and the employees' behaviors become better, so there are stronger effects on organizational performance than with newly implemented OHM. H5.1: A newly implemented OHM has a weaker effect on health-specific organizational performance than an existing OHM. H5.2: A newly implemented OHM has a weaker effect on economic organizational performance than an existing OHM.

Methods

Search Strategy

There are two basic approaches to literature research: systematic and cumulative research (Reed and Baxter, 2009). In systematic literature research, databases are systematically searched using search terms. Within the cumulative literature search approach, the bibliographies of the recorded primary studies are searched for further relevant ones.

Within the systematic approach quite general terms of the research field were used, which are assumed to be found in titles, abstracts or keywords (search terms: health management OR safety management OR health and safety management OR health programs OR safety programs OR health practices OR safety practices). As a result, fewer studies are overlooked compared to more specific expressions. However, the number of studies to be manually reviewed increases.

Various electronic databases were used to identify relevant studies: Academic Source Premier, Business Source Premier, EconBiz, JSTOR and Springer: Business and Economics, Science Direct were used. To identify unpublished dissertations, Dissertation Abstracts on-line is consulted. In addition to the named databases, Google Scholar was also used to identify scientific documents in the form of doc, docx, and pdf. documents that have not yet been published.

In the cumulative search, the bibliographies of all relevant primary studies were searched. In addition, by using the Social Sciences sub-database of the Web of Science (Social Science Citation Index (SSCI)) articles were researched, which refer to the examined article.

Selection Criteria

Primary studies that are selected must examine the relationship between an OHM and one or more organizational performance measures. In this context, indicators or key figures of economic success are selected that are directly related to the health situation of an organization and that influence financial measures. Thus, primary studies with absenteeism and accident/ injury rates are considered as organizational performance

measures. These are grouped together into a health-specific performance. In addition, productivity is considered separately as a purely economic organizational performance measure. This had to be a productivity indicator that relates to enterprise-level productivity.

The primary studies must ultimately be quantitative studies that report relevant statistic for the direct link between OHM and organizational performance. Studies are considered which were published in 1975 or later. The limitation of the period to be considered was made since the mid-1970s, the number of companies implementing a health promotion program has increased significantly. In addition, Antonovsky coined the term Salutogenesis in the 1970s. The restriction to English-language studies has been made since scientific papers are mostly written in English and due to the language skills of the author, it cannot be credibly asserted that studies in other languages are verifiable.

Integration of Effect Sizes

The correlation coefficient was used here as a uniform effect size measure, since it can be interpreted as the covariance of two standardized random variables and thus indicates to what extent the independent and the dependent variable covary, according to how strong the relationship between the two variables is. It is scale-invariant and conceptually corresponds to effect size. To integrate the effect sizes, the Hunter and Schmidt (2004) approach was used. Hereby, the non-transformed correlation coefficients are used to integrate the effect sizes and the moderator analysis with the correction of artifacts in the primary studies to obtain as accurate as possible estimates of the population effect.

An alternative approach from Hedges and Olkin (1985) based on a Fisher's z transformation weights large correlations more strongly than small ones, thereby overestimating the true correlation. Therefore, the more conservative approach of Hunter and Schmidt (2004) was used. Corrective procedures have been used which have become established in social science and for which the necessary information is given in the primary studies: sampling errors and measurement errors of the variables.

The sampling errors are considered here on their weighting. The weighting is done via the inverse of the variance. The measurement errors of the variables were corrected by the reliabilities specified in the primary studies.

For the integration of the effect sizes and the moderator analysis, the random effects model (RE) was chosen. The RE model assumes that, unlike the fixed effects model (FE), there is not only a constant “true effect”, but that this “true population effect” can vary and therefore has a distribution. The reasons for this dispersion are the “within study” variance (see FE model) and the “between study” variance. The main difference between the RE model and the FE model ultimately lies in the consideration of this additional variance component of the “between study” variance. This results in different variances and consequently different weightings in the integration of the effect sizes. Consequently, the values of the integrated effect sizes, the confidence intervals and the derived statements on significance differ (Borenstein et al., 2009).

Metaregression

The RE meta-regression implemented here is used for the hypothesis test. It is based on the assumption that the overall variability of the effects is not fully explained by the moderators considered. Therefore, besides the “within study” variance, the additional component of the “between study” variance has to be integrated into the regression model. Both variance components are also taken into account in the calculation of the weighting factors, as part of the weighted regression. The general model of RE meta-regression (Eisend, 2014) is shown below:

$$ES_i = \beta_0 + \sum_{k=1}^{i} \beta_i X_i + e_i, \text{ with } e_i = v_i + \zeta_i \quad (1)$$

β_0 corresponds to the constant factor, β_i are the regression coefficients preceding the independent moderator variables, and e_i are the error terms. e_i is composed of the "within study" variance component v_i and the "between study" variance component ζ_i. The dependent variable ES_i is the effect size, which indicates the strength of the relationship between an OHM and organizational performance. The independent variables X_i correspond to the moderators. Eight metaregressions are performed in which each moderator variable is merged individually with each organizational performance measure in a regression. The calculated regression coefficients β_i indicate the difference between the average effect sizes for the different forms of moderators. The regression coefficient β_i is tested for significance using a t-test, where the null hypothesis is: H0: β_i = 0. The two-tailed t-test is based on the following test statistic:

$$t = \frac{\hat{\beta}_i}{\hat{\sigma}_{\hat{\beta}_i}} \quad (2)$$

$\hat{\sigma}_{\hat{\beta}_i}$ indicates the standard error of the regression coefficient and $\hat{\beta}_i$ expresses the difference between the effect sizes within the two moderator categories. The choice of the standard error to be estimated is essential as it could result in errors in the calculation of statistical significance. In this work, the revised robust HC3 standard error is used because it provides more reliable results in small samples (N <250) and is robust in terms of heteroscedasticity (Long and Ervin, 2000). The p-value of the t-test provides information about the significance of the difference. Due to the small sample sizes, a bootstrapping is performed to calculate the p-value.

Results

The following figure shows the result of the meta-analysis, the calculated integrated effect sizes for the two organization performance measures. In addition to the integrated effect sizes for the health-specific and economical organization performance, the p-values of the z-test and the t-test are shown as well as results of the sensitivity analysis in the form of fail-safe N and a rank correlation test.

DV	K	$ES_{integrated}$	P_z	P_t	Fail-safe N	$P_{rc\text{-}test}$
HS	*24*	*-0,2527****	*0,000*	*0,000*	*320*	*0,328*
E	*8*	*0,1865**	*0,029*	*0,065*	*9*	*0,500*

*DV: Dependent Variable of Metaregression; HS: Health Specific Performance; E: Economic Performance; K: Number of Effect Sizes of the Primary Studies; ES: Integrated Effect Sizes; P_z: P-Value z-Tests; P_t: P-Value of t-Tests; $P_{rc\text{-}test}$: Begg & Mazumdar Rank correlation test; ***/**/*: Significance at 0,01/0,05/0,1-Significance Level, based on P-Value of the t-Tests.*

Figure 3: Results of meta-analysis: Integrated effect sizes

The effect size of an OHM for health-specific organizational performance is significant at the 1% level (p = 0.000). This means that the implementation of an OHM has a significant effect on health-specific organizational performance and can lead to a reduction in absenteeism. With regard to the sensitivity analysis, the fail-safe N of 320, as measured by the recommendation of Rosenthal 1979 (5k + 10 <Fail-safe N, i.d.F. 5 * 24 + 10 = 130 <320), is sufficiently large and the rank correlation not significant. Thus,

publication bias can be excluded with high probability. H1.1 can be maintained. The effect size of an OHM for economic organizational performance is significant at the 10% level (p = 0.065). That means the implementation of an OHM has a significant effect on organizational performance and can lead to increased productivity. Here, however, the fail-safe N (= 8) is not sufficiently large. The probability of publication bias is relatively high, even if the rank correlation is not significant. H1.2 can be maintained.

Looking at the results of the metaregressions, it should first be noted that the effect of a systematic OHM on the health-specific organization performance at the 5% level is significantly greater (p = 0.026) than in a non-systematic OHM. Thus, a systematic strategic implementation has a stronger effect on the health-specific performance in terms of a reduction in absenteeism, as the implementation of individual elements. H2.1 can be maintained. The effect of systemic OHM on economic organization performance tends to be stronger (β = 0.0450) than in non-systematic OHM, but the difference is not significant (p = 0.811). The assumption suggests that a systematic OHM also has a stronger effect on economic performance in terms of increasing productivity than the implementation of individual elements. However, it is statistically undetectable in this case. H2.2 must be rejected.

DV	Moderator	K	N	ß	P_z	P_t	P_t bootstrap
HS	*NSYS vs. SYS*	*24*	*14115*	*-0,1857***	*0,015*	*0,026*	*0,101*
E	*NSYS vs. SYS*	*8*	*2897*	*0,0450*	*0,804*	*0,811*	*0,479*
HS	*PATHO vs. SALU*	*24*	*14115*	*0,0783*	*0,498*	*0,629*	*0,464*
E	*PATHO vs. SALU*	*8*	*2897*	*0,0144*	*0,944*	*0,945*	*0,512*
HS	*NCERT vs. CERT*	*24*	*14115*	*0,0163*	*0,863*	*0,891*	*0,449*
E	*NCERT vs. CERT*	*8*	*2897*	*-0,1891*	*0,237*	*0,391*	*0,115*
HS	*NEW vs. EXIST*	*24*	*14115*	*0,0712*	*0,484*	*0,551*	*0,427*
E	*NEW vs. EXIST*	*8*	*2897*	*0,0318*	*0,858*	*0,886*	*0,523*

DV: Dependent Variable of Metaregression; HS: Health Specific Performance; E: Economic Performance; K: Number of Effect Sizes of the Primary Studies; ß: Regression Coefficient; P_z: P-Value of z-Tests; P_t: P-Value of t-Tests with HC3-Standard Error (Based on Own Calculation); $P_{t\ bootstrap}$: P-Value of t-Tests Based on Bootstrapping with 2000 Reps (Based on Own Calculation);
****/**/*: Significance at 0,01/0,05/0,1-Significance Level, based on P-Value of the regular t-Tests.*

Figure 4: Results of Meta-regressions

In addition, there is no significant difference in the effects on the health-related organizational performance of a purely pathogenetic OHM approach and a salutogenetic OHM approach (p = 0.629). In terms of absenteeism, a purely pathogenetic OHM approach tends to have a stronger effect (not statistically detectable) than a salutogenetic OHM approach (ß = 0.0783). H3.1 must be rejected. There is also no significant difference between a purely pathogenetic OHM approach and a salutogenetic OHM approach in terms of effects on economic organizational performance (p = 0.945). In terms of productivity, a salutogenetic OHM approach tends to have a stronger effect (statically not detectable) than a salutogenetic OHM approach (β = 0.0144). H3.2 must be rejected. Also, there is no significant difference in effects on the health-specific organizational performance between a certified OHM and a non-certified OHM (p = 0.891). In terms of absenteeism, a non-certified OHM tends to have a stronger effect (not statistically detectable) than a certified OHM (ß = 0.0163). H4.1 must be rejected. The same applies to the economic organizational performance measure, whereby a very low

p-value based on the applied bootstrapping is recorded here (p = 0.391, pt bootstrap = 0.115). Nevertheless, H4.2 must be rejected.

H5.1 and H5.2 must also be rejected because there is no significantly different effect between a newly implemented and existing OHM. In terms of absenteeism, a newly implemented OHM tends to have a stronger effect (not statistically detectable) than an existing OHM (ß = 0.0712). In terms of productivity, it is the other way round (ß = 0.0318).

Discussion

Recommendations

For organizations, the implementation of an OHM is recommended. Implementation can reduce absenteeism and increases productivity. Here are both direct, as well as permanent effects recognizable. In addition, to improve organizational performance, it is not absolutely necessary to have a certification that often appears to be laborious. The implementation can be started with little use of resources. For organizations, the implementation of a systematic OHM is recommended. In principle, however, the focus should not only be on diseases and risks, but also on strengthening health resources. Often it is useful in organizations to start with the implementation of occupational safety management (or use of an existing one) and to carry out a gradual expansion. This can be, for example, through the extension of occupational health and safety committees by health commissioners and other managers as well as employee representatives or through the introduction of health promotion measures.

Implications for further research

20 of the 28 primary studies are from 2010 or later. Further studies on the investigated relationship are expected in the next few years. Thus, after some time, an update of the present research work would be possible. Here, the meta-analyses and metaregressions could be performed without the primary studies that report only betas from multiple regression analyses. For while carrying out this research, Roth et al. (2018) note in their work that the inclusion of betas from multiple regressions can lead to strong distortions of results. In the context of this work, betas from multiple regressions were included in the meta-analysis (Peterson and Brown, 2005). However, the calculated integrated effect size has been reduced, so that this procedure corresponds to a more conservative variant. Inclusion in the metaregressions changed the results negligible. In addition, an extension of this study could follow, in particular with regard to the performance measure of productivity (8 primary studies) to verify larger sample results. In addition, other dependent variables could be considered. Since the present work only examined the direct relationship between an OHM and the organizational performance, further studies on this topic should also include mediators in their analysis in order to answer not only the question of the benefit, but also more detailed recommendations for the procedure for the implementation in organizations. A meta-analytic structural equation model could offer here. Future research on the relationship between OHM and organizational performance should focus more on salutogenetic OHM approaches and its long-term impact. Most of the identified studies investigated the effect of a purely pathogenetic OHM approach and extended to less than five years. It would be interesting to consider the effect of salutogenetic approaches, which in particular would have to be designed in the long term until additional effects through the strengthening of health resources become visible. Finally, a more in-depth analysis would be interesting to address the reasons for the non-existent differences between a certified and non-certified OHM (e.g. Lack of

Commitment in Certified Organizations vs. High Awareness of Systematic Implementation in Non-Certified Organizations).

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How third-party social sustainability certifiers lend legitimacy to multinationals in the supply chain

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Abstract

This study brings the underrepresented perspective of third-party certifiers to the social sustainability literature and explores the ways through which third-party certification can lend legitimacy to organisations. Drawing on Suchman's (1995) legitimacy theory, we reveal that organisations can purchase pragmatic legitimacy, garner moral legitimacy but cannot arguably achieve cognitive legitimacy through simply adopting standards. For would-be adopters, managers need to consider what types of legitimacy can best be gained from the adoption of a certain social sustainability standard. Certifiers also need to develop a better understanding of how their initiatives promote each type of legitimacy.

Keywords: Social sustainability, Legitimacy, Third-party certifier (TPC)

Introduction

A series of different campaigns by non-governmental organisations (NGOs) has heightened public awareness of the potentially unethical conduct of multinational organisations (Burchell and Cook, 2013). Multinationals often struggle with social sustainability issues regarding, e.g. child labour, health and safety, and human rights (Huq *et al.*, 2014; Yawar and Seuring, 2017). As the risk of public criticism about social sustainability issues has increased, third-party certification of social sustainability standards (e.g. Fairtrade and Rainforest Alliance), have been voluntarily adopted by multinational supply chains (Reinecke *et al.*, 2012). These standards are used by multinational organisations as a means of gaining perceived legitimacy (Brunsson *et al.*, 2012) and/or reducing potential legitimacy threats for stakeholders in the supply chain (Vurro *et al.*, 2009). Legitimacy motives are key drivers for social sustainability initiatives, outstripping in popularity those related to profitability (Brønn and Vidaver-Cohen, 2009). It is argued that new actors including NGOs, industry associations and public-private partnerships currently provide the normative framework that corporations use for social sustainability legitimacy (Giovannucci and Ponte, 2005).

In consequence, firms are progressively implementing social sustainability 'signals' in the form of certifications, codes of conduct, sustainability standards and product

guidelines to improve sustainability across their supply chains (Gereffi *et al*., 2005; Mueller *et al*., 2009; Wijen, 2014). Given the proliferation of social sustainability initiatives, the legitimacy of the competing assessments is of vital importance to their longevity. Each one, therefore, draws on particular legitimacy grounds as the justification of their approach as the logical – ergo legitimate – choice for firms seeking external validation of their social sustainability credentials.

Signalling theory (Spence, 1973) suggests a relationship between the adoption of social sustainability standards and legitimacy because "without legitimacy would-be adopters are unlikely to follow a standard" (Brunsson *et al.*, 2012, p. 619). This argument assumes that third-party certifiers (TPCs) lend legitimacy to would-be adopters in gaining perceived legitimacy or reducing potential legitimacy threats; an assumption that has yet to be examined. Most studies of legitimacy have sought to understand the motivations and approaches of the adoption (e.g. Bowler *et al.*, 2017) and consumer's attitudes and perceptions of certified products and retailers (e.g. Anagnostou *et al.*, 2015). However, little is known of the mechanisms for lending legitimacy from the perspective of TPCs. We draw on Suchman's (1995) three forms of legitimacy – pragmatic, moral and cognitive – to investigate what types of legitimacy are associated with these assessments.

We present an exploratory, multi-case study of 8 global TPCs to explore ways through which third-party certification can lend legitimacy to would-be adopters, asking: *How do third-party social sustainability certifiers lend legitimacy to multinationals in the supply chain?*

Literature review

Suchman (1995, p. 574) defines legitimacy as "*a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definitions*". As there are competing TPCs, none of which has a status clearly above the others, the legitimacy of each TPC comes into question. Sustainability 'signalling' increases the legitimacy of the firm only if the TPC holds sufficient levels of legitimacy. Yet legitimacy is one of the key criticisms against TPC (Mueller *et al*., 2009). As Ashforth and Gibbs (1990, p. 177) aptly describe legitimacy: *"like beauty, it resides in the eye of the beholder"* it follows that TPCs must first have legitimacy in order to then lend legitimacy to supply chains. In this section, three forms of legitimacy - pragmatic, moral and cognitive - as presented by Suchman (1995) are thus presented and discussed in relation to social sustainability in supply chains.

Pragmatic legitimacy relates to the self-interested calculations of the audience of the entity seeking legitimacy (Suchman, 1995). Pragmatic legitimacy can take two forms: exchange legitimacy and influence legitimacy (Suchman, 1995). The former relates to support for an entity's policy based on its expected value to the entity's constituents (Dowling and Pfeffer, 1975). For example in the wood industry context firms only want certificates that provide some marketplace benefits to them and are reasonably priced, thus highlighting the importance of pragmatic legitimacy to those considering certification (Schepers, 2010). In the case of social sustainability, this translates to firms selecting third-party certification because of its positive impact on business, e.g. through avoidance of consumer boycotts and/or increased sales (Cashore, 2002). Product labelling that incorporates social sustainability credentials can therefore act as a signal or product quality and a source of competitiveness (Hartlieb and Jones, 2009). The latter, influence legitimacy, concerns constituents supporting an entity because it fits with their larger interests rather than any specific beneficial exchanges. Social sustainability certifiers must therefore understand the self-interest of the supply chain actors that they are

attempting to persuade. Actors may raise concerns about the ease, flexibility and speed with which the certification can be conducted, the relevance of the certification, the availability of suppliers with desired commodities on offer, and its overall financial and efficiency benefits (Cashore *et al*., 2003; Castka and Balzarova, 2008; Glover *et al*., 2014; Heugens and Lander, 2009; Schepers, 2010). Such overall benefits may focus on, for example, increased supply chain visibility offered by the audited chain, and different assessment options for products with different characteristics (Awaysheh and Klassen, 2010; Barratt and Oke, 2007).

Moral legitimacy, on the other hand, does not relate to transactional benefits but to what is seen as the right thing to do, e.g. in relation to social welfare (Suchman, 1995). It involves moral judgments on an organisation's output, processes and forms of management (Palazzo and Scherer, 2006). The pragmatic legitimacy of governance schemes does not remove the need for them to also possess moral legitimacy; they need to have sufficient procedures to gain approval (Schepers, 2010). A clear linkage between moral legitimacy and social sustainability signalling is evident; adhering to a TPC because providing a fair wage and living conditions to workers and suppliers is the altruistic, right, and moral expectation from any firm's actions. Moral legitimacy can be categorised into several alternatives (Suchman, 1995): (1) consequential (based on what the entity accomplishes), (2) procedural (based on what the entity does to achieve the outcomes) and (3) structural (based on how the entity is organised). As for social sustainability, these categories would relate to (1) achieving social justice and balanced global trade, (2) the intensity of monitoring and audit processes, and (3) clear and transparent governance including e.g. the openness of the standard-setting as well as which entities are involved in it (Cashore, 2002; MacDonald, 2007; Prado, 2013; Schepers, 2010).

The third form of legitimacy, cognitive, establishes an entity as legitimate "*when there is little question in the minds of actors that it serves as the natural way to effect some kind of collective action"* (Hannan and Carroll, 1992, p. 34). An entity or a form of organising is seen as the only comprehensible option that fits with everyone's view of the world, or it has become a given, taken for granted where alternatives are unthinkable (Robey, 2003; Suchman, 1995). To date, this form of legitimacy is unlikely to reflect social sustainability certification, as it has not reached a level of being seen superior to others in every way.

According to signalling theory (Spence, 1973), would-be adopters are very likely to follow a social sustainability standard to signal their legitimacy (Brunsson *et al*., 2012). This notion relies on the assumption that TPCs can actually lend the three types of legitimacy to would-be adopters who seek to gain perceived legitimacy or reduce potential legitimacy threats; an assumption that has yet to be examined. In response, we conducted a multi-case study of 8 global TPCs to explore ways through which third-party certification can lend legitimacy to would-be adopters.

Research Methodology

Data was collected via semi-structured interviews with representatives from 8 global TPCs by telephone or Skype (due to the global locations of the representatives) and then transcribed for analysis. In addition, internal documents (i.e. policy and strategy documents), and websites of the certifier were used in the analysis. Data were then coded, compared and discussed. We use Suchman's (1995) three forms of organisational legitimacy (i.e. pragmatic, moral, and cognitive) as a theoretical lens for analysis. Table 1 provides an anonymised overview of the TPCs that took part in the interviews.

Table 1 – Anonymised Overview of Certifiers

Third-party certifier	Products certified	Head office location
A	Cocoa, coffee, tea, cotton, flowers, bananas, dried fruit, honey, gold, fruit juices, rice, spice, herbs, sports balls, sugar, wine, beer, chocolate, sugar, honey, rice, quinoa, cosmetics, oils, walnut.	Europe
B	Oil, nuts, seeds, sugar, bananas, cocoa, fresh fruit, dried fruit, juices, coffee, honey, wine, quinoa, handicrafts, tea, flowers.	Latin America
C	Clothing, textiles, leather, footwear.	Europe
D	Bananas, cane sugar, cocoa, coffee, dried fruit, dried vegetables, flowers, fruit, fonio, fresh fruit, fruit juices, gold, herbs, honey, nuts, oilseeds, quinoa, rice, spices.	Europe
E	Handicrafts, clothing.	Europe
F	Sugar, handicrafts, bananas, coffee, cocoa.	Latin America
G	Coffee, cocoa, electronics, clothing, footwear.	USA
H	Electronics, textiles. clothing, footwear.	Europe

Findings

Despite what might have been expected given the topic, examples of moral legitimacy were less prevalent than those related to pragmatic legitimacy. For pragmatic legitimacy interviewees stressed the flexibility of their third-party certifications: "*[For auditing] internally our rules say they [supply chain actors] will have an initial, renewal and one per year audit but it is possible one maybe skipped according to our internal risk-based methodology, but this is more of an exception than a rule*" (D). "*Depending on the nature of the outcome of the risk assessment, it will be different for each member, so we will look at the complexity of the organization, the supply chain and how many products they have, this will determine their risk level - low to high - and their audit frequency*" (E). "*We take as a starting point the realities and impossibilities of producers within a certain context, that is, for example, one reason why we don't have time frames for compliance progress... and if there is a non-compliance with an issue that is not part of our central requirements then we allow the members to draw up an improvement plan*" (F). The competitive cost of the TPC's audit programme was an important differentiator for Certifier E: "*If you remember we say that if you behave well we will reward members, so having an audit only every 6 years is good as costs are reduced every year compared to other systems*" (E). Others focused on the availability and credentials of their auditors: *"We have local 120 auditors and we look for local ones [to complete an audit]*" (D). "*It's a more focused approach. It takes longer, it takes our assessors longer to do this type of assessment*" (G) and "*we have more than 50 people in the field supporting producers...who are well connected in the country and with our members*" (A). Certifiers D and E were also explicit about the financial benefits of their TPC: "*[supply chain actors] have an increase in 10-15% of trade through [social sustainability signal]*" (D). "*I think most members [of the social sustainability signal] have reported increased sales*" (E).

In drawing on moral legitimacy, Certifier A used its advocacy role as a differentiator. "*We do more than getting them [supply chain actors] to adopt certification, we do advocacy on trade justice…this is an example of what makes us different. We are actually interested and would actively advocate for issues on social sustainability*" (A). Certifier

D focused on collective bargaining being the morally right thing to support. "*We believe in the power of many. So if you have a collection of farmers rather than a single one, their bargaining power is much greater and so they are able to get a better deal out of whatever they are trading*" (D). A point also echoed by Certifier A when discussing their approach to supporting the sale of goods at a fair price as the correct thing to do because "*you are not doing me a favour by buying it*" (A). Morality appeared to underpin the ethos of Certifier F. "*We don't stop talking about it [social sustainability] with our members. About how to maintain moral values and respect these and not become cold and sterile in our procedures*" (F). Making reporting publicly available was used as a moral legitimacy argument from Certifier G. "*The fact that it [social sustainability] is still reported out publicly, I think sets us apart from what I've seen from other [social sustainability] organizations as well*" (G).

In considering assessment procedures as moral legitimacy arguments, stringency was highlighted by Certifier D. "*[For assessment] I know we have a reputation within the trade as being one of the strictest and most rigorous*" (D). Developing bespoke assessment procedures was also viewed as important. "*We have our own standards and our own compliance criteria that are different from some other (social sustainability assessment) organisations*" (E). Certifier B was very clear that standard setting and governance procedures were driven by the producers. Apart from Certifier C, moral legitimacy was used by all TPCs in the study. It seemed to be used to distinguish one TPC from another, with each TPC providing evidence of how their particular approach to social sustainability was based on a moral obligation, stringent assessment procedures and/or transparent governance.

As expected, we did not find evidence of any of the TPCs using arguments based on cognitive legitimacy. There was, however, some discussion about the merging of TPCs "*if competition becomes too tough*" (A) and the move towards a more uniform or 'superstandard'. One TPC, in particular, was less in favour of this approach: "*For social sustainability to have this uniformisation taking place it does worry me. In the end, there will be an orientation to one type of criteria with different franchises who administer these types of criteria but they will have to be very similar or the same ... but in the end, if you look from the poor side of the world and poor producers this becomes a barrier for help and development, the original idea of certification becomes more a filter than a development*" (F). This sentiment was not echoed by all. "*We should not compete in this field…in the end, the aim is to improve the working conditions. So why not work it together?*" (H). These comments could relate in some way to a cognitive legitimacy argument based on social sustainability being the only way to organise supply chains; nevertheless, there was a lack of consensus as to how this can or should be operationalised.

Discussion

In the following, we will provide a discussion of the competing forms of legitimacy as evident among the TPCs.

Third-party certifiers (TPCs) in competition to promote their legitimacy

Recent studies have documented the increase in proliferation of sustainability certifications, particularly within the coffee sector (Ingenbleek and Reinders, 2013; Reinecke *et al*., 2012). For quality and environmental management systems, there are standards that dominate (Boiral, 2003, 2007). Yet this is not the case for social sustainability where a variety of norms, codes of conduct and initiatives are present (Castka and Balzarova, 2008). It is argued that the proliferation of social sustainability

assessment has led to competition for adoption by multinational organisations in order to reinforce the legitimacy of particular assessment practices (Gereffi *et al*, 2001). The likelihood of organisational survival increases with legitimacy (Dowling and Pfeffer, 1975), and thus it should be unsurprising that our research identified that these competing TPCs have to defend their own legitimacy, just as the firms that acquire their certification have to. As our interviews demonstrated, the TPCs have some awareness of the potential competition and vocalised potential risk in not being seen as the legitimate alternative. Being very specific about how they articulate their distinctiveness using different forms of legitimacy was a clear illustration of this. Organisations that do not have complete legitimacy as perceived by their constituents must not only exemplify desirable characteristics but also promote them (Ashforth and Gibbs, 1990). As none of the TPCs in our study possesses the cognitive, taken-for-granted legitimacy, they must argue for their own legitimacy to become perceived as the preferred option. The field of social sustainability is demonstrating meta-standardization, where there is agreement about the 'rules of the game' at a general level, but differentiation exists as regards its assessment (Reinecke *et al*., 2012).

The TPCs in our study seem to utilise multiple legitimacy arguments; although most focus on either a more strategic or a more ethical standpoint to set them apart. Specifically, pragmatic legitimacy appears to be an important emergent theme in our study. In the following section, we discuss this finding in more detail.

Pragmatic legitimacy a key element

Most institutional scholars focused primarily on conformance discuss adoption to gain acceptance, whereas organizational performance scholars argue that firms will always prefer practices that give financial benefits over social conformity (Heugens and Lander, 2009). Firms can take up sustainability standards for instrumental, relational or moral drivers (Wijen, 2014). Motivations to adopt objects of institutional pressures (such as total quality management, sustainability standards or corporate social responsibility) can stem from endeavors for legitimacy and ethical objectives as well as more calculated economic and strategic objectives or infrastructural convenience (Castka and Balzarova, 2008; Crilly *et al*., 2012; Ingram and Simons, 1995; Kennedy and Fiss, 2009). Sustainability standards may be a mechanism to differentiate and charge a premium price (Wijen, 2014). As Kennedy and Fiss (2009, p. 911) succinctly state: "*wanting to look good does not preclude also wanting to do better*".

Our study indicates that these social sustainability TPCs have recognised the coexistence of economic and legitimacy motivations in their target population, as many appear to focus almost exclusively on the pragmatic legitimacy of their scheme through, e.g. a focus on continuous improvement, flexible audit cycles, branding and marketing to assist in sales and providing traceability of the chain. Our findings are in line with Oliver (1991) and Goodstein (1994) who argue that if institutional pressures clash with organisational goals, or reduce decision-making discretion, resistance is more likely. Thus the social sustainability TPCs appear to be offering firms a path of least resistance by developing processes such that they fit with, and provide benefit to, their existing business practices. Environmental supply chain practices have been able to present tangible operational and financial benefits through, e.g. waste reduction and lowering the costs of inputs (Bansal and Roth, 2000; Roome and Wijen, 2006; Russo and Fouts, 1997). Yet for social sustainability in supply chains, the measurement of financial benefits is both less developed and has fewer demonstrable supporting findings (Pullman *et al*., 2009; Sancha *et al*., 2015), prompting the need to emphasise pragmatic legitimacy as identified in our findings.

Standards differentiation is partly driven by "*claims to moral authority over the definition of what a sustainability standard should provide*" (Reinecke *et al*., 2012:798). This was evident in our findings as we noticed parallel strands of what is the 'right thing to do' depending on the focus of the certification under scrutiny. For example, TPC D was explicit about its reputation for 'stringent processes' whilst TPCs A and B, for example, spoke about social sustainability as being the morally correct course of action. It is important to note, however, that these parallel strands may exist within each TPC, and that a focus on one does not preclude the occurrence of the other. For example, a TPC may focus on the moral imperative of social sustainability yet this does not necessarily mean that its standards are weak or its governance lax.

Cognitive legitimacy was not evident from our interviews; which is logical given how we view the issue of social sustainability certification as still only becoming institutionalised. As nongovernmental organisations are increasingly under constant public examination, they could attempt to increase their legitimacy by co-developing sustainability standards (Wijen, 2014). While a couple of the interviewees mentioned that perhaps in the future a 'superstandard' or greater collaboration between TPCs could emerge, none of them actively mentioned their collaboration with other social sustainability TPCs during the interviews, nor brought it forward as a key aspect of their operations. This finding is in line with studies on emerging domains, in which mutual interests are recognised by the actors, yet little coordination is observed (Avetisyan and Ferrary, 2013).

Conclusion

The study has attempted to bring the underrepresented perspective of TPCs to the social sustainability literature and explored the ways through which third-party certification can lend legitimacy to organisations. We reveal the mechanisms used to lend legitimacy to supply chains seeking to gain three different types of legitimacy, i.e. pragmatic, moral, and cognitive legitimacy (Suchman, 1995). Results demonstrate that the most common type of legitimacy lent by TPCs is pragmatic legitimacy, i.e. based on self-interest calculations (Suchman, 1995). Certifiers stressed the availability and flexibility of their auditing programmes and highlighted the financial benefits and rewards of their standards. For example, one certifier mentioned that most firms had reported increased sales after the adoption of their social sustainability standard. In terms of moral legitimacy, based on normative approval resting on what is the right thing to do (Suchman, 1995), certifiers put forward different initiatives to promote moral legitimacy, e.g. advocacy on trade justice, collective bargaining, stringent assessment procedures, and public disclosure. Adopting firms can, therefore, garner moral legitimacy by embracing these initiatives. As expected, cognitive legitimacy, based on comprehensibility and taken-for-grantedness (Suchman, 1995), is unlikely to reflect social sustainability standards, as socially sustainable goods have not reached a level of being seen superior to others in every way. In other words, organisations can purchase pragmatic legitimacy, garner moral legitimacy but cannot arguably achieve cognitive legitimacy through simply adopting standards.

For would-be adopters, managers need to consider what types of legitimacy can best be gained from the adoption of a certain social sustainability standard. For example, TPCs are confident of lending pragmatic legitimacy through, e.g. flexible audit cycles, branding and marketing to assist in sales and providing traceability of the chain. Managers also need to be aware that cognitive legitimacy is unlikely to be obtained through the adoption of a standard. For certifiers, work is needed in developing a clearer understanding of how their initiatives promote each type of legitimacy and hence are attractive to supply chains.

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Social sustainability indicators of food supply chain - cases of food manufacturing firms in Thailand

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Abstract

The purpose of this research is to answer the question *what are the social sustainability indicators for the food supply chain, from food manufacturing firm's perspective in Thailand*. There has been an increased interest in sustainability during the past decades, particularly in social sustainability aspect. However, a study of social sustainability indicators is still in its infancy (Popovic et al., 2019). To date, there are still no specific indicators to measure social sustainability, particularly in the food industry. Hence, this research aims to fulfill the literature gaps by exploring the social sustainability indicators in the food supply chain in Thailand.

Keywords: food supply chain, sustainable supply chain, social sustainability

Introduction

The purpose of this research is to answer the question "*what are the social sustainability indicators for the food supply chain, from food manufacturing firm perspective in Thailand"*. The concept of helping operationalize sustainability is the triple bottom line (TBL), which provides a framework for measuring the performance of the business and success of the organization using three dimensions: economic, social, and environmental (Goel, 2010).

Social sustainability is one of the dimensions in TBL, but this dimension has received less attention in the literature and in practice, compared to the other two dimensions which are economic and environmental sustainability (Mani et al.,2016b; Eizenberg & Jabareen, 2017). The social sustainability refers to how social issues should be managed in a way that increased a corporation's long-term survival (Carter and Rogers, 2008). Social sustainability in the supply chain can be narrowed down to the product and process measures that determine the safety and welfare of the people in the chain (Mani, Agrawal & Sharma, 2015b), including suppliers, customers, employees and community. Despite the increased interest in social sustainability, a study of social sustainability indicators is still in its infancy (Popovic et al., 2019). Therefore, this research aims to explore social sustainability indicators through 4 cases with leading companies in Thai food industry.

This paper is exploratory research. It begins with the introduction, literature review on social sustainability in supply chain and social sustainability indicators, followed by research methodology to explain how the research was conducted. Based on the literature review, the conceptual framework on social sustainability indicators is developed as a data collection tool. Then, the data from 4 case studies are presented, followed by empirical studies and cross-case analysis which refine and enrich the conceptual from the literature. The paper ends with the conclusion that show the key findings and limitations.

Literature review

This research aims to answer the question "*what are the social sustainability indicators for the food supply chain, from food manufacturing firm's perspective in Thailand*". Hence, this section seeks to explore the existing literature beginning with the concept of Triple Bottom Line (TBL), social sustainability in the supply chain, its key indicators as well as its applications in supply chain context as described below in order to identify the key theoretical gaps as well as to build the conceptual framework from the existing literature.

Triple bottom line

The triple bottom line (TBL) is a sustainability-related construct (Elkington, 1998), provides a framework for measuring the performance of the business and the success of the organization using three dimensions: economic, social, and environmental (Goel, 2010). Elkington (1998) defined three dimensions as the economic dimension refers to company practices that affect to the economic system, the environmental dimension refers to a company practices on preserve the environmental resources for future generations, and the social dimension refers to fair practices and benefit to the labour, human capital, and to the community. TBL is the concept beneficial for a company to operationalize sustainability to achieve the economic, environmental, and social dimensions (Seuring and Muller, 2008). Therefore, firms need to adopt the TBL as a framework for firms' sustainability practices.

Social sustainability in the supply chain

Social sustainability is one of the dimensions in TBL, but the dimension has been received less attention in the literature and in practice (Mani et al., 2016b; Eizenberg & Jabareen, 2017). Social sustainability is about verifying and managing both positive and negative business impacts by focusing on social interactions, and is also related on how social issues should be managed in a way that increased a company's long-term survival (Carter and Rogers, 2008). Social sustainability in the supply chain can be narrowed down to the product and process measures that determine the safety and welfare of the people in the chain (Mani, Agrawal & Sharma, 2015b).

To adopt sustainability into a firm, firm need to adopt social sustainability toward all stakeholder in every stage in the supply chain that consist of suppliers, employees, consumers and community (Mani, Agrawal & Sharma, 2015a) to make the social impacts to society. This paper attempt to find how company could adopt sustainability with stakeholders in the supply chain by addressing social issues into their practice.

Social sustainability indicators

Sustainability indicators in economic and environmental dimensions have been increasingly addressed in several papers. However, the social dimension indicators receive less attention from both academia and practitioners (Ahi & Searcy, 2015), the increased interest in social sustainability there is still lack of information for the social assessment (Popovic et. al., 2019). In addition, the literature on sustainable development reveals that the social aspect is still in its infancy due to the lack of theoretical and empirical studies (Eizenberg & Jabareen, 2017). The most commonly mentioned of social sustainability indicator is the rather general category "occupational health and safety" (Mani et al., 2016a; Hutchins & Sutherland, 2008) and other social sustainability indicator such as gender equality (Mani et al., 2016b), labour equality (Hutchins & Sutherland, 2008) and income level and distributions (Spangenberg & Bonniot, 1998). United Nations Division for Sustainable development (UNDSD) classified sustainable indicators framework in social dimension such as equity, education, health, housing, security and population (UNDSD, 2001). Market indices that incorporate use to measure the sustainability, such as the Dow Jones Sustainability Index (DJSI) and FTSE4Good Index, do not fully capture the challenges of measuring sustainability at the level of the supply chain (Ahi and Searcy, 2015).

Therefore, this research on social sustainability indicators will be refined and enriched from 4 companies in the Thai food industry and aims to fulfil the literature gaps by exploring social sustainability indicators.

The conceptual framework

Social sustainability indicator in supply chain divided by the stakeholder that consist of suppliers, employees, consumers and community (Mani, Agrawal & Sharma, 2015a). Each supply chain units consist of social sustainability indicators shows in Table 1 that developed from literature.

Research methodology

This paper is exploratory research and adopted a qualitative research method to answer the research question "*what are the social sustainability indicators for the food supply chain, from food manufacturing firm's perspective in Thailand*".

To achieve the paper's purpose, a multiple case study (Yin, 2009) is applied. Semi-structured and in-depth interviews were conducted with 4 companies in the food manufacturing industry. Cases are selected based on 3 criteria; (i) companies within the food manufacturing industry, (ii) leading companies in sustainable performance and (iii) all companies are based in Thailand. Each firm has been socially contributing to society and is regarded as one of the best social practices in Thailand. In addition, each firm is financially sustainable. Food industry was picked in this research as Thailand's food export value is ranked amongst top five in the world, as a result, the practices in Thai food industry can be one of the world's leading practices. Table 2 presents the 4 companies' profile of this research.

Table 1- conceptual framework

Stakeholder	***Social sustainability indicator***	***Reference***
Employees	Employment	(Spangenberg & Bonniot, 1998)
	Labor Equity	(Mani et al. , 2016a), (Hutchins & Sutherland, 2008), (Mani et al. , 2016b)
	Health and safety	(Mani et al., 2016a), (Hutchins & Sutherland, 2008), (Mani, Gunasekarun, and Delgado, 2018), (Mani et al., 2016b)
	Workplace	(Mani et al., 2016a)
	Child and bonded labour	(Mani, Gunasekarun, and Delgado, 2018), (Mani et al., 2016b)
	Human Development	(Labuschagne, Brent, and Erck, 2005), (Spangenberg & Bonniot, 1998), (Mani, Gunasekarun, and Delgado, 2018), (Mani et al., 2016b)
	Wages	(Spangenberg & Bonniot, 1998), (Mani et al., 2016a), (Mani, Gunasekarun, and Delgado, 2018)
Supplier	Sourcing	(Mani, Agrawal & Sharma, 2015a), (Mani, Gunasekarun, and Delgado, 2018)
	Raw material price/ wages	(Mani et al., 2016a), (Mani, Gunasekarun, and Delgado, 2018), (Mani et al., 2016b)
	Procurement from minority enterprises	(Mani, Gunasekarun, and Delgado, 2018), (Mani et al., 2016b)
	Supplier engagement	(Mani, Agrawal & Sharma, 2015a), (Mani, Gunasekarun, and Delgado, 2018)
	Supplier education and learning	(Mani et al., 2016a), (Mani, Gunasekarun, and Delgado, 2018), (Mani, Agrawal & Sharma, 2015a)
Community	Health & safety	(Mani et al., 2016a)
	Employment	(Labuschagne, Brent, and Erck, 2005)
	Philanthropy	(Mani, Agrawal & Sharma, 2015a), (Mani et al., 2016a), (Mani et al., 2016b), (Mani, Gunasekarun, and Delgado, 2018)
Consumer	Education	(Mani, Agrawal & Sharma, 2015a)
	Safety	(Mani, Agrawal & Sharma, 2015a), (Mani, Gunasekarun, and Delgado, 2018)

Table 2- company profiles

Company	Products	Interviewee	Manufacturing Location	Methods of data collection
Company #1	Organic Dairy Products	Managing Director	Nakhon Ratchasima, Thailand	Semi-structured interview (face-to-face)
Company #2	Organic cereal drinks and bars	Managing Director	Suphanburi, Thailand	Semi-structured interview (face-to-face)
Company #3	Roasted Coffee	Managing Director	Chiang Mai, Thailand	Semi-structured interview (phone)
Company #4	Urban farming vegetables	Managing Director	Bangkok, Thailand	Semi-structured interview (face-to-face)

The conceptual framework on social sustainability indicators is developed as a data collection tool. Three interviews were conducted face-to-face with the managing director at the company headquarters, another one was conducted over the phone for approximately 60 minutes. Data is collected by using a semi-structured interview in this research and conducted in order to provide the informants a freedom to discuss over the topic. Interviews were conducted by one of the authors while the other two transcribed and observations.

To analyze the collected data, each case was analyzed individually then cross-case analysis was used. Finally, the conceptual framework on social sustainability measurement in the food supply chain is refined.

Empirical study & case analysis

Company #1

Company #1 is a dairy products manufacturer, transforms raw milk into wholesome dairy product. The company aims to foster organic ecosystems, free from a synthetic chemical.

The first for supplier, the company provides the supplier's training in manufacturing processes that help to reduce the problem on the lack of suppliers' know-how on production efficiency, which later can help improving their own productivity. Second, the company lets suppliers set the raw material prices themselves that aims to provide financial sustainability for suppliers. Lastly, the company provide fund for supplier's raw material and micro-lending as an initial investment for suppliers, helps tremendously to initiate the first loop of supplier's operations and keep them going. For employee, the company provides low interest micro-lending and high interest deposit fund to help decreasing employees' financial problems, and also pay wages slightly above the national legal minimum wages.

Company #2

Company #2 produces cereal-based products. The company provides knowledge for organic farming to farmers to stop pesticide usage, sources supply from them with fair price, then produces all products in-house and distributes to modern trade.

The company designs work process to avoid employees' heavy lifting. Employees receive individual health insurance and also annual medical examination which exclude

the nation labour law. For financial support, company provide education fund for employees' education for employee retention and also provides fund for supplier's raw material and machine which helps tremendously to initiate the first loop of supplier's operations and keep them going.

Company #3
Company #3 produces roasted ground coffee, sources coffee bean and coffee cherry from local villagers in the mountains. The company mainly focuses on suppliers' well-being economically. Raw material price based on negotiation between all of supplier and the company that is 15-20% higher than market price. In addition, the company provides knowledge to villagers from a local university.

Company #4
Company #4 collaborates with senior citizens club to educates retirees for urban organic farming and lets all retirees become urban farmers which generate their own revenue. Then all products deliver to nearby customer, which reduces logistic cost and maintains product freshness.

The company aims to solve the problem of aging society that retirees doing nothing at home, have no income and also seeing consumer's problem of unaffordable price of organic premium vegetable and how busy of urban life. For community, company generates revenue for retirees and recruits their family member to work with the company.

The case studies enriched and defined the conceptual framework. The cross-case analysis in the Table 3 and Table 4 shows that all of stakeholder consists of each own social sustainability indicators. Practices in all cases almost similar due to a similarity of the main objective that aimed to be a social enterprise.

The new indicators are added for two stakeholders; employees and suppliers. The first two indicators for employees are financial and family aspects. The employees' financial indicators are low-interest micro-lending and high-interest deposit fund for employees in a company for employee retention. The employees' family indicators are employees' children education fund and family involvement in company events, which retain employee relationships. The indicator emerged for suppliers is only from the financial aspect. The emerged supplier financial indicator is financial access (micro-lending) for suppliers which aims to help tremendously to initiate the first loop of supplier's operations and keep them going.

Table 3 – Cross-case analysis

Stakeholder	**Employee**									**Consumer**	
Social Indicators	Employment	Labor Equity	Health and safety	Workplace	Child and bonded labour	Human Development	Wages	**Financial**	**Family**	Education	Safety
Company #1	8 working hours a day. voluntarily overtime.	Male to female ratio is approximately 1:1. Job position based on physical appearance.	Social security. Company pay for employees' illness and accident which exclude social security.	-	-	2-3 training courses a year.	Slightly above the national legal minimum wages. All gender are equal.	Low interest micro-lending and high interest deposit fund for employees.	-	-	-
Company #2	8 working hours a day.	Male to female labor ratio is 15:85, male works as technician and female works in production process. Job position based on Physical appearance.	Individual health insurance. Annual medical examination. Company pay for employees' Illness and accident.	Work process designed to avoid heavy lifting.	-	2-3 training courses a year.	National legal minimum wages. All gender are equal.	-	Employee's family member could join the company's annual party. Employees' children education fund	-	-
Company #3	9-10 working hours a day. Bonus for overtime working. 15 vacation days (flexible).	Female labor is slightly greater than male labor.	Social security.	Working space and resting space are separated	-	In-house training. Monthly outing training.	Slightly above industry average wages.	-	-	Provide information about source of coffee. affordable price for qualitied coffee.	Product traceability.
Company #4	8 working hours a day.	Male to female labor ratio is approximate 1:1	Social security is in progress of registration.	-	-	On-site training 3 times a year.	National legal minimum wages and profit sharing. All gender are equal.	-	-		Short transport retain fresh produce.

Table 4 – Cross-case analysis

Stakeholder	**Supplier**							**Community**		
Social Indicators	Sourcing	Raw material price/ wages	Procurement from minority enterprises	Supplier engagement	Supplier education and learning	**Financial accessibility**	Family	Health & safety	Employment	CSR
Company #1	Create an organic dairy farm network to supply organic raw material.	Suppliers can set the raw material price	Buy other raw material from local organic farmer.	New practices and know-how sharing to supplier. Yearly audit.	supplier's yearly training in manufacturing processes.	Provide fund for supplier's raw material e.g. animal feed, organic fertilizer. micro-lending for supplier's	-	Zero waste community. Biodegradable plastic packaging.	Generate employment for community.	Local river preservation project.
Company #2	Main ingredient from its farmer union	Suppliers can set the raw material price	-	Provide knowledge for organic farming.	Organic farming training	Provide fund for supplier's raw material and machine.	-	Reduce pesticide usage.	Generate employment for community.	-
Company #3	-	Seasonal price negotiation between all of supplier with company, 15-20% more than market price	-	Provide knowledge by local university.	Supplier's training 3-4 courses a year.	-	-	-	Generate revenue for community.	everyone can visit the company and learning best practice from company
Company #4	Organic certified seed provider.	Market price	Procurement from minority farmer.	-	Annual on-site training	-	-	Affordable high quality vegetable	Generate revenue for retirees. Recruits supplier's family member to work as area manager.	Collaborated with senior citizens club to educate retirees to urban organic farming.

Conclusion

According to the case studies, we identified similar and different social sustainability indicators adopted by each company that include an organic dairy product manufacturer, an organic cereal-based products manufacturer, a roasted coffee manufacturer and an urban farming vegetables firm. Results are shown that the majority of social indicators in food manufacturing is related to employment, human development, health and safety, and wages. This is in line with the literature review which states that social sustainability determines the safety and welfare of the people in the chain.

Practices learned in all cases share the similarity of the company's objective on making social impacts to the society. The new indicators are emerged for two stakeholders; employees and suppliers. The first two social sustainability indicators for employee are financial and family aspects. Social sustainability indicator emerged for supplier is financial accessibility.

This paper fulfils theoretical gaps in social sustainability indicators, particularly in the food industry where social issues are highly emphasized and yet to be explored. The findings from this paper are beneficial for both academia and practitioner who seek to develop social sustainability indicators in supply chain. In addition, this research illustrates social sustainability indicators that each firm practices to all stakeholders in food supply chain, the findings will benefit food manufacturing firms in general, not limited to only in Thailand.

Last but not least, the results are based on the findings from only four case companies in the Thai food industry, more cases from different industries can help generalizing the research findings.

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On the measurement of social sustainability scales for multiple group analysis in advanced and developing economies

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Abstract:

This paper validates the social sustainability performance dimension from the fifth round of the Global Manufacturing Research Group survey. The scale is validated using exploratory factor analysis to ascertain no communality among factors. Common-method bias, discriminant and convergent validity, group measurement invariance for economy type (developing and industrialized) are satisfactorily tested. A structural causal model is offered, inspired by the structural contingency theory of organizations, the resource-based and the natural resource-based view of the firm. Future research aim at falsifying theories on the relationships between the type of economy and social sustainability, mediated by environmental management and moderated by uncertainty.

Keywords: corporate social responsibility, multi-group analysis, measurement invariance

Introduction

Sustainability issues are receiving increasing attention from academics and practitioners alike. Despite a growing number of publications on the subject, most papers have focused on environmental or economic sustainability, with relatively few publications focused on social sustainability and its effect on firm operational and strategic performance. However, sustainability effects on performance are often contradictory and may vary according to sustainability dimensions and context (Magon et al., 2018). Furthermore, sustainability practices effects may also differ for strategic and operational performance. For example, regarding context, Betts et al. (2018) found that the adoption of environmental practices and its effect on sustainability performance differ in advanced and developing economies. Manufacturing plants in developing economies appear to be more prone to engage in environmental management practices neoterically than manufacturers in developed economies. These results corroborate earlier findings from

Zhu et al. (2008) that found that manufacturers from the automotive industry in China were adopting more environmental practices than in the UK. It is also consistent with Schoenherr's (2012) findings on environmental practices effects on manufacturing operational performance according to the type of economy. Despite these earlier findings, there is no evidence that the same differences remain for other dimensions of the sustainability triple bottom line (Elkington, 1998), such as the economic and social dimensions. Furthermore, there is no evidence the effects of economy type act on both operational (say quality, costs, delivery and flexibility) and strategic performance (e.g., environmental and social sustainability).

This study combines the lenses of the contingency theory (CT) (Donaldson, 2001), the resource-based-view (RBV) of the firm (Barney, 1991), and the natural resource-based view (NRBV) of the firm (Hart, 1995) to shed lights on the sustainability practices – performance relationships. The CT states that contingencies affect organizational structure, the organizational structure affects performance, and the effects vary according to the context in which the organization operates (Lawrence and Lorsch, 1967, Thompson, 1967). In other terms, according to the CT, there is no unique or universal effect of sustainability practices on social sustainability performance. In Betts et al. (2016), internal monitoring, supplier monitoring and environmental management systems were mediators of the effect of the type of economy on sustainability performance, moderated by production capability. This paper posits that environmental uncertainty (EU) moderates the environmental practices-performance relationships. EU is a contextual variable moderating supply chain (SC) integration and operational performance (Wong et al., 2011), firm orientation, situational uncertainty and business/firm performance (Sitkin et al., 1994; Reed et al., 1996), platform strategy effects on product quality, innovation and profitability (Koufteros et al., 2005), among others. Despite its ample use in operation management practices contingency research (Sousa and Voss, 2008), the literature still fails to fully explore the moderating role of EU on the sustainability practices-performance relationships (Magon et al., 2018). The RBV and the NRBV complement the CT perspective. They help in understanding different mediating effects of the valuable, rare, inimitable and non-substitutable (VRIN) resources, such as the internal and external management practices of sustainability. Within the NRBV, resources that are rare and inimitable are deemed most important, such as pollution prevention technologies (Klassen and Whybark, 1999), and environmental management systems (e.g., Christmann, 2000).

In this context, this paper intends to answer the following research questions (RQs):

RQ1 – Do the type of economy (advanced & developing) have an effect on improved social sustainability and operational performance at the plant level?

RQ2 – To what extent do the internal, external and management environmental practices mediate the effect of the type of economy on improved social sustainability and operational performance at the plant level?

RQ3 – Are the direct and the mediated relationship between economy type and performance moderated by environmental uncertainty?

This paper contributes to filling the gap in the literature in important ways. First, it proposes the validation of a social sustainability scale, which will allow further development of causal models of sustainability practice effects on firm strategic and operational performance. Second, it tests a social sustainability scale for multi-group measurement invariance with a large international data set. Third, it offers a structural model and research hypothesis, based on CT and the RBV/NRBV theories, suggesting new research avenues. After this introduction, the next section presents the structural

model and hypothesis. The description of the methodology ensues. Conclusion and future research close the paper.

Structural model and hypothesis

This section introduces the key constructs guiding the research, and define the structural model and underlying hypothesis relating sustainability practices to operational and social sustainability performance.

Internal and external environmental practices

Sustainable manufacturing practices goes beyond the borders of the focal company in the SC. Internal sustainability management practices include sustainable new product development, procurement, production/manufacturing and remanufacturing. External sustainability includes suppliers and customers in efforts towards green and sustainable SC management (Kleindorfer et al., 2005). Yu et al. (2014) define internal Green SC management as the adoption of sustainability practices within a company, including environmental management systems and certifications (e.g. ISO 14001) and cross-functional cooperation for sustainability. External sustainability practices encompass the inclusion of the focal company's suppliers and customers in planning and management of sustainability practices. Together, internal and external sustainability management practices should lead to improved operational and sustainability performance.

The effect of the type of economy on sustainability performance

Schoenherr (2012) looked into how environmental initiatives such as ISO 14000 certification, pollution prevention, recycling and waste reduction impacted the competitive operational capabilities (quality, costs, delivery and flexibility) of plants in developing, emerging and developed countries. The author concludes that environmental initiatives have been greatly emphasized in emerging economies when compared with industrialized and developing economies. Furthermore, environmental management practices were more prevalent in emerging and developing economies than in the industrialized ones.

A greater effect of environmental management initiatives on operational performance is expected in developing and emerging nations due to the contingent effect of economic development on a plant's operational performance. Here, the location of the plant is used as a proxy to economic development, consistent with Zhu et al. (2008), Schoenherr (2012), and Betts et al. (2018). Plants in industrialized economies are more likely to have implemented sustainability management practices further than their counterparts in emerging and developing economies. Thus, a higher level of effort in applying sustainability practices would be required in industrialized economies to reach the same effect on operational performance. Therefore, the following hypothesis is put forward:

H1 – Environmental management practices' (internal monitoring, external monitoring, environmental management systems) effect on manufacturing operational and social sustainability performance will be higher in developing economies than in more advanced economies.

Mediating role of sustainability management practices

The RBV posits that VRIN resources will be conducive to superior performance. Hart (1995) considers sustainability practices as being VRIN resources. It is expected, according to theory, that plants engaging in higher levels of VRIN management practices will attain higher levels of performance. Consistent with Betts et al. (2018) this research posits that sustainability management practices of internal monitoring, monitoring

sustainability practices with suppliers and the use of sustainability management systems are the "causal mechanisms" explaining how operational and environmental gains are realized. Thus,
H2 – Higher levels of environmental management practices (internal monitoring, external monitoring, environmental management systems) results in higher levels of operational and social sustainability performance

H2a – Engagement in the practices of internal sustainability management mediates the effect of type of economy on operational and social sustainability performance

H2b - Engagement in the practices of external sustainability management mediates the effect of type of economy on operational and social sustainability performance

H2c - Engagement in the practices of sustainability management systems mediates the effect of type of economy on operational and social sustainability performance

The moderating role of environmental uncertainty
Uncertainty can manifest itself as the impossibility to assign probabilities to future events or by difficulties in accurately predict the outcomes of decisions (Zhao et al., 2018). Furthermore, uncertainty may relate to market forces and to the speed of technological change. In this paper, uncertainty embraces market and technological dimensions. Based on Porter's market strategic forces, this paper posits that uncertainty emanates from the degree of difficulty in predicting inputs and demand for products, the intensity of new competitors entering the market, the existence of substitute products, the intensity of competition, and the bargaining power of customers and suppliers. In consequence, the paper posits that:

H3 – Market and technological uncertainty moderates the relationship between type of economy and operational and social sustainability performance.

H3a - Market and technological uncertainty moderates the relationship between type of economy and sustainability management practices.

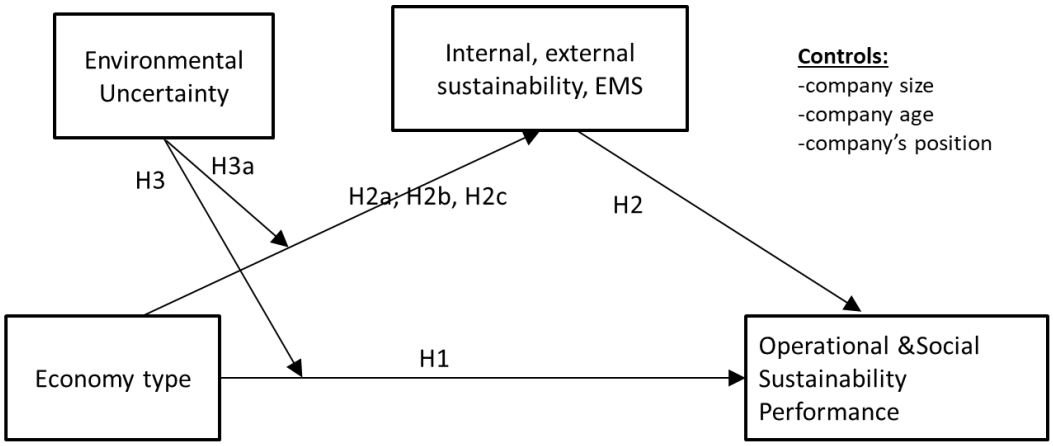
Figure 1 depicts the structural model.

Methods
Data were collected during the fifth round of the Global Manufacturing Research Group (GMRG-V) survey. The unit of analysis was the plant level and in the majority of cases the respondent was the plant manager. Table 1 depicts the sample distribution of countries by economy type.

Table 1 – Sample overview

Countries	**N**	**Countries**	**N**
Advanced	**309**	**Developing**	**440**
Australia	70	China	72
Ireland	30	Croatia	113
Korea	79	Hungary	38
USA	130	India	58

Countries	N	Countries	N
		Poland	79
		Vietnam	80
		Total	**749**



Variables:
-Economy type: Developing & Industrialized
-Environmental uncertainty: forecasting, competition, substitutable products, barriers to entrants, bargaining power of customers and suppliers, technological change
-Internal: energy, water, waste and carbon usage in facilities
-External: environmental requirements, compliance, goals and audits with suppliers
-EMS: Environmental Management Systems – systematic approaches to environmental targets, achievement, monitoring and reporting
-Operational performance: cost, quality, flexibility and delivery
-Social sustainability: occupational-related accidents, insurance, health & safety procedures and monitoring

Figure 1 - Structural model

The scale of social sustainability was inspired by Vachon and Klasen (2006). Table 2 depicts the scale items for social sustainability.

Table 2 – Scale items for social sustainability

S02 During the past two years, to what extent did you engage in the following activities:
1. We actively monitored the occurrence of occupational-related accidents at our facilities
2.* We actively monitored the occurrence of occupational-related insurance claims in our facilities
3. We actively monitored occupational employee health and safety procedures at our facilities
4. We actively monitored the long-term health of our employees at our facilities

S04 During the past two years, to what extent did you engage in the following activities:
1. We provided major suppliers with written occupational health and safety requirements and monitored these
2. We sent occupational health and safety questionnaires to major suppliers in order to monitor their compliance

3. We monitored major suppliers commitment to occupational health and safety improvement goals
4. We conducted audits of the occupational health and safety of major suppliers' employees
S06 Compared to the leaders in your industry in occupational health and safety management, to what extent does your plant engage in the following activities within your facility?
1. We systematically control the impact of our production process on occupational health and safety
2.We implement a systematic approach to setting occupational health and safety targets
3. We implement a systematic approach to achieving occupational health and safety targets
4. We implement a systematic approach to demonstrating that occupational health and safety targets have been meet
S08 During the past two years, please indicate the extent to which your plant has performed from a health and safety perspective.
1. We have reduced the number of occupational-related accidents at our facilities
2. We have reduced the number of occupational-related injuries at our facilities
3.We have reduced occupational-related ill health at our facilities
4. We have reduced the number of occupational-related insurance claims at our facilities

Note: all items are on a seven point Likert scale (1 = "not at all"; 7 = "to a great extent")
* Item #2 dropped due to high covariance with Item #3

Table 3 depicts the scale items for uncertainty.

Table 3 – Scale items for uncertainty

CG02 Please indicate your level of agreement with these statements on competitive environment:
1. The availability of critical inputs is difficult to predict
2. The competitive intensity in your industry is high
3. There are many substitutes in the market for your products
4. Demand for your products is difficult to predict
5. Suppliers of critical inputs have significant bargaining power
6. Your customers have significant bargaining power
7. Your industry is subject to rapid technological change
8. Your competitors are mainly local
9. Each year many new competitors enter your industry

Note: all items are on a seven point Likert scale (1 = "not at all"; 7 = "to a great extent")

All descriptive statistics and correlations were performed with SPSS 25 and measurement invariance was tested with Mplus 8.0.

Results

The validation of the scales was conducted with exploratory factor analysis to ensure all factor loadings in one dimension only, with no primary factor loadings, no cross

loadings among factors, and no communalities (Hair et al., 2006). The results from the exploratory factor analysis using maximum likelihood estimation, varimax rotation with Kaizer Normalization are shown in Table 4.

Table 4 - Rotated Factor Matrix[a] EFA and Cronbach's alpha

	Factor			
	1	2	3	4
Internal Monitoring α = 0.87 (without S02b)				
S02a	0.044	0.175	0.270	**0.680**
S02c	0.014	0.252	0.254	**0.907**
S02d	0.140	0.277	0.327	**0.665**
Supplier Monitoring α = 0.96				
S04a	**0.884**	0.110	0.193	0.075
S04b	**0.928**	0.087	0.156	0.033
S04c	**0.922**	0.113	0.150	0.063
S04d	**0.899**	0.045	0.162	0.051
Social Monitoring Systems α = 0.96				
S06a	0.171	0.281	**0.767**	0.283
S06b	0.187	0.214	**0.861**	0.282
S06c	0.217	0.229	**0.855**	0.246
S06d	0.250	0.202	**0.828**	0.241
Environmental Performance α = 0.95				
S08a	0.090	**0.856**	0.212	0.212
S08b	0.059	**0.876**	0.207	0.233
S08c	0.142	**0.842**	0.210	0.159
S08d	0.081	**0.882**	0.174	0.159

Extraction Method: Maximum Likelihood.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Convergent and discriminant validity and common-method bias were evaluated (Hair et al., 2006). The social sustainability scale was validated for discriminant validity using the Fornell-Larcker (1981) criterion, as shown in Table 5.

Confirmatory factor analysis (CFA) was used to ascertain multi-group equivalence across advanced and developing economies and test for measurement invariance, consistent with the procedures presented in Byrne (2013). First, the baseline models were shown separately for each group, followed in a hierarchical manner by progressively more restrictive models: fully unconstrained (configural), equal factor loadings, intercepts, variances, means, covariances, and latent correlations. Table 6 depicts the results from the analysis of measurement method invariance.

Table 5 - Latent variables means, standard deviations, number of cases, composite reliability (C.R.) and average variance extracted (AVE)

Latent Variables	Mean	Std. Dev.	n	C.R.	AVE	1	2	3	4
1. SOCIAL SUSTAINABILITY INTERNAL PRACTICES (SSI)	5.42	1.33	746	0.80	0.58	***(0.759)***			
2. SOCIAL SUSTAINABILITY EXTERNAL PRACTICES (SSE)	3.32	1.72	737	0.95	0.83	0.193	***(0.908)***		
3. SOCIAL SUSTAINABILITY MANAGEMENT (SSM)	4.75	1.34	743	0.90	0.69	0.598	0.397	***(0.829)***	
4. SOCIAL SUSTAINABILITY PERFORMANCE (SSP)	5.08	1.41	738	0.96	0.86	0.491	0.227	0.498	***(0.926)***

C.R.: composite reliability; AVE: square roots in the main diagonal, in italics and parentheses.
Factor loads and correlations obtained with SPSS 25.

Table 6 – Fit indices for the nested models for multi group confirmatory factor analysis

Models	**χ^2**	**df**	**CFI**	**TLI**	**RMSEA**	**(90% CI)**
1 Baseline Emerging Economies	194.701	84	0.971	0.964	0.055	(0.045 0.065)
2 Baseline Advanced Economies	148.915	84	0.979	0.974	0.050	(0.037 0.063)
3 Configural invariance (Equal	342.813	168	0.975	0.969	0.053	(0.045 0.061)
4 Metric Invariance (Equal	398.625	183	0.969	0.964	0.056	(0.049 0.064)
5 Scalar Invariance (Equal	487.953	198	0.958	0.956	0.063	(0.056 0.070)
6 Equal Factor Variance	450.614	194	0.963	0.96	0.059	(0.052 0.067)
7 Equal Latent Means	413.184	190	0.968	0.964	0.056	(0.049 0.063)
8 Equal Latent Covariances	427.417	189	0.966	0.962	0.058	(0.051 0.065)

Nested models were evaluated using the RMSEA Model Test and the Practical Significance Test (ΔCFI>.01)

Conclusion and future research

The model had an overall good fit to data. The social sustainability scales were consistent in convergent and discriminant validity, and passed the measurement invariance tests, allowing its use for multi-group analysis.

This is the first validation of the set of social sustainability scales from GMRG-V. The results set the ground for full development and application of structural causal models investigating the determinants, moderators and mediators of social sustainability performance using GMRG-V data.

Future research will be directed towards fully testing the research hypothesis outlined in the structural model of Figure 1. Hierarchical conditional process analysis (Hayes, 2013) will be applied to GMRG-V dataset for theory falsification and hypothesis tests for the moderated mediation model. This research will shed lights on the relationships between economy type and operational (costs, quality, flexibility and delivery), and strategic (social sustainability management) performance. It is equally expected that the mediating role of environmental management practices on the relationships between economy type and operational and social sustainability performance will be further tested,

as well as the moderator role of uncertainty, an under researched area in the contextual analysis of sustainability-performance relationships.

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Total Quality Management, Kaizen and Six Sigma

Utilizing System Modelling Techniques in Lean Healthcare Applications

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Abstract

Healthcare systems are under huge pressure to improve efficiency and quality due to increasing cost and demand. To address such challenges, there is an increasing awareness on the utilization of lean in healthcare applications, which aims to implement waste-free operational processes. Another potential approach that can be merged with lean is systems approaches, such as System Modelling Techniques (SMTs), to help identify comprehensive list of wastes in a systematic way. To investigate the potential linkage between lean and SMTs, this paper reviews the literature in the field and provides a conceptual framework for potential link between these two complementary approaches.

Keywords: Healthcare systems, Lean, System Modelling Techniques

Introduction

Healthcare organizations are under huge pressure to enhance the efficiency of their organizational operations due to high cost and demand. In line with this, effective utilization of critical resources, such as design of facilities and human resources, is imperative to provide high quality of care (Hicks et al., 2015a). To improve utilization challenges, healthcare organizations have begun to adopt a range of tools and methods that are successfully employed in other industries, such as manufacturing. From these tools and methods, there has been a growing awareness and interest in lean and systems approaches.

There is an increasing recognition in the healthcare industry to apply lean philosophy to improve the competitiveness with efficient processes since the 1990s (Aherne and Whelton, 2010; Graban, 2016; Mazzocato et al., 2010). It has been applied in particular healthcare settings in various countries (Coletta, 2012; Fillingham, 2007), and a range of tangible and intangible benefits, such as reduction on medical errors and better teamwork; respectively, have been shown in the previous studies (Ballé and Régnier, 2007; Fillingham, 2007). Despite all these benefits, still the usability and sustainability of the lean in healthcare context remains unclear, as its applications are limited to specific healthcare processes (Mazzocato et al., 2012, 2010) and lack of validation of the improving ideas with engagement of the healthcare stakeholders (Baril et al., 2016).

Earlier studies showed that stakeholder's engagement boosts the implementation of the lean applications and sustainability. It may be considered challenging since it requires stakeholders to identify wastes in the work in which they are so invested. Recognizing that a significant number of their daily tasks is wasteful and does not add value can be difficult for them to address. Lean experts noted that by engaging stakeholders, there is a potential that they will better understand how the system works and behaves, understand each other's roles and appreciate the future change. The continuous willingness to participate in process improvement is a good indication of stakeholder's acceptance and satisfaction (Sibbald et al., 2009).

In addition to that, a clear process understanding leads to a more effective improvement (Spear and Schmidhofer, 2005). Lean has a large pool contains more than a hundred tools with specific characteristics and focus, such as root cause analysis, Takt time, project charter, spaghetti map, risk analysis, Kaizen, and amongst others. To visually describe and quantify the system, one of the most popular tools is the Value Stream Map (VSM). It is used extensively since most people find it much easier to understand the process if it was presented visually rather than verbally (Jun et al., 2009). It helps plot all value added and non-value added activities required to bring a specific service or product to the customer in the value chain.

The VSM helps managers and stakeholders in understanding the process, recognize the problems and identify the wastes in the system. However, there are some limitations with using VSM since it is originally created to serve lean implementation in manufacturing. The typical VSM may not always represent important support activities in the patient flow that directly affect the patient journey and process performance. In addition to that, the VSM does not present the processing of materials, such as medication, since it mainly focuses on patient flow and related information (Henrique et al., 2015). Looking at the VSM building process, it is not typical to include customer in this stage, although their voice is an important component in the improvement process, especially in healthcare system where patient-provider relation and behaviour may affect the quality of care (Ramaswamy et al., 2017a).

To describe system structure and behaviour, studies proved the effectiveness of using systems approaches, such as System Modelling Techniques (SMTs), in the healthcare industry, they can specify care in a highly visual way and enhance the understanding of caregivers which will help them in waste and risk identification comprehensively (Jun et al., 2009). So far, very limited range of SMTs has been used in healthcare, such as flow chart, sequence diagram, and hierarchical task analysis diagrams. Past research evaluated different SMTs to provide an indication regarding the potential of using them in identifying different hazards and risks affecting patient safety (Simsekler et al., 2018). However, SMTs were not evaluated in terms of their utility and usability in waste identification in the healthcare field, in particular in lean applications to identify wastes. Further, there is no clear evidence on what types of wastes can be identified by using a particular type of SMT.

In order to shed light on this, this paper reviews the application of lean and SMTs in healthcare further, and provides a conceptual framework for potential link between these two complementary approaches.

Review

Lean thinking, definition and principles

Based on the Toyota Production System (TPS), the concept of Lean aims to improve the overall operational performance of a firm by distinguishing value-added steps from non-value-added activities and eliminating all forms of waste (or *muda* in Japanese) (Sugimori et al., 1977; Womack and Jones, 2005). The fundamental aim of lean thinking is to transform organizational behaviour and culture over time (Smith et al., 2012; Ulhassan et al., 2013).

Lean principles firstly developed in the manufacturing industry, and have been adopted in a range of industries, including service industries and public sector organizations (Radnor and Walley, 2008; Womack and Jones, 2005). Such lean adoptions have also been experienced in the healthcare industry to better utilize the resources and improve the competitiveness with efficient processes since the 1990s (Aherne and Whelton, 2010; Graban, 2016; Houchens and Kim, 2014; Mazzocato et al., 2010).

There are various inherent trade-offs in healthcare. For instance, it can be said that quality of care is equally affected by financial resources and efficiency of resource allocation, such as human resources and space utilization (Leatherman and Sutherland, 2004; Mason et al., 2015). The utilization of human resources is vital to respond to patient demand on time with effective care. Not only human resources but also design of facilities have a huge impact on efficiency and care delivered (Hicks et al., 2015a). For instance, poor utilization of examination & treatment rooms is a huge challenge for healthcare organizations to respond to patients' needs on time. Therefore, any solution should consider the elimination of waste by efficient distribution of all possible resources. For instance, it may be recommended to have better utilization of rooms and space in hospitals with the provision of no single patient rooms. Though this action could increase the room utilization and decrease the number of staff required, it may also cause privacy issues for some patients and increase the rate of infectious diseases. Therefore, reallocation of the resources should consider trade-offs in a structured manner to have a positive impact on patient experience and quality of care delivered.

To consider such trade-offs, Lean offers systematic approaches to develop safe, efficient and waste-free operational processes, as well as suggesting the removal of duplicate processes and unnecessary procedures (Robinson et al., 2012). For instance, (Grunden and Hagood, 2012) used a set of lean tools, such as value stream mapping, takt

time, Just in Time (JIT) and total quality management (TQM), and showed how they can be systematically utilized in healthcare settings.

The application of lean in healthcare is primarily aimed to address the increasing demands on healthcare services and provide efficiency and better quality of care delivered (Drotz and Poksinska, 2014; Joosten et al., 2009; Souza, 2009). Outcome of the lean use in healthcare showed a range of improvements on time savings, cost savings, capacity enhancements and reduction in medical errors, increase in patient satisfaction and reduction in mortality (Fillingham, 2007; Houchens and Kim, 2014; Mazzocato et al., 2010; Shannon et al., 2006). For instance, the Production Preparation Process (3P), which is part of the lean design process, has been applied in a number of US hospitals, and saved huge costs (Coletta, 2012; Nicholas, 2012; Pelly et al., 2013). Studies in the UK also showed improvement via Lean applications on better teamwork, reduction in length of stay and mortality (Fillingham, 2007). Research in French healthcare settings also showed reduction on medication errors and infection rates with the application of Lean (Ballé and Régnier, 2007).

As one important delivery of lean is to focus on value creation through waste elimination. The following type of wastes are expected to be identified through lean (Daultani et al., 2015; Ōno, 1988).

- *Transportation*: waste generated form the movement of product that are not required to perform the process. For example, sending overstocked inventory back to warehouse.
- *Inventory*: waste in result of components, work in process and finished product not being processed. For example, unused or rarely used equipment.
- *Motion*: waste produced when people or equipment moving more than what is required to perform the process. For example, people moving around searching for tools and material.
- *Waiting*: it's simply delay, where product stays idle waiting for the next production step. For example, manufacturing process stopped waiting for component delivery.
- *Overproduction*: waste as a result of production ahead of the demand. For example, the production of component before the next station is ready to receive them.
- *Overprocessing*: waste because of doing work that doesn't add value, usually resulted from poor tool or product design crating activity. For example, interring the same information in more than one place.
- *Defect*: waste of the effort involved in inspecting and fixing defects. For example, manufacturing parts that does not meet requirement.
- *Human potential*: waste due to not engaging employees. For example, employees do not engage and are not provided feedback for improvement.

Despite various wastes that need to be identified, there is no comprehensive study showing the particular role of VSM in waste identification. Further, the general usability, utility and sustainability of lean in general healthcare context remains unclear, as applications are limited to particular healthcare processes within one unit or department (Mazzocato et al., 2012, 2010). Many studies in the literature have a speculative character and not provided empirical evidence (Drotz and Poksinska, 2014; Poksinska, 2010). Previous studies indicated that the nature of lean appears to vary significantly from place to place. Moreover, depending on the scope of the application from a single healthcare setting to whole health system, variation has been experienced in its implementation and

outcomes (Holden et al., 2015; Mazzocato et al., 2010). Only a few implementation efforts crossed the organizational boundaries (Mazzocato et al., 2010). While most research so far indicated successful applications of lean interventions, only a few has shown failed attempts or challenges in its application in healthcare (Mazzocato et al., 2012). Overall, limited embedment of the organizational culture (Burgess and Radnor, 2013) and little evidence on the full implementation of lean activities in healthcare applications have been noticed (Robinson et al., 2012).

System Modelling techniques (SMTs)

Enhancement efforts in healthcare generated various quality improvement methodologies, lean is one of them as explained in the previous sections. Most of the methods require a thorough understanding of the existing system before attempting to implement the improvement actions. The power of process mapping in facilitating the system understanding makes it suitable to serve this requirement (Buckle et al., 2006; Colligan et al., 2010; Jun et al., 2009).

Varies patient flow modelling techniques are reported in the literature (Colligan et al., 2010; Deniz and Özçelik, 2018; Henrique et al., 2015; Hicks et al., 2015b; Mazur and Chen, 2008; Pinto et al., 2013; Ramaswamy et al., 2017b; Robinson et al., 2014). They proved its effectiveness in better understanding the system's operations, also it helps in identifying various problems and improving the performance of the system. Some methods are limited to be used for a single model and may not be expanded into a bigger scale. Others are specified for showing the inpatient length of stay and their clinical patient flows (Bhattacharjee and Ray, 2014). Also, the value stream map that was used extensively in healthcare has some limitations as mentioned earlier.

Researchers were interested in investigating the effect of using a set of process modelling methods or diagram in implementing improvements in quality, safety, and risk. some investigated the influence of different process mapping on quality improvement. The authors compared between using tow diagram. Results showed that the organization of information in an external representation affects the stakeholder's decision making. The participant's preference of one diagram over another depended on the context in which they would be used (Colligan et al., 2010). Others considered wider range of diagrams to evaluate how healthcare employees perceive the usability and utility of each diagram (Jun et al., 2010, 2009). In more dedicated studies, the diagrams were evaluated based on their potential in risk identification (Simsekler et al., 2018), risk identification framework was developed based on that (Simsekler et al., 2018).

Comprehensive research on the system modelling techniques (SMTs) was carried out in the development of prospective hazard analysis (PHA) toolkit (Ward et al., 2010). This study reviewed number of SMTs to find their practical applicability in healthcare particularly in safety management. The toolkit involved the common SMTs that focus on the main element of the system; people, information, and process. The relationship between the elements is categorized into two classes as structural and behavioural categories. While the structural diagrams present the architecture of the system and define its boundaries, the behavioural diagrams further expand the system description within the defined system boundaries, it presents the details of the communication and flow of people and information within the process. Following is the list of SMTs, where the first three are categorised as structural diagrams, and the rest are behavioural diagrams (Ward et al., 2010):

- *Organizational diagram*: describes the hierarchy of people and/or roles within the organization. The departments, teams, and individuals presented as nodes and the relationships as links. It is helps identify the key stakeholders in the system and define the system boundary.
- *Information diagram*: describes a hierarchy of information and/or material used in physical or electronic way. The information or document presented as nodes and the relationships as links. It is useful in understanding the documentation issues, such as the amount of electronic documents used, their link with the physical documents, and the content of each document.
- *Task diagram*: describes a hierarchy of operations (tasks)and plans, the plans present the necessary conditions to undertake these operations. The activities presented as nodes and the relationships as links. The hierarchical nature allows a detailed or brief description of the tasks based on the implementer objective, which makes it appropriate for describing the entire process as well as a specific issue.
- *Flow diagram*: it includes flow diagrams and swim lane diagrams; they describe activity occurrence in sequence or parallel. Activities presented as nodes and the conditions for moving between them as links. The key stakeholders are presented in lanes, and the activities they are responsible for, are located in their lanes. This diagram is useful in creating an understanding of the process.
- *Communication diagram*: describes information and material flows between stakeholders linked by some common process. Information and material flow presented as links and stakeholders as nodes. It is effective in describe the interactions between the stakeholders.
- *System diagram*: describes how data are transformed throw activities, where the data are stored, and the sequence of the activities. This diagram is suitable in creating a collective understanding of the overall process. The diagram presents the patient state and the transition condition to transfer patient from one state to another.

Implementation of SMTs in Lean

In lean applications and implementation, stakeholders' involvement and engagement have a vital importance to identify all potential wastes in dynamic and complex healthcare systems. To guide stakeholders and provide a comprehensive picture about all system-wide wastes, system modelling techniques (SMTs) can be used during the kaizen events or any other related lean applications, such as brainstorming sessions, root cause analysis, etc.

After reviewing lean implementation in healthcare and system modelling techniques, it can be said that there is a potential to implement SMTs in lean to identify a comprehensive list of wastes. With the potential integration, waste identification framework, as conceptualized in Figure 1, can be developed to navigate which SMTs can be used in the identification of particular types of wastes.

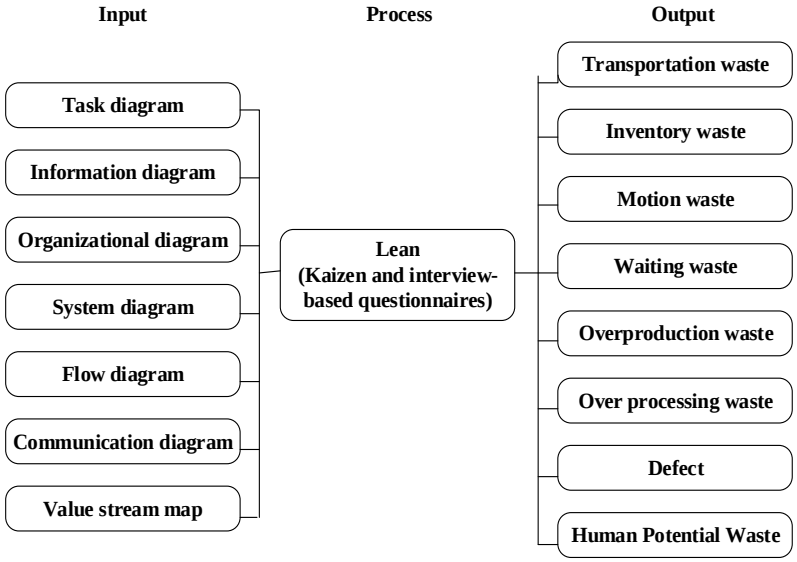

Figure 1 Conceptual Framework on Lean & SMTs Integration

Not only SMTs but also VSM can also be evaluated to see its potential benefits and limitations in current kaizen applications, and potential contribution of SMTs to help reflect the system behaviour further for identifying system-wide wastes.

Conclusions

In lean applications and implementation, stakeholders' involvement and engagement have a vital importance to identify all potential wastes in dynamic and complex healthcare systems. To guide stakeholders and provide a comprehensive picture about all system-wide wastes, system modelling techniques (SMTs) can be used in lean approaches, such as kaizen meetings. Future research needs to evaluate different types of SMTs in a real healthcare setting with healthcare stakeholders to see their potential impact on stakeholder involvement and particular type of waste identification.

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Quality Management for High-Contact Professional Service Firms: A Multiple-case Evidence from Indian Law firms

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Abstract

This paper presents an exploratory study to understand the distinctive quality dimensions of high-contact Professional Service Firms (PSFs). The paper is based on empirical evidences from multiple cases in leading Indian law firms. The paper adopted an exploratory, multiple, embedded and comparative case study design. The empirical evidence from multiple case studies in 10 law firms was used to explore the QM dimensions for PSFs. The results showed that QM in PSFs is a multifaceted and continuous process rather than a straightforward and episodic one. The findings reveal three distinctive dimensions of QM for PSFs

Keywords: professional service firms; quality management; service quality;

Introduction

Globally, the professional service firms (PSFs) are at an inflection point of growth, facing an ever more demanding clientele and ensuing pressures to cut prices and expand service value. For instance, the waxing client dissatisfaction with legal advisory services (or law firms) is evident from a worldwide stagnant growth in legal service demand (between negative 4% and positive 6%), declined lawyer productivity (from 134 to 122 billable hours) and reduced collection realization rates (from 94.6% to 89.1%) during the past decade (Georgetown Law & Thomson Reuters Legal Executive Institute, 2017). Yet, there is limited Service Operations Management (SOM) research to investigate what PSFs should do, and how they should be managed to achieve superior quality (Jayaram and Xu, 2016; Lewis and Brown, 2012; Goodale et al., 2008, Zhao et al. 2004; Harvey, 1990). The established service quality literature ascribed the inconsistencies in

PSFs' service outcome to their emblematic operational characteristics viz. knowledge intensiveness, professional autonomy, altruism, self-regulation and customization (Lovelock, 1983; Schmenner, 2004). However, lately, even the most autonomous services of medical practitioners (Sabella et al. 2014), accountants (Jeffords and Thibadoux, 1993) and engineering designers (Boone, & Ganeshan, 2001) have recognized the economic benefits of a systematic implementation of customer-focused quality management (QM) systems and practices (work measurement, coaching, employee training and reward system to name a few) that have paid manufacturing sector off in a big way in the past (Flynn et al., 1994).

Considering the academic research on QM in PSFs, the recent editorial note for the special issue of Journal of Operations Management (JOM) on "Professional Service Operations Management" (Harvey et al. 2016) emphasized the role of client awareness and precision in the recognition of relevant service quality attributes. The authors also highlighted the role of proxy indicators of quality (such as partnership-based organization structure) in the firm's service quality assessment. Additionally, the need for managing the network or interactive quality during the extended service delivery process typical to PSFs was also highlighted. A large part of service quality research on professional services is into modelling the client's expectation-perception gap (Parasuraman et al., 1988; Zeithaml, 1988). There has been little focus on how PSFs should be managed to achieve superior quality (Zhao et al. 2004). A process-focused research for exploring such service provider's activities, procedures and behaviours that drive the client's expectations and/or perceptions during the extended service delivery process in professional services is scant in the literature (Svensson, 2006). Therefore, this paper presented an exploratory study to understand the distinctive quality dimensions for professional services followed by the development of a conceptual model for QM in PSFs. The study used empirical evidences from multiple case studies in law firms to examine the QM practices in high-contact PSFs. The study was narrowed down to a specific professional service sector (legal advisory services) in line with the past research (Brandon-Jones et al. 2016; Lewis and Brown, 2012), which established that sector-specific insights played a crucial role in deriving competitive advantage in professional services. Given the exploratory nature of the research, the study adopted multiple, embedded (Yin, 2003), and comparative (Dul and Hak, 2008) case research design to achieve the research objectives. This

qualitative research design was suitable to gain a holistic (systematic, encompassing and integrated) view of the context of study.

Literature Review

Distinctive characteristics of PSFs and associated QM challenges

PSFs are conceptualized as one service category in generic service typologies in the service marketing literature (Silvestro et al., 1992; Schmenner, 2004). For PSFs, these typologies have emphasized some shared operational characteristics such as high level of customer contact and labour intensity (Lewis and Brown, 2012). However, these typologies fell short in recognizing the distinct QM and operational (control) challenges related to programmability of tasks and measurability of outcome faced by various professional service providers (Goodale et al., 2008). Harvey (1990) emphasized that unlike other service firms, the nature of operations management decisions in PSFs are driven by the relative power of the three stakeholders i.e. the professionals, the clients and the top management (firm). In a study based on the evidences from a specific PSF setting (law firms), Lewis and Brown (2012) emphasized that unlike other service categories, in PSFs the professional-client exchange is asymmetrical and required varying degree of customization in process design for different clients; there are less variables involved in the processes, creating an opportunity for commoditization; and the notion of professional identity greatly influences the efficiency of a PSF. Based on an empirical investigation in Management Consulting firms, Brandon-Jones et al. (2016) demonstrated the need for a contingent approach towards management of operational quality in PSFs. The authors showed that both the firm-level (scale of operations, degree of specialization) and individual-level (leverage, partnerships) characteristics impact the planning and control of the professional service quality.

Researchers have extensively discussed the QM challenges in PSFs using theoretical and conceptual research approaches (Fischer et al., 2014; Goodale et al., 2008). Some of these challenges are high process variability (due to high level of customer contact); limited scope for standardization and automation (due to high level of customization and knowledge intensity of the processes); input/output based operational planning and control measures (hours billed instead of process measures); and limited emphasis on the internal quality monitoring (due to strong

influences of explicit code of conduct and implicit norms). Further, defining the direct QM measures for PSFs can be tricky due to disparate quality evaluation criteria adopted by the service provider and receiver (Haywood-Farmer and Nollet, 1994; Lehtinen and Lehtinen, 1991). Therefore, it is important for the professional service providers to understand the direct and indirect QM indicators and manage them effectively to warrant a satisfying client experience.

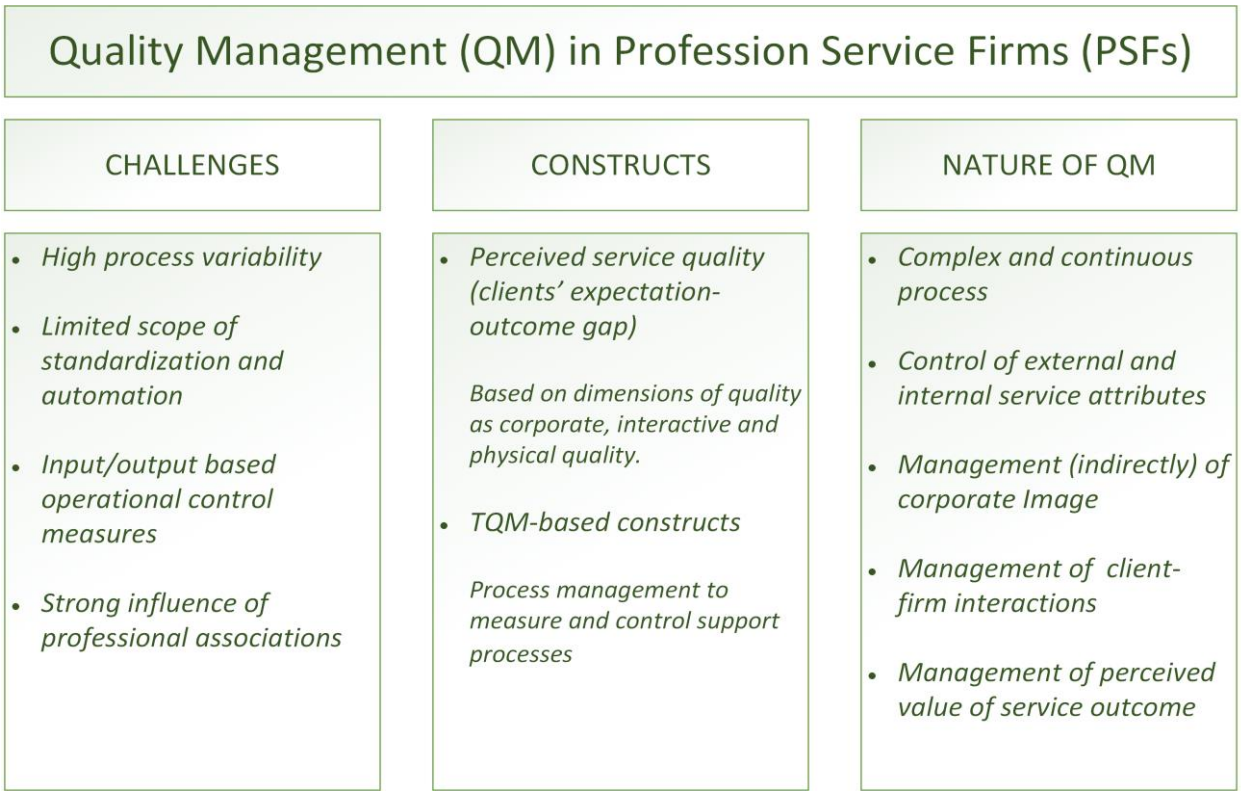

Figure 1: Preliminary research model for QM in PSFs

Research Methodology

The purpose of this exploratory study was to develop a conceptual model for QM in high-contact PSFs. Adoption of a qualitative research design was appropriate for the early stages of theory-building to achieve the research objective, considering the limited research done so far on the complex phenomena of QM in PSFs (Miles and Huberman; 1994; Siggelkow, 2007; Eisenhardt, 1989). The paper used multiple, embedded and comparative case-study research design (Yin, 2003; Dul and Hak, 2008; Silverman, 2002).

Case Selection

This study was conducted in the Indian legal service sector. The Indian legal advisory service sector is world's second largest legal market (in terms of number of lawyers with 1.3 million lawyers) and is currently preparing for opening-up to foreign legal professionals (INBA, 2017; Chinna, 2012). For the exploratory study, the Indian legal sector was represented by 10 leading law firms with leverage ratio (i.e number of non-partner lawyers to equity/salaried partners) of 8.5 to 3.3. All the selected firms were general partnership firms known for Corporate & Business Law advisory services (though these firms also offered advisory in mergers & acquisitions, insurance, tax, and capital markets) and were ranked in band 1 & 2 (law firm ranking from 1-6, 1 stands for best; ranking is based technical ability, professional conducted and other quality attributes) by Chambers and Partners (Chambers and Partners, 2017).

Data collection and analysis

The data was collected at multiple points in time in the selected case settings during the fall of 2017. The primary method of data collection was semi-structured or standardized open-ended interviews (Rubin and Rubin, 1995) using an interview protocol as the instrument. For a detailed description of case findings, multi-stage data processing and analysis process, suggested by Miles and Huberman (1994) was adopted.

Findings

The major findings regarding the design of QM activities in the case studies are summarized in Table I and Figure 2.

Table I: Design of QM activities in legal advisory services

Dimension of Quality	QM Objective	Design of QM activities	LF1	LF2	LF3	LF4	LF5	LF6	LF7	LF8	LF9	LF10
Corporate Quality	Firm's image	Partner-driven networking and referral generation	●		●				●	●		
		Policy (practice development) and internal team (partner and staff) driven						●			●	●
		External professionals (PR) driven		●		●	●					
Interactive Quality	Support process control	Controlling personnel recruitment and retention requirements	●					●		●	●	
		On-going monitoring of client feedback, process manuals along with controlling personnel recruitment and retention		●		●	●					●
		Merit-based compensation system together with other measures					●					●
		Use of statistical methods, which are not common for process management in law firms										
	Client-firm interaction management	Intangible signs of service quality (lawyer's technical competence and specialized expertise)	●		●		●		●	●		
		Building tangible evidence (office and staff appearance)									●	●
		Cautious blend of tangible and intangible cues of service quality at all touchpoints (SLAs, client testimonials)		●		●						
Physical quality	Perceived value delivered	Time-based billing supported by accurate/detailed timekeeping systems.	●		●			●	●	●		
		Customized billing structure (time-based and fixed fee).		●		●						
		Value-based alternative fees arrangements (AFAs)					●				●	●

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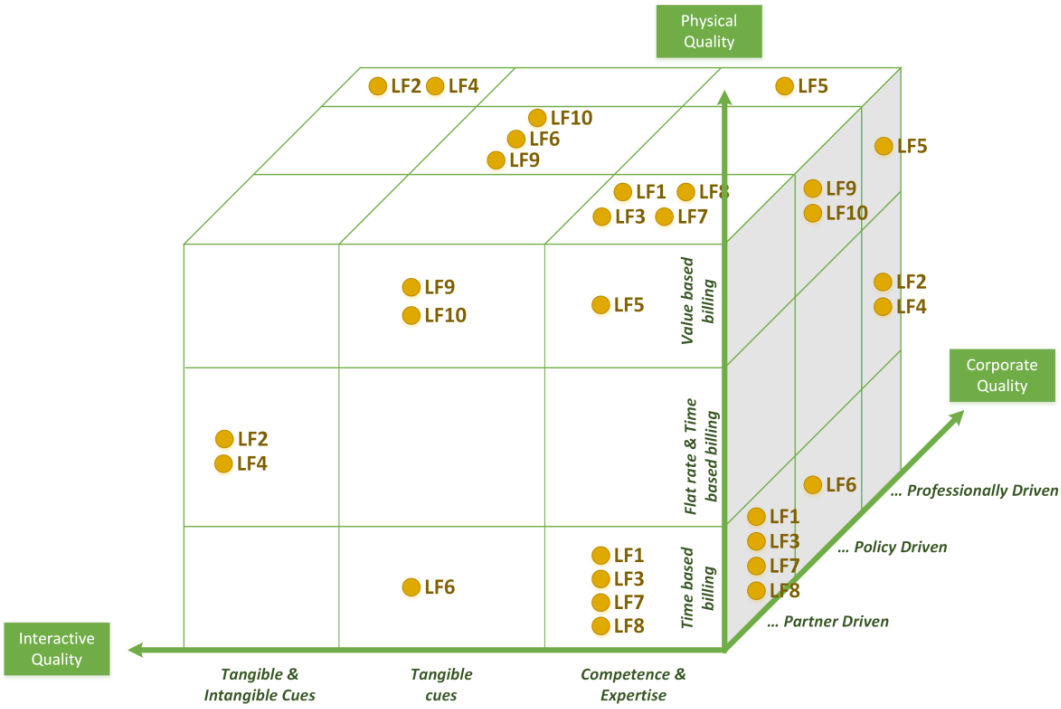

Figure 2: Dimensions of quality

Discussion and Conclusion

Broadly, the empirical findings showed that the unique personnel (lawyer) and organizational characteristics of law firms make QM a multi-dimension and continuous effort rather than a straightforward and episodic process. This observation is in line with (Ritsema et al. 1992) the definition of professional service quality as a process of continuously meeting the specification agreed by the client and the professional, considering the efforts and anticipated outcome, and incorporating all the self-evident needs of both the parties. Additionally, the findings also support the observation by Harte and Dale (2005) that it is difficult to define quality measures and controls in professional services because of their highly intangible, labour intensive and customer-centric nature. It was substantiated that external image/reputation (corporate quality), internal client interface & support process/procedures (interactive quality) and perceived value for monetary and non-monetary costs (physical quality) broadly cover the complete scope of quality management in PSFs (Lehtinen and Lehtinen, 1991). Further, for managing the corporate quality, the findings illustrated that projection of firm's 'corporate image' should be targeted especially at the client-market served (global and domestic corporate clients

in these cases) with thorough understanding of the competition. This observation is aligned with the argument by Jääskeläinen and Laihonen (2014) that lack of awareness about the alternative service providers makes the 'image and reputation' crucial in client's selection of professional services. In fact, managing partner in one of the firm with international reputation explicitly endorsed "the need to work on developing a brand identity" to attract corporate clients worldwide. Additionally, a great degree of creativity and diversity was observed in firm's choice of image-building solutions, owing to the regulatory restrictions on legal advertising (in India) (Figure 2). This observation is in line with Nachum's (1999) proposal that creativity and reputation are variables that drive a PSF's competitiveness. The observed solutions for image-building were not only driven by senior management (firm representation in prominent forums by partners) and dedicated internal teams (practice development team working on continuous personnel engagement) but also steered by specialized external professional (external PR arranges and realizes publicity opportunities for the firm). On the content of corporate image building activities, endorsement of firm's legal acumen (trainings/workshops on recent statute, representation in law conferences) emerged as the primary agenda followed by highlighting the social responsibility endeavours (pro-bono work in association with NGOs).

This paper contributes to the SOM theory by focusing on the operational quality aspects in PSFs from service provider’s perspective, which was mainly explored from customer’s perspective, so far. The paper contributes proven QM attributes and dimensions for PSFs to the existing knowledge base on operational control and QM issues unique to professional services (Brandon-Jones et al. 2016; Lewis and Brown, 2012; Holschbach and Hofmann, 2011, Goodale et al. 2008). An indirect control on firm’s image through a constant engagement of professionals (people outside the marketing function) emerged as the primary dimensions of QM in PSFs (Cameran et al. 2008). Further, the findings showed that an effective design of service encounters in PSFs is achieved through instilling tangible and intangible components in the client-interaction (including both front-end and backend aspects) (Ponsignon et al., 2011; Svensson, 2006). Finally, due to the ambiguity in the definition and scope of service outcome in PSFs, managing the perceived value of services vis-a-visa costs (and efforts) is crucial for these firms (Lapierre, 1997).

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Quality management in cross-cultural settings: challenges and possibilities for quality managers

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Abstract

This paper aims to present challenges of quality management in cross-cultural settings and suggest possible handling strategies for quality managers based on a multiple case study. The result suggests that management leadership, employee engagement and empowerment, and continuous improvement are the QM values affected the most by national culture of subsidiaries. However, the degrees of discrepancy depend on the strength of organizational culture. Hence, the suggested handling strategy is to educate employees with standardized QM techniques and tools to establish means and measures for QM values that are promoted via strong organizational culture focusing on quality and customers.

Keywords: cross-cultural management, quality management, multinational company

Introduction

Quality management (QM) has been known as a strategy to establish, improve and sustain quality of products and services (e.g. Flynn et al., 1995; Weckenmann et al., 2015). QM is based on a set of values such as management commitment and leadership, customer focus, employee engagement and empowerment, continuous improvement, process management, and decisions based on facts (Sousa and Voss, 2002). These values are basics for QM practices or techniques that are supported by tools (Dean and Bowen, 1994; Hellsten and Klefsjö, 2000; Kim et al., 2012). Many studies have indicated that the way an organization perceives QM values and uses QM techniques and tools depend markedly on culture (Hellsten and Klefsjö, 2000; Prajogo and Sohal, 2006; Gambi et al., 2015). Therefore, culture influences the perception of QM values and the practice of QM.

As companies nowadays go beyond national borders, their multinational settings are complex with high cultural diversities. Subsidiaries are a part of the company networks having the company's organizational culture, but they are as well embedded in local contexts shaped by national culture (Drogendijk et al., 2010; Schotter and Beamish, 2011). Since culture affects how people think, feel and act (Hofstede et al., 2010), employees with different national cultural backgrounds tend to have different expectation and understanding toward the same values (Brislin, 1993). As for QM, there is a tendency that employees in subsidiaries might understand the concept of quality, perceive QM values, practice QM techniques and use QM tools differently. This may cause issues of mismatch quality levels – such as higher defect rates, uneven product quality, and unstandardized processes between the subsidiaries creating challenges for quality managers (Vecchi and Brennan, 2009; Barouch and Kleinhans, 2015). According to

Thiagarajan and Zairi (1997), employees in the company must have a shared understanding of QM values leading to common practices to effectively manage quality.

Therefore, the purpose of this paper is to explore challenges of QM in cross-cultural settings of multinational companies and to suggest possible strategies for quality managers to handle those challenges.

Theoretical framework and conceptual model

Culture

Culture is defined as "the collective programming of the mind which distinguishes the member of one group or category of people from another" (Hofstede et al., 2010). It influences individual behavior and the interpretation of other people's behavior (Spencer-Oatey, 2004). Schein (2010) defines three levels of culture: underlying assumptions, espoused values and artifacts. The underlying assumptions are common beliefs and values in a group that are difficult to change. They actually guide behavior and tell the group members how to perceive things. Espoused values can be seen as a result of group learning. It is a shared beliefs and values that have been proved to be accepted by the group members such as strategies, goals, or philosophies. For example, if a manager successfully convinces the group to act according to the strategy, and if it works well in reality so that the group has a shared perception of this succeeded strategy; then this strategy starts transforming into the group's espoused value. Finally, the artifacts are at the surface level and can be seen, heard and felt. They are, for example, organizational structure, processes, or products of the group.

According to Schein (2010), these three levels of culture are mutually depended. The underlying assumption is the essence of a group's culture influences espoused values and reflect into the observable artifact on the surface. On the contrary, artifact can gradually affect the espoused values which might finally transformed into the underlying assumption in some cases. However, this transformation is not common and usually takes long time.

Quality management (QM)

QM is a management strategy consisting of technical and social aspects (Sousa and Voss, 2002; Vecchi et al., 2011). The technical aspect consists of methods and tools focusing directly on product and process quality such as process management tools, measurement method, and statistical process control (Flynn et al., 1995; Fotopoulos and Psomas, 2009; Vecchi et al., 2011). On the other hand, the social aspect is related to people and organization as a set of values creating environment to support effective use of the technical one (Flynn et al., 1995; Fotopoulos and Psomas, 2009; Vecchi et al., 2011). These social and technical aspects of QM cannot be performed separately, as they are interrelated and mutually support each other (Anwar and Jabnoun, 2006).

However, the general issues of sustainable QM adoption in organizations are those related to the social aspect. Previous studies show that the foundation of common QM practices based on a shared understanding of QM values that are uniformed across culture will facilitate sustainable QM adoption (Vecchi et al., 2011). Therefore, it is important for a company to establish a shared value of QM throughout their multinational settings. Based on literature review, these are the common QM values adopted in this study.

- *Management commitment and leadership* aim at managers to emphasize on quality and quality management, to set up quality strategies and to promote them throughout the whole company (Flynn et al., 1995; Lagrosen, 2002).

Management is expected to provide support and resources for activities such as employee training and continuous improvement (Flynn et al., 1995).

- *Customer focus* implies that organizations always focus and try to fulfill customer needs (Dean and Bowen, 1994; Lagrosen, 2002). Customers can be viewed as two different kinds: external and internal. The external customer usually means the end customer outside the organizational boundary, while the internal customer refers to the next process step down the line of work (Bergman and Klefsjö, 2010).
- *Employee engagement and empowerment* promote the idea of giving quality responsibility to the employees, not just to the quality department (Lagrosen, 2002). Employees can design and make decisions about their own tasks (Dean and Bowen, 1994) and supervisors function more as coaches than controllers (Anderson et al., 1994).
- *Continuous improvement* means everybody improving, everywhere and every day (Imai, 2012). Organization must always strive to improve products, services or processes for better performance (Bessant et al., 1994; Lagrosen, 2002). It needs to be managed strategically as a continuous process with a clear framework and supportive infrastructure such as flatter organizational structure, employee involvement and empowerment, and scientific approach to decision-making (Bessant et al., 1994).
- *Process management* as a value refers to how company organize and develop its structure based on a chain of activities creating values for customers (Lagrosen, 2002; Bergman and Klefsjö, 2010). Improving one process step would impact the other, leading to higher performance of the whole organization (Dean and Bowen, 1994).
- *Decisions based on fact* indicates that decisions should be made based on systematically gathered and analyzed information (Dean and Bowen, 1994). Several QM methods and tools can be used to support the data collection and analysis – e.g. checklist, statistical process control (Bergman and Klefsjö, 2010).

Quality management from a cross-cultural perspective

Previous research in cross-cultural QM shows that culture and QM are related. At national level, many studies reveal that QM perception and practices varies across countries which might be implied as a result of national culture differences. For example, Mathews et al. (2001) studied QM practices in UK, Finland, and Portugal, and found some differences that could be related to national culture in the way QM was adopted in each country. Lagrosen (2002) suggests that meaning of quality and problems concerning quality are differences in different country, and they tend to have diverse strategies to overcome the problems. In terms of cultural dimensions, power distance and uncertainty avoidance (Hofstede et al., 2010) are the dimensions that seem to mainly affect national differences of QM (Mathews et al., 2001; Lagrosen, 2002). However, several studies present different QM values that tend to be influenced by national culture. Flynn and Saladin (2006) suggest that leadership, employee engagement and empowerment, process management, decision based on facts are the QM value that have correlations with dimensions of national culture. According to Lagrosen (2003), customer focus, process management and continuous improvement are the most influenced by culture. Moreover, Vecchi and Brennan (2009) suggested that some cultures are more suitable to implement specific quality program. Therefore, company should develop quality strategy that can be

effectively adopted in any local culture and then adapt their quality practices to the local national culture of the subsidiaries.

Conceptual model

The conceptual model of this paper is presented in Figure 1. The underlying assumptions are seen to be influenced by national culture of each subsidiaries. The espoused values related to strategies, goals and philosophies are represented by QM values, while the artifacts at the surface level are linked to QM tools and techniques that can be clearly seen in the company and working processes.

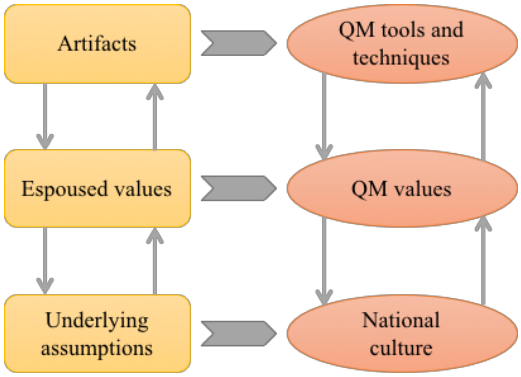

Figure 1 – Conceptual model of the paper based on Schein (2010)

The model suggests that national culture of subsidiaries influences the employees' perception of quality and understanding of QM values which in turn have an effect on the use of tools and techniques to practice QM. Therefore, there might be discrepancy between subsidiaries of the same multinational company situated in different countries in QM values and practices. Nevertheless, as artifacts can slowly influence espoused values that might finally transform into underlying assumptions (Schein, 2010), there is also a chance that standardized use of QM tools and techniques in multinational settings might induce common understanding of QM values creating a unified quality culture in an organization. This quality culture can act as a strong organizational culture that might overcome the differences stemming from national culture.

Methodology

The paper is based on a multiple case study in a manufacturing sector. The data was collected via semi-structured interviews with quality engineers, managers and directors in seven multinational companies, resulting in total 11 interviews. The interview questions were designed based on various QM values and practices to discuss the interviewee's experiences of working with quality management in a complex cross-cultural setting of multinational company. Besides, some related documents were studied – e.g. company annual reports, quality strategy documents, meeting presentation.

The collected data were analyzed using qualitative content analysis (Corbin and Strauss, 2014). The first step was to identify differences and similarities of perception of quality and QM values, as well as how employees in different subsidiaries of the same multinational company practice QM, and use various QM methods and tools. Then, the advantages and challenges of cross-cultural QM were determined. Finally, the strategies to handle those challenges were suggested.

Case company descriptions

As the cultural influences could come from either national or organizational culture, the case companies were carefully selected to represent multinational companies with manufacturing subsidiaries in different countries. Consequently, in each case company, the organizational culture could be predicted to be a common culture of the global company, while the cultural differences were expected to be stemming from the local national culture of each subsidiary. The case companies vary in terms of products, size and time on the market, as shown in Table 1, representing a diverse group of samples.

Table 1 – Case company descriptions

Company	**Product**	**Size**	**No. of countries with manufacturing subsidiaries**	**Approx. years on the market**
Alpha	Highly complex products in defence and security sector	Large	5	80
Beta	Fabrics for hygiene, medical and industrial sector	Medium	10	50
Delta	Contract manufacturer for electronics industry	Medium	7	40
Gamma	Outdoor power products and innovative solutions	Large	5	Over 300
Phi	Transport solutions	Very large	13	130
Mu	Cooling solutions to commercial vehicle industry	Small	5	120
Omega	Farm machinery	Small	2	60

Empirical findings

Based on the interviews, all companies claim to have strong focus on quality and substantial experiences with quality management. However, they have different levels of international experiences. *Omega* and *Mu* are small companies that do not have long experiences in working globally. They have not yet established close collaboration between subsidiaries and their organizational cultures is rather weak. For example, there is no globally standardized quality strategies in *Omega*. The subsidiaries have been operated quite separately because the management thinks it is easier. On the contrary, in the large companies with long history – company *Alpha*, *Gamma*, and *Phi*, they have more experiences in internationalization and the organizational cultures are much stronger. For example, in *Phi*, they setup global quality strategy every year which is broken down to each business unit and department. As for company *Beta* and *Delta*, they are somewhere in the middle. Although they are younger than both *Omega* and *Mu*, they have more international experiences.

Perception of quality and QM values

In *Alpha*, *Gamma*, and *Phi*, the interviewees claim that perception of quality among employees in various subsidiaries are quite the same. Although there are some differences in *Phi*, the interviewees explain that the deviation is very small compared to the local society outside the company. Regarding to *Beta* and *Delta*, they work with quality quite differently in various subsidiaries. For example, quality is self-responsible by the production teams in some subsidiaries of *Delta,* while it is still traditional control with sampling check by quality department in some other. The interviewee thinks this is partly

because of cultural differences that employees do not have the right perception of quality and QM values to take responsible for quality by themselves, so that they still need to do this quality control in those subsidiaries. Moreover, the interviewee from *Mu* express that employees from some countries have difficulties in understanding the concept of QM.

Regarding management commitment, the studied companies have not experienced differences in this QM value. However, leadership style is influenced by local national culture of the subsidiaries as stated by all the interviewees. In *Phi*, managers need to locally adapt how they lead people to fit local culture and organizational settings of the subsidiaries such as hierarchical structure. However, the differences in leadership style among subsidiaries can be mitigated by moving around management between the headquarter and the subsidiaries to learn about each other's local culture and organizational settings, as well as promote and strengthen the common organizational culture. Moreover, the company try to establish the mindset for the leaders to accept the diversity of national culture.

Based on the interview, all companies try to setup strong focus on both internal and external customers. However, there are different levels of customer focus in *Mu* and *Omega*. For *Mu*, the main reason is because they have not yet tried to cooperate between subsidiaries, so the internal customer focus is rather low. In *Omega*, employees in some cultural backgrounds take product specification for granted. They think it is just slightly outside the specification and will not harm the customers. In other cases, they have not experienced big difference in customer focus as a value between subsidiaries. However, there are differences at practical level in terms of management of customers, such as personal contact in customer service and complaint handling, in *Beta*. Though employees in both *Delta* and *Phi* seem to have different pictures toward external customers, the interviewees state that it depends more on their distance to the customers rather than culture.

In all cases, levels of employee engagement vary among the subsidiaries, but at different degrees. The interviewee from *Alpha* stated that national culture influenced employee engagement, especially the dimension of power distance. This view is agreed by the interviewees from *Beta*, *Delta* and *Gamma*. They think that employee empowerment significantly affects engagement. In *Mu*, despite the same level of commitment, there are differences in employee engagement due to different norms, perception of quality and understanding of QM values. At *Phi*, management needs to understand local culture and hierarchical structure of the local organization in order to create a proper working environment for the employees to enhance their engagement. Therefore, employee engagement and empowerment are closely related to the leadership style of management. The leaders are trained to deal with power distance and hierarchical structure by trying to be open-minded and give positive feedback to quality problems and promote quality in the suitable way. Also, they try to delegate, involve and give responsibilities to the employees in the line organization to empower them and make them feel engaged. An interviewee from *Phi* accept that this process of empowering and engaging employees is more difficult in some cultures, but *Phi* tries to overcome these national culture obstacles using strong and unified organizational culture.

Since all the case companies have some experiences in QM, they have established routines to systematically collect information and analyze data. However, there are still differences in decision making process in terms of formality and to which degree the employees should make decisions on their own without escalating the issues to supervisors or managers, as seen in *Gamma*, *Phi* and *Omega*. Consequently, *Beta*, *Delta* and *Phi* provide a lot of training in quality techniques and tools so that the employees have knowledge to deal with quality issues and can make decision by themselves to some

extent. Also, *Phi* tries to standardize decision making processes and set standards for all the subsidiaries. Yet, there are still some differences in solving small quality problems, while the severe cases are more of the same practice.

Continuous improvement is promoted everywhere in all companies. Nevertheless, there are differences in the practices among subsidiaries, for example, how to share ideas, how the continuous improvement events are organized or how to manage change caused by improvement. Special reward and competition are used in some cases. For example, they set up monthly improvement competition between subsidiaries to urge continuous improvement at *Mu*. *Delta* needs to have special rewards to employees in some subsidiaries in order to promote continuous improvement and encourage idea sharing. On the contrary, this special reward has been seen as a counter-productive solution for continuous improvement in *Phi* and they had stopped doing it quite a long time ago. Instead, they treat continuous improvement as a part of the working task that every employee needs to perform. It is not an extra event, but a part of the working routine. The interviewees from *Alpha* and *Gamma* agreed that culture influenced continuous improvement, especially the dimension of power distance, in connection with employee engagement and empowerment.

As for process management, all companies except *Mu* have strong focus on processes and quality methods, and they promote standardized process maps in all subsidiaries. Yet, there are small differences in how subsidiaries are more process- or result-oriented. Interviewees from *Beta*, *Gamma* and *Phi* similarly agree that some culture tend to focus more on processes while other are more result-oriented. As a result, employees from various cultural background collaborate differently, but it is important on how they try to accept the diversity and understand each other.

Challenges and possibilities of cross-cultural QM

Some challenges have been pointed out by the interviewees. Both interviewees from *Beta* and *Mu* express that it is hard to standardize a joint view of quality and to perform up to the same quality level in all subsidiaries. This relies heavily on how the employees perceive the quality concept and QM values, and then how they practice and work using methods and tools to ensure the same quality level. Also, it is challenging to engage and motivate employees with different cultural backgrounds to understand and accept the diversities and see the benefits of working together, as stated by interviewees from *Delta* and *Gamma*. Lastly, it is ambitious for *Phi* to create strong organizational culture and promote it globally especially in this rapid changing world.

Although there are many challenges in cross-cultural QM, some possibilities are mentioned. All interviewees agree that the diverse cultural backgrounds of employees provide different ways of thinking and solving problems. It also gives a lot of inspirations and good discussions in *Delta*, *Gamma*. and *Phi*. Moreover, new values and traditions enter the company by themselves through this multinational setting. Even though they might take more effort in training employees in some subsidiaries due to their cultural backgrounds, there are also chances to develop the employees as well as learn from each other.

Analysis and discussion

The findings suggest that leadership, employee engagement and empowerment, and continuous improvement are the QM values that seem to be affected mostly by national culture of subsidiaries. Differences in these three QM values have been experiences in all the case companies, just with various degrees. Moreover, they are the QM values that are directly related to people and closely correlated with each other. Precisely, continuous

improvement substantially relies on employee engagement and empowerment enhanced by management leadership. This result partially supports both Flynn and Saladin (2006) and Lagrosen (2003). Decision based on facts suggested by Flynn and Saladin (2006) to have correlations with national cultural dimensions does not have significant differences in terms of values, but rather in practical level of decision-making process in this study. For customer focus, the difference seems to be stemming from distance to end customers rather than culture which is not in line with Lagrosen (2003).

These discrepancies in perception of quality and QM values are mutually dependent, as QM values are intertwined (Anwar and Jabnoun, 2006). For example, the need for different management styles in various subsidiaries could lead to different level of employee empowerment and engagement. Then, different levels of employee engagement and empowerment affect how the employees solve quality problems, and how they perform improvement work. Consequently, subsidiaries might try to locally cope with the issues resulting in even bigger discrepancy at the artifacts level, such as different hierarchical structures and various rewarding systems to enhance employee engagement in continuous improvement. This sub-optimization might be beneficial in a short run as it leads to the desired results, but it creates wider gaps between the subsidiaries at both values and artifacts levels. Hence, the challenges in cross-cultural QM arise from national cultural differences between subsidiaries affecting the understanding of values and reflected in the tools and techniques as shown in figure 2.

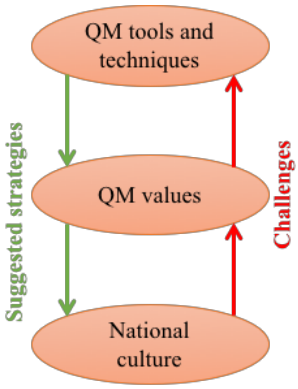

Figure 2 – Model of challenges in cross-cultural QM and suggested handling strategies

Nevertheless, the differences in each QM values vary significantly between the case companies, mostly due to how strong their organizational cultures are. Companies with less experiences in internationalization and weak organizational culture have more differences in perception of quality and understanding of QM values, as well as practices of QM tools and techniques. They also face bigger challenges in establishing a joint view of quality and to ensure the same quality level among subsidiaries. As for the companies with high experiences, they have been focused on training of QM tools and techniques to setup the same understanding of the technical aspects of QM in all subsidiaries. Then, they sustain the standardized use of the QM tools and techniques by unified organizational culture. One strategy is to rotate leaders, mostly at top management level, among the headquarter and subsidiaries to learn and adapt leadership style, as well as promoting the same perception of quality and QM values. Moreover, these rotating managers act as agents transferring QM practices and values, and contribute to the creation of strong quality culture throughout the whole company.

Therefore, the possible strategy for companies to handle cross-cultural challenges in QM is to focus on tools and techniques. This is illustrated with the green arrows in figure 2. Employees in all subsidiaries need to be trained about the standardized QM tools and techniques to establish means and measures for practicing QM values, which also act as a supporting structure for the whole QM system. Regarding QM values, a strong focus on quality and customer can be used as a basis for building strong quality culture throughout the whole company. This strong quality culture as an organizational culture together with the supporting QM tools and techniques is suggested as a strategy to mitigate national cultural influences at subsidiaries.

Conclusion

There are differences in perceptions of quality and QM values between subsidiaries situated in various countries that can be stemming from national cultural differences. These discrepancies lead to different practices of QM techniques and tools that might result in mismatch levels of quality between subsidiaries, creating challenges for quality managers in cross-cultural settings. Based on the result, the most affected QM values are management leadership, employee engagement and empowerment, and continuous improvement. These three QM values are directly related to people and strongly contingent on each other. However, the degree of differences varies from company to company based on the strength of organizational culture focusing on QM. In the companies with strong quality culture, the differences seem to be rather small in perception of QM values and appear mostly at practical level such as how to organize continuous improvement work. On the contrary, companies with weak quality culture face bigger challenges stemming from various perceptions of QM and unstandardized practices of techniques and tools.

Based on Schein (2010), the possible strategy to handle QM challenges in cross-cultural settings is suggested. Multinational company should focus on QM tools and techniques by standardized them throughout the whole company and provide substantial training to the employees in all subsidiaries. This will act as a supporting structure for the QM system, establishing means and measures for QM values. In order to promote strong quality culture, QM values must be made clear to all employees in all levels. Moreover, one strategy to mitigate national cultural gap is to rotate managers between headquarter and subsidiaries acting as agents promoting quality culture in the global organization and transferring common QM practices and values in between subsidiaries.

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Revisiting the linkages between safety and quality in manufacturing firms: a thematic literature review and research agenda

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Abstract
This paper provides a thematic literature review on occupational safety, quality, and the linkages between safety and quality. Quality is a well-developed concept in Operations Management (OM) and there exist numerous quality management programs and frameworks. Occupational safety is an established concept in safety literature, yet there are only a few studies in OM literature on safety. The reason for the oversight of safety in OM literature is speculated to be the absence of linkages between safety and competitive constructs (e.g. quality, productivity). This paper aspires to call attention to and spark interest in safety research in OM literature.

Key words: quality, safety, operations management

Introduction

Employee and employee involvement are widely recognized as a critical factor in quality management and quality improvement, noticeably through the concept of quality circle (see e.g. Reddy & Berger, 1983; Snee, 1986; Takeuchi & Quelch, 1983; Walter, 1983) and Deming's 14 principles for effectively managing quality in the organization (Deming, 1981, 1982, 2000). Worker involvement in continuous quality improvement activities (e.g. recognize problems on the shop floors as they occur) is a determining factor of well-run quality management programs. However, employees must be motivated to participate in these activities. As safety is a basic need, motivational theories suggest that worker perceptions about workplace safety will play a key role in creating or prohibiting this motivation (see e.g. Argyris, 1957; Kaminski, 2001; Murray, 1938). Nevertheless, with a few noticeable exceptions (e.g. de Vries et al., 2016; de Koster et al., 2011), the role of employee safety in operations management (OM) has been oversighted. Furthermore, Brown's (1996) proposition to include workplace safety among the competitive priority constructs (i.e. quality, cost, delivery, flexibility) until this day remains largely unanswered.

Consequently, despite tremendous technological advancement and Industry 4.0, the increases in fatal work-related diseases and fatal occupational accidents during the period 1998-2015 are alarming. It is estimated that there are more than 7,500 job-related deaths every day: 1,000 from occupational accidents and 6,500 from work-related diseases (Hämäläinen *et al.*, 2017, p. 11). One of the possible reasons for such inconceivable increases

is the fact that many corporate decision makers still see safety as an annoying cost or an inevitable regulatory threat (see e.g. Brown, 1996; Das *et al.*, 2008). Until corporate decision makers are convinced of the competitive benefits of employee safety, this problem will persist. As a response to such issue, OM literature has theoretically linked employee well-being and operational performance (Brown et al., 2010; Das et al., 2008). Specifically, Das et al. (2008) establish a theory of the linkages between safety and quality. Nonetheless, empirical tests of these linkages are *"surprisingly absent"* in OM literature (Pagell & Gobeli, 2009, p. 281).

This paper aims to voice support for Brown (1996)'s seminal call for more safety research in Operations Management and aspires to advance her proposition to include occupational safety among competitive priority constructs.

Literature review

1. Human resources in quality management

Employees and employee involvement have long been among the most critical factors of quality management programs and are featured widely in quality literature. By the end of 1980s, many prominent quality researchers have identified employees as a critical factor of quality management. Saraph et al. (1989) synthesize earlier quality literature and identify employee training, employee relations, and employee participation in quality data collection and reporting as three of the eight critical factor to quality management in both manufacturing and service sectors. Among those numerous quality gurus that emphasize the significance of employees and employee involvement in quality management by the end of 1980s, Kaoru Ishikawa is considered by Saraph et al. (1989) the leader in highlighting employee participation and quality circles. Ishikawa (1976) emphasizes *total quality control* and stresses the importance of training supervisors and employees to improve quality. Philip Crosby is also best known for his people-oriented issues in quality management (Saraph et al., 1989). Crosby (1979) demonstrates his proponent of the cultural and behavioral aspects of the quality management process, for e.g. employee motivation and rewards. Leonard & Sasser (1982) also endorse open participation by employees in quality improvement and emphasize employee training and development. Adam et al. (1981) adopt an organizational theory perspective toward quality that also includes employee training and employee relations. Reddy & Berger (1983) suggest an independent product assurance group that is staffed by cross-functional employees. The well-known Deming's 14 principles for effectively managing quality in the organization prescribes the removal of barriers to employee participation and teamwork, the removal of numerical goals and quotas for employees, underlines effective communication between foremen and employees, and endorses companywide training and education in quality (Deming, 1981, 1982, 2000). Since the 1990s, an increasing number of companies have focused on improving business processes through comprehensive adaptation of total quality management (TQM) to the entire organization (Tanninen et al., 2008). More recently, Kaynak (2003) reviews literature on TQM, identifies the relationship between TQM practices, and studies the direct and indirect effects of these practices on different performance levels. Accordingly, employee training, employee relations, and employee involvement in quality management practices are still

featured prominently in more recent quality literature, namely: Flynn et al. (1994), Ahire et al. (1996), Black & Porter (1996), and Malcolm Baldrige Award (Criteria for Performance Excellence, 2002).

2. Occupational safety

Workplace safety as a thematic focus is well-represented in applied psychology, organizational behavior, business ethics, and safety research journals. For e.g., Barling et al. (2002) study how safety-specific transformation leadership predicted occupational injuries. Ansari & Moderress (1997) illustrate best practices in safety at Boeing. Smith (1995) discuss safety management and its empirical effects at a Baldrige award-winning company. Among different aspects of occupational safety, employee perception of occupational safety, more specifically *safety climate* (from the employee side), and *safety-specific transformational leadership* (from the manager side) attract attention from safety scholars.

2.1. Employee perception of safety

Employee safety perception is a well-established concept and one of the main components of occupational safety literature. Three key dimensions of employee safety perception in safety literature are: (i) employee perceptions of supervisor safety practices, (ii) employee perceptions of managerial attention to safety, and (iii) employee perceptions of formal safety procedures and information dissemination (Hofmann & Stetzer, 1998; Zohar, 2000; Katz-Navon et al., 2005; Das et al., 2008).

Safety climate denotes employee perceptions of the organization's policies, procedure and practices concerning occupational safety (Barling et al., 2002). According to Griffin & Neal (2000) and Neal & Giffin (2002), perception of safety climate predicts safety knowledge and motivation. Moreover, Hofmann & Stetzer (1996) also find that perception of safety climate predicts safety behavior. Cree & Kelloway (1997) find that employee perceptions of managers' and supervisors' commitment to safety are strongly related to perceived risk and willingness to participate in safety programs. The direct impacts of employee perceptions of safety on actual safety performance are also demonstrated in a growing body of literature (e.g. Wallace et al., 2006; Zacharatos et al., 2005; Hyekye, 2005; Cooper & Phillips, 2004; Zohar 2002; Oliver et al., 2002; Barling et al., 2002; Brown et al., 2000; Hofmann & Stetzer 1998; Zohar, 1980).

Evans et al. (2005), in a study of wood manufacturers, find an indirect relationship between quality perceptions and safety performance through productivity perception. Accordingly, employee quality perceptions are negatively related to their productivity perceptions, which in turn negatively correlated with safety performance. Aside from this notable exception, there has not been much research on how safety climate affects competitive factors (Das et al., 2008).

2.2. Safety-Specific Transformational Leadership (SSTL)

SSTL is a form of transformational leadership focusing on achieving safety outcomes (Barling et al., 2002). Similar to generic transformational leadership (Avolio et al., 1991), SSTL comprises of four factors: (i) idealized influence: acting as a role model with regards to safety, (ii) inspirational motivation: communicating a vision in which safety plays an essential role, (iii) intellectual simulation: encouraging employees to think about how they can work more safely, and (iv) individualized consideration: being actively involved with the

safety of individual employees (de Vries et al., 2016). Barling et al. (2002) and Kelloway et al. (2006) find that SSTL is indirectly associated with occupational safety and that SSTL predicts occupational injuries through the effects of perceived safety climate. De Koster et al. (2011) note that SSTL affects safety performance directly. De Vries et al. (2016) report a negative relationship between SSTL and occupational accidents. De Vries et al. (2016) also examine the relationship between SSTL and quality/productivity; nevertheless, they do not identify any statistically significant relationship.

It is also worth noting that despite its popularity in safety and applied psychology literature, with a few exceptions, e.g. de Koster et al. (2011), de Vries et al. (2016), occupational safety has not been featured widely in OM literature. Das et al. (2008) and Pagell &Gobeli (2009) speculate that a possible reason for such scarcity is the lack of theory and evidence linking safety to the competitive factors (e.g. quality, productivity, delivery, etc.). Pfeffer & Velga (1999) claim that practitioners often struggle with the connection between employee well-being and operational performance. Not only do practitioners struggle with such connection, but also do academicians. It is challenging to reach a definitive conclusion about the relationship between any aspects of employee well-being, specifically employee safety, and operational performance from any stream of literature. A notable exception is the meta-analysis by Orlitzky et al. (2003) that establishes a positive relation between corporate social performance and economic performance. Das et al. (2008) also establish the theoretical linkages between safety and quality; however, they also lack empirical evidence due to the limited sample size.

2.3. Safety disconnect

There is a fundamental uni-dimensionality of the way safety literature approaches safety perception. The concept of *safety perception* in safety literature is primarily from the employee side. Safety perceptions of individual employees are the only reflector of the informal safety climate in an organization (Das et al., 2008). Concentrating merely on employee perceptions ignores the role that managers' perceptions and actions has in safety climate (DeJoy, 1994; Flin et al., 2000; Neal & Griffin, 2002). Coyle et al. (1995) acknowledge that a gap between managerial and employee perceptions of safety is a signal of a dysfunctional safety climate. Conversely, the absence of such gap is a crucial enabler of a safety climate (Clarke, 1999). Prussia et al. (2003) note that as the gap between managerial and employee perceptions of safety grows, the likelihood of the two parties disagreeing about the causes of unsafe behavior also grows, affecting negatively the development of safety programs. To overcome this uni-dimensionality and to gain a more comprehensive understanding of safety perception, Das et al. (2008) propose to incorporate manager safety perceptions and coin the term *safety disconnect* to describe the discrepancy between employee perceptions of safety and organizational (managerial) perceptions of safety. As the notion of *disconnect* is based on perceptions, it is conceptualized at the individual level.

The concept of disconnect is not new in management literature. Generally, disconnects represent inconsistency, cacophony, discrepancy, or incompatibility in the perceptions about a specific aspect of workplace conditions and policies. Disconnects can exist at various levels in an organization, e.g. individual and organizational-level perception (Hofmann & Stetzer, 1998). Disconnects can be about different organizational aspects, e.g. disconnects on competitive priorities and practices (Swamidas, 1986; Kathuria et al., 1999) or disconnects on manufacturing investments and executions (Boyer & McDermott, 1999). Disconnects can

develop between different groups of people in an organization, e.g. managers and operators (Boyer & McDermott, 1999), blue-collar and white collar employees (Moris et al., 1999), or factory workers and miners (Gyekye, 2006). The concept of *disconnect* has been linked with competitive outcomes. Dess (1987) reports a negative correlation between the disconnect in business priorities and financial performances. St. John (1991) finds that the perceptual disconnects between marketing and manufacturing affect negatively market performances. Similarly, Pagell & Krause (2002) find that the absence of disconnects between manufacturing and purchasing improves manufacturing performances. Based on such rich body of literature on *disconnect*, one can expect that safety disconnect would impact adversely safety performance (Das et al., 2008). Nevertheless, before Das et al. (2008), there had been no researches studying the impacts of safety disconnect between managers and employees on competitive constructs, specifically quality outcomes.

Using motivational theory and cognitive dissonance theory as the premise, Das et al. (2008) theorize the linkages between safety disconnect and quality outcomes and find a negative relation between safety disconnect and quality outcomes from their empirical test. However, the authors themselves admit that their empirical test lacks generalizability due to the limited sample size. Nonetheless, Das et al. (2008) provide a rare example of a study that link safety with a competitive construct, i.e. quality outcomes.

Future research avenues

After Brown's (1996) and Das et al.'s (2008) call for more safety research in OM literature, there have been a few more studies on the topic, e.g. de Koster et al. (2011) and de Vries et al. (2016). Nevertheless, a thorough search of the relevant literature yields no other articles besides Das et al. (2008) that link safety to competitive constructs. De Vries et al. (2016) do examine the links between safety and quality/productivity but find no statistically significant relation. Thus, even though more than a decade has passed, the link between safety and competitive constructs still remains mostly theoretical in both safety and OM literature.

After a systematic review of related literature, this paper aims to highlight the need for more research on the linkages between occupational safety and competitive outcomes (e.g. financial, reputational, quality, etc.) and especially more empirical tests on these linkages to answer the *"surprising absence"* of these empirical tests (Pagell & Gobeli, 2009, p. 281). While new attempts at theoretically testing the existing theories are highly anticipated and appreciated, replication research is another avenue to achieve such goals that this paper aims to promote.

As strong theories come from confirming and evolving ideas (Flynn *et al.*, 1990), this paper encourages replication research on the linkages between safety and quality. Replication research is vital to scientific knowledge, as strong theories come from verifying, validating, conforming, and evolving ideas (see e.g. Flynn *et al.*, 1990; Hempel, 1967; Hubbard et al, 1990; Popper, 1978). According to Rosenthal & Rosnow (1984), literature of un-replicated findings is of marginal value. While replication research is not a rare phenomenon in natural sciences, there is a lack of interest toward conducting replication research among OM academics (Easley *et al.*, 2000). Thus, in addition to calling attention to research on the linkages between safety and quality, this paper also aspires to call attention to the scarcity of replication research. Das et al. (2008) is one the studies that deserve to be replicated. While De Vries et al. (2016) do not find any relation between SSTL and quality/productivity outcomes, Das et al. (2008) find some negative relation between safety disconnect and quality

outcome, yet their empirical test lacks generalizability due to the limited sample size. This limitation can be easily overcome by replicating the empirical test with a larger and more encompassing data set.

Conclusion

This paper aims to synthesize both quality and safety literatures and the often oversighted connection between safety and operational performance. This paper strives to call for more attention, especially empirical attention, to the linkages between safety and competitive constructs, especially quality outcomes. Despite the growing interest on occupational safety from both practitioners and academicians, the linkages between safety and competitive constructs still remain mostly theoretical. Before the linkages are well-established and corporate decision-makers are convinced of the competitive benefits occupational safety brings about, it is challenging to stop and reverse the incomprehensible increase in the number of occupational accidents and incidents.

Additionally, this paper is the author's first attempt at an expansion of TQM to include safety, which responds to Brown (1996)'s call for safety research in OM and voices support for her proposition to include safety among the competitive priority constructs.

For practitioners, the paper helps raise awareness of the role of occupational safety as an economic opportunity instead of a regulatory cost. For procurement and tendering professionals in industries where product quality is a critical factor (e.g. healthcare equipment), it offers another indicator for a reliable quality performance.

Besides digging deeper in the linkages between safety and competitive constructs in manufacturing and production (i.e. product economy), future research could study the impacts of safety disconnect on quality performance in other segments, e.g. service and experience economies, and/or expand the definition of safety to include online (virtual) safety.

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Process Mining for Six Sigma: Plugging into Big Data

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Abstract

Six Sigma is one of the most successful quality management philosophies of the past 20 years. However, the current challenges facing companies, such as rising process and supply chain complexity as well as high volumes of unstructured data, cannot easily be answered by relying on traditional Six Sigma tools. To meet this need, based on design science, we present an approach for integrating Process Mining into the Six Sigma toolset to enable enhanced data analytics. The results of a first expert evaluation workshop provide insights into its application possibilities and ideas for future research.

Keywords: Process Mining, Six Sigma, DMAIC

Introduction

New challenges for companies in recent years include an increasing complexity of products accompanied by complex processes and supply chains (Bozarth *et al.*, 2009). With the help of big data as the "gold" of the 21st century, digitalisation promises faster and more efficient processes and innovative products. This article focuses on using companies' internal data for business process improvement via Six Sigma (6S).

As one of the most popular and successful process improvement methodologies and management concepts (Shafer and Moeller, 2012; Jacobs *et al.*, 2015), 6S originated in manufacturing and was later applied to other industries, such as the service sector (Heckl *et al.*, 2010). Three practices are critical for 6S: The role structure (belt system), the structured improvement procedure (DMAIC), and its focus on metrics (Zu *et al.*, 2008). In this article, we do not focus on the human and organisation theory aspects of 6S. Instead, we concentrate on its data analysis aspects and the technological connection to information systems. 6S relies on a systematic, fact-based approach, including "classical" inductive statistics such as hypothesis testing or the design of experiments. Based on the new digitalisation challenges, the traditional 6S approach is confronted by limitations. For example, 6S is unable to analyse large amounts of unstructured data, which is the basis of big data analytics. In our article, we present an approach for integrating Process

Mining (PM) technologies into the 6S toolset to enhance its data analysis capabilities. Most processes in large corporations are supported by or executed in IT systems that store large amounts of data. Enterprise resource planning, customer relationship management, workflow management, and manufacturing execution systems contain valuable process-relevant data that are often not accessible under the usual improvement project circumstances. This article presents a concept that allows access to and usage of these data by integrating PM technologies into the 6S toolset.

Our research method is design science, which is increasingly being adopted in operations management (Holmström *et al.*, 2009; van Aken *et al.*, 2016). This method is particularly popular in information systems research and is often used there to create, implement, and evaluate innovative frameworks and IT artefacts (Hevner *et al.*, 2004). In operations management, design science is explicitly recommended for research with high practical orientation, which matches this article's intentions (Browning and Treville, 2018). In our article, we present the concept for including PM into the 6S methodology and assess it by using expert evaluation and a technical experiment. At the centre of the article is the concept of using PM in 6S projects by showing how it can be integrated into the define, measure, analyse, improve, and control (DMAIC) project phases. Therefore, we focus on exploratory research, which can later be followed by explanatory research. In this article, we answer the following research question:

'*How can Process Mining be successfully added to the Six Sigma methodology?*'

We start with the research background and a general introduction of PM and its characteristics and potential. We then present the concept of integrating PM into the 6S toolset and describe a variety of scenarios in which 6S projects can benefit from PM. We evaluate the concept by executing a technical experiment in an expert workshop and then end our article with a conclusion and outlook.

Research Context

Research about Six Sigma

6S research started in the late 1990s and became much more comprehensive and diverse after 2004 (Aboelmaged, 2010). Research initially focused on manufacturing and the 6S toolset, but more and more articles appeared beginning in the late 2000s addressed cultural and soft factors, such as leadership, as well as domain-specific challenges and customisation of 6S, for example, in the service and public sector (Antony *et al.*, 2017).

The majority of 6S research remains rather practice-oriented. However, its lack of theory has already been identified and addressed in the literature (Linderman *et al.*, 2003). Schroeder *et al.* (2008, p. 540) summarise the common elements from the literature and define 6S as follows:

Six Sigma is an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives.

The meso structure integrates both micro and macro levels of analysis and is created in parallel to the existing organisational hierarchy. 6S generally is not considered a project management method only. In fact, it targets the whole organisation as a system and establishes a coloured belt system comparable to martial arts standards. We mainly focus on the black belt role in this article, as these 6S experts are intensively trained in statistical methods and typically have more project experience than green belts (Coronado and Antony, 2002). Although we keep the elements of the 6S definition intact, we aim for extending the toolset in 6S projects. Until now, the topic of PM has not been included in popular 6S books (Pyzdek and Keller, 2014) or the ISO standard for 6S (International Standards Office, 2011). Most of the elements of 6S were included in its toolbox decades

ago. In a comprehensive literature review regarding the most frequently used tools and methods in 6S literature, neither data mining and its most important methods nor PM were found (Uluskan, 2016). There are a few examples, however, for using data mining techniques in 6S projects. Zwetsloot *et al.* (2018) present three case studies involving data analytics experts as consultants for black belt projects. George (2019) summarises a large number of case studies where 6S already could benefit from data mining, such as applications of neural networks, artificial intelligence, and deep learning. The overall field of big data is recognised as having a very large potential for 6S while still not being extensively researched (Antony *et al.*, 2017). Gunasekaran *et al.* even speculate that a new philosophy beyond 6S and total quality management (TQM) could emerge in the next few years. However, instead of thinking about a successor, we present a concept to enhance and update the 6S toolset while keeping its philosophy intact.

Research about Process Mining

According to van der Aalst (2016, p. 15), PM "can be seen as a means to bridge the gap between data science and process science". The latter is regarded as the "broader discipline that combines knowledge from information technology and knowledge from management sciences to improve and run operational processes" (van der Aalst, 2016, p. 15). In their "Process Mining Manifesto", a large number of researchers from 53 different institutions concretised this view on PM and declared it as an enabling technology for management approaches such as continuous process improvement, TQM, and 6S (van der Aalst *et al.*, 2012). Four years later, van der Aalst *et al.* (2016) renewed their recommendation for future research directions to "bridge the current gap between Process Mining and Six Sigma".

PM analyses the event logs of IT systems, which have an initiator, refer to other tasks or activities, refer to a process instance (case), and are marked by a timestamp. PM therefore can analyse and display the execution sequence of process steps, decision rules, communication paths, and processing rules, enabling us to analyse the historical data of a selected time frame and measure the real process flow, which typically includes several process loops and flaws. Algorithms for process diagnostics analyse process traces (Jagadeesh Chandra Bose and van der Aalst, 2010) to support the following three major types of PM as differentiated by van der Aalst (2016, p. 33):

- **Discovery**: Create a process model out of the event log data. A pre-existent model is not required; the model can be generated purely based on the data in order to "discover" the real process with all of its connections, potential loops, and sequence variety.
- **Conformance**: Compare an existing process model with the discovered model created from the event log data to verify or contradict the conformance of a current process model. Conformance can be used for various purposes, including checking for violations of process rules, process monitoring, and auditing.
- **Enhancement**: Use the information from event logs to find ways to improve the current process. Possible solutions are to automatically correct the current process model or to extend the model with additional data, such as throughput and processing times, frequencies, decision rules, and quality measures.

Our concept will show that all three types can be of use for 6S.

PM generally is applicable to any sector and case where its data requirements are met. Major support factors for its introduction are high-volume process executions, high complexity in the process sequences, and high cost or competitive pressure. Implementations up to today are mostly seen in the finance and accounting departments across all industries. PM in manufacturing processes is generally possible, but its rather

complex use cases are still in an early stage. Typical pilot candidates to start an initiative are order-to-cash and purchase-to-pay processes.

Integrating Process Mining into Six Sigma's DMAIC

Many classical 6S projects analyse existing process models or can only rely on the input of a few workshop participants to understand the process flow. Usual data analysis is based on data reports, individual data selections, or manually performing new measurements. Analysing trustworthy existing data saves resources for the interpretation of the data and for more efficient projects compared to manual data collection. In addition, the refinement of existing process models generated out of data is much less time-consuming than building the models from scratch.

A major component of 6S is the belt system mentioned previously, which includes the green belts and black belts for typical project leaders and yellow belts for project members (Hoerl, 2001; Antony and Karaminas, 2016). When integrating PM into the 6S approach, organisations will need to determine who will analyse the PM data. There are two main alternatives: The PM knowledge can either be included in the black belt training as an additional data analytics topic, or it can be offered to 6S project managers by a separate organisational unit specialising in data analytics, as in the case studies analysed by Zwetsloot *et al.* (2018). We make no specific recommendation about this detail as our research to this point does not reveal clear superiority of one of the alternatives over the other.

In the following subsections, we will describe how PM can be integrated into 6S's five structured project phases.

Define

As the first of five project phases, the define phase provides the basis for a successful project. The main aims are to determine the project scope and its goals, which will be important throughout the project and for the eventual calculation of the project's benefits. Defining the right project measures is highly important for the potential effect of the project. Further instruments in this phase include, amongst others, the voice of the customer to develop the indicators critical to quality, a stakeholder analysis, and the suppliers, inputs, process, outputs, and customers (SIPOC) diagram for a first rough process step overview.

Although its strengths lie in the later project phases, PM can support the define phase by contributing first data insights via screening the available processes. With the help of a first look into the process data, the project scoping can be supported to avoid an endless project (scope too wide) or an overly limited project. Furthermore, the choice for major project goals could be verified and their target values roughly substantiated.

Measure

The emphasis of the measure phase in most projects lies on the data as it covers the collection of data and its planning. The project leader is responsible for contacting and considering every potentially useful data source to create a process analysis that is as complete and accurate as possible. Collecting new data is usually more cumbersome and time-consuming than using existing data. Unfortunately, existing data are often not available for all needed process aspects, or its validity cannot be trusted. Another perspective in the measure phase is the detailed comprehension of the as-is process. A typical element is to model the most relevant processes by creating flow charts or Business Process Model and Notation (BPMN) models.

PM offers another source of data for 6S projects, which, in most cases, has not been used before. Manually connecting to an SAP system and extracting timestamps at multiple points in the process is considered extremely time-consuming and could even make it necessary to contact IT consultants to create specific data queries or interfaces. PM software vendors specialise in the interfaces of common software products and can therefore deliver the needed data much faster at lower cost than the manual method. Due to the analysis of the event logs, PM typically focuses on measures such as throughput time, idle time, and waiting time. Additionally, the presented discovery type of PM can support or even replace the manual process of model creation. The model created on the data could be used for an expert workshop to verify the process and build upon it to reach a complete picture of the as-is process. Combined with the throughput and waiting time data, the creation of value stream maps is also possible. Finally, the conformance of process models can support the measurement of standardisation. PM can easily count the number of process variants, and the process experts can determine which of those are conformant to the business rules or to what extent the process standardisation already is or is not successful.

Analyse

Data are more important in the analyse phase where the main goal is to create causal relationships to identify which factors influence the process most significantly and, therefore, how we can positively influence its most important indicators. This work can be supported by brainstorming techniques to find potential influence factors (hypotheses) and to use the expert knowledge of the process-related employees. The most significant outcome of this phase is the transformation from many potential influence factors to the identification of the few most important factors that will be addressed later in the next phase. For this transformation, the input and experience of employees and process experts as well as the detailed analysis of all available data can be of use.

PM can offer many useful aspects based on the analysed event log data. Most PM software products can identify potential bottlenecks in the processes and visualise them in the generated process models. These automated findings can then be the basis for an expert workshop to verify and discuss the hypotheses and combine them with further findings from other sources. Validating existing hypotheses by PM data is also a valuable contribution in this project phase. The comparison of different layers of data, for example, several factories of the same company, can also be transferred to PM. The algorithms can determine whether the processes are actually being executed the same way or whether different factories deviate from the standard and receive better or worse performance results. Furthermore, with the help of the process indicators and timestamps, the most efficient process, the shortest process, and so on could be selected from amongst multiple variants to be discussed by the project team as a candidate for the future process.

Improve

The improve phase directly follows up on previous work. The main causes identified in the analyses now represent the requirements for improvement. Potential improvement ideas have to be developed and evaluated, followed by finally selecting the best-fitting ones for implementation. In some projects, the design of experiments allows different process configurations to be tested to arrive at the best result.

The PM enhancement especially can support the redesign of the processes; however, the data can also be used to verify potential benefits from process changes or to quantify the scope of change. If conformance is a major topic in a project, process variants can be harmonised and standardised amongst different locations, shifts, persons, and so on. In

the PM software market, advanced functionalities for simulation and forecasting are expected (Gartner, 2018). They could be used by project managers to calculate prospective effects of planned solutions and assist the selection of the best solutions regarding costs or benefits. For now, PM enables the prioritising of detected issues and making fact-based decisions on which improvement measures should be started first.

Control

In the fifth and final project phase, the sustainability of project benefits is the major topic. Main project indicators are measured again now to determine the exact achievement of the improvements and to calculate the project benefits. Few key measures are summarised in a process control plan for long-term process monitoring. The goal is to keep the new (higher) process performance and quickly detect significant performance changes.

PM can also assist in this phase in many ways. For the benefit calculation, the process standardisation can easily be measured again. The same applies to all the analyses in the measure phase as well as the implemented solutions in the improve phase, which now have to be controlled for changes and success. Furthermore, PM facilitates business activity monitoring, which can be used for continuously monitoring performance indicators (Janiesch *et al.*, 2011). Another useful aspect is compliance monitoring. Quality managers can monitor the emergence of new process variants or the proportion of non-regular process executions. PM can also automate or at least support recurring process audits and process certification initiatives.

Implementation and Evaluation

Every design science artefact needs an evaluation. We combine two design science evaluation techniques by executing an expert evaluation and discussing and implementing a technical experiment (Peffers *et al.*, 2012). Our research approach follows the work of Hevner (2007) by describing a cycle between creating and evaluating a concept. With regard to the categorisation of Pries-Heje *et al.* (2008), we are executing an ex post artificial evaluation strategy.

As company cases about the combination of PM and 6S are rare, we chose to evaluate our approach by using an expert workshop. The workshop team consisted of 12 persons with different types of expertise, including PM software representatives, statistics doctorates, experienced 6S (master) black belts, and lean experts. The workshop had two main elements, which we worked on in parallel:

- **Expert evaluation**: To receive feedback on our approach regarding how to integrate PM into 6S's DMAIC cycle, we presented the current method draft, discussed it with the workshop participants, and proposed changes and extensions to the approach.
- **Technical experiment**: We introduced a comprehensive data set to the participants that came from a large automotive supplier company with about 10,000 employees and annual sales of about 2 billion euros. The data set contained event logs of receiving, processing, and answering claims. Together in the group, we explored the claims process using the *LANA* PM software to experiment with its applicability for 6S.

The analysed data already provided important input for the fictional 6S project's define phase as it delivered a good overview about the process and its measures. The PM software created the process model shown in Figure 1 and had already annotated existing indicators. An important factor for the main goals of the project is the automatic acceptance of claims if they are not processed within a specific time frame. Main indicators for the process therefore are throughput time, claim acceptance rate, and first

pass yield. In the measure phase, the workshop participants went into the details of the PM model. All process activities were logged with timestamps and connected to potential influence factors, such as product group, location, country, division, customer, and order volume. The main process indicators could be visually analysed both via Figure 1 and inside the software when browsing through each step or following the flow. The execution counts of each step could be broken down into process variants, leading, for example, to different endings of either accepted or rejected claims. Checking for conformance was possible, as well as comparing the discovered model with others from employee workshops or work instructions to identify deviations.

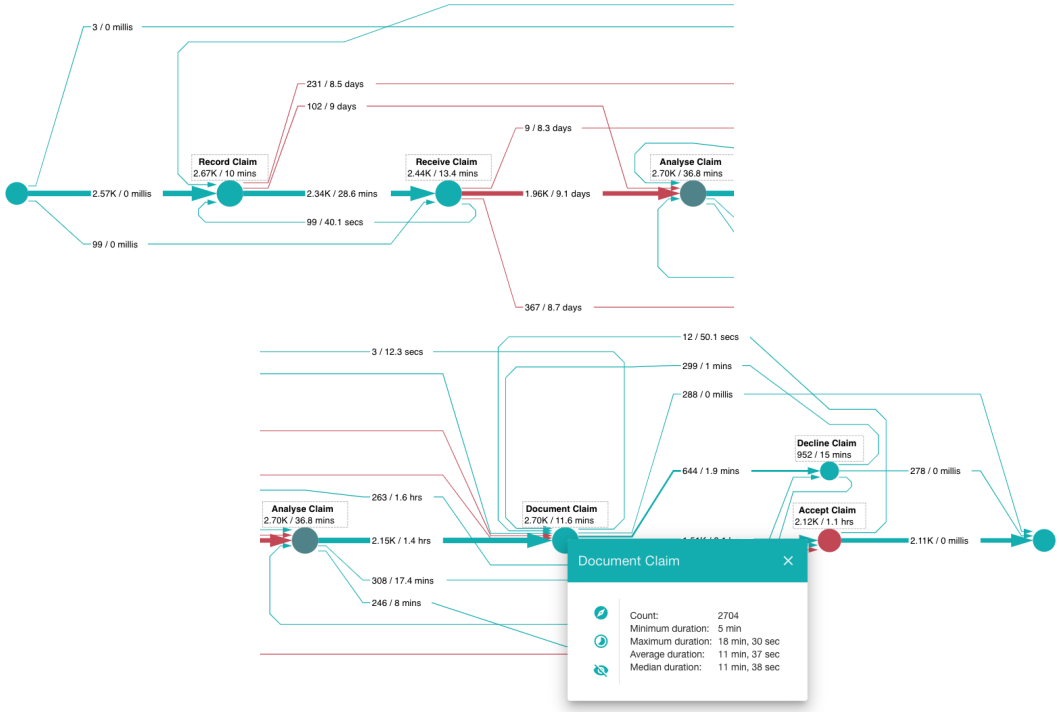

Figure 1 – Process visualisation from the LANA Process Mining software

In the analyse phase of the experimental project, different attributes and their influence on the key indicators were compared to find the most important influence factors. This analysis was triggered by specific expectations of the workshop participants, that is, which factors to analyse. Alternatively, an automatic mode could already highlight the most significant influence factors. In our experiment, a clear bottleneck was identified, as more than 60% of claims were processed after more than 10 days. This delay was even worse for a single product group. At this point, the work should be continued in the classical 6S way by including more data sources, process analyses, and expert opinions to find the most significant influence factors, which will be addressed in the improve phase. A typical aspect for improvement is the optimal allocation of human resources. The PM analysis can support this allocation as it provides the processing times and quantities. In the control phase, the PM system can be used to take over some of the process control activities to create continuous process monitoring to sustain the project's improvements.

After discussing both the approach to integrating PM in the DMAIC and the technical experiment, the workshop ended with discourse about which processes benefit most from PM. The results are as follows:

- Most activities of the process should be implemented digitally or be continuously supported by IT systems that store process data about the executions, such as timestamps, sequence of activities, and so on. Workflow management systems are a good example. If only a small section of the process is handled digitally, the benefits are very limited.
- Historical data are relevant for process analysis and improvement. PM can only deliver its full potential benefit if high volumes of historical data are available for the process analysis. Another option is the real-time PM, which is more complicated, has higher requirements for the process, and can only process new cases and not potentially large amounts of already stored data of past executions.
- If manual data collection is very complicated, time-consuming, and/or costly, PM can deliver its full potential.

Another major point of discussion centred on the aspect of data quality. A traditional element of the measure phase is the measurement system analysis (MSA) in which the project manager must validate the reliability and reparability of the measurements. The accuracy, trueness, biases, stability, and linearity of the measurements are of interest as well. The MSA can be very time-consuming, and, if the results are not good enough, the measurement system has to be significantly changed, leading to further project extensions. Regarding data quality, we agree with Hoerl *et al.* (2014, p. 223) on the importance of the following "building blocks of statistical thinking": clear problem statement, process understanding, analysis strategy, variation sources, quality data, domain knowledge, sequential approach and modelling process. High-quality analysis is not achieved by just "pushing a button" to let the PM software solve every problem. The mentioned domain knowledge and process understanding let the project manager decide how to set the analysis scope and how to interpret its results. Experienced 6S trainers typically ask the following question: "Do you completely trust your data?" Without high data quality, the best algorithms and technologies cannot be successful. On the contrary, they could deliver inaccurate results, misleading projects into wrong directions (Hazen *et al.*, 2014).

PM is a positive aspect when working on data quality because it can serve as a trigger to reflect and work on improving data, especially during the PM setup process in which insufficiencies can be identified and data generation can be optimised. Establishing PM in a process area can lead to a procedure comparable to the MSA to reach a status in which the data creation fulfils the quality requirements.

Conclusion and Outlook

The implementation results and the discussions with 6S experts show that PM is well suited to enrich the 6S toolset. The digital event logs proved to be very valuable sources for 6S improvement projects. Therefore, we recommend the integration of PM into the 6S toolset. PM supports and expedites the documentation, improvement, and control of processes, which may leave project managers with more time for improving processes rather than preparing manual analyses.

Our design science study shows strong limitations and can only mark the beginning of research about the idea to combine 6S and PM. We developed a method for integrating PM into the DMAIC cycle, evaluated and improved it with the help of an expert workshop, and finally used a technical experiment to show its general applicability. Future research should extend the analysis scope and ensure the practical relevance of the research. For this purpose, researchers could use case studies or action research to describe real cases of PM and 6S in companies.

We also see PM as a good starting point for process automation activities, as it can help prioritise the steps where the return on investment (ROI) of an automation solution is highest. A combination with robotic process automation (RPA) was recommended in a recent study by Gartner (2018) and promises a good fit with the DMAIC cycle to be implemented during a 6S project.

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The impact of implementation TQM practices on Innovation in the Palestinian service companies

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Abstract

The purpose of this paper is to examine the relationship between TQM practices and Innovation in the Palestinian service sector. Data were collected through surveying 220 Palestinian companies.

Results derived from this study show that TQM practices (Soft TQM practices and Hard TQM practices) have positive and significant relationship with all kinds of innovation (Incremental product innovation, Incremental process innovation, Radical product innovation, Radical process innovation and Administrative innovation).

This study is the first empirical test for measuring and examining the impact of TQM practices on innovation in Palestine.

Keywords TQM, TQM practices, Innovation, service sector, Palestine.

Introduction

Quality plays an important role in the overall strategy of companies. The main challenge of global companies is to acquire a share in the global market by understanding of the needs and wants of the customers (Zakuan et al., 2010). The majority of the companies apply tools of quality to enhance the quality of their products. In respect, the world focuses on total quality management (TQM) due to its tangible results in the sustainability of companies and in achieving organizational success (Baidoun & Zairi, 2003).

The current era is characterized by constant and growing changes in all aspects, which leads companies to seek more efficiency, creativity, innovation and cast off old and traditional systems to open paths to development and continuous improvement. Thus, the concept of TQM comes in handy to develop the needed methods and procedures. The

implementation and practices of TQM are the key strategies to achieve competitive advantage, and improve performance in order for companies to remain in the market and for sustainability. Consequently, companies with all their activities and sizes apply the principles and practices of TQM (Al-Sha'ar, 2014; Bon & Mustafa, 2013).

The importance of TQM has increased on all levels globally, regionally and locally. This importance led to many production and service companies to give it great importance. Business literature show that the use of TQM by companies is based on a set of fundamental factors. These factors provide a flexible culture that supports innovation and creativity, consolidate the commitment of top management to TQM principles, focus on customers and stakeholders, personnel management and empower them to make decisions, as well as the adoption of management methods based on data analysis and facts in decision making procedures (Al-Sha'ar, 2014).

Studies show that the use of TQM concepts and practices will eventually lead to excellence in innovation. Customer care, production development, results and the adoption of a constant preventive and treatment system will definitely lead to outdo others and excel over them. Based on different studies and researches in production and operations management, creativity and innovation in all their elements refer to the creativity and innovation of the product and operation. Furthermore, Administrative innovation is considered a key factor that helps companies achieve competitive advantage (Li et al., 2001). Many studies and researches explored the impact of TQM on innovation, some of which noted that impact while some did not (Kim et al., 2012; Bon & Mustafa, 2013; Singh & Smith, 2004; Prajogo et al., 2008; Hoang et al, 2006). Over the years, service companies became increasingly important in the local and global economy. Additionally, the contribution of this sector increased not ably within the gross national product (GNP) in the majority of countries, especially in the last two decades (Bon & Mustafa, 2013).

This study aims to highlight the impact of TQM on innovation in the Palestinian service companies to contribute in developing suggestions, and solutions to improve services provision and the use of the best methods and procedures by these companies. Additionally, this study is considered one of its kind in Palestine in regards to its aim to understand the impact of TQM practices on innovation in the Palestinian service companies. Moreover, Service companies constitute a big share in the Palestinian community, as they directly influence the needs of the population and provide them with tangible services.

Although, there exist many studies on TQM, these studies focused on linking the relationship between the practices of TQM with innovation especially in the service sector. Most of the studies focused on the industrial sector. It is also worth mentioning that Arab companies in general, and Palestinian companies in particular did not apply TQM and were not particularly interested in innovation.

Theoretical Framework

Total Quality Management

The concept of TQM is a modern terminology in business adopted by many companies. Moreover, the concept of TQM was based on a set of standards and principles which encourage management to adopt these concepts. As TQM is a comprehensive concept, it

was difficult to provide a concrete definition to quality. Many experts proposed definitions to TQM based on the visions they conceived from it (Herzallah et al., 2014).

TQM is known to be a mutual partnership between all members of the organization and its different commercial operations to produce products and services with financial added values which meet and exceed customers' needs and expectations (Dale et al., 2016).

TQM is also known to be a comprehensive approach to improve competitive advantage, efficiency and flexibility by planning every activity, organizing and understand it, as well as involving every single individual at all levels of the company (Oakland, 2014).

One can consider it a management philosophy that strives to continuously improve in all fields of the organization, and which cannot be achieved unless TQM is used at all stages from resources acquisition to customer services and after services (Kaynak & Hartley, 2008).

Total quality management practices

TQM practices are considered a managerial and organizational practices which are implemented continuously in a company to improve performance. The practices are not objectives but activities and operations employed by the company to reach its organizational objectives. The importance of implementing these practices is to improve the company's success rate through improving productivity and communication, as well as achieve customers' satisfaction, lower costs and low goods damage, and improve company's performance to achieve competitive advantage (Talib, 2013). Furthermore, Studies differed in highlighting the elements and practices of TQM, but most recent studies adopted eight practices for TQM (Herzallah et al., 2014; Kim et al., 2012; Kaynak & Harly, 2008; Saraph et al., 1989). The key practices in TQM are as follows:

1. Management leadership: It is the acceptance of responsibility by managers for quality including planning total quality, allocating resources, re-designing quality, evaluating quality and participating in the efforts for improving quality (Saraph et al., 1989). It is imperative that the top management is committed to quality as decisions associated to quality are considered as strategic decisions.
2. Customers focus: It is the degree companies understand the necessity to meet customers' needs and expectations to gain their continuous satisfaction (Ahire & Ravichandran, 2001). Furthermore, customers are considered one of the important elements that TQM is based on, as they are the basis for TQM activities.
3. Training: It is the degree to which the company provides its employees with statistical training and training linked to quality and its techniques (Kim et al., 2012). Training of employees and learning are key fundamentals of TQM, as they provide the best methods to improve the level of the individual. The more training related to TQM involve all the employees and uses statistical and technical techniques in measuring quality and developing, the more they will help achieve success in the implementation phase of TQM (Goetsch & Davis, 2014).
4. Employees relationships: This measures the extent of employees' involvement in making efforts and attending meetings pertinent to quality. Also, their contribution in the activities of quality management, as well as their participation in the decisions involving quality, assuming full responsibility in matters related to

quality, commitment to high quality performance and the degree of awareness of employees in relation to continuous quality improvement (Kim et al., 2012; Saraph, 1989).

5. Data quality and report writing: It is the degree the company uses high quality data gathering and utilizing, measure quality at the appropriate time and receive the needed feedbacks of the data quality from employees and managers to resolve problems, as well as evaluate them based on quality performance (Kim et al., 2012; Saraph, 1989).
6. Relationship with suppliers: The degree to which the company relies on suppliers which results in long relationships and are chosen based on the principles of quality rather than price, as well as their ability to meet the company's requirements and develop the products (Kim et al., 2012; Saraph, 1989).
7. Product or service design: The degree of involvement of all company departments in reviewing the designs, and in the efforts made in the clarity of the specifications. In addition to the company intent to foster productivity and highlight quality to avoid duplication in design (Kim et al., 2012; Saraph, 1989).
8. Process management: The degree to which the company achieves the conditions and steps of process management, using preventive maintenance, self-inspection of employees, use of statistical techniques and automated tests to lower the deviation of process (Kim et al., 2012; Saraph, 1989).

The practices of TQM can be divided into two parts (Herzallah et al., 2014). Soft TQM practices: These are practices that are related directly to the human element and include management leadership, customers focus, employees' relationships, training and suppliers' management. Hard TQM Practices: These are practices that are related directly to machines and systems and include data quality and reports, product or service design and operations management.

Innovation

Innovation is the practical implementation of an idea in a new form or new product, or the creation of new ideas without overdoing the benefit behind the idea (Schilling, 2008). Innovation can be also defined as the process of introducing a new idea, behavior, or anything new, and is viewed as new as it differs qualitatively from other existing things (Seidler-de Alwis & Hartmann, 2004).

Innovation can also be said to be the power to create a new product, service, technique or a production process and implement it, which has benefits and is of value (Schermerhon et al., 2000).

Types of innovation

Innovation is divided into different types which need different types of knowledge and which have an impact on competitors and consumers. Schilling (2008) and Kim et al. (2012) tackled different types of innovation as follows:

- Product / service innovation: It is shown in the outcomes of the company in the form of products and services. It aims to change the specifications, material and performance components of the product or service through improving on it,

developing it or producing a totally new alternative to it. Furthermore, Product innovation is the process of reaching for new ideas to create new products, services or improving products or current services to meet the needs and wants of customers and achieve competitive advantage for the company.

- Process innovation: It is the process through which the company manages its operations such as the techniques it uses in the production or marketing of its products and services. The objective behind it is to improve the efficiency and effectiveness of the production. Additionally, process innovation is very important when the company seeks to increase productivity and the quality of the product which is in line with TQM goals.
- Radical innovation: This type of innovation focuses on developing new things and totally different from existing solutions. It is deemed to be new and different.
- Incremental innovation: This type of innovation produces small changes or changes to the already existing practices of work performance.
- Administrative Innovation: it as the process that characterizes an individual when facing stressful situations, and coexists with them deeply in order to face them according to his/her own views in a new innovative way that differs from others (Bloani, 2008).

Hypotheses of the Study

The study tested the following hypotheses as:

H1: There is a significant impact of soft TQM practices and their variables (commitment of top management and leadership, customer focus, training, employees' relationships, suppliers' management) on innovation (service innovation, process innovation, administrative innovation.

H2: There is a significant impact of hard TQM practices and their variables (data quality and reports, service design, process management) on innovation (service innovation, process innovation, administrative innovation.

Study Methodology

A questionnaire was devised as a study tool to measure the objectives of the study and implement them after reviewing the previous studies and literature. The questionnaires comprised 65 questions divided into thirteen dimensions based on the Likert scale five-response categories.

The study population consisted of all general managers, executive managers, vice managers, quality management managers, production operations managers in the services companies in Palestine, West Bank which include: banks, insurance companies, telecommunication and internet provider companies, computers and information technology companies, hotels, and any company working in this sector. A complete census was used on the applicants of the population of the study within the administrative positions in the companies that include the above-mentioned managerial levels. They were chosen on the basis that they possess more knowledge, understanding and ability to evaluate more than others. Moreover, the sample comprised of 220 applicants.

Analysis and Results

Validity and Reliability of the Study Tool

The construct validity of the scale for TQM practices (soft and hard) was verified. The correlation coefficient was calculated from the average of each question of the scale with the overall average. The degree of its significance was also examined at $\alpha \leq 0.05$ on the actual applicants of the sample. The results showed that the correlation coefficient of the questions of the scale for TQM practices on the overall is statistically significant at $\alpha \leq 0.05$. The correlation coefficient was between 0.395-0.708, which indicates that the scale for TQM practices has a good degree of internal consistency.

The construct validity for the scale of innovation was also verified. The correlation coefficient was calculated from the average of each question of the scale with the overall average. The degree of its significance was also examined at $\alpha \leq 0.05$ on the actual applicants of the sample. The results showed that the correlation coefficient of the questions of the scale for innovation on the overall is statistically significant at $\alpha \leq 0.05$. The correlation coefficient was between 0.472-0.677, which indicates that the scale for innovation has a good degree of internal consistency.

The reliability of the study and its different axes was measured through Cronbach's alpha internal coefficient as an indicator for consistency on all 65 questions. The value of reliability of the TQM practice tool as a whole was 0.94, while the value of reliability for innovation was 0.91. Thus, the questionnaire is deemed to have a high level of reliability.

The data was processed using the Statistical Package for the Social Sciences (SPSS). The hypotheses of the study were analyzed at $\alpha \leq 0.05$ through the use of Person Correlation, Multiple Analysis Regression and One-way ANOVA.

Results of Hypotheses Testing and Discussion

Results for H1: A test was made on whether there is a correlation between all independent variables (soft in all its dimensions) and all the variables related to innovation (in all its dimensions) through Pearson Correlation test.

Results have showed that there is a positive relationship between all variables of soft TQM practices and all variables of innovation. As well as between all variables of soft TQM practices as a whole and all variables of innovation as a whole. The significant level was calculated at 0.00 which is less than 0.05 with a strong positive relationship as the correlation coefficient was between 0.390-0.728, which indicates that impact can be tested between these variables.

Multiple Regression test was used to test the hypothesis. The results obtained from this test have showed that there is a statistically significant impact on the variables of soft TQM practices on service innovation were the f-value was 33.253 which is significant at 0.000. The coefficient of determination was 0.437 which indicates that the variables of soft TQM practices constitute 43.7% of the service innovation. In addition, there is statistically significant impact at $\alpha \leq 0.05$ for the variables of commitment of top management and leadership, training, employees' relationships, suppliers' management of soft TQM practices in relation to service innovation where the t-value was, respectively, 2.741, 2.246,

2.085 and 2.101 and the statistical significance was, respectively, 0.007, 0.026, 0.038 and 0.037. These values are lower than 0.05 which indicates that there is an impact for each of them on service innovation. On the other hand, there was no impact for the variable of customers' focus on service innovation were the t-value was 1.657 with a statistical significance of 0.099 which is higher than 0.05 and indicates that it has no impact on service innovation.

Moreover, there is a statistically significant impact on the variables of soft TQM practices on process innovation were the f-value was 32.643 which is significant at 0.000. The coefficient of determination was 0.433 which indicates that the variables of soft TQM practices constitute 43.3% of the process innovation. Also, that there is statistically significant impact at $\alpha \leq 0.05$ for the variables of commitment of top management and leadership, employees' relationships, suppliers' management of soft TQM practices in relation to process innovation where the t-value was, respectively, 4.306, 3.220 and 3.620 and the statistical significance was, respectively, 0.000, 0.001 and 0.000. These values are lower than 0.05 which indicates that there is an impact for each of them on process innovation. On the other hand, there was no impact for the variables of customers' focus and training on process innovation were the t-value was, respectively, 0.483 and 1.661 with a statistical significance of, respectively, 0.630 and 0.098 which is higher than 0.05 and indicates that they have no impact on process innovation.

Furthermore, results have showed that there is a statistically significant impact on the variables of soft TQM practices on innovation management were the f-value was 27.166 which is significant at 0.000. The coefficient of determination was 0.388 which indicates that the variables of soft TQM practices constitute 38.8% of the innovation management. The table also shows that there is a statistically significant impact at $\alpha \leq 0.05$ for the variables of commitment of top management and leadership and employees' relationships of soft TQM practices in relation to innovation management where the t-value was, respectively, 4.222 and 1.997 and the statistical significance was, respectively, 0.000 and 0.047. These values are lower than 0.05 which indicates that there is an impact for each of them on innovation management. On the other hand, there was no impact for the variables of customers' focus, training and suppliers' management on innovation management were the t-value was, respectively, 1.293, 1.692 and 0.213 with a statistical significance of, respectively, 0.197, 0.092 and 0.831 which is higher than 0.05 and indicates that they have no impact on innovation management.

Results for the H2: A test was made on whether there is a correlation between all independent variables (hard in all its dimensions) and all the variables related to innovation (in all its dimensions) through Pearson Correlation test.

Results have showed that there is a positive relationship between all variables of hard TQM practices and all variables of innovation. As well as between all variables of hard TQM practices as a whole and all variables of innovation as a whole. The significant level was calculated at 0.00 which is less than 0.05 with a strong positive correlation as the correlation coefficient was between 0.456-0.705, which indicates that impact can be tested between these variables.

Multiple Regression test was used to test the hypothesis. The results obtained from this test have showed that there is a statistically significant impact on the variables of hard TQM

practices on service innovation were the f-value was 49.625 which is significant at 0.000. The coefficient of determination was 0.408 which indicates that the variables of hard TQM practices constitute 40.8% of the service innovation. Results also have showed that there is a statistically significant impact at $\alpha \leq 0.05$ for the variables of data quality and reports and operations management of hard TQM practices in relation to service innovation where the t-value was, respectively, 2.756 and 5.206 and the statistical significance was, respectively, 0.006 and 0.000. These values are lower than 0.05 which indicates that there is an impact for each of them on service innovation. On the other hand, there was no impact for the variable service design on service innovation were the t-value was 1.622 with a statistical significance of 0.106 which is higher than 0.05 and indicates that it has no impact on service innovation.

In addition, Results have showed that there is a statistically significant impact on the variables of hard TQM practices on process innovation were the f-value was 45.239 which is significant at 0.000. The coefficient of determination was 0.386 which indicates that the variables of hard TQM practices constitute 38.6% of the process innovation. Results also have showed that there is a statistically significant impact at $\alpha \leq 0.05$ for the variables of data quality and reports and operations management of the hard TQM practices in relation to process innovation where the t-value was, respectively, 2.624 and 5.170 and the statistical significance was, respectively, 0.009 and 0.000. These values are lower than 0.05 which indicates that there is an impact for each of them on process innovation. On the other hand, there was no impact for the variable service design on process innovation were the t-value was 1.347 with a statistical significance of 0.179 which is higher than 0.05 and indicates that it has no impact on process innovation.

Moreover, results have showed that there is a statistically significant impact on the variables of hard TQM practices on innovation management were the f-value was 39.628 which is significant at 0.000. The coefficient of determination was 0.355 which indicates that the variables of hard TQM practices constitute 35.5% of the innovation management. The table also shows that there is a statistically significant impact at $\alpha \leq 0.05$ for the variable of operations management of the hard TQM practices in relation to innovation management where the t-value was 5.558 and the statistical significance was 0.000. This value is lower than 0.05 which indicates that there is an impact on innovation management. On the other hand, there was no impact for the variables of data quality and reports and service design on innovation management were the t-value was, respectively, 1.683 and 1.170 with a statistical significance of, respectively, 0.094 and 0.243 which is higher than 0.05 and indicates that they have no impact on innovation management.

Conclusion, Applications, Limitations and Additional Researchers

Studies show that soft and hard TQM practices are directly correlated to innovation in all its forms. According to the findings of this study, it can be affirmed that implementing TQM practices is valuable for companies and organizations which lead to innovation and in turn to sustainable competitive advantage. If Palestinian companies seek to stay in a strong competitive environment in local and global markets and compete with other international companies, they need to improve the quality standards of their products and use new methods in production and industry.

The study recommends that Palestinian companies use new methods and ways to compete in the global market. They need to investigate more, seize new opportunities for innovation and creativity as well as effectively exploit existing skills at the same time. Companies need to provide the necessary resources, keep up with the new technologies and change management through the development of innovative products (Lichtenthaler, 2009; Prajogo et al., 2008) in order to maintain sustainability in the market that is characterized by an environment of rapid development in technology.

The importance of the study stems from the focus on a vital sector in Palestine which is the service sector. This sector has an important role in increasing the socio-economic level of a country, and is a vital sector in Palestine. Due to the dynamic changes in the global economy, companies' managers need to acquire more competencies in implementing TQM system and introduce technological innovation in their operations to keep pace with global developments and achieve the highest competitive edge. The study also contributes in guiding the companies' managers on the key concepts of TQM and innovation. The results of this study are deemed important for decision makers in the Palestinian companies as they provide a clear mechanism to enhance the competitive advantage of the Palestinian companies through the implementation of TQM practices and supporting innovation. It also explains the obstacles that they face when applying TQM practices. This study is very important especially in developing countries such as Palestine where service companies seek to implement new philosophies to achieve their goals, improve their performance, increase their competitive edge and improve the economy of the country.

There are some limitations in this study that are important to mention. First, the selection and distribution of the study sample is one limitation as Palestine is divided into two parts: West Bank and Gaza Strip. All the participants in this study are from the West Bank and there are none from the Gaza Strip due to the political situations in Palestine and the geographical topography between the West Bank and Gaza Strip. Second, the data gathered for the purpose of this study was based on the service sector only. Future studies can expand on this study to: 1) implement studies on the challenges of implementing TQM in the service companies; 2) perform a comparative study on the degree of TQM implementation between the different service companies and industrial companies and; 3) conduct a study on the effect of implementing TQM on institutional performance for service companies.

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Reducing cycle time using six sigma in the pharmaceutical industry

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Abstract

This study details the deployment of Six Sigma in the production and delivery system at a pharmaceutical company in Ireland. Over the past decade, teams have worked with the organization to reinforce the importance of target based manufacturing. This paper details one project with the objective to reduce cycle times for batches of products from order placement to shipment. The DMAIC framework was selected to meet the company's quality, cost and delivery targets. After implementation, the order lead-time of products and batch paperwork were reduced by upwards of 25 percent, defects were reduced and a quicker customer response was provided.

Keywords: Lean and Agile Operations (12), Healthcare Operations Management (7), Total Quality Management, Kaizen and Six Sigma (39)

Introduction

With the volatility and strain being placed on the pharmaceutical industry today, efficient supply chains for organizations in this sector have never been more important and modeling these systems is becoming equally important (Settanni et al., 2017). Not only can inefficiencies affect sales and growth, they can also affect customer satisfaction, and in the worst cases, can potentially affect patient outcomes. Supply chain delays can cause unwanted and unintended problems downstream. For example, Einset and Marzano (2002) and Jacobs et al. (2015) showed in their studies that many organizations operate at a quality level which is equivalent to spending between 15% and 20% of their revenues

on non-value added, wasteful, activities such as rework, inspection/testing, and losses.

One way to eliminate such waste is by establishing a solid business process management and systematic supply chain improvement system using statistical and business process methods. This kind of transformation towards a standardized order process means that pharmaceutical companies have to rethink their supply chain processes and process improvement methodologies within the context of their business network. According to Alt & Puschmann (2005) pharma companies still have a way to go in adopting process improvement systems in their internal processes compared to other industries. In their view, reducing cycle and waiting times can assist big pharma in improving process efficiency and efficacy through building better relationships with their customers (Alt & Puschmann, 2005).

In this article, we will present a process improvement case where cycle time is much longer than the desired time. Using the Six Sigma methodology, along with the associated tools and techniques, we will investigate how to reduce cycle time in a particular service line and make suggestions on how to keep future problems from cannibalizing any gains made from our work. Our primary research question is whether a focused effort on cycle time reduction, using Six Sigma, can lead to performance improvements in the pharmaceutical industry. More specifically, when using well published tools such as value stream maps, fishbone diagrams, etc., and less documented tools such as the X-Y matrix, can we achieve cycle time reduction leading to less rework and/or higher quality?

Research Motivation and Literature Review

Six Sigma approaches and cases have been well published in the scholarly literature (Laureani and Antony, 2017). One of the most prevalent process improvement techniques for industry cases is the use of Six Sigma as a statistical measure of controlling defect rates within a system by reducing process variation. Defects can broadly be defined "as anything which does not meet customer needs of expectations" (Antony, 2006, p. 246). Brady and Allen (2006) describe Six Sigma as a structured and systematic approach to process improvement that aims to generate efficiency in the operations and efficiency of the activities in organizations by fostering an internal business orientation (Schmiedel et al., 2014; Vom Brocke et al., 2014).

According to a recent study by Takao, Woldt and da Silva (2017), Six Sigma is a rigorous and disciplined program that uses data and statistical analysis to define a problem, measure the process, improve the company's operating performance (by eliminating defects, errors, or failures), and control the manufacturing, service, and transactional environment (Takao, Woldt and da Silva, 2017, p. 2).

Investigating Reducing Cycle Time Using the DMAIC Methodology

Six Sigma is also referred to as a "more detailed outline of Deming's plan-do-check-act cycle by guiding the initiative through a five stage cycle of define-measure-analyze-improve-control (DMAIC)" (Pepper & Spedding, 2010, p. 142; Andersoon et al. 2006; Andersson et al., 2014; De Mast & Lokkerbol, 2012; Pande et al. 2000). Each stage uses a set of techniques and methods in order to measure the critical issues in that particular stage. According to Pepper & Spedding, (2010, p. 143) key performance metrics are used to set "a clear focus on measurable financial returns through a sequential and disciplined manner and establishes an "infrastructure of champions" with its training style of introducing "belt" qualifications within the organization to lead the way in data-driven decision making for improvement efforts." To achieve this, management commitment and open communication, are important for the success of a process improvement (Arora et al., 2005; London, 2005). Less support was often found with longer implementation

times of policies. While in many cases, the application of Six Sigma is explored in the construction industry, there are also select cases in the pharma industry (Nunnally and McConnell, 2007) as well as service industry (Stewart and Spencer, 2006).

The company hosting the project detailed herein is Helsinn-Birex Pharmaceuticals (Helsinn, https://www.helsinn.com/), a privately owned, Swiss-based, pharmaceutical company with manufacturing operations based in Ireland and the United States. Helsinn was listed as one of the top 1000 companies in Ireland and employees approximately 177 employees (Irish Times, 2019). Further, The Irish Times (2019) notes: "The Helsinn Group has been built on the basis of a unique business model, focused on the in- and out-licensing of pharmaceuticals, with the recent additions of medical devices in therapeutic niche areas." One example of Helsinn's passion towards continuous improvements is that they strive to have at least 70 percent of their workforce trained at a Six Sigma yellow belt level, or higher.

Methodology, Results, and Findings

To answer the research question, an exploratory, case study-based approach with a single case design was selected (Eisenhardt, 1989; Yin, 2014). Four criteria were adopted and applied in this case study: (1) completed Six Sigma project in the pharma industry, (2) an order management system being put into place, (3) challenges with the order management process, and (4) access to data. The researchers involved with this project were tasked with conducting a process improvement analysis of Helsinn's Klean Prep production line due to their abnormally long cycle time from the date an order is received to the time it is ready to be shipped. Our primary metric was cycle time (in weeks), and our secondary metric was the number of times rework is completed and the percentage of rework for each step in the process. With this project came many limitations and constraints, some of which include:

Time: The team was limited to a one month duration to complete the project. This included gathering the data, analyzing it, and making recommendations on how to improve the process. Additionally, the team was only allowed to visit the company grounds one or two times a week, complicating and condensing the data collection and analysis process.

Data: While the team had access to large amounts of data, it was not easily understood what story the data was portraying. With access to ample large data sets can come 'analysis paralysis,' in management decision making (Bumblauskas et al., 2017).

Industry Knowledge: No member of the core student team had worked in the pharmaceutical industry. The manufacturing of these products from start to finish is a complicated process. Not having industry or institutional knowledge created a gap that had to be quickly overcome given the project duration and timeline.

Regulations: The pharmaceutical industry has intense regulations that must be adhered to at all times. This complicates decision making in order to improve a process. Great care must be taken to make ensure that these regulations are not compromised in any way. This is a unique consideration when compared to other Six Sigma case studies across other industries.

Assumptions: Assumptions needed to be made regarding some of the data that was collected. Bias could be introduced here, skewing results that are not desirable.

The underlying project management framework within the Six Sigma methodology is known as DMAIC, which stands for Define, Measure, Analyze, Improve, and Control. Using this approach, we were able to model ways to reduce cycle time in the Klean Prep line for Helsinn. Each stage of the process is outlined in the subsequent sections.

Define: One of the initial project goals the team established was to determine the cycle

time for all process activities in the Klean Prep supply chain at Helsinn. At the time of the project in 2011, Helsinn was spending roughly 13 weeks from receiving customer orders to shipping finished goods to customers. This relatively long cycle time reduced product competitiveness. Because of the nature of the pharmaceutical industry, good manufacturing practices (GMP) require certain activities to be controlled in very specific manners. Much of what seems like non-value added activity may actually be due to regulations or may be done to comply with GMP. The goal of the project team was therefore to determine where time was allocated for each activity in the Klean Prep supply chain process. Figure 1 was created to give an overview of the Klean Prep process flow. Helsinn's material requirements, or resources, planning (MRP) system uses an item master that holds parameters for the lead-times of each order status. The supply chain manager uses this tool when scheduling the order for production. The supply chain manager takes into account the customers' requested ship date(s) and the capacity of the production line(s). Once a ship date is determined, the supply chain manager works backward to schedule the time allocated for QA approval, production, generating a parts list and ordering materials (i.e., develops an aggregate production plan).

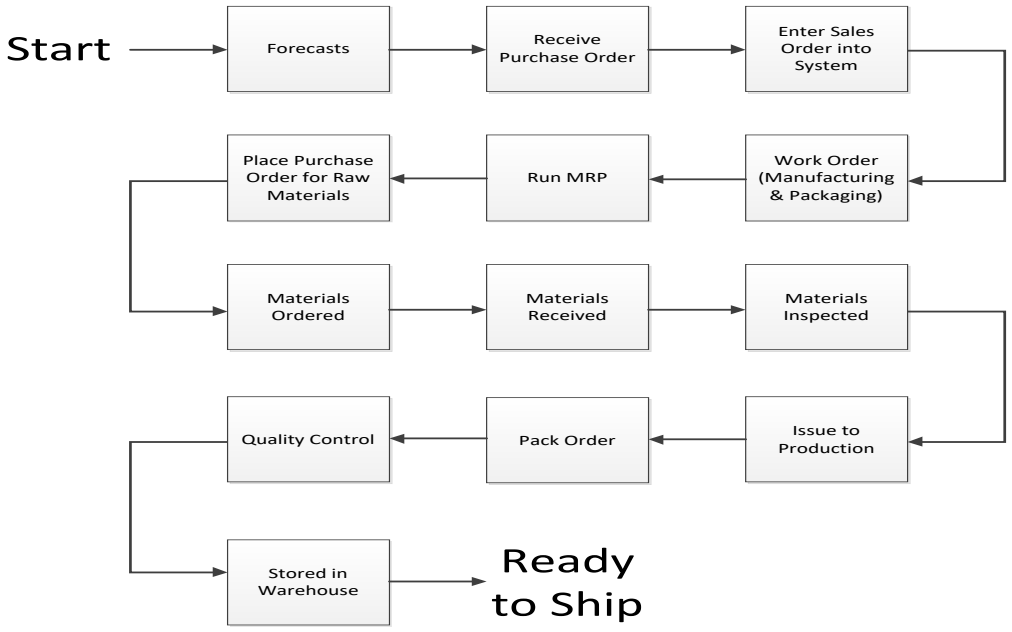

Figure 1 – Macro-level flow chart

Measure: Another objective specified in the team's project charter was to create a value stream map of the Klean Prep supply chain from the creation of a work order to approval by Quality Assurance and final shipment. The primary goal was to identify where time was being spent going throughout the process and to determine which activities have the most variability in cycle time. Figure 2 provides a fishbone, or Ishikawa, diagram (Ilie, 2010; Wong, 2011) which is a beneficial tool to help identify all the possible factors affecting the cycle time before any data collection and analysis begins.

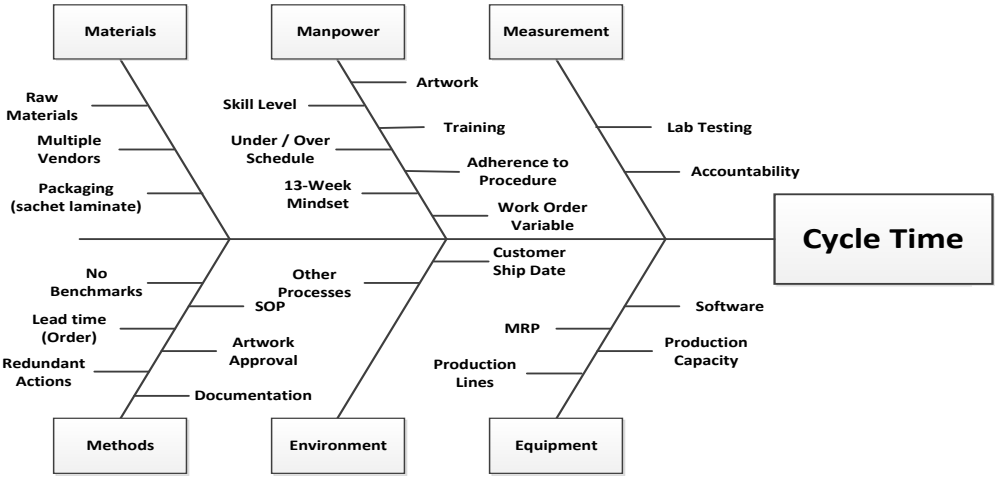

Figure 2 – Fishbone diagram

Six categories of factors that affect cycle time were deemed appropriate for this project: material, manpower, measurement, method, environment, and equipment. The factors associated with each category represent the possible causes for variation in the Klean Prep cycle time. For example, within the environment category, the customer's requested ship date is an issue when considering cycle time of the process. The schedule is set up to give a 13 week lead-time. Some customers will submit an order requesting delivery to be shorter or longer, depending on their time schedule. Helsinn would then adjust their time schedule to meet the customer's demand. If the customer requests delivery after the original 13 week lead-time, Helsinn will delay ordering materials until they are needed to meet the deadline. Working in this just-in-time (JIT) fashion, it is easy to see how the cycle time can vary from customer to customer.

In the methods area, not having benchmarks was deemed to be an issue. Creating a benchmark for a procedure not only helps managers and line workers to perform a procedure correctly, but it also assists in monitoring the procedure to see if it is under control. A benchmark can lead to creation of standard operating procedures (SOP), which can be used to reduce rework and lower variance, making the process more efficient.

After assembling the fishbone diagram, an XY diagram was used to analyze important factors in varying cycle time and the impact they have on the metrics of the project. In this case, the primary metric used was the total average cycle time and the secondary metrics were (a) cycle time variance, (b) number of times rework is performed, and (c) percent rework performed in a lot. An XY diagram works by taking the input variables that are most important and cross-analyzing them with each metric, which are ranked on a scale of one to ten, with ten being the most important. The numbers inside the diagram represent the affect the inputs have on the outputs, or metrics. Figure 3 shows an XY diagram for this project.

After ranking the metrics and cross-analyzing them with the input variables, Figure 3 shows that the time materials are ordered is the largest factor in the cycle time, followed by SOPs, the schedule, and having no benchmarks in place. This can be seen in the table provided as part of Figure 3. These factors provide a good indication on what to review when making suggestions for improvements in the process. While SOPs were considered the second most important factor, it is imperative to remember that in the pharmaceutical industry these procedures must be followed at all times. These are government regulated procedures and GMPs that must be adhered to. If they are deviated from, the company could face legal action or recourse.

XY Diagram Table

Demo

Delete

View Summary

Process:	Klean Prep
Date:	6/29/2011

Ranking Scale:
1- none, 3- marginal, 9- highest

	Output Variables (Ys)	Description	1	2	3	4	5	6	7	8	9	10	
			Average Cycle Time	Cycle-Time Varience	Rework (times)	Rework (%)							
		Weight	10	6	4	4							
	Input Variables (Xs)												Ranking
1	No Benchmark		3		9	9							102
2	Schedule		9	3									108
3	SOP		9	1	3	3							120
4	Redundant Action			9									54
5	MRP		3	1									36
6	Relationship with Vendors			3	1	1							26
7	Time of Material Ordering		9	9									144
8													
													590

Input Variables		
Description	Ranking	Rank %
No Benchmark	102	17.29%
Schedule	108	18.31%
SOP	120	20.34%
Redundant Action	54	9.15%
MRP	36	6.10%
Relationship with Vendors	26	4.41%
Time of Material Ordering	144	24.41%

Figure 3 – X-Y matrix diagram

It is important to note that the fishbone diagram and the XY diagram are working diagrams. As time goes on, they should be updated to deter future problems. After a problem is fixed, there may be a new problem that should be focused on. Keeping an updated version of each diagram will help identify flaws in the future, making the process more efficient and easier to deal with if there is a problem later on.

Analyze: Helsinn's MRP system automatically records a time stamp when specific activities occur. Time stamps from a sample of n = 33 different lots were used to determine the average length of time each activity takes in the process. The time stamps did not occur at the exact points in the original process map, so an alternative map was created that tracked the routing of the work order. The sales order process flow occurs in parallel to the work order. At certain points in the sales order data, the process actually reverses and goes upstream. This makes it difficult to track the exact cycle time for each activity in the sales order flow. As a secondary metric, the number of process reversals was calculated for each lot given. Since the cycle time was not known, there was not a way to be totally confident in which activities are the most time consuming, but where the process typically reverses can be determined.

The average total cycle time of the work order was found to be 13.15 weeks with a standard deviation of 4.5 weeks. The average cycle time for the sales order was 14.39 weeks with a standard deviation of 5.7 weeks. The sales orders and work orders run in parallel to each other. Sales and work orders are scheduled to meet a specific ship date which is specified by the customer and the supply chain planner. Figure 4 provides a box plot to illustrate high variance steps in the Klean Prep supply chain process. Boxplots are very useful for identifying quartile ranges and outliers and have been well documented

across many industries including healthcare (Williamson et al., 1989).

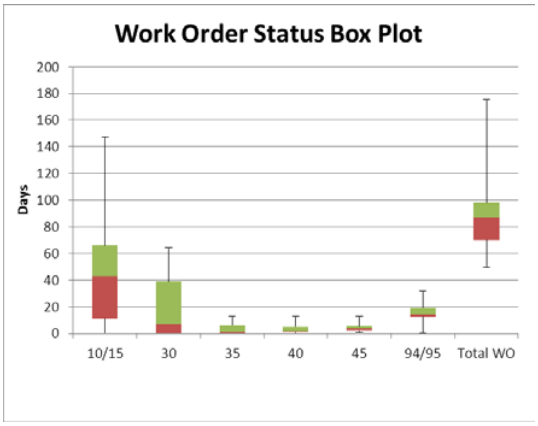

Figure 4 – Work order box plot

Part of this has to do with scheduling issues and the availability of raw materials. The steps with the largest variability are 10/15 (Create the Work Order/Attach Routing) and 30 (Generate the Parts List) as detailed the figure. These steps in the process are also the ones with the longest cycle time. Figure 5 shows a value chain map of the cycle times in the work order process flow.

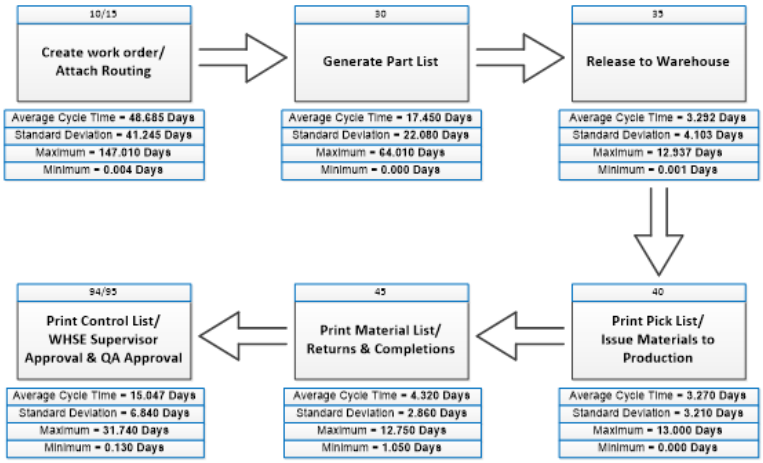

Figure 5 – Klean Prep value stream map

As can be seen in Figure 5, the average cycle time to create the work order and attach routing is the longest of any status. The cycle time for this step of the process is an average of 48 days with a standard deviation of 41 days. A couple of factors hinder this process. Helsinn waited one week after the sales order was confirmed to order packaging materials. The lead-time on those materials could be up to 4 weeks long. The orders must also be run through the MRP system before buyers receive a message to order materials. The packaging materials are ordered on a JIT basis. This means that they will be ordered to arrive in accordance with the production schedule, but no earlier. Buying materials in bulk can lead to discounted costs for Helsinn. The MRP system gives buyers a window of opportunity to determine whether or not they can purchase the materials together.

The lead-time between creating a work order and generating the parts list is largely

impacted by waiting for customers to confirm artwork changes. Packaging materials cannot be ordered until artwork changes have been confirmed. Artwork changes could be due to a color change on the box, moving text to another location on the package, a change of address, or any new regulatory measures on drug packaging.

The second longest part of the process is waiting to generate the parts list. This takes an average of 17 days, but the standard deviation is 22 days. This is a massive swing in variability. Helsinn's policy, at the time, was to not commit any material to the order until all the materials were received. In this way, materials were not committed to the order until they are in the warehouse and ready to be moved to production. Once material is received, the parts list can be generated. For the secondary metric, the number of reversals in the sales order flow is examined, as shown in Figure 6.

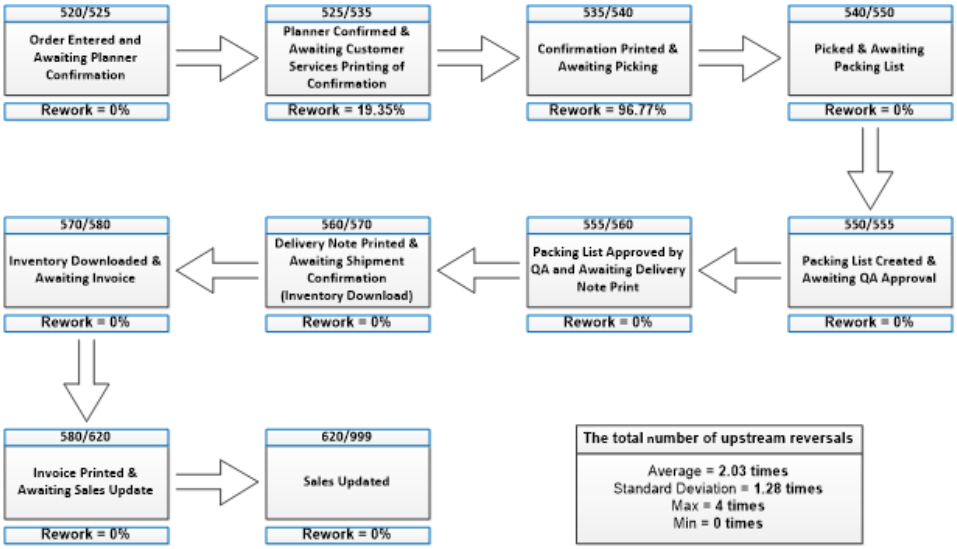

Figure 6 – Klean Prep sales order flow

It was found that there was an average of two instances of rework in each order. In every case of reversal, the process was backtracking from either status 540 to 535 or 535 to 525 (as defined in Figure 6 and subsequently). The normal flow from status 525 to 535 is identified as "Planner Confirmed and Awaiting Customer services". Status 535 to 540 means that the order is "Picked and Awaiting Packing List." In 19% of cases, there is rework required on status 525 to 535. Rework on 535 to 540 occurs in 97% of cases. This rework is generally due to confirmation of changes in the sales order with the customer. Any time there is a change in the sales order it must be reconfirmed with the customer before proceeding to the next status.

Improve: ***Benchmarks:*** Helsinn, as of 2011, had no benchmarks set in place for each individual status. Implementing a specific benchmark for each status may serve to reduce the variability that occurs. It would also set a standard for scheduling those specific steps in the process.

Artwork Investigation: It was also recommended that Helsinn investigate which customers are changing their artwork frequently and which customers are stable. Once stable customers are identified, it is possible to order those packaging materials as soon as sales orders are received. This can reduce a portion of the lead-time between creation of the work order and generation of the parts list. At times, there could be up to 25 artwork changes under consideration. This can slow the process down if not enough manpower is available to tackle all of the changes at once. In 2011, there was only one employee

responsible for artwork. It would be worthwhile to investigate how many artwork changes occur in a year and to perform the cost/benefit analysis on hiring additional artwork support. Helsinn might also consider forming contracts with customers, ensuring that artwork changes are approved within a certain amount of time before the order is placed. Implementing a year-long contract period where artwork does not change can also allow Helsinn to be more confident in ordering packaging materials when sales orders are received. Exceptions should be made for regulatory changes.

Eliminate Rework: Sales order rework should be investigated as well. Rework occurs regularly which costs time in the sales order work flow. Since the processes are parallel, it's impact may not be substantial enough to cause concern.

MRP Opportunities for Change: The actual cycle time for each status may vary from the time allotted in the Item Master parameters. If this is the case, schedules made from the Item Master will not accurately reflect the needs of each department. It was recommended that Helsinn might benefit from looking into the actual cycle time versus the [default] parameters in the MRP system. If there are discrepancies, the Item Master should be adjusted to account for the time constraints of each department. Changes to the MRP parameters can lead to adjusted schedules that reorganize time in a more efficient manner.

Control: If any suggestions are seriously considered, maintaining gains after implementation is critical to the success of the overall project. For this to occur, constant checks on benchmarks should be performed as to not revert back to previously identified and/or corrected problems. This could help deter future rework throughout the process, while at the same time helping to identify future problems. Thus, the process has the potential to continue to improve if the right control measures are taken. Tracking the variance over time would also help identifying future problems quickly. Keeping out in front of the problems, i.e., taking a proactive approach, will also help remedy them in a timely manner.

Discussion, Conclusions, and Future Work

In summary, this article details a case study derived from real data obtained from a pharmaceutical company (Helsinn) providing support for our hypothesis. With reduction in variation, rework and waiting time, better decisions can be made, and costs can be reduced. In some instances the projects executed for Helsinn over the years have yielded reductions of upwards of 25 percent of cycle time. An improvement process using Six Sigma tools and operating within the DMAIC framework was formulated to reduce the cycle times.

This is one of many projects conducted by the authors and student research teams under their supervision at Helsinn over the last decade. In one case, the Helsinn team took the results to their Senior Management in Switzerland for final decision making and action. More should be published in this area to further illustrate the importance of Lean and Six Sigma in a continuous improvement journey. Another post-project development was an impact versus effort quadrant model which uses an eight step methodical process developed by authors and a Fortune 500 organization. This should be further elaborated upon in future work. The goal of reducing cycle time using Six Sigma in the pharmaceutical industry has yielded dividends and should continue to do so for many years to come.

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The effectiveness of sustainable practices within the EFQM Excellence Model: a longitudinal analysis

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Abstract

Among Business Excellence Models that guide organizations towards high performance, EFQM is widely adopted in Europe. Given demands for better management of resources and sustainable practices, within EFQM is the principle of Creating a Sustainable Future. This study investigates whether EFQM has been effective in disseminating sustainable practices. Data from a population of recognized-for-excellence organizations by a partner of the EFQM in Spain, from 2000 to 2014, are used. The evolution of criteria on sustainability and their association with Society and Business results are examined, thus testing the premise that sustainable organizations perform well on social, environmental, and economic aspects.

Keywords: sustainability, quality management, business excellence models, EFQM

Introduction

Following the Brundtland Comission's definition of sustainable development (WCED, 1987), several definitions of sustainability have emerged in the literature. In common, they emphasize environmental, social and economic performance, so that sustainability is about conducting business with a long term goal of maintaining the well-being of the economy, the environment and society (Hassini et al., 2012). Environmental resources are limited, so that companies need to operate in a way that minimizes their negative environmental impact (Shrivastava, 1995). In this vein, the European Foundation for Quality Management (EFQM) Excellence Model, which is the most widely adopted business excellence model in Europe, defines fundamental principles that form the foundation for achieving sustainable excellence in any organization (EFQM, 2012). Specifically, the notion of creating a sustainable future is embedded in the model, and thus EFQM addresses the institutional pressures faced by organizations to explicitly balance economic, environmental, and social impacts of their day to day activities (Edgeman and Hensler, 2001). Organizations are encouraged to consider sustainability in all stages from product/service design, material sourcing, manufacturing processes, and delivery of the final product/service to the customers, to the end-of-life management of the product after its useful life (Srivastava, 2007). Efforts to reduce carbon-footprint, how these efforts are coordinated with partners, and replicated in the

supply chain are also key features towards delivering a sustainable future. Consequently, with its focus on processes and practices, the EFQM Model can be a driver of sustainable development (e.g. Cierna and Sujova, 2015; Gorenak, 2015; del Rio et al., 2017; Pérez and Escrig, 2018), especially as it has become a global model with over 50,000 users worldwide (EFQM, 2019).

Sustainability is stressed in recognitions for excellence, since the goals of the UN Global Compact are either explicitly or implicitly covered in the criteria defining the EFQM model. Hence, the EFQM model provides a framework to promote and recognize sustainable success and guides organizations that seek to achieve excellence. Based on a standardized Recognition Scheme, trained EFQM assessors evaluate organizations according to 32 sub-criteria, which lead to scores on 9 criteria, of which 5 are 'Enablers' and 4 are 'Results'. Enabler-criteria cover what an organization does and which management practices are in place with respect to each criterion (Leadership, People, Strategy, Partnership and Resources, Processes, Products & Services). While, Results-criteria cover what an organization achieves in terms of People, Customers, Society, and ultimately, Business results. Although the EFQM model does not explicitly link the sub-criteria related to sustainability and results criteria, one would expect that what recognized organizations do in order to create a sustainable future, as implied by different sub-criteria in the model, would impact their Society results and Business results scores. In other words, the triple bottom line as a concept for an overall evaluation of performance, implies co-movement between sustainability, social and economic performances.

This study identifies the implicit sustainable future orientation in the EFQM model and examines whether this orientation, which implies the adoption of sustainable practices, can explain Business and Society Results. In the remaining sections, the theoretical background and the research question that guides the investigation are summarized. Secondly, the empirical study and results are reported. Finally, the implications for practice and future research are drawn, and the paper concludes.

Sustainability and Performance

The Triple Bottom Line model (Elkington, 1999) entails that an organization concerned with sustainability should be responsible for the impact of their activities on social (people), environmental (planet) and economic (profit) issues. Since the development of this model, there has been a growing interest in more ethical or transparent ways of running businesses and in related concepts, such as corporate sustainability or corporate social responsibility (CSR). As Van Marrewijk (2003) or Montiel (2008) stated, corporate sustainability and corporate social responsibility might have followed separate paths, but share the same vision, so that nowadays the two concepts have become interchangeable. Indeed, both streams of literature refer to organizational activities that imply commitment to stakeholders and accountability of economic, social and environmental issues while managing operations (Aguinis and Glavas, 2012; Larran et al., 2016; Mehralian et al., 2016). Moreover, as Asif et al. (2011a) highlighted, sustainability also requires the adaptation of business strategies to emerging stakeholders' requirements.

As several authors recognized (e.g. Husted and de Sousa 2017; Mendes and Dias, 2018), Stakeholders Theory implies a managerial decision-making that accounts for the demands of all stakeholder, rather than a focus on shareholders, so that value is generated and sustainable results are achieved. Hence, organizations engaging in sustainable practices are likely to operate consistent with the expectations of their stakeholders, which potentially results in competitive advantage and higher performance

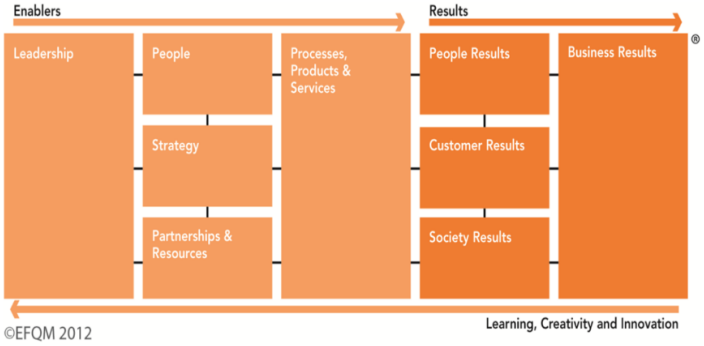
(Porter and Kramer, 2006; Mehralian et al., 2016). Accordingly, there is a business-case for sustainability (e.g. Carroll and Shabana, 2010). Despite conflicting evidence on the business case for sustainability (Brammer et al., 2006), a meta-analysis by Orlitzky et al. (2003) concluded that there is positive association between business performance and key elements of sustainability. Sustainable practices were reported to impact customer's perceptions of differentiation and quality (e.g. Aguinis and Glavas, 2012), which are likely to affect business results. Peršič et al. (2018) also found that the adoption of ISO 26000 can positively influence financial performance. In the specific context of Spanish organizations, Muñoz et al. (2012) observed benefits of having standards of socially responsible management for business and environmental performance. Moreover, Mendes and Dias (2018) concluded that sustainable approaches based on quality management and socially responsible practices improved financial and operational performance, as well as the quality of working-life. In summary, sustainable practices can benefit businesses and society.

The EFQM Excellence Model as enabler of change towards sustainability

How can sustainability be integrated into management practice has been subject of ongoing research, with some concluding that, where quality-related initiatives are in place, social responsibility is easily promoted (e.g. Van Marrewijk, 2003, Tarí, 2011). In fact, quality management has evolved from customer-focused to stakeholder-focused (Mellat-Parast et al., 2014), and when addressing the quality management and social responsibility nexus, Ghobadian et al. (2007) observed that both are rooted in a common philosophy that can lead to non-financial and financial benefits. Hence, current quality management recognizes the impact on society of what an organization does, and account for the need to balance and fulfil different stakeholders expectations (Mehralian et al., 2016; Mendes and Dias, 2018). Similar to the Malcom Baldrige National Quality Award that specifies social responsibility and various stakeholders' interests within its assessments, the EFQM Excellence Model is a useful platform to guide organizations in placing sustainability into practice.

The EFQM Excellence Model

The EFQM Excellence Model is a non-prescriptive quality management framework that facilitates the understanding of the relationships between what an organization does and the results it achieves. It provides a systematic structure, which allows organizations to thoroughly review their management practice and can guide them towards sustained success (Bou et al., 2009; de Menezes and Escrig, 2016). The current framework, as per EFQM (2012), is based on nine criteria, as depicted in Figure 1.



Source: EFQM (2012)

Figure 1. EFQM Excellence Model criteria

The "Enabler" criteria cover the actual organizational practice, while the "Results" criteria cover what is achieved. The RADAR logic of the assessments reflects the dynamic nature of the Model and provides a structured scheme for systematically reviewing the nine criteria. Therefore, the EFQM model indicates the areas that managers should focus their attention in order to improve performance and, as illustrated by the arrows in Figure 1, the model accounts for the feedback-loop from management practices to results and learning (Zwetsloot and van Marrewijk, 2004). When an organization applies for EFQM recognition, its practices are assessed against the model in Figure 1, so that points are allocated to each sub-criterion by trained assessors based on evidence. Recognition for excellence can be given at three levels (300+, 400+, 500+) depending on the score obtained (maximum score =1000). Recognition is valid for two years, after which an organization (or unit) would need to apply for reaccreditation.

Sustainable practices embedded in the EFQM model

Anninos and Chytiris (2012) noted excellence and sustainability are linked. Since society and the environment can be stakeholders (e.g. Garvare ad Johansson, 2010; Siva et al., 2016), Stakeholders Theory informs not only social responsibility, but also the EFQM model, which states that excellent organizations "achieve and sustain outstanding levels of performance that meet or exceeds the expectations of all their stakeholders" (EFQM, 2012: 2). Considering that sustainability can be reached when an organization recognizes the concerns of its main stakeholders and develop strategies to satisfy their expectations, the EFQM model can be used to address stakeholders' demands in pursuit of sustainability (Asif et al., 2011b). Indeed, embedded in the model is the concept of Creating a Sustainable Future, accordingly "excellent organizations have a positive impact on the world around them by enhancing their performance whilst simultaneously advancing the economic, environmental and social conditions within the communities they touch" (EFQM, 2012: 5).

The EFQM model's Creating a Sustainable Future is a transversal concept, as is manifested through distinct sub-criteria in the model (EFQM, 2012; del Rio et al., 2017). The adoption of the EFQM model can raise awareness of sustainability, and enable related practices as part of a quality management approach to be developed, continuously assessed, and refined. According to EFQM (2012), Creating a Sustainable Future is an orientation that underlies the following sub-criteria, i.e.: 1a.Leaders are role models for social responsibility; 1c.Leaders engage with external stakeholders; 1e.Leaders manage change effectively to ensure the sustainable success; 2c.Integrate the concept of sustainability in the core strategy; 4b.Finances are managed to secure sustained success; 4c.Buildings, equipment, natural resources are managed in a sustainable way; 5b.Products and services are developed to create value to customers in a responsibly way.

Considering guidelines on these sub-criteria, organizations adopting the EFQM model develop their own practices to integrate sustainability in their vision, mission and values. They preserve the environment, collaborate with customers, suppliers and other partners, and promote the integration of their business activity in society through sponsorship of socio-economic or cultural projects. In doing so, their actions confirm that the EFQM model is a basis for the practical implementation of social responsibility (CEG, 2018). Several case studies (e.g. Pedersen and Neergaard, 2008; Avlonas and Swanninck, 2009; Ascigil, 2010) also support the view that social and environmental concerns can be integrated into everyday practice via the adoption of the EFQM model. For instance, Pedersen and Neergaard (2008) observed how management commitment,

a driving force in the EFQM Model, is also a prerequisite to addressing environmental management, and developing dialogues with stakeholders, ethical programs or codes of conduct. Pérez and Escrig (2018) concluded that the greater the maturity in the adoption of the EFQM Model, the greater is the development of sustainable practices. Yet, these studies have not addressed the triple bottom line.

The EFQM model enables measurement of social, environmental and economic results
As per del Río et al. (2017), creating value regarding the triple bottom line is in the essence of the EFQM model, for the impact of the implementation of sustainable practices can be identified in Results on economic status, social and environmental benefits. In fact, Kok et al. (2001) highlighted that results criteria in the EFQM model include the core of corporate social responsibility. While being economically viable is in the EFQM criterion that assesses Business results, social and environmental responsibilities are included in the criterion assessing Society results (Cierna and Sujova, 2015; del Río et al., 2017). Business results considers the key elements in the organizational policy and strategy, and focuses on internal measurements of achievements regarding the planned-performance, i.e. financial indicators and performance indicators on key processes. Society Results accounts for the general impact on society and on the local community, both in the socio-cultural and environmental dimensions. It specifies that excellent organizations "achieve and sustain outstanding results that meet or exceed the needs and expectations of relevant stakeholders within society" (EFQM, 2012: 19). Hence, recognized for excellence organizations demonstrate: involvement in community, support for education, health, sports, efforts towards reducing noise, pollution and other damages from its activities, as well as policies towards preserving and maintaining resources (e.g. reduction of packaging). Following recognition, organizations can benefit from its reputation.

Sustainability approaches can influence performance
Although the EFQM model, Figure 1, does not specify the relationship between having an orientation that creates a sustainable future, as embedded in its concepts, and results criteria, a positive association is expected. First, as reported above, the literature on the business case for corporate sustainability underlines that sustainable practices can impact dimensions of performance. Secondly, since the EFQM model is a tool to assess how enablers influence results, a correlation between Creating a Sustainable Future and results is envisaged. In fact, different studies on the EFQM model support relationships between enablers-criteria and results-criteria (e.g. Bou et al., 2009; Escrig and de Menezes, 2016). Specifically, del Río et al. (2017) and Calvo et al. (2018) concluded that there is positive associations between EFQM-enablers and Society results.
A sustainability orientation is reflected on how leaders are agents of change. As such, they behave ethically and responsibly, scan social and environmental data, focus on stakeholders when designing the organizational strategy. In addition, within Creating a Sustainable Future, managerial commitment is assessed by investments in resources that do not harm the environment, guiding clients on responsible use of products, and identifying improvements in products and services according to the expectations of customers and other stakeholders. Hence, having a sustainability orientation may imply savings due to efficient use of resources (financial, material, information, infrastructures), as well as reputational gains. Moreover, the RADAR scheme in the EFQM model, as a continuous improvement methodology, facilitates that a sustainability orientation is carried out systematically in order to ensure progress. According to Anninos and Chytiris (2012) excellence entails self-improvement,

progress based on adaptation to new situations via continuous self-assessment and improvement of results. RADAR promotes a corporate behaviour that enables organizations to systematically address emerging stakeholders' demands and integrate sustainability into their operations. EFQM therefore enables sustainable practices to be implanted in routines and processes, and ensures the fulfilment of an organization's responsibilities towards society (Mehralian et al., 2016). Consequently, we explore the following research question: *Can an orientation towards creating a sustainable future impact Society results and Business results as predicted by the EFQM model?*

The Study

The data are from a population of organizations awarded EFQM recognition by the Club de Excelencia en Gestión (CEG), a partner of the EFQM in Spain. The dataset contains 2,069 observations corresponding to recognitions from January 2000 to September 2014 obtained by 1,350 organizations. For each unit, the data include the level of recognition and their dates of issue and expiration; the size, the activity and the location of the unit assessed; and the scores on each sub-criteria, which are only available when a unit was recognized for excellence (total score ≥300). Given the availability of scores, we restricted the sample period to the last 8 years, for which there are 5 or more organizations recognized for excellence in the year. This leads to an unbalanced panel with 147 observations and 110 organizations: the maximum number of time-measurements per organization is 4, with only 25% of the sample having more than two sets of assessments (recognitions) in the period; and the number of organizations recognized in a year varies from 5 to 50.

If there is an orientation towards Creating a sustainable future, it can be inferred from the correlation between the scores in the 7 sub-criteria that reflect this concept in the EFQM model. Considering the number of sub-criteria and yearly sample sizes, it is assumed that the correlations between pairs of sub-criteria does not vary significantly with time, and the data are pooled so that factor models can be estimated. Using Stata 15, principal factor and a maximum likelihood estimations imply that underlying the sub-criteria there is a single common factor: only one eigenvalue is greater than 1; a measure of the amount of variance in a sub-criteria that is not explained by the common factor is such that it varies between 16% to 45%, and is on average 25%; in addition, if a two-factor model were estimated, the first factor accounts for 95% of the variance, and the second factor is rejected by a likelihood ratio test. Considering the estimates based on maximum likelihood one-factor model, scores on this orientation are predicted for each organization at each year when it is recognized for excellence. This measures EFQM's Creating a Sustainable Future orientation, which is the independent variable in this study. The dependent variables are the actual scores on Society results and Business results achieved at recognition.

Figures 2 and 3 illustrate the association between dependent and independent variables. We note the difference in scale and identify an outlier in Figure 3, which is excluded from the analysis that follows. Further preliminary analysis of this subsample also highlighted that most organizations are in the services sector, but there is variation in size (number of employees). In addition, when the dependent variables are plotted for organizations that have more than one recognition in the period, it can be seen that their starting points (intercepts) vary, which is consistent with the three levels of recognition in the sample. Given these observations, random effects models ($Results_{it} = \beta_1$ Sustainability Orientation $_{it} + \beta_2$ $size_i + \alpha + u_{it} + e_{it,}$) that control for the size of the organization, using a binary variable that indicates whether the organization is small or medium, were estimated using Stata 15. The results are summarised below.

Figure 2: EFQM's Society results and Sustainability Orientation

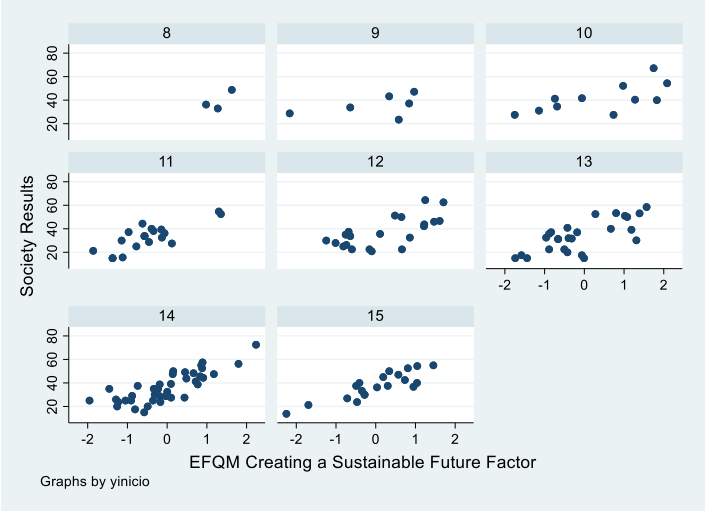
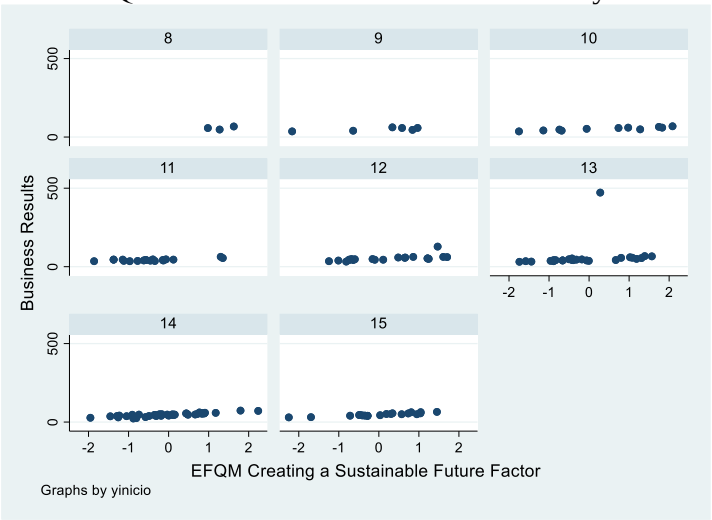


Figure 3: EFQM's Business results and Sustainability Orientation



Results

Tables 1 and 2 summarize the estimated models for Society and Business results, respectively. It can be seen that having a sustainability orientation is positively associated with both types of results (P-value=0.00). Based on the variance of the error terms, the intra-class correlation (ρ) is computed and shows how much of the variation in the data is due to the year in which recognition was awarded. In both models, this value is greater than 0.05, thus justifying the treatment of the data as separate panels. The fit statistics, Chi-Square and R-Square indicate that a significant proportion of the variance in Results are captured. Society results vary with the size of organization (p-value=0.04), but this is not the case with regards to Business results. In all, both models imply that an orientation towards Creating a Sustainable Future can benefit the organization and society.

Table 1: Society results & Sustainability Orientation (N=147)

	Coefficient	SE	P-value
Sustainability Orientation	8.65	0.761	**0.00**
Organization is SME	-3.35	1.63	**0.04**
Constant	38.43	1.32	0.00
σ_u	5.70	Wald (χ^2)	166.60
σ_e	5.49	Prob >χ^2	0.00
ρ	0.52	R-Square	0.57

Table 2: Business results & Sustainability Orientation (N=146)

	Coefficient	SE	P-value
Sustainability Orientation	8.81	0.757	**0.00**
Organization is SME	-0.81	1.707	0.63
Constant	48.38	1.396	0.00
σ_u	7.21	Wald (χ^2)	152.16
σ_e	3.92	Prob >χ^2	0.00
ρ	0.77	R-Sq	0.60

A limitation of this study is the sparseness of the data, which is due to the fact that most organizations in the dataset have not achieved recognition for excellence. Indeed, this confirms what is stated on EFQM's website: *"All organisations strive to be successful, some fail, some achieve periods of success but ultimately fade from view, and a few achieve sustainable success, gaining deserved respect and* admiration." (EFQM, 2019). Future research may therefore engage with other EFQM partners and build a database with a larger population and additional years, as the data also demonstrates that with time the number of recognitions increase.

Summary and Conclusions

This paper contributes to the literature addressing the integration of sustainable practices into management systems and its findings support Zwetsloot and van Marrewijk's (2004) statement that the basis for sustainability can be constructed on the experiences of business excellence models. Organizations that have been awarded an EFQM recognition exhibit a sustainability orientation displayed in the use best practices implicit in several enablers sub-criteria. Given the performance indicators within the Society results criterion, recognized for excellence organizations track social and environmental impact, in addition to economic performance. Yet, small and medium organizations differ in Society results, and this corroborates the findings from previous analysis of organizations awarded EFQM recognition (e.g. Escrig and de Menezes, 2016). As Ascigil (2010) argued, a potential explanation is that closeness to the local communities in which they operate is greater in SMEs, thus the pressures are more immediate, require rapid response and proactivity, as well as resources that may not be available in SMEs.

Scholars such as Kok et al. (2001), Pedersen and Neergaard (2008) or Asif et al. (2011b) stress that the EFQM Model focuses on the needs of stakeholders, but only to the extent that there is a direct relationship with the economic responsibility of the organization. This study confirms that the EFQM model incorporates the triple bottom line: economic growth, respect for the environment and social progress, and thus integrates the tree pillars of sustainability. This is encouraging, since sustainability has

been one of the trends and topics of interest highlighted in the different versions of the EFQM model. In addition, the positive correlation with both types of results indicates that EFQM has been effective in guiding companies on what sustainability means, providing approaches to its achievement and ensuring coherence between the apparently conflicting responsibilities that organizations assume to its shareholders and society.

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Increasing the value of quality management systems

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Abstract

Over one million organisations have a Quality Management System (QMS) certified to the ISO 9001 standard; however, the system requires a lot of resources and its value has been questioned. The purpose of this paper is to investigate how different types of uses of QMS correlates with management perceptions of QM in terms of respect, cost, and strategic importance. The paper is based on a survey within eight organisations and shows that a compliance-orientated QMS usage will more likely lead to a view on quality management as costly, and of little respect, than a business- or improvement-oriented QMS usage.

Keywords: Quality Management Systems, Quality Management, Value-adding QMS

Introduction

Today, more than one million companies and organisations globally are certified in accordance with ISO 9001 (*ISO Survey*, 2017). In organisations' Quality Management (QM) work, a significant amount of time and focus is given to the Quality Management Systems (QMS) (Elg et al., 2011), thus it is important that QMS adds value to the organisations (Lenning & Gremyr, 2017). The interest in QMS has further grown by its potential to support implementation of sustainable development efforts through integrated management systems, or by improving environmental management systems based on learnings from QMS (Siva et al., 2016). This potential has, however, not fully been exploited and Allur et al., (2018) suggest that increased formalization and bureaucracy, induced by a certified QMS, is a reason stated for cases in which QM is perceived as hindering rather than supporting implementation of sustainable development efforts. Even with a focus on QMS per se, i.e. not as a support for an environmental management system, QMS have been subject to critique for providing limited value in its support for quality improvements, hindering creativity, and being disconnected from actual practice (Poksinska et al., 2006).

At the same time, evidence suggests that QMS provides a critical and well-established infrastructure with potential to create value and support continuous improvements (Lenning & Gremyr, 2017). To achieve as much value as possible, one critical factor is to have managements' support and appreciation of QM work overall (Beer, 2003; Joiner, 2007; Kaynak, 2003; Lakhal et al., 2006). The purpose of this paper is to investigate how different types of uses of QMS correlates with management perceptions of QM in terms of respect, cost, and strategic importance. Drawing on the various ways of operationalizing QM proposed by Maguad (2006), this study investigates three types of QMS usage: QMS as support for developing the quality of an offering, QMS as a tool for daily management, and QMS as a tool for standardization and documentation. The study focuses QMS that are certified to ISO 9001, and correlations between the three ways of using QMS and managers' view on QM.

The main contributions of this paper to the existing body of research on QMS are: to describe three different ways of using a QMS; to detail and nuance the understanding of why QMS are perceived as non-value adding by focusing ways of working with QMS and not QMS overall; and to add to the research evaluating QMS impact mainly on financial performance by also studying possible impact on management's perception of QM. In the following a background to QMS usage and three ways of using QMS is provided, followed by a method chapter, findings, discussion of the findings, and finally conclusions drawn.

Theoretical Background

Born with the ideas of Deming, Shewart, Juran, and Ishikawa, soon four decades ago, QM has evolved to become a management philosophy and approach (Hackman & Wageman, 1995). QM has been presented to be based upon three pillars, namely; principles, practices and techniques (Dean & Bowen, 1994); the principles being customer focus, continuous improvements, and teamwork.

The ISO 9001 management system standard, being a QM tool and a common basis for a QMS, has become universal (*ISO Survey*, 2017). ISO 9001 is argued to have potential to contribute to quality improvements (Sousa & Voss, 2002) and improved operational performance (Kaynak, 2003). However, the value and the effect of a QMS is argued to depend on different factors such as QM maturity, implementation strategy, and people involvement and certification audits (Poksinska, 2010).

The type of motivation for implementing a QMS is also argued to influence the performance of the system. Organisations focusing on real quality improvements achieve higher benefits from their QMS implementation in e.g. quality and operational improvements, compared to those organisations that implement and seek certification of their QMS for external motives, for example image or customer requirements (Boiral & Amara, 2009; del Castillo-Peces et al., 2018; Poksinska et al., 2002; Sampaio et al., 2009). Thus, a QMS implemented based upon external requirements, tends to focus more on compliance control, and less on organisational efficiency (Alič & Rusjan, 2010). Therefore, to achieve the possible benefits from a QMS a change in practise, and commitment from all members in the organisation are required while it is argued that there are only a few internal or external benefits from the standard i.e. ISO 9001 itself (Poksinska, 2010).

In the following three different ways of working with QMS will be outlined. The three ways draws on Maguad (2006) who argued that quality in the 21st century could be categorised based on three different orientations; business management oriented, improvement oriented, and compliance oriented. However, it is argued that all three

orientations must coincide in order for an organisation to be successful in their QM work (Maguad, 2006).

Quality Management Systems as a tool for daily management

Maguad (2006) argued that business management-oriented quality demands an integrated deployment of strategy, and attention to critical success factors e.g. vision of the business, markets, and core processes. It also requires involvement from top management and every employee in continuous improvement efforts (Maguad, 2006). On an overall level, Sadikoglu & Zehir (2010) studied relationships between TQM practices and multiple performance measures and revealed that all TQM practices studied e.g. training, employee management, continuous improvement, information & analysis were significantly and positively correlated with measures on employee performance, innovation performance, and firm performance.

Regarding use of QM tools, one aspect that has been in focus is that the explicit potential of the tool to support a perceived and contemporary need is critical. To support QM tool usage it is necessary to have a structured deployment, which depends e.g. on training (Lee, 2004), and that training should be offered just-in-time when needed so that employees directly can practice what has been taught (Bunney & Dale, 1997). Furthermore, if tools are introduced when a team or department has a defined need, these tools are better understood and used in applications compared to tools deployed as a group e.g. as a part of a company-wide improvement program. In other words, a perceived benefit from a tool appears tightly coupled to it being deployed and used in a way that directly supports the daily activities in an organization.

Narrowing down to QMS as a tool for QM, it has been shown to have effects not only on effectivity, product and service quality, but also on employees and employers e.g. related to health and safety at workplaces (Levine & Toffel, 2010). Furthermore, Levine & Toffel (2010) show that after being certified firms experienced a growth in both sales and employment considerably quicker compared to firms that were not certified; thus the authors argued that managers should consider an ISO 9001 certification as valuable.

Proposition 1: If QMS is used as a support for managing the organisation, management will likely show respect for QM, not view QM as cost-driving but rather view QM as being of strategic importance.

Quality Management as a support for developing the quality of the offering

To achieve customer satisfaction and ensure sustainable organizational success it is argued that emphasis should be on continuous improvements. This improvement-oriented view on QM promotes an integrated approach for process improvements, involves the whole organisation and has wide range of applications e.g. on service and support operations (Maguad, 2006). In a study of customer-interacting service employees, Coo and Verma (2002) found that the employee's perceptions of the implemented QMS had an impact on service quality i.e. reliability, responsiveness, assurance, empathy and tangibles (Parasuraman, Zeithaml, & Berry, 1988), and in turn firm performance. Coo and Verma (2002) further argue that one success factor to these perceptions were strong leaders that were involved in promoting QM.

In e-commerce it has been argued that knowing how to improve loyalty and increase repeated purchase is important to stay competitive (Honore Petnji Yaya et al., 2011). Honore Petnji Yaya et al. (2011) show in a study of customers using online banking that service quality was a key forecaster of both satisfaction and loyalty. All dimensions of service quality; that is reliability, responsiveness, assurance, empathy and tangibles

(Parasuraman et al., 1988) had positive effects on loyalty and satisfaction. Hence, it can be assumed that if QMS is perceived to impact the product/service quality and hence have effects on satisfaction, this will be noticed by management and lead to positive views of QM.

Proposition 2: If QMS is seen as supportive of the development of the quality of the organisation's offering, management will likely show respect for QM, not view QM as cost-driving but rather view QM as being of strategic importance.

Quality Management Systems as a tool for documentation and standardization

A focus on providing documentation, developing procedures and ensuring consistency is argued to result in a compliance-oriented approach to QM (Maguad, 2006). Implementing a QMS standard like ISO 9000 drives standardization and how such standardization impact an organisation is argued to depend on three variables; what is standardized, how is the implementation done, and to what extent are activities standardized (Poksinska, 2007). First, if there is a low motivation for implementing a QMS it is argued to result in that organizations only fulfill the minimum requirements in the ISO 9000. Fulfilling only the minimum requirements may result in that the implementation of a QMS focuses only on describing the existing work practices i.e. standardizing present practices instead of practicing the standard (Poksinska, 2007, 2010). Second, if the result of a standardization is positive or negative is also affected by how the standard is implemented i.e. if the standardization is done with employee involvement (enabling), supporting changes of deficient practices or if the standard is implemented top-down (coercive), where management want to discipline work. Finally, the level of standardization need to be right and independent of the person performing the work. Poksinska (2007) argues that a person's interest in his or her job is reduced if there is a high level of standardization.

In a study on experiences from the implementation and certification processes in small organizations (Gustafsson, Klefsjö, Berggren, & Granfors-Wellemets, 2001) concluded that there is risk to describe i.e. document, everything in detail. Moreover, documentation created as part of implementation and certification of a QMS was reported to be time- and resource consuming. Poksinska, et al. (2006) found in a study of ISO 9001 in small organizations that QMS were perceived as a tool for handling documentation, not a tool for managing processes. Implementation of ISO 9001 was perceived as a bureaucratic and something that increased paperwork, which was a demotivating factor. Findings also pointed towards problems to find an ideal level of standardization of work instructions. Work instruction and procedures should not be too general to be able to provide support for users, neither too detailed to limit employees' freedom in performing their work (Poksinska et al., 2006).

Proposition 3: If QMS is used as a tool for documentation and standardization, management will likely show little respect for QM, view QM as cost-driving, and not view QM as being of strategic importance.

Methods

Research instrument

The study was based on a survey instrument containing 43 questions, developed through a literature review, input from senior practitioners as well as researchers, and input from previously validated questionnaires. In specific, this paper draws on a set of items focusing the main function of the QMS (Poksinska et al., 2006), and management's perceptions of QM (Elg et al., 2011) (see Table 1).

Table 1 – Research instrument

Statements		**Scale**
To what extent do you agree with the following statements about the function of your QMS?	Our QMS has a significant impact on how our organisation works (impact on work)	0 = No opinion/do not know 1 = Do not agree 2 = Partly agree 3 = Agree to a large extent 4 = Fully agree
	Our QMS is a tool that supports efficient management of our organisation (efficient management)	
	Our QMS is a tool that help us to fulfil our customers' needs (customer needs)	
	Our QMS is a tool for managing our quality work and improve the quality of our products/services (product/service quality)	
	Our QMS is a tool to handle documentation (documentation)	
	Our QMS is a tool to standardise our processes (standardisation)	
To what extent do you agree with the following statements: in our organisation management…	…show little respect for QM in our daily work (little respect)	0 to 10 0 = No opinion/do not know 1 = Do not agree 10 = Fully agree
	…regard QM as a costly activity (costly)	
	…acknowledge the strategic importance of QM (strategic)	

Sample

Eight large-sized Swedish organisations (> 1000 employees) participated in the study. Each participating organisation identified 30-50 respondents on different hierarchical levels. The respondents within each organisation were chosen among employees that had dedicated time and responsibility for QM work. The total number of responses were 249 (response rate = 81%), the number of respondents per organisation ranged from 16 to 51. For this paper the subset of questions used in the analysis focused management perceptions of QM and overall view on the QMS, these questions were only asked to respondents with management responsibilities and resulted in a subset of 108 respondents.

Data collection

The survey was administered by e-mails, including a customized invitation letter for each organization and a link to the survey (using the web-based tool SurveyMonkey). The survey was open for one moth per organization, including two rounds of reminders.

Data analysis

Since the analysed statements are jointly exhaustive, answers in which no alternative was chosen were considered to be missing values. After excluding rows containing missing values, 108 of the original 249 observations remained. Of these, nine had rows containing the answer "no opinion". Since this answer cannot be interpreted as an ordinal value, these observations were excluded as well, resulting in a sample of 99 observations.

Spearman's rank correlation coefficient was used to evaluate the monotonic relationships between the ordinal variables.

Findings

On an overall level, the data shows that the respondents to a large extent agree with all statements regarding the function and use of the QMS in their organisation (see Table 2).

Table 2 – Distribution of data

Statement	1 = Do not agree	2 = Partly agree	3 = Agree to a large extent	4 = Fully agree
Impact on work	5	0	78	16
Efficient management	19	0	69	11
Customer needs	13	0	66	20
Product/service quality	12	0	73	14
Documentation	4	0	77	18
Standardisation	5	0	73	21

It appears that QMS as a 'tool to handle documentation', 'tool for standardisation', and as having 'significant impact on how the organisation works' are the three statements where most respondents to some extent agree and in other words recognise their way of working with QMS. For statements where there is a group of respondents not agreeing at all, the three other statements stand out. The statement for which most respondents do not agree is that QMS is 'a tool that supports efficient management of our organisation', followed by QMS as 'a tool that help us to fulfil our customers' needs', and QMS as 'a tool for managing our quality work and improve the quality of our products/services'. As QMS and activities related to designing, implementing, and maintaining the system is a large part of what a QM function does, it arguably will influence how managers view QM overall. Figure 1 shows the correlations between the level of agreements on the statements related to the function of QMS, and management's view on QM in terms of respect, cost, and strategic importance.

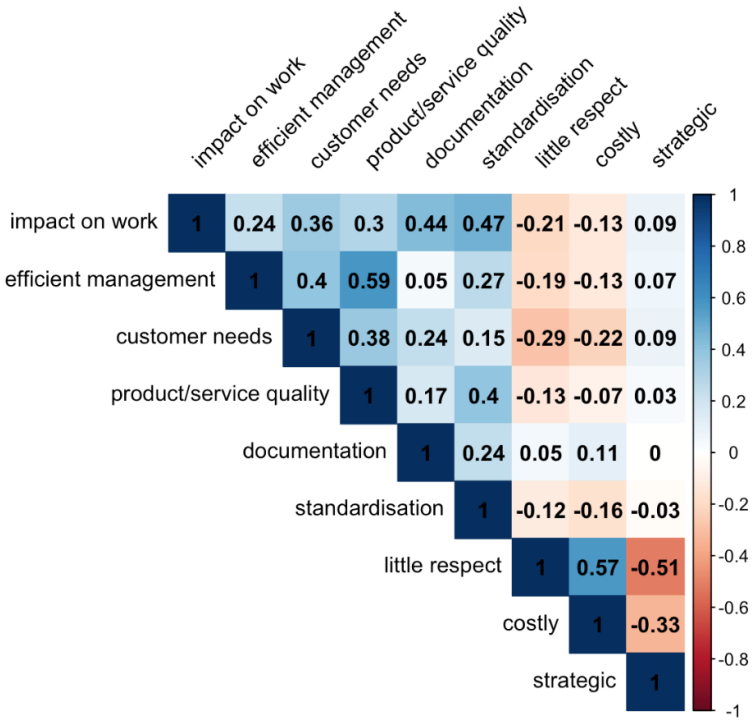

Figure 1 – Correlation matrix

First, proposition 1 focus on a business management-oriented use of QMS, relates to two functions of QMS: impact on work, and efficient management (Table 1). Although the correlations are small these two functions of QMS correlates negatively to management viewing QM as costly and with a lack of respect, on the other hand there is a positive correlation to viewing QM as being of strategic importance. Hence, the data points in the same directions as outlined in proposition 1.

Second, proposition 2 encompass the statements on QMS as a tool focused on customer needs and a tool impacting product/service quality; these two constitute what this paper refers to as an improvement-oriented use of QMS. In the same way as the statements underlying proposition 1, the statements of 'customer needs' and product/service quality' correlates positively to management acknowledging the strategic importance of QM. Moreover, there are negative correlations with QM being viewed as with little respects, and as a costly activity. Looking at the correlation values, these are largest for the statement regarding 'customer needs', which might depend on larger variation in the responses.

Last, and third, proposition 3 refers to a compliance-oriented use of QMS and concerns documentation and standardization. Again, the correlations are small, but the results are mixed as compared for the other two propositions. The statement focusing QMS as a tool for documentation, displays correlations supporting parts of proposition 3, i.e. positively correlates with little respect for QM and a view of QM as being costly. However, the statement on documentation does not correlate with QM being seen as strategic. Moving to the other statement on a compliance-oriented QMS use ('standardization'), the correlations do not support proposition 3. The use of QMS as a tool for standardization negatively correlates with all three views on QM, i.e. does not appear supportive of a view on QM as costly or QM being little respected. However, it does have a negative correlation with QM being viewed as strategic (as outlined in proposition 3). Again, the correlations are small and further investigation is needed.

Discussion

To support improved QMS usage and increase the perceived value added by a QMS, there is a need to move beyond the broad conception of QMS usage and move towards a more detailed analysis. This paper contributes to research on QMS by outlining three different ways of using QMS rather than studying QMS usage overall. Drawing on Maguad (2006) three types of QMS usage are described as either business management-, improvement-, or compliance-oriented.

First, the business management-oriented use of QMS is operationalised by QMS 'significantly impacting the way an organisation work', and 'is a tool that supports efficient management of an organisation'. As assumed in proposition 1, these functions appear to support that management will likely show respect for QM and not view QM as cost-driving but rather view QM as being of strategic importance. This is in line with previous research by e.g. Bunney and Dale (1997) establishing that deployment of QM tools will be more successful if the tools are perceived as closely connected to, and potentially can improve, current work practices.

Second, the improvement-oriented use of QMS is based on QMS as 'a tool that help us to fulfil our customers' needs', and 'a tool for managing our quality work and improve the quality of our products/services'. The proposed impact of these functions is supported, i.e. ensure respect for QM, not viewing QM as costly but as strategic (proposition 2). Hence, using QMS to fulfil customer needs and improve the quality of the product or service will positively impact managements' perception of QM overall. Previous research has shown that improved quality of the product/service lead to increased customer

satisfaction and loyalty (Honore Petnji Yaya et al., 2011; Parasuraman et al., 1988); thus, if QMS is used in a way that can be linked to improved quality and customer satisfaction this will likely impact managements perception of the value added by the QMS.

Third, in relation to proposition 3 that QMS is used as 'a tool for documentation' and 'standardization', would be correlated with management showing little respect for QM, viewing QM as cost-driving, and not viewing it as strategic the results are more mixed. A focus on documentation is as stated by e.g. Allur et al. (2018) perceived as bureaucratic rather than a respected and value-adding activity, however a certification is still of value e.g. as a qualifier in certain business relations (Boiral & Amara, 2009; del Castillo-Peces et al., 2018). This might be a reason that the documentation focus does not appear to have the anticipated negative correlation with management viewing QM as strategic value. Moreover, a standardisation-focused use of QMS does not appear to reduce respect for QM, neither seeing it a costly. Perhaps this can be linked to Poksinska's (2007, 2010) notion of practicing the standard rather than standardise current practices. In other words, if standardisation is done with an improvement approach rather than one of pure documentation, it will likely be perceived as beneficial. This is also linked to the function of QMS as having 'impact on work', which is classified as a business management-oriented QMS usage. If this is practiced and QMS is allowed to impact actual practices, it will likely mean that QMS is used to standardise and at the same time improve existing work practices.

Overall, the findings supports literature pointing to challenges of QMS in terms of focus on compliance rather than organisational efficiency (Alič and Rusjan, 2010), and sometimes not being relevant for actual practice (Poksinska et al., 2006). However, by distinguishing QMS usage in the three orientations presented above, this study indicates that documentation focus is what might be the cause to many negative perceptions of the value of QMS. On the other hand, many respondents fully agree that QMS is 'a tool that help us to fulfil our customers' needs', which has a relatively high correlation with management viewing QM as strategic. Contrary to the view of limited value from QMS, this paper supports e.g. Poksinska (2007) and Lenning & Gremyr (2017) in that there is potential value of QMS, and that this perceived value will increase if QMS usage is mainly business management- and improvement-oriented, although wisely documented and standardised processes are also required to maintain a certified QMS.

The data set underlying this paper is limited in size and the correlations established are small, more research would be needed to enhance the trustworthiness of the findings. This research could be either empirical or conceptual.

Conclusions

Based on an extended view of QMS, this paper has elaborated on three types of QMS use: business management-, improvement-, and compliance-orientated use. It is shown that the way organisations use QMS influence management's respect for, and view of, QM in terms of it being costly and/or strategic. For a business management- and improvement-oriented use the propositions based on previous research is supported, i.e. theses ways of using QMS correlates with management viewing QM as respected, strategic, and not cost-driving. For a compliance-oriented use of QMS, earlier research suggests this to be the reason for many of the negative perceptions of QMS and leading to a view of QM as costly, less respected and of less strategic importance. However, for a compliance-oriented use of QMS the findings are somewhat contradictory to the anticipated proposition. It is suggested that a perception of limited value of QMS is mainly due to a focus on documentation whereas work on standardization, which is also part of a compliance-oriented QMS use, does not carry similar negative implications. In summary,

this study highlights how the perceived strategic value of QM can be increased through a deliberate design of an organisations ways of using QMS.

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Exploring QMS Audit Practices in the Digital Era

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Abstract

Quality auditors are essential for Quality Management System (QMS) development, and communication is necessary for its performance. The digitalisation of the economy, especially Industry 4.0. (i4.0), introduces several digital elements all over the supply chain. This paper presents a preliminary exploration of the influence of digitalisation in internal audits practices. The research enquires QMS auditors about the implementation of current Information and Communication Technologies (ICT) in their practices. Then, it explores the importance of i4.0 and new technologies for the companies on which the auditor performs its activities. Finally, it investigates the implemented technologies based on QMS auditors' recommendations.

Keywords: Industry 4.0, New Technologies, Information and Communication Technologies.

Introduction

A certified Quality Management System (QMS) requires an internal audit (ISO 9001, 2015) and this certification is the minimal business requirement for several industrial organisations (Govindan, et al., 2010). Quality audits facilitate the compliance of the standards (Hernandez, 2010) and the auditors influence the efficiency of the QMS implementation (Phillips & Kluse, 2012). Furthermore, the audit strategy requires communication for its performance (Kymal, 2016).

The digitalisation of the economy, especially Industry 4.0. (i4.0), introduces several digital elements all over the supply chain (Sommer, 2015). This new industrial paradigm requires the integration of the different aspects of an industry (Rüßmann, et al., 2015; Germany Trade & Invest, 2014) and quality practitioners have an essential role in this new industrial revolution (Ranganath, 2017).

Therefore, this paper presents a preliminary exploration of the influence of digitalisation in internal audits practices. The research enquires QMS auditors about the implementation of current Information and Communication Technologies (ICT) in their practices. Then, it explores the importance of i4.0 and new technologies for the companies on which the auditor performs its activities. Finally, it investigates the implemented technologies based on QMS auditors' recommendations.

Quality Audits and Industry 4.0

Audit belongs to the requirements for the development of a Quality Management System (QMS) (ISO 9001, 2015). The clause 9.2 of the norm stipulates Internal Audit as a systematic, independent and documented self-assessment process that procures evidence

of the QMS and objectively assesses its fulfilment (ISO 9001, 2015). The external audit complements this evaluation in its element of independence towards the organisation. Companies overtake the effort of a quality audit to obtain the ISO 9001 certification, which in several cases is the minimal requirement to develop business within a sector (Govindan, et al., 2010). Furthermore, organisations obtain significant benefits from the implementation of these standards (Swann, 2010) including the enhancement in their organisational knowledge (Wilson & Campbell, 2016).

Quality audits have relevance to the business, and it goes beyond the efforts of compiling documents of evidence the QMS fulfilment. The audits are a source of improvements (Lenning & Gremyr, 2017) and knowledge (Wilson & Campbell, 2016). The audit practices provide to the business evidence-based possibilities of improvements using the corresponding knowledge. Furthermore, the audit facilitates the compliance of the standards to obtain respective certification (Hernandez, 2010). Therefore, the role of auditors is essential for QMS. Specifically, auditors influence the implementation of QMS (Phillips & Kluse, 2012).

A significant component of the quality audit strategy is communication (Kymal, 2016). The compilation of documents and the general evidence to assess the QMS of the organisation requires a communication strategy that allows the auditor to obtain the corresponding data for the evaluations and possible additional suggestions for improvements. Chapter 7.2 of the standards contain specifics about this matter (ISO 9001, 2015). Relevant documents reduce the subjectivity of the assessment (Montoya Quintero & Cogollo Florez, 2018) and a better communication strategy facilitates the comprehension of the vast documentation of a QMS and other systems (Kanon, et al., 2017).

The introduction of the concept Industry 4.0 (i4.0) offers organisations a new manufacturing paradigm (Baur & Wee, 2015) with several digital elements all over the supply chain (Sommer, 2015). Approaches such as smart factories (Rashid, et al., 2011) or the industrial application of the Internet of Things (IoT) (Islam, et al., 2015) complement the understating of this new era of manufacturing. The i4.0 includes new technologies such as cyber-physical systems, big data, real-time connectivity, among others (Lasi, et al., 2014).

The primary requirement of the implementation of this new industrial paradigm is the integration of the different aspects of an industry (Rüßmann, et al., 2015; Germany Trade & Invest, 2014). Furthermore, the most relevant driver of the digitalisation of the economy is the Internet. There is increasing constant use of the Internet around the world (Internet World Stats, 2018) through emails, social media and other technologies (Haigh, et al., 2015).

Then, this new industrial paradigm requires the integration Quality practices that correspond with the digital changes faced by organisations. QMS audits are an essential part of any industry (Govindan, et al., 2010; Swann, 2010). Therefore, QMS auditors have an important role within this new industrial revolution (Ranganath, 2017) and since communication is essential to the QMS audit practice, this search explores the implementation of Information and Communication Technologies (ICT) in the QMS auditors practices. Additionally, it investigates the introduction of digitalisation in their practices. The aim is to explore current practices in respect of digital tools. This understanding provides information about the areas on which auditor requires knowledge enhancement, and it also opens the discussion about the role of audits in a digitalised economy.

Methodology

This paper presents a preliminary exploration of the influence of digitalisation in internal audits practices. The literature review offers a vast understanding of the QMS auditors' practices and their importance to implement and develop the QMS in an organisation or to obtain a particular certification such as ISO9001. In the other hand, the digital transformation of the industry, or i4.0, develops a new paradigm for industrial organisations. Then, this research requires to approach the QMS auditors to start the development of the knowledge regarding the QMS practices in the i4.0 world.

The selected research design implements an online survey in summer 2018 (Bryman & Bell, 2015) among internal auditors related to the Czech Society for Quality (CSQ). The survey explores the ICT appropriation of the auditors for QMS activities and personal use within the last five years. The survey also enquires about the use of digitalisation as a tool or solution within the QMS activities in the same period. The implementation of a seven-level Likert scale facilitates the assessment of ICT usage. The range starts at "I don't use/I don't have" towards "actively use it for Personal and Work purposes". Personal use has less score that the usage at Work.

The CSQ is the appropriate source of QMS auditors. It is the nongovernmental institution dedicated to disseminating the QMS knowledge in the country among other management systems (Czech Society for Quality, 2019). The CSQ educates and certifies QMS internal auditors, and it also develops the external auditors for certification activities. Then, the research identifies internal auditors trained at CSQ and CSQ accredited internal auditors with current activities in the industry. Additionally, the certification process requires the identification of the current internal auditor at the organisation.

The captured data offers the opportunity to implement statistical analysis (Bryman & Bell, 2015) of different aspects of the internal auditors' digital knowledge and digital quality improvements from the last five years. The study includes a descriptive analysis of the QMS auditor's population and the relationship between personal use and work use of ICT tools. Furthermore, the data offers information about the importance of digitisation for QMS auditors.

This research explores the current QMS audit practices in the Czech Republic. Moreover, the Czech economy reports the highest industry contribution of the GDP within European Union and the country is considered technically advanced and the fastest growing economy in the EU (CZSO, 2017; Growth Lab, 2017). Therefore, research on the industry in the Czech Republic provide relevant information for the development of QMS practices in other countries. Furthermore, although the response rate of the online survey is low, the findings provide preliminary assumptions that required a qualitative approach such as focus groups to understand the reasons behind these findings (Bryman & Bell, 2015; Mayring, 2000). Additionally, this low response rate might evidence a weak implementation of new technologies in QMS practices.

Findings

The survey respondents are QMS auditors with knowledge, experience and often implementing audits. The population structure concerning the educational level of QMS auditors is similar to that of the country (OECD, 2014). The majority of QMS auditors completed secondary education (92%), and half of them (48%) received a university degree with less having above level of formal education (14%). The analysis of training taken by all respondents illustrates that they acquired their knowledge about QMS audits at specific courses on audit (54%), QMS (7%), Lean management (19%) or Six Sigma (20%). Furthermore, the auditors realise their activities in 2018 (87%) two up to five times (67%) in the Czechia (66%) and also out the country (34%). The experiences out of the

country include at least one audit (38%) and more than five (21%). Additionally, the respondents report intensity of one audit per quarter (31%), per month (30%), per semester (19%), per year or more (11%) but also per week (9%).

The implementation of digitalisation in QMS practices still low. One-third of the respondents (33%) indicate an extent of use of digitalisation in their auditing activities between 21% - 40% and less than a third (27%) between 41 % - 60 %. The 20% respondents indicate a lower extent of use (0% - 20%), the 14% of respondents state a high extent of use (61 % - 80 %) and 6% of respondents report reports the highest extent of use (81 % - 100 %).

Moreover, more than half of them recognises the importance of digital elements in their practices. Specifically, 45% of the respondents distinguish that digitalisation has several items with applicability in QMS practices, 33% identifies a lot of elements for implementation while 12% declare that digitalisation is per se the new only element for the QMS practices.

Furthermore, one-third of respondents (30%) acknowledge that digitalisation is a current issue to be included in the QMS practices. Other 11% of the respondents allocate digitalisation as an issue in the next year. The next third (36%) expects digitalisation to be an issue in two or five years from now. Besides, 9% of the respondents expect digitalisation to be an issue in about ten years, and 14% of them argues that digitalisation is not and it won't be an issue for QMS practices.

The respondents (34%) express a high use of communication technologies for work and personal reasons when someone asks for it. Moreover, an important group of respondents (23%) do not have or do not use ICT. The active personal use of ICT (17%) complements the less active users (14%). The less use of ICT for Work purposes (14%) is similar to the active use of ICT for work and personal matters (14%). The lowest usage of ICT (6%) corresponds to work issues when someone asks for it.

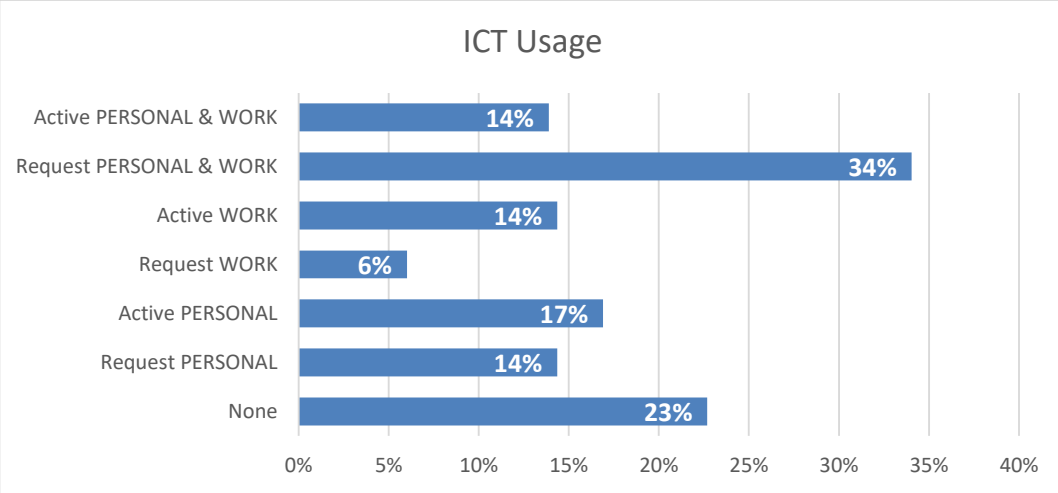

Figure 1 – Percentage of ICT usage

The communication technologies with the most extensive use among the respondents are telephone (18%), email (18%) and SMS (16%). The technology of file sharing indicates 11%. Modern platforms of communication such as LinkedIn (9%), WhatsApp (5%) or Facebook (8%) represent less usage among the respondents. Additionally, the highest intensity of ICT use is found among traditional technologies while new technologies obtain their highest concentration among personal use or even not use.

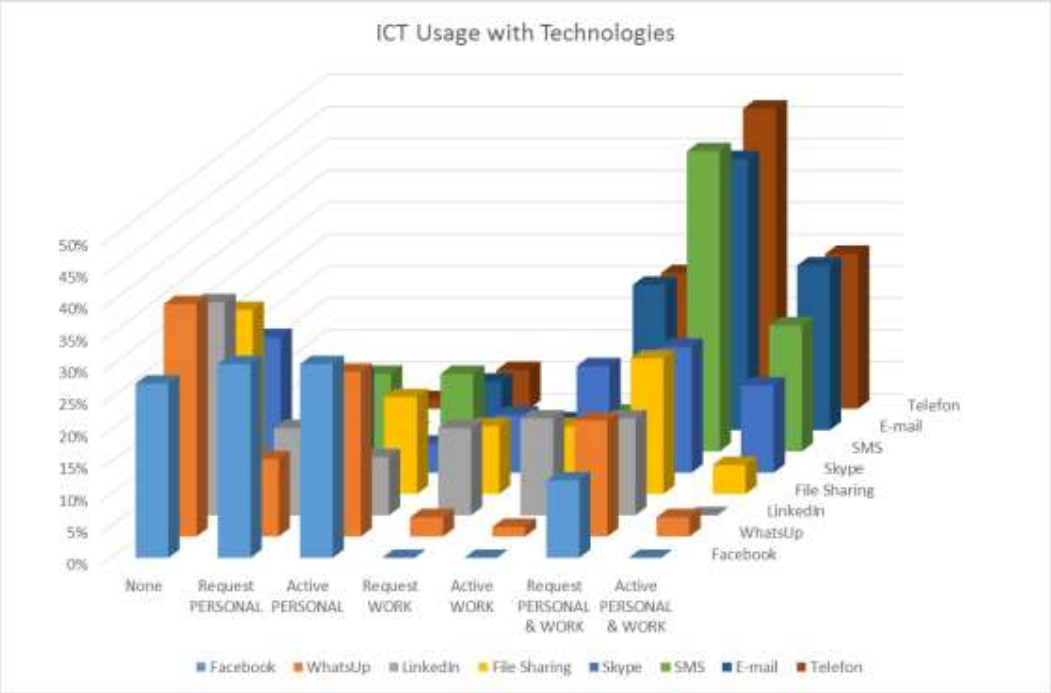

Figure 2 – Percentage of ICT usage with technologies

Furthermore, the companies for which the auditors perform their activities promote learning and knowledge about relevant topics of digitalisation (38%), some of the topics in the field (29%), some specific initiatives at work (15%) or the support is unlimited (14%) with just few organisation without support (5%).

Moreover, there is a lack of strategies to develop or implement digitalisation within QMS. The larger group of companies (39%) uses some digital elements with implementation in QMS internal audits, but a similar group (35%) uses fewer elements of them in QMS audits. Some firms (12%) have digitalisation as an integral part of the strategy, and others (8%) uses several elements of them in QMS audits. The lowest representation (6%) do not consider digitalisation as part of their strategy.

During the last year, the suggested implementations from QMS auditors do not apply digital elements (39%) or the solution has up to 20% of digital elements (35%). In other cases, the implementation has between 21% - 40% (7%), 41% - 60% (7%), 60% - 81% (9%) or 80% - 100% (2%). Additionally, the QMS auditors' recommendations prompt the inclusion of new technologies in improvements such as general automation (22%), electronic communication (22%), big data (19%), simulations (14%), robots (14%), smart machines (7%) or additive manufacturing (2%).

Conclusion

The preliminary findings open several questions on respect the reasons behind the lack of digitalisation among the QMS practices. The digital transformation of the economy, especially i4.0, requires the digital integration of the entire supply chain (Sommer, 2015) and quality is an essential part of it (Kymal, 2016; Hernandez, 2010). Moreover, this research shows that the integration of QMS practices is low. There is still a lack of inclusion of digitalisation in the firms' strategies, but also the recommendations and solutions from auditors offer low involvement of digitalisation. Furthermore, the auditors recognise a low involvement of digitalisation in their practices. Since QMS audits are a source of improvements (Lenning & Gremyr, 2017) and knowledge (Wilson & Campbell,

2016), auditors must take an important role in the digital transformation of their organisation providing possible solutions with higher use of new technologies.

A suggestion for this leadership role in the digitalisation of the organisation is the use of new ICT in their current QMS practices. Documentation is essential for QMS audit (Montoya Quintero & Cogollo Florez, 2018; Kanon, et al., 2017). Current technologies facilities the work with documents throughout real-time reports, file sharing or even paperless initiatives (Henderson, 2016; Vidyarthi & Coffey, 2016).

This research also shows that the organisation are willing to support the creation of knowledge about digitalisation. However, their strategies lack the digital element. Then, the efforts to learn about digitalisation might lead to information without real application in the organisation. The role of the QMS auditor as a knowledge creator in the organisation (Wilson & Campbell, 2016) is essential to facilitate the implementation of new technologies and digital solutions. QMS auditing might become the most important driver of the transformation, or it also can become its main obstacle.

The current situation illustrates that the solutions or recommendation of the QMS auditors contains a lower level of digital elements. Then, future research must concentrate on the reasons behind this absence of digitalisation. Which, so far, might be the lack of knowledge of the auditors about the possibilities of new technologies in their processes or the resilience of the organisations on the digitalisation of the industry. In both cases, the auditors have an important role in the success of digital implementation.

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Technology Management in Operations

Drones in the factory: Developing field-tested and grounded technological rules

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Abstract

Modern drone technology offers untapped potential for increasing productivity and safety in factory operations. Yet, only a few factories have experimented with indoor use of drones and there are no field-tested guidelines for how evaluate such applications. We engaged in a design science project with a manufacturer of sanitary products. The purpose of our study was to develop grounded technological rules that can be used to identify, select, test and implement profitable drone applications in factories. The developed prescriptive knowledge help managers, engineers and consultants to make informed choices when exploring the potential of drones in manufacturing environments.

Keywords: Drone technology, Manufacturing operations, Design science

Introduction

Industrial applications of unmanned aerial vehicles (UAV), commonly known as drones, have grown quickly (Panetta, 2018). The oil, gas, and petrochemical industries for example use drones to inspect hard-to-reach equipment, detect hazardous gases, and site surveillance. The construction industry is using drones to inspect complex infrastructure assets such as bridges and buildings. To date however, industrial drone use has been almost exclusively outdoors and few firms have experimented with 'in factory' applications. Proponents argue that drone technology has untapped potential (e.g., higher productivity, improved safety) in factory operations, but how do we evaluate the quite different challenges and opportunities for indoor drones (Floreano and Wood, 2015)? Current indoor manufacturing applications are limited to supporting inventory recording, factory planning and inspection. For example, drones are used for cycle counting in large warehouses (Hoffmann, 2017), for taking photos of current factory layouts (Melcher et al., 2018), and for internal inspection of confined spaces such as tanks, silos, furnaces, chimneys, boilers, and pipelines (Maghazei and Netland, 2018).

Are drones simply another form of advanced manufacturing technology (AMT)? Or, because of their versatility (e.g. they have multiple formats and can be paired with various complementary technologies like simultaneous localization and mapping (SLAM), motion capture, thermal imaging, material handling, etc.), do they follow different technological 'rules'? In this paper, we use a design science approach, informed by the AMT literature, with a cooperating firm to study the process of drone application detection, testing and evaluation. To do so, we use the "context, intervention, mechanism, and outcome" logic (CIMO) defined by Denyer et al. (2008). From this, we develop grounded technological rules that can be used in manufacturing to identify, select, test and implement practical drone applications.

Theoretical background

In order to address the research objective, we follow a management engineering approach focusing on 'engineering a solution' rather than applying of existing insights (Groop et al., 2017). That said, our fieldwork is deeply informed by knowledge from the existing AMT literature, in particular categorizing three distinct phases of technology adoption: *evaluation*, *implementation*, and measuring *effects* of AMT in different organizations and contexts (Maghazei and Netland, 2017).

The first phase, AMT evaluation, is mostly concerned with the economic justification of different technological options. It comprises three parallel and interacting elements: (1) choice and technical feasibility, (2) financial justification, and (3) strategic commitment to gaining competitive advantage from any AMT investment (Langley and Truax, 1994, Ramasesh and Jayakumar, 1993). Such evaluations are inevitably complex and often contested processes, due to the difficulty of establishing tangible (e.g. quantifiable and often financial) and non-tangible (e.g. non-quantifiable and often non-financial) factors (Saleh et al., 2001). Technological innovations that are completely new to organizations add more degrees of uncertainty (Wang et al., 2008).

The second phase, AMT implementation, is associated with unpredictability due to the innovative nature of the process (Boer and Krabbendam, 1992). Although some AMT failures are due to lack of investment in infrastructure (Boyer et al., 1997), many AMT implementations fail due to insufficient organizational preparation (Voss, 1986, Chung, 1990). Successful AMT implementation requires both technological and organizational preparations, rather than "just installing a new piece of equipment" (Boer and Krabbendam, 1992, Zammuto and O'Connor, 1992, McDermott and Stock, 1999). Changing organizational routines remains a determinant of success in adoptions of technological innovations (Edmondson et al., 2001). Organizations that prioritize the development of human factors are likely to achieve more benefits from the implementation of new technologies (Small and Yasin, 1997, Co et al., 1998).

Concerning the third phase, measured AMT benefits are frequently debated (i.e., are AMT worth the investment?). Different forms of AMT are reported to improve flexibility, direct labor costs, product changeover costs, process variability, work-in-process inventories, and product quality (e.g., Swink and Nair, 2007, Braglia and Petroni, 1999, Udo and Ehie, 1996). There is also (an increasingly important?) reputational benefit that can be realized from publicity about automation and newsworthy articles in trade presses (Meredith, 1987b, Swamidass and Kotha, 1998). However, few organizations have been able to achieve all the promised effects of AMT adoption (Swink and Nair, 2007, Udo and Ehie, 1996, McDermott and Stock, 1999).

While the existing literature on AMT provides a useful starting point, it does not offer a sufficient basis for evaluating the application of drones in manufacturing. This is in part, as discussed above, a consequence of drone functionality (i.e., versatility, variety of flying

capabilities, etc.) and, in part the very different provenance of such technology (i.e., developed for military and leisure applications).

Research methodology

Design science is driven by research questions targeting field problems or exploring new opportunities (Denyer et al., 2008, van Aken et al., 2016). It is a well-suited method for developing "field-tested and grounded technological rules to be used as design exemplars of managerial problem solving" (van Aken, 2004, p. 221). Technological rules (or design propositions) aim to produce prescriptive knowledge by linking interventions with intended outcomes through generative mechanisms in order to solve field problems (Romme, 2003). The justification of research products are primarily focused on pragmatic validity, which can be guaranteed through field-testing (Denyer et al., 2008).

To apply design science research, we followed the CIMO logic introduced by Denyer et al. (2008). The CIMO logic explains in which *context*, what *intervention* and *mechanisms* can produce certain *outcomes*. The context is the research environment that consists of a mix of social and technical factors (Denyer et al., 2008). Contextual layers include individuals, interactions among individuals, physical settings, and the wider infrastructural systems (Pawson et al., 1997). Interventions are alternatives in the hands of managers to improve existing entities or to realize new entities (Denyer et al., 2008). Generative mechanisms describe what happens and will be triggered after interventions in a given context, which can help us understanding why this happens (i.e., causality). Expected outcomes are effects from the interventions, such as improvements in human conditions and the effectiveness of organizations.

Field tests

We engaged in a design science project with a leading Swiss manufacturer of sanitary products (henceforth called "the company") in order to develop technological rules through experimenting with drone applications. First, we collected data from the company through observations and informal interviews in order to develop a long list of potential drone applications. Second, we asked for the feedback of top managers from the company through a survey about the feasibility and scalability of each application. Third, we analyzed the collected data in order to prioritize and select the application for experiments. We also conducted interviews with six company managers to evaluate and prepare for the experiment. Fourth, we planned the implementation, assessed the risks, and prepared the production area for the experiment. Fifth, we conducted the experiment with the help of a drone service provider. Sixth, we summarized our findings after the experiment by debriefing the project with the drone service provider, and a follow-up meeting with 12 managers and employees of the company who were involved in the experiment.

In the company, we identified several potential applications of drones. We selected two applications in the area of maintenance for experiments, namely the visual inspection of metal silos and the thermography of injection molding machines. Visual inspection of silos allows the company to identify metal degradation and corrosion early. The alternative technologies for the visual inspection of silos can be ladders, scaffolding, and man lift cranes. The thermography of injection molding machines allows for mapping heat losses, thus improving isolations and reducing downtimes of the machines. The alternative technologies for the thermography of injection molding machines are using mounted cameras in ceiling conveyors or handheld cameras and ladders. We used manually controlled drones for the selected applications during the first experiments in the company. Figure 1 shows pictures from the field test.

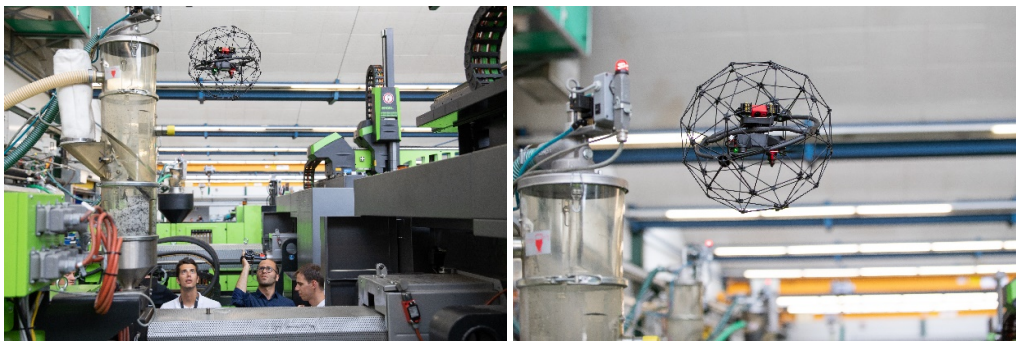

Figure 1 – Photos from our experiments in the factory.

Simulation

In the next phase, we used the learnings to develop a simulation model for using autonomous drones for machine inspection. The objective of the simulation was to examine the feasibility and technical requirements of using autonomous drones in factories following a certain flight trajectory and conducting a certain operation, such as inspection. To do so, we used RotorS, a modular drone simulation framework, developed by Furrer et al. (2016) (see Figure 2). It allowed us to use different controllers and state estimators to simulate our use case in the same production site that we conducted piloted drone experiment. RotorS simulator is developed for autonomous flights in Gazebo that is an open source robot simulation software.

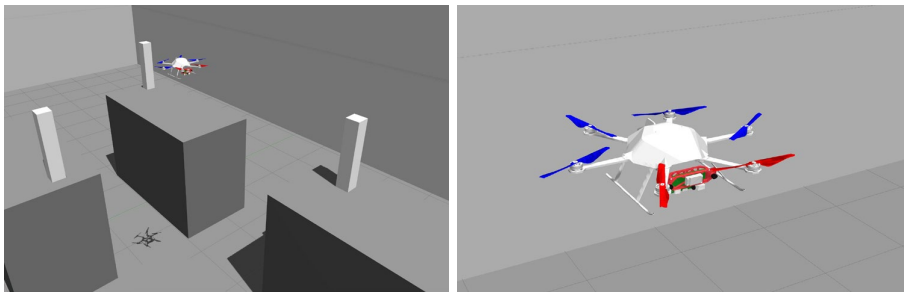

Figure 2 – Snapshots from Gazebo simulation software using Firefly hexacopter.

Simulation can potentially reduce the risk of trial and error and allows for experimenting with technologies that are not yet commercially available by analyzing near-misses (Denyer et al., 2008, Furrer et al., 2016). In fact, implementing an autonomous drone for indoor application has technological complexities, namely localization, obstacle detection and avoidance algorithms, control algorithms, and failsafe systems. The development of an autonomous drone system is costly and still under research. Moreover, implementing a potentially high-risk application can increase the disturbance to the system in case of failures, and "[m]anagers are understandably reluctant to have entire operational systems subjected to manipulation and experimentation when the outcome is uncertain" (Groop et al., 2017, p. 16).

Solution design and discussion

Technological rules can be built on existing artefacts, yet with innovative combinations in order to address emerging field problems (Arthur, 2009, Groop et al., 2017). We base our technological rules on the technology adoption of AMT literature, namely evaluation, implementation, and measuring effect while following the CIMO logic. In the case of

adopting drone technologies, evaluation mainly incorporates the analysis of context in terms of both the type of *drone application* and the *manufacturing environment*. The implementation of a drone application in a manufacturing environment is mostly concerned with the type of interventions that organizations implement and associated mechanisms that those interventions trigger. Measuring the results of a drone application corresponds to the success or failure of adopting drones to achieve intended outcomes.

Context – Drone applications

We classify the type of drone applications into *prevalent*, *progressive*, and *prospective* according to the degree to which manufacturing companies are using, experimenting or researching them. Based on the current state of drone technology and mounted sensors, we argue that a combination of following technological features determine the type of drone application: indoors vs. outdoors, flight time, payload, flight reliability, flying beyond visual line of sight (BVLOS), and the level of autonomy. Evidence shows that outdoor applications are currently more prevalent in manufacturing environment. Indoor applications of drones with between 10 to 30 minutes flight time, and sensors below ca. 5 kg with acceptable quality, and limited levels of automations are mostly progressive. Drone applications that need long flight endurance above 30 minutes, use heavy and precise sensors above 5 kg, fly BVLOS, and need high autonomy with machine learning algorithms are mostly prospective.

Context – Manufacturing environment

We classify the manufacturing environment into *ready*, *receptive*, and *resistant* towards the use of drone technology. Our classification for manufacturing environment is mostly based on AMT and organization science literature and our evidence. What determines the type of manufacturing environment is associated with the *physical characteristics* of organizations, and the *potential productivity gains* from adopting drones. The physical characteristics includes: area, height of ceilings, noise sensitivity, density of workers under drone flights, risk of damage to equipment in the case of drone failures, presence of hazardous, chemicals and gases, and number of moving objects in the air such as robot arms, cranes, lift trucks, automated storage and retrieval systems (AS/RS).

Evaluating the productivity gains from adopting drones includes both financial and non-financial benefits. Firstly, organizations measure the degree to which drones can financially add value, for instance in the case of inspection, through reducing the size of inspection teams, increasing the speed, and reducing machine downtimes. Secondly, organizations measure the frequency of the operations that will be carried out by drones, for instance, some inspections by drones have to be conducted weekly/monthly as part of regular preventive maintenance or they are only carried out during overhaul maintenance. The financial benefits should be compared with the cost of drone procurement, training, and spare parts. Non-financial benefits are associated with increasing the safety of workers, efficient data collection, and publicity, to name a few.

Yet, multiple factors can influence the degree to which manufacturing organizations are *ready*, *receptive* or *resistant* to adopt drones. For example, one of the factors that makes a manufacturing company *ready* for the adoption of drone technology is firm's technology level and readiness for automation (Jimenez et al., 1992, Meredith, 1987a). Dimnik and Johnston (1993) discuss social dynamics, personal beliefs and motivations of manufacturing managers to use new technologies, which promote championing behaviors of AMT adoption by the theory of reasoned action. Championing includes behaviors toward experimenting with new technologies with a limited scope in real-life

settings (familiarization) as well as convincing others about the benefits of innovating with new technologies (promotion) (Dimnik and Johnston, 1993).

There are multiple reasons for why organizations are resistant to adopt drone technology. Oliver (1997) explains such a resistance with institutional isolating mechanisms either as a function of organization's *unwillingness*, or as a function of organization's *inability* to acquire and imitate resources such as a new technology. In terms of unwillingness, top management is reluctant to adopt drone technology because it can contradict with company's 'low-tech' culture, or poorly fits with cultural belief system and norms, or is inconsistent with physical characteristics of organizations (Oliver, 1997). In terms of inability, a company can be unable to adopt drone technology because of the lack of skills, know-how, proximity to knowledge sources, and capabilities that are tacit, unique, or path dependent (Oliver, 1997).

Intervention and Mechanisms

We selected our industry partner for the experiment from the *receptive* class of manufacturing environment. The main reason was that *ready* organizations were among those who have already experimented drone applications in their settings, and were often reluctant to engage in a research project for experimenting drone applications. Obviously, *resistant* companies were not open for experiments with drone technology. We explain the summary of defined interventions and mechanisms that each intervention can trigger in Table 1.

Outcomes

Using drones for the visual inspection of silos increases the frequency of inspections, reduces the hazards of workers who operate in high altitudes, and reduces the cost and setup time of using expensive technologies such as man lift cranes. Using piloted drones for the thermal inspection of machines provides a better overview of the equipment in hard to reach areas, is faster in collecting several thermal images compared to humans climbing ladders, and can be used in multiple production areas flexibly compared to ceiling conveyors. Autonomous drones can also increase the frequency of inspections besides the benefits from piloted drones, as well as reducing the cost of training and drone pilots.

Nevertheless, there are technological and organizational limitations for using drones in a manufacturing environment. For example, high quality sensors are often heavy, which increases the size of drones or decreases flight times. Moreover, the application of drones requires organizational preparations such as training pilots, defining new safety measures, and integrating drones into working environment. Noisy operations and privacy issues are also challenging.

Table 1 – Technological rules for the adoption of drone technology in a receptive organization.

Context		**Interventions**	**Mechanisms**	**Outcomes (suggested)**
Organization	**Application (Experiment)**			
Receptive	Prevalent (Inspection of metal silos)	• Invest in drones • Train pilots • Document best practices and know-how	• Evaluating both financial and non-financial benefits and return on investment can facilitate mainstream adoption of drones	• Increase the frequency of inspection • Increase safety • Increase the efficiency of inspection

			• Benchmark analysis can help avoiding documented failures	
	Progressive (Thermography of injection molding machines with piloted drone)	• Use service providers for experiments • Release press news about the results of experiments	• Learnings from experiments help managers to outline a plan for drone adoptions	• Better overview • Increase speed • Increase flexibility
	Prospective (Thermography of injection molding machines with autonomous drone)	• Evaluate potential applications of drones • Increase awareness about the future applications of drones by sending relevant staff to drone exhibitions and seminars	• Developing and maintaining a compatible manufacturing environment for future applications • Top management commitment to drone technology allows for creating trust at the organization for future applications	• Better overview • Increase speed • Increase flexibility • Collect more data • Reduce the use of drone pilots

Conclusion

The industrial applications of drones are growing and manufacturing industries have begun to evaluate the use of drones as a potentially new form of AMT. We develop and present technological rules for drone applications in a manufacturing environment. The proposed solution design assists managers, engineers, and consultants making informed choices when exploring the potential of drones in specific manufacturing settings. The application of drone technology in manufacturing operations is facing multiple challenges that holds many industries back from adoption. This study represents an overview on what drones can offer, how they can be implemented, and why they are viable alternatives for certain operations.

Limitations

The application of CIMO logic for empirical OM research is scarce, thus its application virtually involves new challenges. Groop et al. (2017) provide caveats for using CIMO logic in an OM design science research. Firstly, small changes in the context may affect the feasibility of outlined interventions. For instance, in our study, many physical limitations in our experiment can be non-existent in the other manufacturing environment, thus restraining the feasibility of defined interventions. Secondly, the implementation of outlined interventions in an operational system can trigger unpredictable mechanisms resulting in undesirable effects. For example, unexpected failures of drone experiments and disturbance in manufacturing operations can influence the trust and commitment of top management for drone adoption. Thirdly, observing unintended consequences can stimulate design researchers to modify outlined interventions or developing new interventions. For example, our interventions for autonomous drones were developed after observing the consequences of piloted drones. Having these caveats in mind, clarifying and exemplifying the boundary conditions relevant to the context of empirical

research and technological rules can increase the external validity of designs (Busse et al., 2017, Groop et al., 2017, Whetten, 1989).

A second limitation is that we could not run a full-fledged test on autonomous drones due to the infancy of the technology. In this study, we mitigated this limitation by experimenting with simulation. We used simulation for the use of a new technology that is not yet commercially available, but has high potentials in the future of manufacturing operations. This helps scholars to examine the use of technologies that are not available in the market, to explore the use cases that are not prevalent for benchmark analysis, and to interact with the companies that are reluctant for field experimenting. Combining methods can also increase the quality of research in OM (Boyer and Swink, 2008, Singhal et al., 2008).

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Digital Strategy and Transformation: a Systematic Literature Review

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Abstract

Nowadays, manufacturing companies have been facing a complex phenomenon of technological advance, often named Industry 4.0, that is reshaping companies' strategy and organization, products and services, supply chains and operations. At the best of our knowledge, the academical panorama lacks an exhaustive literature review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems. Accordingly, this paper carries out a systematic literature review with the aim of mapping the publications and systematizing the often-fragmented literature on this field to propose directions of future inquire that could inspire scholars and support practitioners.

Keywords: Digital Strategy, Digital Transformation, Literature Review, Industry 4.0

Introduction

Nowadays technologies progress like a dense avalanche of advancements pouring into the environment (Brynjolfsson and McAfee, 2014). The rhythm of growth has been exponentially hastening in recent times indeed, and this has been provoking shocks in the realm of management (Westerman et al., 2014; Brynjolfsson and McAfee, 2017; Venkatraman, 2017). This complex phenomenon, often named Fourth Industrial Revolution or Industry 4.0, is reshaping companies' strategy and organization, products and services, supply chains and operations (Porter & Heppelmann, 2014). The concept of Industry 4.0 (I4.0) was initially introduced in Germany in 2011 (Lu, 2017), referring to the integration of physical objects, human actors, intelligent machines, production lines and processes across organizational boundaries, with the aim of realizing a system in which all the processes are integrated and information is shared in real time (Hozdić, 2015).

This wave poses an important challenge to companies that more and more are required to deal with the opportunities offered by the digital technologies which are at the core of

the Fourth Industrial Revolution. Aware of both the limited financial resources as well as of their level of digital readiness, companies need to make some strategic choices, selecting and exploiting the set of digital technologies that better fit with their own context (Hess, 2016).

In other words, to remain competitive companies are called to strategically govern the digital change by formulating and executing a clear strategy to keep pace with the new digital reality (Matt et al. 2014).

Since the beginning of the 2010s, a large proliferation of papers on this subject matter has been observed, but often in a quite fragmented fashion and using an ample variety of terminology. At the best of our knowledge, the academic panorama lacks a complete and exhaustive literature review on how companies can strategically govern the digital change provoked by technology advancements and occurring in business systems. To date indeed, the newness of the topic and the wideness of the combined domains blur the knowledge on the company ground and torment researchers and experts across their affairs by creating overlaps between words and meanings, constructs and definitions, and by fostering unuseful varieties of vocabulary, and diverse perspectives on the same objects and phenomena.

Accordingly, this paper carries out a systematic literature review (SLR) on this field, with the aim of charting the map of the publications and systematizing the often-fragmented literature on this field into a comprehensive body of organized knowledge, underlining the different perspectives and proposing some directions of future inquire that could inspire scholars and support practitioners.

In pursuance of these targeted objectives, the SLR has been guided by the following research questions:

- RQ1: Which are the perimeter and the current state of the art in the field of research?
- RQ2: Is there a way to frame and organize the knowledge belonging to this field?
- RQ3: Which are guidelines to drive future researches on this field?

Findings of the research contribute to systematize the often-snipped literature on how to govern the change provoked in companies by digital technology advancements. Results of the literature review show that the field under investigation may be framed into four blocks, namely: Digital Transformation Strategy; Digital Transformation Execution; Leadership & Culture; and Models. Hence, our review will depict the nature and the main contents of these blocks, to what extent they are intertwined, and which are the leverages managers may employ to govern the change. Along this line, in the final part of the paper, a discussion on the current detected gaps is carried out, and some avenues of future researches are spelt out.

Methodology

Towards achieving our aim and answering the research questions, a systematic literature review on how to strategically govern the digital change provoked by technology advancements occurring in companies has been carried out. The field under investigation, which concerns the process followed by companies to strategically select the most prominent digital technologies and then drive their implementation within the companies, revolves around two main key areas. From one side the opportunities offered to the companies by the set of digital technologies and the Fourth Industrial Revolution, and, from the other side, the strategic process they have to follow to govern within the company this change. Accordingly, two different groups of keywords have been selected to carry out the literature review on the ISI Web of Science Database (core collection):

- Group 1: it contains the keywords to intercept the papers referring to the Fourth Industrial Revolution (i.e. "Industry 4.0"; "Industrial Revolution"; "Smart Factory"; "Smart Manufacturing") and the ones referring to Digitalization or Digital Transformation (i.e. "Digital*").
- Group 2: it contains the keywords related to the investigation of how firms can strategically cope and manage these digital technology advancements which is the baseline of the studied field. The focus has been given to the governance of this kind of transformation ("Strateg*"; "Transformation*"; "Change"; "Roadmap"; "Cultur*").

We combined a) the terms belonging to group 1 and group 2; and b) the terms belonging to group 1 with each combination of two terms belonging to group 2. a) and b) where searched respectively in titles and topic (i.e. abstract, title and keywords). In this way, we were able to capture most of the papers covering the field under investigation.

The queries that were accomplished on the 12th of March 2019, returned 10.114 results at first, reduced to 508 by applying some basic filtering options proposed by ISI as the research area (i.e. Management, Business, Operations Research Management Science), the English language, and the document type. Duplicates have been subsequently removed. The application of these criteria provides us with 459 papers, that were subsequently analyzed by the authors.

Consequently, in order to check the pertinence of these papers with the field under investigation (e.g. how to strategically govern the digital change provoked by technology advancements occurring in companies), we read the abstracts of these articles and we excluded those articles that were not pertinent, and 168 relevant articles remain. The reading of the full articles made it possible to identify the 59 most pertinent articles.

At the end, after 16 papers and 8 books have been added via a snowball process, the final dataset was composed by 83 contributions. It may be argued that the final database is made up in most part by ISI ranked journals (i.e. the queries searched on ISI-WoS Database), while the snowball process added mostly practitioners' articles. We believe that this balance is valuable, bearing in mind the topicality and the hype of the theme discussed.

Finally, all the selected articles have been carefully mapped in a structured spreadsheet with different dimensions, namely: - the field, - the topic and the purpose of the article, - the construct/s under investigation and its definition (when provided), - the description of the theoretical ground, - the methodology, - the main findings. The analysis of this spreadsheet made it possible to develop a framework that organizes the contributions of the literature on the field and sheds some light on the state of the art on the theme as well as on gaps and avenues for further researches.

Field of research

Giving a general overview of the papers, the overall counter of publications per year on the field has been growing exponentially and the curve has just reared in the last three years (max[1996-2015]: 5; 2016: 8; 2017: 10; 2018: 28). The mounting interest around the topic witnesses its relevance and renews the necessity of this work.

The large part of the publications empirically test their arguments on real cases (Figure 1), interviews and surveys, secondary data analysis or action research, but the analysis of the papers also shows the presence of a consistent set of papers (i.e. "Opinions") which expound findings without the backing of a proper scientific methodology – and this principally happens with the articles dealing with strategical matters.

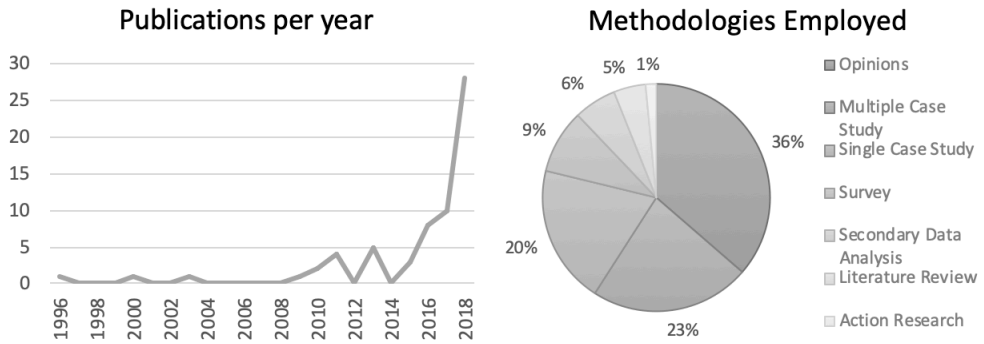

Figure 1 Publications per year and methodologies employed

The deep analysis of the papers shows that the articles on the field are quite fragmented and they deal with different aspects of the phenomenon, thus making it difficult to get a clear picture of it. To try to systematize the variety of these contributions, we develop a framework meant to integrate the different dimensions that shape the research field on how to govern the transformation provoked in companies by digital technology advancements. This framework (see Figure 2) is composed of four blocks.

The first two blocks – Digital Transformation Strategy (DTS) and Digital Transformation Execution (DTE) - constitute the backbone of the field and describe the process of digital transformation process (DT) triggered by the injection of digital technologies into companies. The second two blocks instead revolve respectively around the technical skills, Leadership and Culture companies need to be equipped with to be successful in the change process, and the Models literature supplies to comprehend these kinds of transformations. In this view, these latter two blocks sustain the field's backbone providing knowledge and tools to the people enlisted in the digital transformation process.

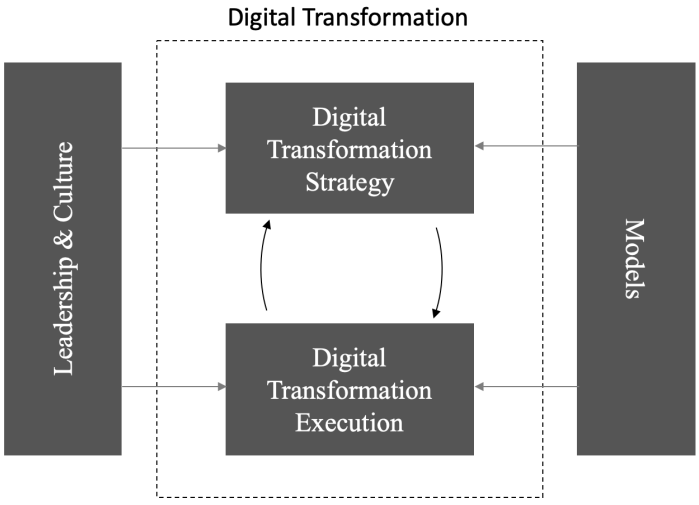

Figure 2 The architecture of a Digital Transformation Process

The Digital Transformation

The backbone of the field describes the process of governing the transformation of the company triggered by the injection of digital technologies. This process may be broken down into two diverse blocks, referring respectively to its strategical conception (i.e. Digital Transformation Strategy) and its execution (i.e. Digital Transformation Execution). More neatly, inside the concept of Digital Transformation there is one set of papers that concern Digital Transformation Strategy (DTS), where a company needs to explore the opportunities offered by technology (Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Konlechner et al., 2018) to select which to invest on (Mithas et al., 2010; Ardolino et al., 2018; Ghobakhloo, 2018; Pappas et al., 2018; Ross et al., 2018) and how to organize and control the strategical change (Tichy, 1983; Bharadwaj et al., 2013; Andriole, 2017; Davenport & Westerman, 2018). DTS papers conceptualize the path to be executed, argued in the second group of papers, which instead deal with the practical deployment of strategy into actions to transform the business model (Ross et al., 2016; Gobble, 2018) or with the management of the business-system-technology integration (Woodard et al., 2013; Agarwal & Brem, 2015; Teubner, 2018; Gastaldi et al., 2018). Consequently, as Digital Transformation Strategy lies in abstraction by the very nature of strategies, as its operations are made in the land of representations and models of reality (Gavetti and Levinthal, 2000), it has concrete effects on reality only through the Digital Transformation Execution (DTE) block (Gavetti and Rivkin, 2007). The proposed distinction comes out by the analysis of the aim and main constructs presented in the analyzed papers and will be clearly described in the subsequent sections.

Digital Transformation Strategy

Papers within this block deal with how to strategically address the opportunities and risks that originate from digital technologies, planning the company journey towards being digitally transformed (Singh &Hess, 2017). In order to refer to this concept, authors often employ different labels (i.e. digital transformation strategy, digital strategy, digital business strategy). A part from the different labels, the common features, which delimitate the boundary of the concept, relay on the fact that it governs the digital transformation: a) by defining objectives and priorities to provide directions (Mithas et al., 2010; Hansen et al., 2011; Mithas et al., 2013; Ross et al., 2016; Ardolino et al., 2018; Ghobakhloo, 2018; Konlechner et al., 2018; Pappas et al., 2018; Ross et al., 2018); b) by organizing the structure to enable the execution of digital initiatives (Agarwal & Brem, 2015; Hess et al., 2016; Sia et al., 2016); and c) by gauging progress to reroute efforts or investments when required (Sebastian et al., 2017).

Moreover, authors who use the label digital business strategy (Mithas, 2010; Kettinger, 2011; Bharadwaj et al., 2013; Grover and Kohli, 2013; Markus and Loebbecke, 2013; Mithas et al., 2013; Woodard et al., 2013; Sia et al., 2016) emphasize the integration between information technology (IT) function strategy and business strategy, which has its root in the need to achieve a peaceful and effective co-existence between IT and business strategy, thus suggesting a juxtaposition of their purposes and plans (Henderson & Venkatraman, 1992).

Beyond the definition of the concept of DTS, papers show that firms might craft their digital strategy to achieve two main objectives:

Value Propositions. A company can transform its value proposition to elevate "the performance implications of IT strategy beyond efficiency and productivity metrics to those that drive competitive advantage and strategic differentiation" (Bharadwaj et al., 2013). Ross et al. (2017) draw how companies use to pursue either a Customer

Engagement Strategy, whether they decide to focus on boosting their customer experience (Lanzolla & Giudici, 2017; Haenninen et al., 2018; Kotarba, 2018; Subramaniam et al., 2019), or a Digitalized Solution Strategy, if they bet on R&D chances to innovate their value proposition by combining products, services and available data (e.g. new smart and connected product, platform, analytics service-based) (Woodard et al., 2013; Porter and Heppelman, 2014; Echterfeld and Gausmeier, 2018).

Processeses. A company, pursuing an Operational Excellence Strategy (Ross et al., 2017) may decide to transform its processes. The matter is how to invest on the redesign of the way activities to deliver value propositions are performed, taking advantage of technology to generate more outputs employing less inputs (Zuehlke, 2010; Erol et al., 2016; Dremel et al., 2017; Sanders, et al., 2016; Szozda, 2017; Gastaldi et al., 2018; Kaidalova et al., 2018; Mittal et al., 2018). Moreover, authors sustain companies are required to consider adapting their processes whenever a change in their value propositions occur (Benner, 2009; Ross et al., 2016; Dremel et al., 2017; Lanzolla and Giudici, 2017; Ross et al., 2017).

Digital Transformation Execution

Digital Transformation is the product of the execution of a Digital Transformation Strategy (i.e. Digital Transformation Execution - DTE), where strategies transform the reality towards their exploitation by mean of actions (Gavetti and Rivkin, 2007; Ross et al., 2016). Accordingly, the overall subject matter of the second block is how to exploit the strategical transformations of value propositions and/or processes by leveraging on technologies (Day-Yang, L. et al., 2011; Gastaldi et al., 2018; Wagner et al. 2018; Weill and Woerner, 2018). Comparing to the previous block, here the knowledge is much more fragmented due to the absence of a referential theory and also because researches mostly and simply describe use cases of technology and how they have just been implemented (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018). Despite the complexity in navigating the knowledge of this block, the analysis on the research aims and the findings of each paper contained into the dataset allowed us to identify three patterns on DTE, regarding Industry 4.0, Lean Management and Project Management.

DTE & Industry 4.0. As salient detail, the contributions referring to the construct Industry 4.0 (i.e. The Fourth Industrial Revolution) mainly focus and prioritize the digital transformations of manufacturing operations and supply chains, and the way an Operational Effectiveness strategy (Ross et al. 2017) may be executed. (Hozdić, 2015; Lee, et al., 2015; Lu, 2017; Bienhaus & Haddud, 2018; Yin et al. 2018).

DTE & Lean Management. Going inside the contributions referring to the digital transformation of Supply chains and Operations, we notice a niche of contributions inquiring the relationship between Lean Management (LM) (Womack and Jones, 1997) and Digital Transformation, and we can outline two outlooks. On one side, Bortolotti et al. (2014) claim the effective execution of a Digital Transformation cannot avoid laying on already efficient and streamlined processes. This is the reason why tracking LM may lead to an operational readiness to change (Sanders et al., 2015; Mrugalska and Wyrwicka, 2017; Besser Freitag et al., 2018). On the other side, Kolberg and Zühlke (2015) overturn the concept, arguing that LM is enabled by Digital Transformation, because technology is broadening the chances for manufacturing and service companies to reinforce their efficiency by solving problems in ways afore unthinkable.

DTE & Project Management. Indeed Digital Transformation Executions are often described as a package of digital coordinated projects, (Erol et al., 2016; Goelzer and

Fritzsche, 2017; Dremel et al., 2017; Singh & Hess, 2017; Bertoncel, 2018), and this opens a question on the role of Project Management in the Digital Transformation process, although few publication refers explicitly to the issue (Schüritz et al., 2017; Teubner, 2018).

Leadership & Culture

The third block considers the academical interest on the impact of the organizational and cultural variables into a Digital Transformation (i.e. DTS and DTE). Compared to the rest of the papers, this block presents a dissonant peculiarity on the methodologies employed by scholars, that is the preponderance of hypotheses tested by surveys and statistic techniques, while case studies are the rule in the other papers. In this niche of knowledge results figure out two main topics discussed by scholars: technical skills, leadership, and cultural background requirements.

From the analysis, these requirements seem a prerogative to make a Digital Transformation effective, mainly for two reasons: first, they must to be fostered whatever the DT will be (Ross et al. 2016; Sia et al., 2016; Westerman, 2016; Dremel et al., 2017); second, it is "difficult, rather impossible, for a network of typical manufactures to achieve them in a short run" (Ghobakhloo, 2018)

Technical skills. Some publications claim that a Digital Transformation to survive in time without having a negative impact on performances need people to be equipped with some technical skills (Weizi et al., 2016). These are required to understand, deploy and manage the opportunities offered by technologies and the dynamics of the change their introduction involves Sia et al., 2016; Davison and Ou, 2017; Ross et al. 2017). Such skills are hybrid skills (Weizi et al., 2016; Schwarzmueller et al., 2018), for example, the ability to perceive week signals of disruption (Bertoncel, 2018) or to handle the analysis and conversion of big amount of data to make decisions above valuable information (Davenport and Patil. 2012; McAfee, Andrew, et al., 2012; Schallmo et al., 2017).

Leadership. Literature maintains the central role leadership plays in the Digital Transformation process, and in particular the interaction between leadership and technology advancements that is baptized as e-leadership (Avolio et al. 2014). Weizi et al. (2016) divide the construct of e-leadership in two layers, where at micro level it deals with the abovementioned skills requirements, and, at a macro level, e-leadership challenges the redesign of company's governance to allocate responsibilities to tackle a DT. On this account, the analysis on the dataset pinpoints a stream of research on the relationship between Chief Information Officers and Chief Executive Officers (Weizi et al., 2016; Hansen et al., 2011; Oberer & Erkollar, 2018), and the opportunity/possibility of introducing a new referential profile the Chief Digital Officer – CDO to supervise the DT (Singh & Hess, 2017).

Cultural Background. Some contributions address the theme of which kind of organizational culture is more suited to engage a Digital Transformation. From the analysis, two significant features emerge: agility and innovation (Ross et al., 2017; Dremel et al., 2017). In particular, Schwarzmueller et al., (2018) state "organizational culture should be transformed to a culture of involvement, in which decisions are taken together, a culture of innovation, that ensures agility based on the acceptance of suggestions, and a culture of training, in which staff is constantly developed (Patterson et al., 2005)." Furthermore, other authors hint companies need to pursue openness to change (Ghobakhloo, 2018) to adapt more quickly and shorten adaptation time to new working habits (Weizi et al., 2016), and, eventually, create a culture of decision making based on data instead of experience and intuition (McAfee et al., 2012; Dremel et al., 2017).

Models

The Models block collects the contributions which provide knowledge on the opportunities offered by technology advancements and on guidelines companies may follow to implement a Digital Transformation They are divided into three different groups: Frameworks, Roadmaps and Methodologies, and Assessment Tools.

Frameworks. As defined in the introduction of the paper, Digital Transformation is a consequence of the technological evolution which companies wrestle along their journey. Literature maintain diverse publications that try to build knowledge around this phenomenon (Porter & Heppelmann, 2014; Rometty, 2016; Westerman et al., 2014), inquiring how technologies progress, and/or their social impact, and/or the types of mutations they are provoking on companies (Brynjolfsson and McAfee, 2014; Porter & Heppelmann, 2015; Weill and Woerner, 2015; Brynjolfsson and McAfee, 2017; Venkatraman, 2017).

Roadmaps and methodologies. In this group are contained all the contribution referring to methods (i.e. standards and steps) (Bibby & Dehe, 2018; Mittal et al., 2018), guidelines, roadmaps and tools (Westerman, 2016; Andriole, 2017; Gobble, 2018) which a company could use for architecting and standardizing its Digital Transformation (Liu, Day-Yang et al., 2011; Porter & Heppelmann, 2015; Matt et al., 2015; Erol et al., 2016; Parviainen et al., 2017; Dremel et al., 2017; Ghobakhloo, 2018; Weill and Woerner, 2018). Methodologies can be applied to any type of digital transformation, and their focus ranges from the entire company to a specific project. Literature is rich of anecdotal cases of successful integration of technologies towards a digital transformation (Kohli and Johnson, 2011; Agarwal & Brem, 2015; Hansen and Sia, 2015; Oks et al., 2016; Dremel et al., 2017; Kaidalova et al., 2018), but a thorough reference methodology to handle the problem of Digital Transformation still lacks (Nwaiwu, 2018).

Assessment tools. This stream of papers provides contributions on instruments which support managers or companies in measuring and evaluating the degree of technological integration into company's processes. This results in a seminal provision to position companies into a reference system that can better drive the digital transformation process (Plomp and Batenburg, 2010; Bibby & Dehe, 2018; Heavin & Power, 2018; Kontic & Vidicki, 2018).

Conclusion

Although this is a preliminary review on how to strategically govern the digital change provoked by technology advancements and occurring in business systems, some contributions to both research and practice have been provided. On the academic side, the paper systematizes the knowledge on the field and provides a framework to orient future researches. On the managerial side, our research offers some insights on the strategic aspects of the digital transformation that endeavour and supports organizations and managers that are tackling the challenges offered by the new digital era.

The paper has also some limitations, that can drive further developments. Results maintain that literature on the field is still in its infancy, suggesting that future research should go more in depth in comprehending how digital transformation can be developed and executed. The performed queries are more focused on the digital strategy conceptualization rather than its exploitation. So, additional research could be performed through a wider sample to validate and enrich the considerations addressed on Digital Transformation Execution subgroup.

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If Blockchain is the answer what is the question?

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Abstract

The purpose of the paper is to identify the issues and challenges to employing blockchain technology for different operations context. The paper analyses five cases to identify drivers and barriers to adopting the technology. Our findings suggest that interoperability and platform dependency can limit the wide-scale deployment of the technology. Additionally, trust in rule-based software automation and consensus among supply chain actors can inhibit effective adoption. In summary, the paper finds that care should be taken when applying blockchain, since there are many situations where its implementation is not feasible or not beneficial.

Keywords: Blockchain, Challenges, Limitations

Introduction

Blockchain has emerged as a technology that can provide visibility, traceability and transparency in business operations, which will lead to better accountability. The potential usefulness of the technology has been reported in many sectors such as: energy (Adoni et al., 2019); health-care (McGhin et al., 2019); digital supply-chain (Min, 2019); retail (Morkunas et al., 2019); financial services (Tapscott and Tapscott, 2017); and transportation (Lei et al., 2019). The key properties of this technology that makes it a valuable proposition to handle heterogenous transactions in different sectors are discussed below and these have been reported in the pilot studies undertaken by technology providers such as IBM (2017), Capgemini (2017) and in academic research.

- ***Immutability****:* The transactions recorded in a blockchain cannot be tampered, deleted and revised, i.e. the process and information stored in each block is irreversible, thus providing an accurate view of the activities. However, the

authenticity and quality of the information will depend upon the author and source.

- *Distributed:* The blocks and corresponding chain is stored among all the entities in the network participating in the transactions, which increases visibility of the information. However, access restrictions may apply depending on the nature of the information and the rules associated with the creation of blocks.
- *Decentralised:* The transactions occur based on automated rules set in the network (mainly through a process of consensus), which eliminates the need of a central authority, i.e. this potentially will lead to faster transactions, and eliminates the risk of the data being held centrally in a server (as in contemporary information systems). However, as the size of the chain increases the processing time to create or retrieve a block will increase.
- *Automation*: Most processes in the network, i.e. creating a record, processing transactions, are executed automatically by the software codes deployed in the network. The cryptographic verification process ensures authenticity of the transactions and makes the process incorruptible, i.e. devoid of errors (if the software codes do what they are meant to or agreed upon in a suitable manner). It is worth highlighting that the process of rule creation and revisions is a grey area and will depend on the context and purpose of using the technology.
- *Single Unified Ledger:* This helps in aggregating all the records in a single network, i.e. provides the actors with high-level as well as low-level view of all the transactions, linked-information efficiently, thus reducing the information and cognitive overload to some extent. Employing blockchain analytics to provide such a view can be complex and inefficient, due to size of the chain and automated access rights imposed by automated rules.

The existing literature has focussed mainly on the advantages offered by the technology in different business sectors. Though, the merits offered by the technology are demonstrated through pilot projects undertaken by technology providers, it is necessary to understand the challenges to large-scale adoption of the blockchain and readiness of businesses to deploy the technology.

Issues and challenges identified from the literature.

The literature gathered from various business disciplines, information systems and computing science was systematically reviewed to identify the potential challenges associated with the adoption of the technology from a business perspective. Though, the emerging technology has been tipped to transform businesses in a 'positive way', the key issues associated with the technology (usage, implementation and deployment) and organisation needs (value of using the technology, skills and expertise) are yet to be understood and discussed comprehensively. *Table 1* will present the key challenges that can be potential barriers towards the wide-scale adoption of the technology in business domain (in-particular global supply-chains which are increasingly becoming complex). A quick review of the table highlights: the need to understand that will aid in managing and implementing the technology (skills and expertise); agreement between various businesses adopting the technology on the automated rules (process and author), and operational software platform; assessing the long-term benefits of the technology (i.e. consider its efficiency to process multiple transactions and viable integration with the existing operations and processes).

Table1: Summary of key challenges reported in academic literature and business (Y means that the challenge has been briefly discussed/mentioned in the literature)

Challenges	Min (2019)	Morkunas et al., (2019)	Atlam and Wills (2019)	Casino et al., (2019)	Kamble et al., (2018)	Kshetri (2018)	Deliotte (2018)	Capgemini (2017)
Access control/ authorisation						Y	Y	Y
Compliance: legal and regulatory	Y	Y		Y		Y	Y	Y
Computing power	Y			Y		Y	Y	
Data Management			Y	Y				
Efficiency and performance			Y	Y		Y	Y	Y
Skills and expertise	Y				Y		Y	
Platform standardisation		Y	Y					Y
Operational Costs		Y					Y	Y
Organisational Resistance [within firm]	Y	Y				Y	Y	
Organisational Resistance [between firm]	Y					Y	Y	
Privacy	Y		Y	Y			Y	Y
Scalability	Y		Y	Y			Y	Y
Security								
Strategy to			Y	Y				Y
Suitability				Y	Y			
Trust in automated software	Y	Y		Y				Y

Review of industry pilot cases

Blockchain is considered as a valuable solution in different areas because it can record transactions in a secure, transparent, decentralised, efficient, and low-cost way (Schatsky & Muraskin, 2015). It can simplify the transmission of information to eliminate the commonly conflicting layers found in supply chains, making information more reliable,

timely, highly visible and incorruptible. The purpose of this section is to present different instances in which blockchain has been implemented to investigate the themes identified in the literature review and to understand the requirements to leverage the potential of this technology. The five cases selected are looking at the food industry, energy, disaster relief, housing and banking. The findings stemming from the review of the pilot cases is summarised in Table 2.

- ***Food Supply Chain.*** The food supply chain is an excellent example of the potential value of blockchain. Freshness of food, especially meat, is a significant health concern. That was the motivation behind Provenance (Provenance, 2019), a company that has implemented blockchain to provide more certainty and transparency in the food supply chain. The purpose is to allow users/companies to know more about the origin, travel and destination of food. Talking about meat that can allow users to trust the "kill" dates in their meat products, thereby ensuring freshness. In fact, the company implemented a similar idea in Indonesia, in which they used blockchain to track tuna from the moment it was caught until it reached the consumer (Safaryan, 2017). That way, it was possible to add traceability to the supply chain and ensure consumers about the journey of their product. The potential of blockchain in this setting is not only to increase traceability though. It can allow to support commodity management to reduce duplication of certificates and paperwork, allow marketplace creation by connecting suppliers and customers, increase data sharing among different members of the supply chain through collection of information from different sensors at different stages, increasing access to capital investments, and enhancing payments (Noel, 2018).
- ***Energy.*** Introducing a fully decentralised energy system is another potential venue for blockchain. The technology available nowadays allows people to be not only consumers of electricity, but also producers. Blockchain has the potential to support transactions among customers with different roles. Elektrify is a good example of the use of blockchain to allow these interactions (Electrify, 2019). In fact, a project between Busan City, Nuri Telecom, Pusan National University, Busan City Gas, and Korea Industrial Complex Corporation tries to exploit this possibility, to improve power generation and distribution in the region (Marley, 2019). This would also facilitate the creation of a micro-grid in regions of the country, which is a project currently pursued by Korea Electric Power Corporation (KEPCO). Beyond that, also in Korea, Swytch, is partnering with Chuncheon to use smart meter and blockchain technology to incentivise and provide benefits for companies and people looking to reduce carbon emissions (SmartCitiesWorld, 2018). On top of that, blockchain can also be used to allow metering, billing and clearing processes (PwC, 2016), which shows the reason this technology is very promising for other countries as well.
- ***Relief and disasters.*** Collaboration and cooperation are very complicated in situations in which a disaster has affected a region because of the multiple number of organisations involved. Governmental organisations, non-governmental organisations, charities and civil organisations try to provide support for the affected people, but it is complicated to provide a honed response because of the duplication of efforts and the centralised systems used by these organisations. The U.S. government realised that blockchain could be effectively used to enhance collaboration. Blockchain can be used to create a decentralised system through improved information sharing exploiting its traceability, transparency and immutability (Akilo, 2018). In that way, organisations could have more clarity about

the activities of the other stakeholders, helping guide their activities. Moreover, this would allow to pool resources and introduce a coordinated response. This benefit, however, would not be only for the organisations. Transparency and traceability would allow donors to increase trust in NGOs and charities and ensure a more efficient response to the victims. From that perspective, blockchain can allow to provide support for donations and financial transaction in disaster settings (Phil, 2018).

- ***Housing.*** The housing industry represents an area with huge potential for the implementation of blockchain. A very interesting example comes from the intersection of housing and public policy. The Kenyan National Housing Fund provides government-funded housing for families in need. However, the scheme has been criticised because of fraudulent activities and corruption (Aki, 2018). The use of blockchain would allow to ensure the transparent distribution of houses because blocks cannot be altered once these have been added to the chain. The notoriously porous land registry database would be recorded using blockchain to ensure that houses go to the people who need them. Additionally, funds would be more difficult to embezzle, and bribes would be reduced considerably (Sharma, 2018).
- ***Banking.*** The most notorious application of blockchain is related to cryptocurrency. Looking at financial services, blockchain has an incredible potential to improve transactions. The We.Trade platform from HSBC in collaboration with another 9 banks is a clear example (Finextra, 2018). HSBC has been at the spear point of the use of blockchain to improve financial transactions. In 2018, the bank was able to perform the first trade finance transaction using R3's Corda scalable blockchain platform, in the situation of a Cargill shipment of soybeans going to Malaysia from Argentina (HSBC, 2018). The purpose of this test was to use a shared application instead of applications in multiple systems, which reduced the transaction time from days to less than 24 hours. This outcome showed the feasibility of trade digitisation and emphasised the potential to reduce fraud risks in letters of credit, and introducing more efficient procedures (Ganesh, Olsen, Kroeker, & P, 2018).

Research Agenda

An important contribution of this research is to convert the themes identified in the literature and illustrated through analysis of cases, into possible directions for future research. We identify four research questions that demand attention, if blockchain is to be seen as a valuable technology for operations management.

- ***Interoperability.*** Research on blockchain focuses on the benefits and the characteristics, but often overlooks the technical requirements and implications. For example, each actor in the system must possess the required expertise and equipment to effectively share data. Therefore, research should investigate the minimum technical requirements and how big a challenge it may be to bring organisations to the required standard. Additionally, when discussing cases in which individuals also read or write data, this becomes even more complex.

Table 2: Summary of the business cases

Cases	Technical		Social	
	Interoperability	Platform	Rule-based software automation	Consensus among actors
Food SC	Different levels of IT expertise and equipment among different links from supply chain (from fisherman to retailer).	Data recording methods and technology might be inconsistent. Different stakeholders can have multiple platforms.	Rules development and agreement can have a significant effect on the different links in the SC	Permissions for data editing/access need to be properly agreed. Acceptance to technological innovation can be challenging.
Energy	The decentralised system requires similar technology for users/producers and organisations to record/update.	Highly complex system with multiple nodes in which a single platform across all users/producers would be required.	Data protection can be problematic because of GDPR. Data sharing rules would need to be clearly defined.	The level of access to producers/users should be well-established and agreed upon. There is a need to ensure consistency in practice.
Disasters	There is a varying level of technological proficiency and resources among actors, particularly donors.	Multiple platforms should be integrated, and databases consistently prepared.	The different type of participants would need to define who would be making the rules, how/if these can be modified and how are all the stakeholders integrated.	The combination of private and public funding could affect the interests of different stakeholders. Decisions on how much information is shared and what information can be taken should be agreed.
Housing	Technological requirements for data collection and recording need to be defined. The expertise to implement blockchain would be essential.	Different branches of government need to interact through the integration of different systems.	GDPR requirements can be complicated. The level of personal data shared, its use and level of access would need to be carefully stated.	It requires involvement of contractors/suppliers and governmental officials to identify the kind of data shared and who would be the main participants.
Banking	Technological proficiency would need to be consistent across actors.	Multiple platforms should be integrated into a single platform.	Decisions should be made about to what extent should data be shared, who will be defining the rules and how/if these can be modified.	Banks and authorities would need to agree on what data can be taken from the transaction and what access level is required from the different parties.

- ***Platform dependency.*** As with information technology, the extent to which blockchain delivers benefits is affected by the data in the system. This means the platforms used, the way in which they are used by actors and the level of expertise of these actors are all important. In particular, the way that data are captured and communicated could be crucial. For example, if objective data are captured using a standardised approach, the data will be more trusted than data input manually, with implications throughout the lifetime of these data. Research should seek to understand data management, platforms and readiness for blockchain implementation.
- ***Trust in rule-based automation software.*** Rule-based systems, whether electronic, economic or otherwise, are important in enabling business. Trust in such systems, however, is greatly affected by the source of the rules. Whether blockchain rules are set by regulatory bodies or by individual companies and whether they can be modified by individuals or not can affect the trust and hence the adoption or success of blockchain. Research should investigate the behavioural aspects in particular, to understand how and when blockchain can command sufficient trust to be adopted.
- ***Consensus among supply chain actors.*** The adoption of the technology will require an understanding and agreement between all the actors (for example, supply-chain entities) participating in the blockchain network. This will require have an agreement on the rules set-up within the network, using a platform provided by a technology provider, which will require integration with the existing processes, and participating in the transactions (i.e. willingness and mindset to use the technology). The consensus between the firms will be driven by the potential benefits offered by the technology to the individual firms and the awareness/ expertise of the managers about this new and complex technology. The consensus within firm will be driven by the organisation culture to take risks i.e. adoption a technology whose benefits are yet to be validated through long-term usage and technical complexities involved to integrate with existing process in the firm, which will require persuading the management and updating the skill-set of the relevant employees throughout the processes involving technology adoption, deployment and maintenance. Research should understand and investigate various consensus factors within and between firms that will lead to wide-spread adoption of blockchain and eventually make it scalable.

Managerial Implications

Operations Managers in a variety of business contexts may find blockchain being offered as the silver bullet that will solve all problems. Examples, including the cases discussed in this research, demonstrate the breadth of applications, from supply chains for consumer products, to government contracts and from energy to banking. Blockchain can be applied in almost every business context. Before leaping into the unknown, however, managers should question whether it should be used in their specific context. This research outlines four key questions that should be considered before deciding that blockchain offers the appropriate solution.

- ***What kind of expertise is required?*** Implementing a blockchain based solution requires both strategic and technical expertise. The former is to evaluate and

decide on the most appropriate implementation of technological possibilities. The latter must be updated as the technology will evolve, and its complexity increases. This complexity is particularly clear in cases such as the energy one, in which the number of actors contributing energy (and data) is enormous. Ensuring that all of these actors are appropriately connected and that the sources of data are integrated, as well as being certain that the system will remain suitable over time, represents a considerable technical challenge.

- ***Who has the right to input data?*** Assuming the required technical expertise and strategic decision making are in place, one of the key challenges is platform governance. Consider, for example, the case of the food supply chain, in which traceability depends on the information in the system, how it is input and how it is communicated. If false data are input, these will be stored and transmitted through the whole system. While using blockchain should give confidence that fish have been caught legally or food safety standards have been maintained, this confidence would be unfounded if an actor in the supply chain has deliberately or inadvertently supplied inaccurate data. It is essential, to be sure that the right people have the right access and use it appropriately for blockchain to be useful.
- ***Who will decide the rules, and can they be modified?*** Access rights are among the aspects that should be defined in the rules of a blockchain system. For example, in a smart contract, it is important that access is restricted to those affected by the contract and that decisions are made when rule-based conditions are met, e.g. once payment is made by one party, the ownership of a property is transferred to that party. Managers should be aware of which actors can decide the rules, for example, in a supply chain, will suppliers have any say and, should the members of the supply chain make changes, will there be ongoing implications? Moreover, should the situation change, the original rules may no longer be relevant, but if they cannot be changed, blockchain may not be appropriate. For example, if a buyer and seller change their agreement, so that a higher amount is payable at an earlier date (or vice-versa) it is possible that blockchain would limit flexibility and prevent changes.
- ***What level of transparency is good for business?*** Blockchain provides potential benefits in terms of transparency and traceability. An important consideration, however, is whether this is always desirable. In most business contexts, holding back some operational details can be very important. For example, knowing which sources of supply are used or how efficient equipment is can affecting negotiating positions between buyers and suppliers. The transparency offered by blockchain can be of benefit between partners in a supply chain, but managers must consider whether too much transparency may be involved. Consider, for example, a situation where a supplier also supplies competitors, who therefore have access to information. Or an alternative situation in which the agreement with a supplier ends and their access to their own data is restricted. Neither of these situations suggest that the benefits of blockchain should always outweigh the costs.

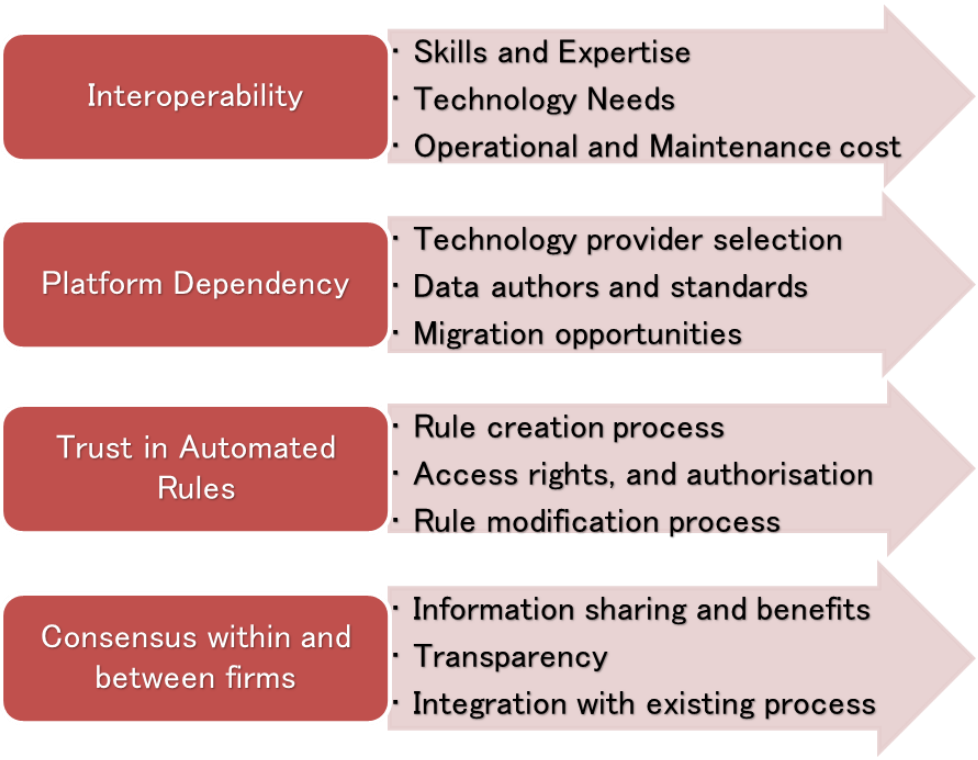

Figure1: Consolidating research agenda and implications for managers

Conclusion

The limitations of the blockchain technology has received less attention, leading to an inaccurate impression that it can address any challenge pertaining to transparency, reliability, effectiveness, efficiency, accuracy, decentralized information storage and distributed information. The paper contributes to theory by developing the understanding of the key challenges of blockchain implementation and proposing a research agenda (Figure 1) that warrants further investigation to understand potential realistic solutions for addressing these challenges. For operations managers, the paper offers a useful starting point to reflect on several key questions that are likely to impact intra-firm relationship, inter-firm relationship and key decisions pertaining to benefits of adopting blockchain (i.e. both short and long-term). However, the key question for the managers *is 'If blockchain is the solution, what is the problem'*.

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A content based literature review on the application of blockchain in food supply chain management

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Abstract

To address food insecurity and achieve efficient food recall, many technologies have been investigated in recent years. One of the most promising technologies is Blockchain, which already been successfully used in financial aspects such as bitcoin, is attracting interests from food supply chain management. As blockchain has characteristics such as decentralization, security, immutability, smart contract, it is therefore expected to improve sustainable food supply chain management and food traceability. This paper uses content analysis methods to carry out a comprehensive systematic literature review in blockchain adoption within food supply chain. We proposed four propositions and five potential challenges.

Keywords: Blockchain, food supply chain

Introduction

Food systems are complex and keep changing over time (Wognum *et al.*, 2011; Yakovleva, 2007). Customers have growing concerns of food security and quality, and an increasing demand of food supply chain transparency. From the food safety survey in 2018, more than two-thirds (68.3%) of participants worry about food fraud problems (Fortune, 2018). According to the World Health Organization (WHO, 2015), almost 1 in 10 people get sick due to foodborne disease each year. Food hazards can cause more than 200 diseases by bacteria, chemical and other contaminations, the foodborne and waterborne diarrhoeal diseases can kill about 2 million people annually including children (WTO 2015). Food crisis ranks the seventh risk in terms of impact by the World Economic Forum in 2018 (WEF, 2018). The most well-known food scandals include Sanlu milk scandal in China (2008), horse meat scandal in the UK (2013), outbreak of E.coli of Romanian lettuces in America (2018) which are only a piece of the food recall iceberg. In 2018, there were 1935 recalls reported, according to US Food and Drug Administration (FDA 2019).

Moreover, globalisation and outsourcing make food system even more complex with more suppliers and companies involved (Christopher *et al.*, 2011; Roth *et al.*, 2007). The longer geographical distance of food supply chain from producers to consumers has also became a challenge to maintain food quality and to achieve fast food recall when necessary. It is not just customers who have doubts, food companies also suffer economic loss from product recalls, which can cost on average $10M for a food company for one recall (Tyco Integrated Security, 2012). Indirect losses and further damages on brand reputation and sales are countless. Within a complex food supply chain, efficient traceability system can make significant contribution in food recall. It can isolate certain products and ingredients from the root of the problem in fast speed to prevent further loss.

Blockchain, as a decentralized platform that not only allows peer to peer direct transaction, eliminates middlemen, but also validate information by cryptography and records history permanently has drawn a lot of attentions, is believed to be a compromising solution to impove traceability and revolutionise the modern food supply chain (Kouhizadeh and Sarkis, 2018). The primary aim of this paper is to investigate how blockchain has been used in the food supply chain area, and how this technology can help to address food security issues. This paper applies a literature review method and expects to answer the following research questions:

Question 1: What are the researches have been carried out upon blockchain's adoption in food supply chain management (FSCM)?

Question 2: What benefits can blockchain bring to the FSC?

Question 3: What are the challenges of blockchain's adoption in FSC?

Previous researches have introduced a few integrations of blockchain and FSC, with the application of Internet of things (IoT) (Tian, 2016; 2017), by applying case studies (Verhoeven *et al.*, 2018), or Survey (Hackius and Petersen, 2017). The studies presented both benefits and challenge of blockchain adoption. However, no literature review has been carried to explore this topic in a systematic manner. Therefore, this paper is trying to fill the gaps, by collecting and summarising related papers, and giving a deeper analysis of the literatures to answer the questions mentioned above. The structure of the following chapters is as follows: the second chapter is a literature review on the background of the key concepts, third chapter is the research methodology and review processes, the propositions and discussions are in the fourth and fifth chapter, while the final chapter is the conclusion to summarize the whole research.

Literature review

Food supply chain

Food supply chain is defined by Folkerts and Koehorse (1997, p. 11) as "a set of interdependent companies that work closely together to manage the flow of goods and services along the value-added chain of agricultural and food products, in order to realize superior customer value at the lowest possible costs". Compare to the other industries, food products have more vulnerable value chain, and require more attention over handling processes (Aung and Chang, 2014; Ting *et al.*, 2014; Yu *et al.*, 2013). The natural feature of changing quality all the time make keep food safety and quality a challenge (Aung and Chang, 2014). Outer environments such as temperature and transports can also contribute to affect products quality and freshness. Besides, complex food supply chain also means higher risks of products failure, which includes food borne disease, food poisoning, low quality food, counterfeit products, or mislabelling and undeclared ingredients after producing (Lin *et al.*, 2018; Ting *et al.*, 2014; Tyco Integrated Security, 2012). Food security is a shared responsibility in a supply chain, and requires efficiency and closer partner collaboration to maintain the value chain and eliminate products failure.

Modern centralized food supply chain heavily relies on the central powers to control information flow, which can be the threats to the transparency, information equality and trusts (Tian, 2016; Tian, 2017). Lack of transparency can lead to certain risks include: information inequality between stakeholder (Mao *et al.*, 2018), bribery (Tian, 2017), information fraud, etc. Therefore, a single failure can lead to the disruption of the whole supply chain (Tian, 2017). For certain products, such as organic, kosher, vegan or fair trade products, it is even harder for consumers to know the products and information authenticity. Even laws and authority verifications have been helpful, deep concerning and lack of trust of food industry and food quality still remind.

Blockchain

The concept of the decentralized peer to peer ledger was introduced by Nakamoto in 2008. It has been successfully applied in financial area such as Bitcoin, and it triggers huge interests in multiple areas including, supply chain, property, voting, etc. The fundamental technology of blockchain has a few main features: decentralization, immutability, security and smart contract.

- Decentralization

Decentralization eliminates the central powers and address information inequality by allowing direct transaction between users. Users have equal power to examine transactions, to keep copies of records and to access entire transaction history. In food supply chain, from the raw material suppliers to customers, products information can be recorded along the whole supply chain and ready to be retrieved upon on demand. For example, the end users, consumers, can obtain the detailed information on the products include authenticity and origins, etc. Producers can also monitor their suppliers to make sure raw material quality meet requirements. Therefore, decentralised supply chain can eliminate information inequality and build trust.

- Security

Data security can be achieved by blockchain consensus algorithm. Transactions are examined by users to define computer calculations. When decentralization eliminates central power on the network, it also prevents a supply chain breakdown because of a single point failure will not lead to the failure of the whole network, which can reduce the chance of hacking. Technically, hacking can only be achieved when the majority (at least 51%) of users are taken over, which will take a considerable amount of energy/time. Therefore, the more complicated blockchain network with more users, the more difficult for the hacking behaviour to happen. When applying into food supply chain, blockchain can keep records and data safe, and eliminates the risks of hacking and data stealing.

- Immutability

Blockchain ensures the records are original and authentic by its immutability feature. This means history data cannot be altered without warning other users, which can prevent the human intervention on records. This feature makes blockchain as a powerful proof to investigate for accountabilities under food crisis and food recall. It can prevent any stakeholders change history and escape from responsibilities. It is also an evidence for ensuring producing process especially for products such as organic, halal, fair trade, etc., immutable records can provide customers buying confidence. However, immutability cannot always guarantee the raw information authenticity, it can be considered as a strategic tool to encourage stakeholders to take responsibilities for their information.

- Smart contract

Smart contract is a digitalized program which operates automatically when certain agreements are met. The use of smart contact can significantly speed up transactions and enhance trust, save time and labour. For example, in 2014, Maersk have found that over 30 people and organizations have got involved when shipping a container of roses and

avocado from Kenya to Netherlands (Park, 2018). It also took 34 days include 10 documents processing days to finish a whole shipping activity, which is also not include missing paper caused delay and time extension (Park, 2018). As the smart contract based on the agreement of all partners, therefore, no single user can make changes. In another word, it can replace "the letter of credit" and protect the partnerships. For instance, the payment can be sent to producers automatically once the products arrived to warehouse.

Traceability

Traceability has many definitions so far, the earliest definition was by International Organization for standardization (ISO 8402, 1994): "the ability to trace the history, application or location of an entity by means of recorded identifications". More precisely, "food traceability is part of logistics management that capture, store, and transmit adequate information about a food, feed, food-producing is correct animal or substance at all stages in the food supply chain so that the product can be checked for safety and quality control, traced upward, and tracked downward at any time required. (Bosona and Gebresenbet, 2013, p.35)".

From the definition, record-keeping is an important element for building good traceability. It not only allows companies to have a clearer view of the supply chain, make better decisions and avoid potential quality risks by providing precise records; but also gives the ability of tracing backward and tracking forward along the supply chain during food recall, which can improve the speed of isolating and finding certain products from certain suppliers (UN global Compact, 2014). For sustainability purpose, traceability is also a way to monitor environmental impacts, therefore, encourage companies to be more sustainable. By demonstrating the resources and products flow, customers have better knowledge and trust on the buying products. Traceability can be the added value to the food products, and be used as a marketing tool to attract more customers and enhance customer trusts. (Dabbene *et al.,* 2014; Golan *et al.,* 2004). The record keeping can also be used as a strategic tool to encourage suppliers to provide quality products (Aung and Chang, 2014; Golan *et al.,* 2004).

Traditional traceability system largely relies on paper-based system or internal computer system, which can be time consuming and incapable for other stakeholders (Aung and Chang, 2014). Traceability can also differentiate companies from success and failure during food recall by accelerating recalls and saving unnecessary costs (Golan *et al.,* 2004). FDA reports that it can take averagely 57 days for a recall, or even up to 10 months sometimes (Mccallister, 2017; O'Donnell, 2017). The slow products recall can lead to deep concerning of food safety and damage company brand image. Technologies include Radio Frequency Identification (RFID), barcodes, smart tags, Wireless Sensor Network (WSN) and DNA based techniques, can provide more efficiency but can be expensive.

Blockchain is considered as a compromising solution to achieve efficient traceability. The early research by Tian (2016) proposed a conceptual framework which integrates blockchain and IoT, and suggested the benefits, include improving efficiency and transparency. There are also many pilot studies that provide the practical implication. The real world pilot study was carried by Walmart tracing mangoes (Yiannas, 2017). Compare with traditional traceability system, mango tracing time reduced from nearly seven days to 2.2 seconds by using blockchain.

Methodology

In order to answer the research questions, this research adopts a literature review method. There are several review papers on blockchain and SCM, however, none of them have a specific focus on food supply chain (Wamba *et al.,* 2018; Wang *et al.,* 2018). These

papers provide the foundation of this research. Fink (2005, p3) defined literature review as "a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents". This paper adopts a content based literature review on the application of blockchain in FSCM. This paper not only thoroughly reviews blockchain, but also considers some practical applications, and aims to provide a more precise and integrated understanding of blockchain and its influences.

This literature review applies six-stage refinement process suggested by Durach et al. (2017): define research question, set inclusion and exclusion criteria, determine searching databases, apply criteria, synthesize relevant literatures, and report findings. Research questions have been provided in the introduction. Therefore, research keywords are blockchain and the food supply chain. Web of science, Scopus and Ebsco are the three online bases that applied for relevant academic literature searching, as the three databases have a wide range of resources, and have been used extensively in SCM research. Peer-reviewed journal articles are seen as a way of high quality communication between research fellows. However, in this paper, due to the early stage of blockchain and the limited published articles, other resources such as conference papers, grey papers, consulting reports, third party reports that can provide more updated information are also considered. The initial search came out 57 results in the three databases.

Removing the duplicated papers and applying inclusion & exclusion criteria (Table 1), the number of useful papers reduced to 23 in the final process (Diagram 1). The final 23 papers are categorized and evaluated by content analysis method (Table 2), which is a systematic and objective research method that been used to quantify phenomena, documents or communications (Seuring and Gold, 2012).

Table 1: Inclusion/Exclusion Criteria

Inclusion	Exclusion
Published in English language	Published in other languages
Papers focus on food supply chain only	Papers focus on any industry rather than food supply chain industry
Published since 2008 to present	Published before 2008
Papers focus on blockchain	Papers focus on other technologies
Peer review/ conference papers, and grey articles	Business news
Management focus	Technique focus

Descriptive analysis is the first insight into all the papers, and suppose to provide a basic view of the selected papers. Among the selected papers, due to the young age of technology, the earliest paper (1 out of 23) was released in 2016, and eight papers in 2017, and the 14 papers were 2018 and onwards. The time trend shows that blockchain tends to gain an increasing research interests in food supply chain area. This also explains well that 13 out of 23 papers are technology and innovation related conference papers. Papers are focusing on different aspect of food supply chain, however 12 out of 23 of the papers focusing mainly on traceability. Papers mainly adopted conceptual framework (13 out of 23), and pilot cases (6 out of 23), three theories (3 out of 23) and survey (1 out of 23) respectively.

Table 2: List of papers by content analysis

Categories		Tian (2016)	Faye (2017)	Ge et al (2017)	Hackius and Petersen (2017)	Kumar and Lyengar	Lin et al (2017)	Tieman and Darun (2017)	Tian (2017)	Tse et al(2017)	Caro et al (2018)	Hua et al (2018)	Galvez et al (2018)	Kshetri (2018)	Leong et al(2018)	Lin et al (2018)	Perboli et al (2018)	Rejeb (2018)	Tan et al (2018)	Tripoli and Schmidhuber (2018)	Vara et al (2018)	Verhoeven et al(2018)	Yiannas (2018)	Pearson et al (2019)
Focusing area	Food traceability	✓	✓				✓		✓		✓	✓	✓		✓	✓			✓				✓	✓
	Blockchain adoption			✓						✓												✓		
	SCM				✓	✓		✓						✓			✓	✓			✓			
Benefits	Transparency	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
	Information authenticity	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓
	IoT management	✓	✓		✓	✓	✓		✓		✓		✓	✓	✓	✓		✓		✓				
	efficiency	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Challenges	Lack of understanding			✓	✓								✓		✓				✓	✓		✓		
	Immature technology			✓					✓	✓		✓		✓			✓			✓				✓
	Stakeholder cooperation			✓										✓	✓		✓			✓				✓
	Trade secrets			✓			✓					✓		✓	✓	✓				✓				✓
	Raw data authenticity			✓			✓							✓		✓								

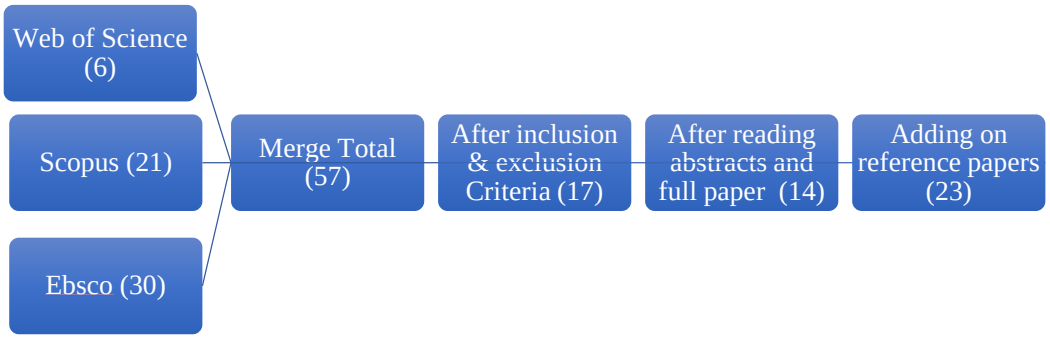

Diagram 1: Paper selection process

Finding and discussion

Blockchain is believed can address the inefficiency in current traceability and enhance trust during food recall (Yiannas, 2017). Galvez et al (2018) suggested that blockchain is a powerful tool to avoid food fraud and to improve traceability efficiency includes time and costs saving, risks reducing, and increasing trust. Similarly, Caro et al (2018) agreed the ability of blockchain on providing transparency and auditability by built blockchain traceability systems. A pilot study of blockchain based mango tracing system was launched in 2016 by Walmart and IBM. By current traceability system, it took almost 7 days to collect all the information of mango movements, and required every stakeholder to contact with each other to get to know the required details (Yiannas, 2017). By blockchain, the time to contact and wait for response from other stakeholders can be eliminated. The movements of mangoes are recorded by each stakeholder along the supply chain, and ready to be checked anytime. The trace time reduced from nearly 7 days to 2.2 seconds by blockchain (Yiannas, 2017).

- Proposition 1: Blockchain can positively improve food traceability

In the centralised supply chain, leading companies tend to choose selected information to open up to the public, which can cause the lack of transparency and trust issues within a supply chain, especially for certain products such as Halal, organic, etc (Tieman and Darun, 2017). Besides of companies themselves, even authorities can contribute to cover up unlawful hazards. For example, the China Sanlu milk scandal did not get exposed on the first place due to the cover up by company managers and local authorities (Barboza, 2008). Information credibility is questioned in centralized food supply chain (Hua *et al.*, 2018). Blockchain, as a decentralized platform, allows authorised users have equal powers to have a copy of history and access it directly without central power intervention, which can prevent any large powers over the information flow and provide transparency along the supply chain, may be the solution for information inequality.

Information fraud is another major concern within centralized supply chain, where transparency and visibility remain low. Companies can erase or change history to escape from taking responsibilities or hiding the truth (Biswas *et al.*, 2017; Caro *et al.*, 2018; Tian, 2016; Tian, 2017). By blockchain, once transactions are validated and are added on the blockchain, the original records stay permanent and can be retrieved anytime (Tian, 2017). In 2016, Walmart and Tsinghua University traced pork in China from-farm-to-fork. The finding shows that blockchain can improve information authenticity, reduce information errors and gain trust (Yiannas, 2017). This pilot case suggested that the

digitalization of records and documents not only can save time from manual paper check, but also eliminate risks from information fraud.

- Proposition 2: Blockchain can address food supply chain information asymmetry and information fraud

Many studies have combined blockchain technology with IoT, and suggested that blockchain can help to manage IoT and make supply chain more efficient (Galvez *et al.*, 2018; Leong *et al.*, 2018; Lin, *et al.,* 2018; Tian, 2016;2017). IoT such as RFID, WSN, connects objects and provides intelligent, reliable and high speed information exchange. Information such as temperature and humidity can be captured automatically by IoT sensors in near real-time, which is significantly important for food products, as the quality is closely related to the external environment (Lin *et al.,* 2017;Tian, 2016). The automation by IoT can increase the efficiency of monitoring and reduce human intervention and errors (Lin *et al.,* 2018; Tian, 2016; 2017). By combining with smart contract, once anything goes wrong such as losing temperature control, the digitalized program can be triggered automatically and send register users warnings, which can prevent further damage (Caro *et al.,* 2018; Lin *et al.,* 2017; Tian, 2017). There are a few blockchain pilot studies that have incorporation with IoT, such as WWF using smart tagging combine blockchain to prevent illegal tuna fishing in Fiji; Belagricola uses IoT and smart contact to track grains and ensure the quality (Leong *et al.,* 2018).

- Proposition 3: blockchain can positively integrate with the IoT management in a food supply chain

By using blockchain, food supply chain is found to be more sustainable by efficient products management and fast food recall. When products information is updated on blockchain in near real-time basis, stakeholders can have the awareness of products situation immediately. For instance, Walmart realized that fresh products such as mangoes can wait to be checked up to four days in the boarder (Yiannas, 2017). In this case, Walmart can accelerate the products checking process and give mangoes more shelf lives. The improvement of information transparency can improve the supply chain efficiency and eliminate unnecessary products wastes. Depends on the information, companies can make more accurate customer demand forecasting based on the point of sales data (Wang *et al.,* 2019).

- Proposition 4: blockchain can reduce food wastes

The references also suggest following challenges:

Lack of deep understanding of the blockchain technology

Public still has not enough knowledge of blockchain, even many people working within the SCM area still having troubles to fully understand about blockchain potentials (Hackius and Petersen, 2017; Galvez *et al.,* 2018). Verhoeven et al (2018) suggested that many companies tended to choose blockchain as a solution before diagnosing company issues, which show a lack of deep understanding of blockchain true potentials. For instance, Verhoeven et al (2018) suggested that in Walmart's pilot study of tracing mangoes, the tracing speed increase by blockchain should due to the eliminating of manual validation process rather than change to an efficient platform. Leong et al (2018) also suggested that different stages of the supply chain might have different requirements on technology adoption.

Technology scalability issue

The second challenge is called the "scalability trilemma" by the founder of the smart contract platform Ethereum -- Vitalik Buterin (Perboli *et al.,* 2018). It is hard to achieve decentralization, scalability and security at the same time, only two out of three can be achieved at one time (Ometoruwa, 2018; Perboli *et al.,* 2018). Scalability determines how

large the capacity the network can be. Currently, Ethereum can process 15 transactions per second, while other platform such as Visa can process 45,000 transactions per second (Coindesk, 2019). Mining process can ensure high degree of decentralization and security; it can also cause slow speed of validations when a large number of transactions are happening. For vast global food supply chain, the scale can reach about Petabyte per year by assumption (Pearson et al, 2019). Pearson et al (2019) assumed that blockchain is more likely to happen in niche areas in a food supply chain, where the blockchain potentials are necessarily needed. Different stages of the food supply chain may have different requirements for blockchain adoption (Leong et al, 2018)

Raw data manipulation before uploading to blockchain

Although, blockchain can provide a robust way to keep records, many studies have concerned about raw data manipulation, for example by tempering with IoT sensors (Galvez *et al.,* 2018; Lin *et al.,* 2017). It is also possible to make damages on products without notifying blockchain users (Kshetri, 2018). In this case, third parties such as governments and certifications can get involved by making regular checks to ensure raw data authenticity (Tian, 2017; Leong *et al.,* 2018). Meanwhile, the immutable recording can also encourage stakeholders to take responsibilities for their products and information.

It is hard to require all stakeholders within a food supply chain to adopt blockchain

It is difficult for all stakeholders get involved due to the different levels of knowledge and infrastructures. The implementing and infrastructure mentioning fee can also be the barriers (Leong *et al.,* 2018; Pearson *et al.,* 2019; Perboli *et al.,* 2018). Perboli et al (2018) suggested that the implementing fee of blockchain can be highly sustainable and can be paid back by saving on the costs. They also suggested that replacing the system partially by blockchain is more reasonable. It is also important for developers to make blockchain easy to use and to deploy with low initial costs (Leong *et al.,* 2018; Pearson *et al.,* 2019).

Regulations/laws need to be updated

By examining the external environment factors for blockchain implementation, Tse et al (2017) suggested that third parties also gain benefits from blockchain. Many countries and authorities have showed their interests and supports (Tse *et al.,* 2017): China has published Blockchain White book and launched blockchain related projects (Tse *et al.,* 2017); ISO Blockchain (TC307) was also working on developing a global blockchain standards (Pearson *et al.,* 2019). However, there is no strict blockchain policy in food supply chain area so far. As Leong et al (2018) and Pearson et al (2019) suggested that policies and rules need to be developed to protect users and company secrets. It is a challenge to invite all stakeholders on board before some completed policies and rules are being launched.

Contributions and limitations

This paper, to our knowledge, is the first to investigate how blockchain engage into food supply chain specifically. The paper provides a fundamental and comprehensive understanding of blockchain and its potential impacts, which will not only can be a useful guide for new researcher in relevant area, but also can provide some deep insights for practitioners such as company decision-makers. By identifying and analysing the most related papers, this work lays a solid ground for future research on this area, and points out some research directions. This paper also gives technology adopters a better understanding of blockchain, and explains them some possible adoption challenges and reminds them to use blockchain fit right into the issues.

Despite from the contributions, the author also would like to point out some limitation and future research areas. First of all, due to the immaturity of the technology, the paper is based on very limited number of theory-based researches with several pilot case studies,

which may lead to research bias. The big success of Bitcoin may cause a "hype" of blockchain and potentially lead to positive perspectives. In this case, the future research can focus on blockchain implementation in the real world and provide more empirical evidence. Secondly, food supply chain is complicated and various. This paper bases on the food supply chain in general, which can remind the future research to focus on specific food products and present more precise findings.

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Determinants of risk factors and benefits associated with Industry 4.0 technologies: Insights from German cases

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Abstract

This study investigates the application of current Industry 4.0 technologies as measures to counteract risk factors within companies and supply chains. Drawing on a database of more than 300 Industry 4.0 projects all around Germany, this study not only empirically explores which technologies and risk factors are currently relevant among practitioners – but also evaluates the applicability of various technological solutions for the purpose of mitigating existing supply chain risks.

Keywords: Industry 4.0, Risk Management, Digitalization

Introduction

Rapid technological developments in the fields of data generation, processing and storage left a mark on society and economy during the last decades. This extends to huge improvements of artificial intelligence and algorithms for data analysis. These technologies have also become increasingly employed in supply chain- and production processes (Tjahjono et al., 2017; Xu et al., 2018). This development can be tied to various drivers and motivations on the side of decision-making instances. While many projects are initiated for image or hype reasons, Industry 4.0 technologies often also serve as measures to deal with existing challenges and risks within companies or supply chains.

On the other hand, new technologies and their application raise new challenges for practitioners as well – regardless of the branch. For example, Guha and Kumar propose that the application of Internet of Things (IoT) and predictive manufacturing in healthcare supply chains raises risks related to data security, high costs of implementation and hidden problems/costs even after successful implementation of projects (Guha and Kumar, 2017). While this is a problem with extensive practical implications beyond the healthcare sector, scholars have just started to explore the possible interrelations and

mutual effects between supply chain risks and digital technologies. While there are few conceptual works using illustrative examples to outline possible relationships (e.g. Ivanov et al., 2018), the literature lacks exploratory empirical investigation of these phenomena. To the best of our knowledge, this is the first attempt at integrating insights from empirical, multiple cases of projects in order to extend the debate on digitalization and supply chain risks. Thus, the study aims to answer the following research question: How are industry 4.0 technologies employed to address various sources of supply chain risks within production and supply chains and which factors impact this relationship?

This study expands the work of Schlüter et al. (2017) and Ivanov et al. (2018) by investigating how technologies behind Industry 4.0 can affect supply chain risk using a large sample of 300 Industry 4.0 projects in Germany. In particular, the study addresses three main objectives:

- Analyse the supply chain risk factors that practitioners address through the use of specific Industry 4.0 technologies;
- Evaluate the benefits practitioners associate and aim for with the implementation of different technologies;
- Evaluate additional factors that influence the relationship between supply chain risks and Industry 4.0 technologies.

The paper is structured in six sections. The following section 2 briefly discusses the state of the art, while section 3 and 4 describe the methods and data used. Section 5 presents the main findings, while section 6 concludes with several theoretical and practical contributions.

Literature Review

The literature on supply chain risk management provides numerous models and frameworks for types and sources of risks as well as mitigation strategies (Chopra and Sodhi, 2004; Kersten et al., 2007; Rao and Goldsby, 2009). However, little is known on the interdependencies of these supply chain risks and Industry 4.0 applications as of yet (Ivanov et al., 2018). Current literature in this stream is only emerging at the moment and contains fragmented and mostly conceptual insights. Recent studies contain a strong focus on big data technologies and put the emphasis on outlining potential application areas of these technologies in supply chain operations, e.g. Kuo and Kusiak (2018) on the use of big data in customer research and manufacturing and Roßmann et al. (2017) on big data for demand planning and return management. These studies also point out potential risks associated with the implementation of Industry 4.0 technologies, such as data manipulation, safety and security (Guha and Kumar, 2017; Roßmann et al., 2017), risks due to different levels of technological maturity between supply chain partners (Roßmann et al., 2017), coordination complexity and information disruption risks (Ivanov et al., 2018) and hidden costs after implementation (Guha and Kumar, 2017). They do not evaluate applications of Industry 4.0 technologies for the purpose of addressing existing supply chain risks in detail, though. Other authors focus only on potential new risks of Industry 4.0 implementations, without addressing the interdependencies with existing risks being reduced at the same time (Tupa et al., 2017).

Overall, current literature mostly just covers risk management regarding Industry 4.0 by analysing potential new or intensified risks, but not by evaluating the role of Industry 4.0 applications as measures for mitigating existing risks. This perspective is only addressed by studies pursuing conceptual analysis of potential benefits or motivations for projects in that field. In this regard, current literature lacks empirical evidence based on cases of Industry 4.0 implementation and associated risk factors. This study aims to

address this research gap and to explore the relationship between supply chain risks and Industry 4.0 technologies based on cases from Germany.

Methods

In order to explore risk factors associated with Industry 4.0 empirically, a multiple case study design is employed in this study. For this purpose, the study draws on insights from 300 cases of Industry 4.0 applications in Germany. These cases are based on the well-known 'platform Industry 4.0', created and managed by the German Federal Ministry for Economic Affairs and Energy in cooperation with the Federal Ministry of Education and Research (Federal Ministry for Economic Affairs and Energy, 2018). This platform was set up with the objective to transfer learnings and best practices from the implementation of Industry 4.0 projects across German companies. In this regard, the platform provides standardized categories with pre-set possible data fields for each case, namely company size, region, product examples, value creation, application example and development stage. Moreover, for every project, several leading questions are answered. These questions include insights on challenges, benefits, approach adopted for the implementation of Industry 4.0 and lessons learnt. This database of cases was selected for several reasons. First, the cases presented on the platform represent the current state of the art of Industry 4.0 implementation in Germany. Second, the database is comprehensive and representative since it includes projects from various regions within Germany, different types of companies, industry applications and technologies employed.

Therefore, by using the 300 cases, this study can develop first empirical insights on risk factors associated with the adoption and implementation of Industry 4.0 projects. The analysis of cases in our approach followed a five-step procedure, as shown in Figure 1.

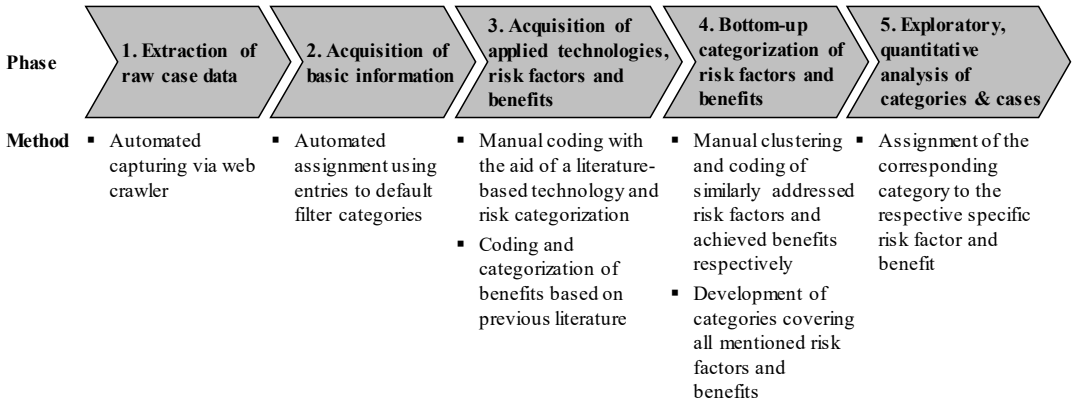

Figure 1 – Steps and applied methods

Data Overview

Several cases have been excluded from the initial database of 359 cases. Reasons for exclusion included missing key information concerning the technology used, benefits, risk factors, etc. A final dataset of 300 cases with complete information was used for further investigation.

This dataset can be described in terms of several characteristics. First, the majority of the cases are located in Baden Wuerttemberg, North Rhine-Westphalia, Bavaria and Lower Saxony – which are the four largest federal states of Germany. Nevertheless, all federal states are represented through companies with use cases, making the sample representative for the whole of Germany. 43 percent of the companies participating in the platform rank among the Small and Medium-Sized Companies (SME, 1-250 employees).

Companies of the other three size categories (250-5000, 5000-15000, >15000 employees) are represented similarly with approximately 20 percent each. Third, the 300 cases entail a strong focus on production processes, since nearly two-thirds apply to 'manufacturing industry' and more than half of the cases state 'production and supply chain' as the part of the value chain in question.

With regard to the technologies used, the case description includes a wide range of names for different technologies. Based on appropriate literature (e.g. Schlüter and Hetterscheid, 2017; Oztemel and Gursev, 2018), we identified 56 basic technologies or technological components relevant within the scope of current applications of Industry 4.0. Of these, 46 occurred within the examined cases. Due to the broad range of basic technologies and the size of the overall database, we aggregated the technologies into the following twelve higher-order technological groups, presented in Table 1.

Table 1 - Technological groups with examples

Technological group	**Examples**
Mobile actuators	*AGV, UAV…*
Stationary actuators	*Industrial robot…*
Sensors	*Temperature, humidity…*
Identifiers	*RFID/NFC, QR-Code…*
Mobile devices	*Smartphone, handheld…*
Wearables	*Data glasses, data gloves…*
Human-machine-interface	*Touchpad, motion capture…*
Machine-machine-interface	*Bluetooth/BLE, WLAN, 3G…*
Cloud computing	*Private/Public cloud…*
Software solutions	*ERPS, MES, dashboards…*
(Big) data	*Analytics, data mining…*
Additive manufacturing	*Selective laser sintering…*

Out of all companies, 197 are technology providers while the remaining 103 have implemented Industry 4.0 technologies in their business model or production processes during the last few years. As seen in Table 2, the relative composition by company size differs between technology providers and technology users.

Table 2 - Distribution of provider/user and company size

Technology	**Company size/Number of employees**				
	1-250	**250-5000**	**5000-15000**	**>15000**	∑
-provider	*96*	*44*	*32*	*25*	*197*
-user	*34*	*19*	*16*	*34*	*103*
∑	*130*	*63*	*48*	*59*	*300*

Findings

In this chapter, we analyse ex-post benefits connected to the Industry 4.0 applications described in the use cases as well as ex-ante challenges mentioned by the practitioners. In both cases, we compare the perspectives of providers and users of Industry 4.0 solutions to examine if these may diverge significantly. Through the analysis of benefits, we conceptualize variables with positive impact on current supply chain risks: these variables may reduce the exposure to existing risks factors in supply chains. The challenges extracted from the case analysis are conceptualized as potential risk factors that practitioners want to address by the use of Industry 4.0 solutions. After highlighting

benefits and risk factors associated with the technologies, the study examines relationships between benefits and technologies as well as between technologies and risk factors, also taking into account the distinction between technology users and providers.

Benefits - Positive impact on supply chain risks

In the fourth phase, we aggregated all benefits identified within all cases and used a bottom-up approach to cluster them substantially. As a result, we derived a total of 14 higher-order categories regarding fundamental opportunities and desired benefits of Industry 4.0. Figure 2 shows the frequency in absolute numbers for all of these categories respectively. It is conspicuous that the accessibility and visualization of data – which means real-time knowledge about conditions and ongoing processes on the shop floor level – is prevalent among the achieved benefits of Industry 4.0 applications. Making own production more flexible and adaptable to volatile demands and increasingly individualized customer needs is another frequent topic.

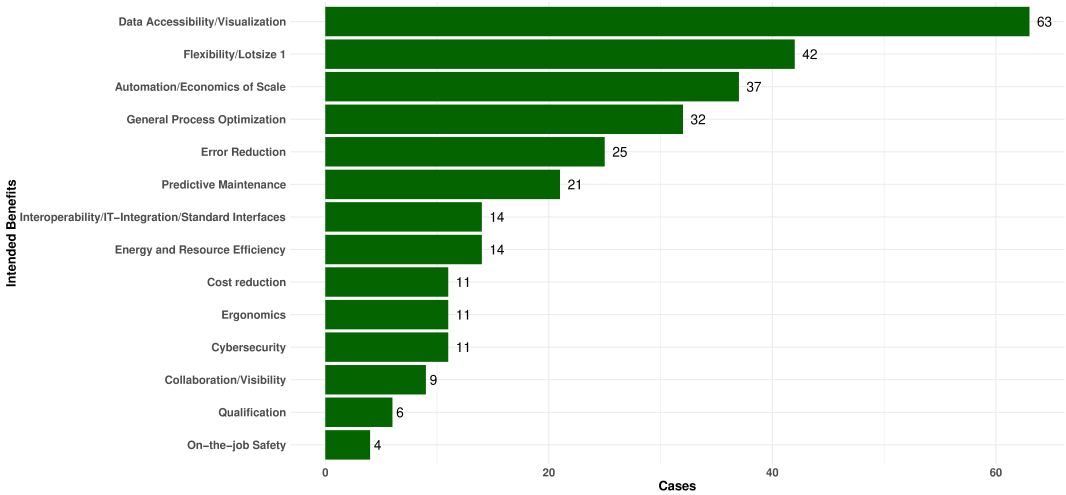

Figure 2 - Overall distribution of intended benefits

Supply chain risk factors

In the following phase, we aggregated all identified risk factors and used a bottom-up approach to cluster them substantially. As a result, we derive a total of twelve higher-order categories regarding fundamental risk factors addressed by applications of Industry 4.0, which serve as mitigation measures in this context. Figure 3 shows the frequency in absolute numbers for all of these categories respectively. The results show that the susceptibility to errors and high costs of already existing, often manual and therefore labour intensive processes is by far the most common risk factor among the examined cases. Following next are the inflexibility and high latency of the existing production system in confrontation with a high diversity of variants as well as an increasing individualization of customer needs.

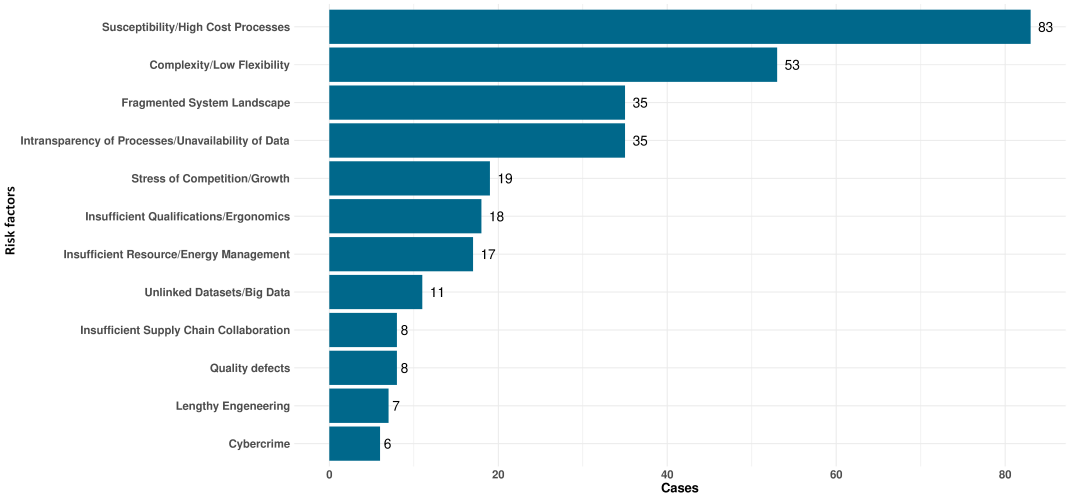

Figure 3 - Overall distribution of risk factors

With 35 indications each, two risk factors within the scope of IT are also mentioned quite frequently. First, many companies face a fragmented landscape of IT systems and experience difficulties linking existing systems to one and another, or integrating new systems into the existing infrastructure. Second, the control layer or the decision-making personnel in general lacks knowledge about current conditions and ongoing processes on the shop floor level, especially regarding machine statuses, order progresses and unpredictable incidents like machine malfunctions.

Figure 4 shows the relative shares of the six most frequent risk factors within each of the four different enterprise sizes, divided into provider and user perspective.

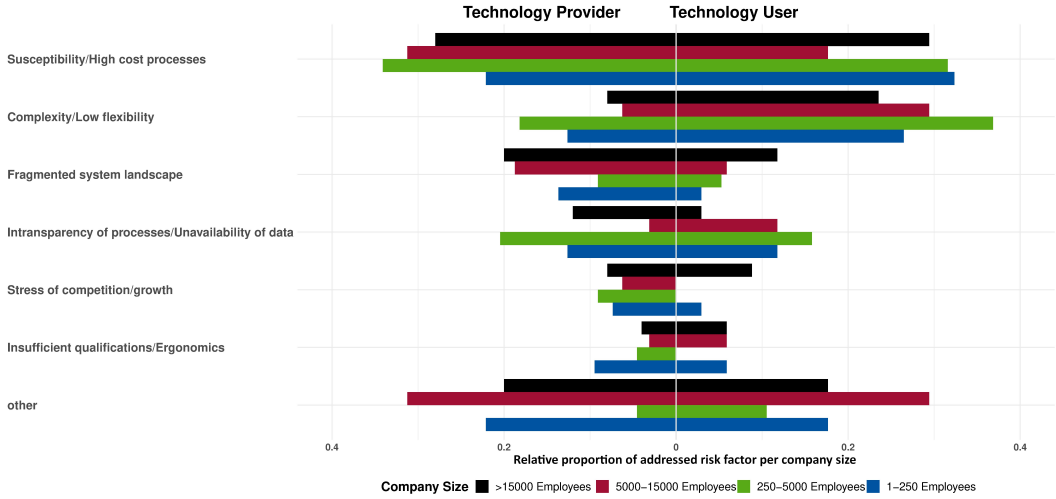

Figure 4 - Risk factors, divided into provider/user perspective and company sizes

It is notable that, compared to the provider side, on the user side much larger shares of all types of companies state increasing complexity, insufficient inflexibility and high latency of the existing production system as prevailing risk factors. This may indicate insufficient insights into customer needs on the provider's side. Alternatively, state-of-the-art applications of industry 4.0 may not be particularly suitable to mitigate this risk factor from the providers' perspective. The opposite applies for 'fragmented system landscape', which is more of a core topic to providers of all sizes than it is for users.

Exploring interrelations between technology, benefits and risk factors

Our data set also allows further insights by examining relationships between the different case characteristics like employed technologies or addressed risk factors. Figure 5 shows the proportionate composition of assigned benefits for each technology respectively, from the perspective of Industry 4.0 providers.

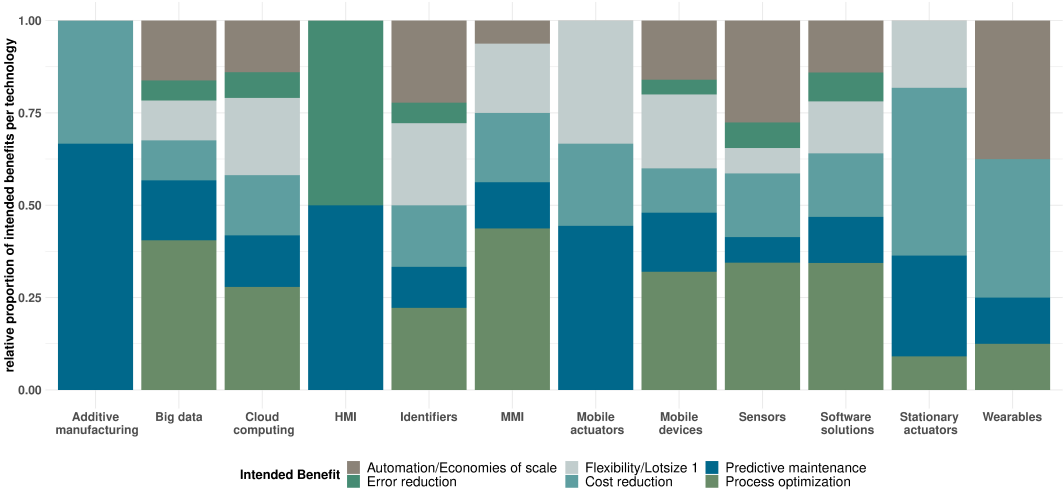

Figure 5 - Benefits accompanying specific technologies, provider perspective

While some technologies like additive manufacturing seem to have only a limited scope of application, i.e. predictive maintenance and cost reduction, there are also technologies like big data, cloud computing, software solutions and sensors that have a very broad spectrum of intended benefits, including all six most frequently mentioned ones. This versatility is likely a main driver for the intensive deployment of these technologies as seen in Figure 5.

In Figure 6 we show the proportionate composition of assigned benefits for each technology respectively, this time from the perspective of Industry 4.0 user. Interestingly, this perspective diverges significantly from the provider perspective in some cases – which indicates different understandings, experiences and expectations regarding the respective technologies and goals of its implementation.

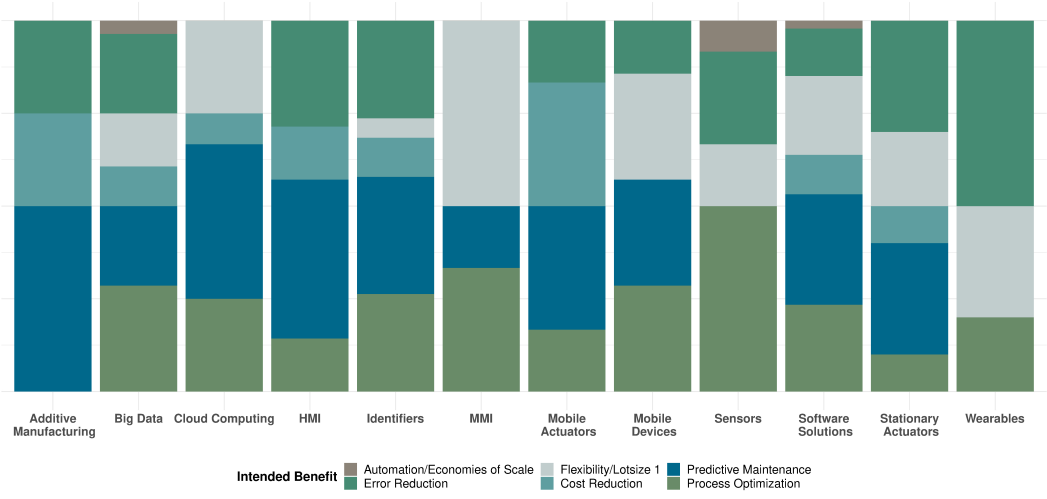

Figure 6 - Benefits accompanying specific technologies, user perspective

While big data and software solutions are still utilized for all six most frequently mentioned benefits, for cloud computing and sensors this is no longer the case. Technology users so far do not associate cost reduction with the implementation of sensor technology, while cloud computing is not utilized for automation/economics of scale and error reduction. On the other hand, the benefits of technologies like human-machine-interfaces and additive manufacturing are perceived as more versatile, utilizing them for benefits that are not considered in the provider perspective so far.

Another interesting aspect is how providers and users perceive technology by the means of its ability to address the twelve identified risk factors. Figure 7 shows which technologies were applied in order to address the twelve risk factors respectively from the providers' point of view.

For almost all risk factors, software solutions are the most used technology, tailed by (big) data management technology and cloud computing. These three technologies cover almost more than 50 percent of the solution approaches, thus dominating the field. What is also worth mentioning is the extensive application of machine-machine-interfaces to address insufficient supply chain collaboration as well as additive manufacturing to counteract quality defects.

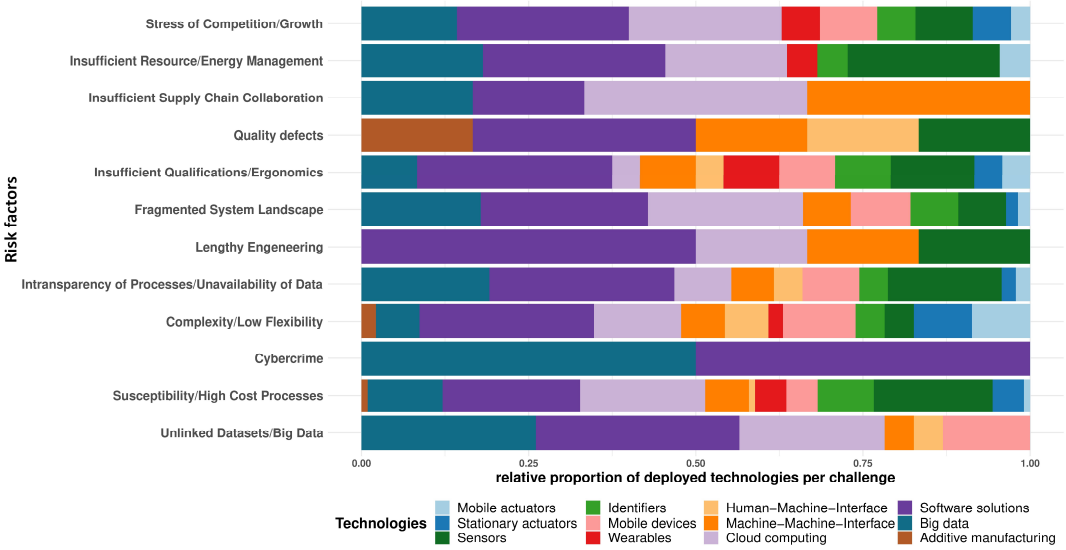

Figure 7 - Technologies addressing specific risk factors, provider perspective

Figure 8 shows, which technologies users implemented to address the twelve risk factors that companies are facing. In comparison to Figure 7, we see the perspectives of providers and users significantly diverging.

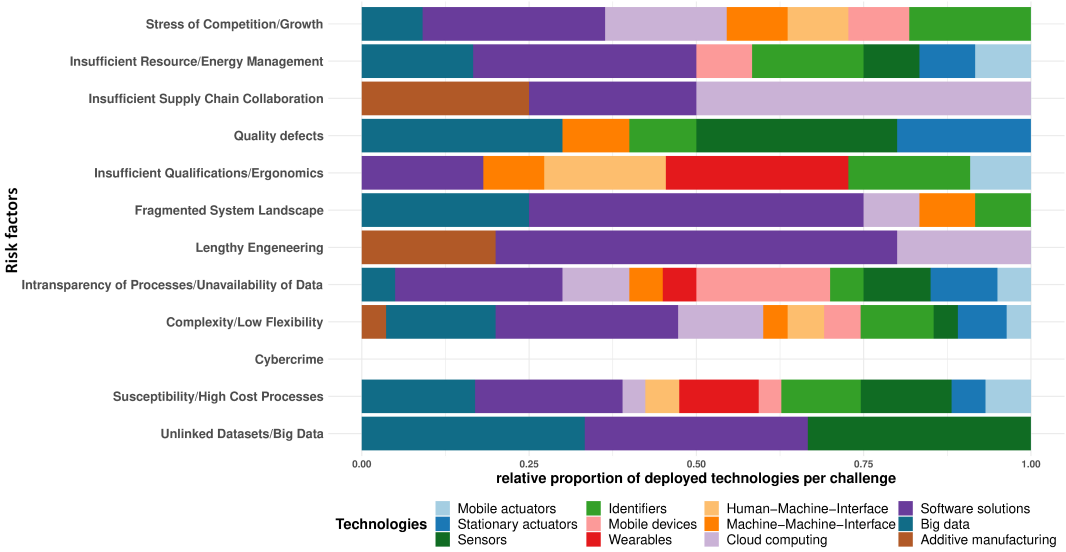

Figure 8 - Technologies addressing specific risk factors, user perspective

First, there are no cases in the database of users concerning the risk factor of cybercrime, indicating that this issue is often ignored or perceived as a merely potential risk, not worth addressing through specialized technological applications. Second, there are differences between the providers' and users' perspectives for the remaining eleven risk factors. While software solutions, big data and cloud computing are still deployed most frequently, they no longer make up the majority of applied technologies for all risk factors. This is most apparent for quality defects, which is not addressed by either software solutions or cloud computing. Furthermore, while providers greatly consider machine-machine-interfaces in order to address insufficient supply chain collaboration, users do not consider this at all as of yet.

Discussion and conclusion

This study put forward the following research question: How are industry 4.0 technologies employed to address various sources of supply chain risks within production and supply chains and which factors impact this relationship? Through our examination of 300 cases of Industry 4.0 technology implementation across Germany, several key insights emerge. Technologies employed in Industry 4.0 projects tend to reduce exposure to current supply chain risks, such as demand-side risks (volatile demands, increasingly individualized customer needs) and operational risks such as errors caused by manual processes or malfunctions of machinery. Our insights also suggest that the perspectives of technology providers and users tend to be very different regarding benefits and risk factors. Moreover, the results showed how some technologies seem to be more versatile as means of risk mitigation, and how users' and providers' assessments diverge in this regard. Yet, these technologies may also pose additional risks to supply chains, namely inflexibility, high latency of the existing production system, increasing complexity, integration with current IT systems and lack of adequate knowledge and skills of key personnel. Based on this work, these new risks should be evaluated to enable trade-offs and interdependencies of risk factors.

With this, our study contributes to the emerging literature on supply chain risks and digital technologies with an empirical investigation of opportunities and risk factors based on ongoing Industry 4.0 projects in Germany. The findings also entail some important implications for managers. First, managers can employ specialized software solutions since they are ever-present in mitigating different types of risk factors. Cloud computing can be employed to address insufficient supply chain collaboration and therefore managers can design integration projects around the use of the cloud technology. In addition, purely digital, often location-independent, easily adjustable applications like cloud- and software solutions present numerous opportunities for supply chain risk reduction and are quite popular among practitioners. Second, technology providers and users can enhance their communication in order to balance their diverging views and experiences, in particular concerning the risk of cybercrime. The user side often disregards cybercrime, which is mostly addressed as a key risk factor by providers of Industry 4.0 solutions.

The study presents also several limitations, which open avenues for further research. First, the database inherits the limitation and biases of secondary data. In order to account for this, these insights need to be further explore based on primary data, such as expert interviews. Second, the study adopts a bottom-up perspective on supply chain risks, building on the constructs found in the cases description. The next step is to compare the higher-order constructs with literature on supply chain risks in order to develop a more comprehensive image of supply chain risks and digital technologies. Moreover, this study presents a good starting point for exploring new risk factors accompanying Industry 4.0 solutions and examining trade-offs with the mitigation of existing ones.

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An Empirical Analysis on Factors Influencing Smart Product Development from Industry 4.0 in Indian Context

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Abstract

Smart product development (SPD) in industry 4.0 facilitates decision making during different activities involved in development process. Contextual evidence shows such activities are influenced by several factors; however there remains little understanding on factors influencing SPD from industry 4.0 in Indian context. Present study aims to identify and develop perception based prediction model to investigate critical factors influencing SPD. Two dimensions extracted viz. “technological” and “strategic” factors have significant positive impact while out of five identified critical factors three have significant positive impact i.e., technology & innovation, system integration and collaborative engineering. Thus, increasing quality of industry 4.0 can be accomplished with proper integration of technologies.

Keywords: Critical factors, India, Industry 4.0, Smart product development

Introduction

With the advancement of digital technologies and a paradigm shift to industry 4.0 manufacturing industries have been found to be in major transformation towards adopting smart manufacturing (Feeney et al., 2015). This new industrial trend affects organizational structure and customer’s demand (Gilchrist, 2016) which resulted into development of complex and smart products with new capabilities thus influence product life cycle that is somewhat different from conventional product development approach (Nunes et al., 2017; Ahmed et al., 2019). Industry 4.0 is an integration of “intelligent systems, machines, production and processes to form a well-defined network” (Kagermann et al., 2013, cited in Ahmed et al., 2019). It is a concept that involves combined components of “cyber physical systems (CPS)”, “internet of things

(IoT)" with cloud based models as disruptive technologies (Wang et al., 2015; Dalenogarea et al., 2018). It produces new types of products with intelligent systems embed in it. Despite the recognition of the term "smart" as extensively used by many organizations and researchers, still today there is no consensus of consistent definition. The concept of "smart product" is a network based integrated approach that spans entire manufacturing process and control production stages/processes autonomously (Nunes et al., 2017). It is characterized by its computation and data-storage facilities and its way of interaction with other objects. From developing economy like India manufacturing industry resembles high priority sector in terms of wealth creation and employment generation. However, such development initiative is still in its concept phase and has got immense potential to bring positive effects in terms of cost, quality, productivity, time, flexibility and innovation. Traditional product development approach consisting of multiple processes and sub-processes that interferes decision making information and knowledge capture (Ahmed et al., 2019) and hence real time decisions cannot be taken (Wasim et al., 2013). This becomes an imperative for development of frameworks for smart products so as to offer unprecedented customer insights. In-spite of several advantages in combining industry 4.0 and SPD, majority of the Indian industries are in state of dilemma with respect to its adoption and implementation. Contextual evidence indicates that factors that influence traditional product development approach may not be same as in case of smart product development. Thus the purpose of this paper is to identify the critical factor dimensions that affect smart product development from Indian industry 4.0 perspective. Accordingly the following objectives have been considered.

Objectives: (i) To identify and predict the influence of critical attributes or indicators on SPD; (ii) To identify critical factor dimensions and its influence on SPD.

Hypotheses Development

Technology and Innovation

With high-technology development influenced by innovation facilitates product design and development process. Such innovation led technological development engenders substantial changes in existing market that leads to successful product development. Quality of the product can be improved with technology intervention as organizations are moving towards digitalization in context of industry 4.0. Development process of smart product entails diffusion of advanced technologies and equipment, advanced production procedures with upgraded software and databases. Thus it is expected that 'technology and innovation' would increase the process flow by focusing on process innovation. Accordingly the following hypothesis is proposed.

H1: Technology innovation has positive influence on smart product development

Collaborative Engineering

Collaboration, in terms of human interface perspective, aids towards execution of series of activities which provides channel for team. Collaborative product development from

engineering perspective is a technology oriented process that is used to design innovative and improved products by exploring new markets so as to gain competitive advantage (Büyüközkan and Arsenyan, 2012). From the literature it is evident that collaborative process is followed in many industries those are involved in complex product and service development including research and development (Feller et al., 2005). Collaborative engineering also focuses in handling problems in relation to partner selection and evaluation which is critical for product development success. Thus following hypothesis is proposed.

H2: Collaborative Engineering has positive influence on smart product development

System Integration

Pertaining to SPD from Industry 4.0 perspective, SI refers to cyber physical systems that interconnect physical systems and communication infrastructure (Baheti et al., 2011). Integration of cyber technologies make products internet enabled that generates lots of data and communicates with other interconnected products. These facilitate product development process which can be achieved in cost effective and effectual manner. With system integration approach flexible operations could be performed by adjusting combination of standardized modules that speed up the product development process and reduces time to market. Thus following hypothesis is proposed.

H3: System integration has positive influence on smart product development

Sustainability

Sustainability is considered to be a critical attribute that strategically addresses the risk management in product development. With reference to environmental perspective issues pertaining to sustainability related to smart products focuses on reducing wastes, resources and energy thus moving towards green products. Reducing series of activities pertaining to traditional product development approach would eventually make the process efficient and eliminate any special causes of defects which ultimately lead to product development success. Moreover, economic sustainability facilitates agility and smooth flow in smart product development with objective to maximize profit and minimize costs. Thus the following hypothesis has been proposed.

H4: Sustainability issues have positive influence on smart product development.

Lean Operating System

Lean implementation is initiated by cyber physical system (CPS) which results in elimination of wastes by maximizing productivity. Such implementation produces products at low production costs, with good quality, better accessibility to market and customer satisfaction. Lean aspects of product development include knowledge based engineering focusing on smart technology, mistake proofing, and continuous improvement as core enablers for process development (Khan et al., 2013). Knowledge based platform proposed in work of Ahmed et al. (2019) demonstrates the influence of

advanced lean technology in product development process using knowledge-based engineering. Thus the following hypothesis is proposed.

H5: Lean Operating System issues have positive influence on smart product development.

Methodology

In order to address the research objective the present study adopts qualitative and quantitative approaches. A comprehensive search on related literature has been conducted to identify critical attributes of SPD in context of industry 4.0. To carry out qualitative based approach a semi-structured questionnaire was prepared in understanding the contextual attributes and accordingly an in-depth interview is carried out from ten manufacturing organizations where respondents were from top management and managers who have got experiences of working in domain of product development. Criteria for selecting respondents were such that they should have atleast served for minimum of eight to ten years as senior manager category with respect to design, R&D, marketing aspects of product development. Organizations involved in manufacturing products that includes consumer based household appliances and intelligent medical devices are considered in this study. Overall five critical attributes have been finalized to be taken into consideration from industry 4.0 perspectives. With identification of critical attributes of SPD attributes a structured questionnaire is developed and respondents were asked to give their opinion for each attributes on 5 point Likert scale ranging from “5= strongly agree” to “1= strongly disagree”. A structured questionnaire was sent to around 250 organizations, out of which 200 organizations responded. Out of 200 questionnaires received 35 found to be with missing data thus total 165 questionnaires were taken into consideration for further data analysis. Overall 165 respondents’ opinion is finally captured for data analysis. SPD is taken as dependent variable in terms of product development success considering operational performance measures. To establish link between predictor and dependent variables proposition have been drawn considering literature and contextual understanding (Büyüközkan and Arsenyan, 2012; Hermann et al., 2014; Kiel et al., 2016; Jianfan et al., 2017; Mrugalska and Wyrwicka, 2017; Kamble et al., 2018). Thereafter, a step-wise multiple linear regression modelling is performed to study the influence of all the five models on SPD. Secondly, factor analysis with PCA (principal component analysis) is done on five attributes to extract and identify the critical dimensions. Third, the extracted critical dimension is further subjected to regression analysis to predict and understand the relationships between extracted factor dimensions and dependent variable (SPD success). In this study SPD is taken as dependent variable which is measured by both operational and quality performance.

Data Analysis and Results

This research is exploratory in nature. From quantitative perspective firstly a step wise multiple linear regression modelling is executed which shows all five models are statistically significant with positive and significant impact on SPD. The data being

captured were further subjected for corroboration to see whether it could be analyzed through factor analysis or not. Accordingly, we performed the following analysis: (i) Correlation Analysis: Correlations were high among the practices; (ii) stepwise regression model of critical attributes on SPD (iii) Bartlett's Test of Sphericity: Found to be significant ($p < 0.05$), this shows the acceptability of data; (iv) Kaiser Meyer Olkin Test (KMO): KMO test has been found to be 0.752, which is well above cut-off range; (iv) cronbach alpha: overall is 0.791, F1 is 0.823 and F2 is 0.696. Therefore based on analysis it can be concluded it is appropriate to conduct factor analysis (Meyers, 2006; Pallant, 2007). Before conducting factor analysis we performed univariate and multivariate statistics of the variables and discovered no apparent outliers (Jun et al., 2006). To further confirm the existence of normality we conducted two tests i.e. Kolmogorov-Smirnov and Shapiro- Wilks tests, which shows p value to be greater than 0.05 and therefore revealed normal distribution.

Table 1. Correlation Matrix

	SPD	TI	SI	CE	LOS	SUST
SPD	1.000					
TI	0.686	1.000				
SI	0.639	0.651	1.000			
CE	0.537	0.554	0.619	1.000		
LOS	0.334	0.321	0.370	0.224	1.000	
SUST	0.333	0.365	0.370	0.253	0.554	1.000

Table 2. Stepwise Multiple Linear Regression Model

Models	Predictors	β Coefficients	Std. Error	t statistics	Adjusted R^2	R^2 Change	Std. Error	F value	VIF
1	Constant	1.207	0.214	5.646***	0.468	0.471	0.769	145.064***	
	TI	0.676	0.056	12.044***					1.000
2	Constant	0.732	0.225	3.259***	0.530	0.065	0.722	93.352***	
	TI	0.462	0.070	6.645***					1.734
	SI	0.343	0.072	4.744***					1.734
3	Constant	0.582	0.239	2.435**	0.535	0.009	0.718	64.017***	
	TI	0.430	0.071	6.030***					1.852
	SI	0.287	0.079	3.642***					2.084
	CE	0.133	0.076	1.738*					1.733
4	Constant	0.311	0.317	0.981	0.537	0.005	0.716	48.641***	
	TI	0.419	0.072	5.845***					1.879
	SI	0.264	0.081	3.275***					2.189
	CE	0.136	0.076	1.788*					1.736
	LOS	0.104	0.080	1.300					1.175
5	Constant	0.300	0.322	0.933	0.535	0.000	0.719	38.691***	
	TI	0.417	0.073	5.746***					1.913
	SI	0.263	0.081	3.237***					2.204
	CE	0.136	0.077	1.782*					1.736
	LOS	0.094	0.091	1.039					1.514
	SUST	0.015	0.070	0.219					1.541

Note: *Dependent Variable is Smart Product Development (SPD); TI: Technology and Innovation; SI: System Integration: CE: Collaborative Engineering; LOS: Lean Operating System; SUST: Sustainability*

Durbin Watson value: 1.987 ; ***p value < 0.001; **p value < 0.05; *p value < 0.10

Factor analysis is performed on five critical indicators as identified from review of literature and contextual understanding based on qualitative study. We conducted factor analysis on explanatory variables/indicators with objective to determine minimum number of factors that accounts for maximum variance in data. The factors were extracted using principal component analysis (PCA with varimax rotation). The objective of deploying PCA is to reduce the number of variables (Jolliffe, 2002). PCA is used to "extract maximum variance from the data set with each component thus reducing large number of variables into smaller number of components" (Tabachnick and Fidell, 2007), which facilitate easier interpretations. Table 3 exhibits rotated component matrix which shows all the five variables having factor loading of more than 0.5 and further could be reconfigured into two factor dimensions as being extracted. Factor dimensions extracted are labeled as "Technological" (F1) and "Strategic" (F2).

Table 4. Factor Analysis

Variables	Factor Loadings		Total Variance	KMO
	F1	F2		
TI	0.811		75.80	0.752
SI	0.837			
CE	0.864			
LOS		0.869		
SUST		0.850		

Note: Rotation Method: Varimax with Kaiser Normalization

The overall reliability analysis shows Cronbach's alpha to be 0.791 which validates the reliability of the study. Further reliability analyses show Cronbach's alpha values for factor dimensions F1 and F2 to be 0.823 and 0.696 respectively, which validates the reliability of the factors being extracted. Regression analysis is performed on two extracted factors. The model explains the variance ranging between 46.8% to 53.5% i.e. the predictors explains the variance in the dependent variable well which is more than the standard 40%. Durbin- Watson index suggests that there is no problem of autocorrelation in data. F-value and VIF indicates that overall model has no multicollinearity problem.

Table 3. Coefficients Target: SPD

Model Term	**Coefficient**	**Sig.**	**Importance**
Intercept	3.678	.000	
FAC_1_transformed	0.717	.000	0.883
FAC_2_transformed	0.273	.000	0.117

Note: F value: FAC1_1 is 141.5 and FAC2_1 is 20.557

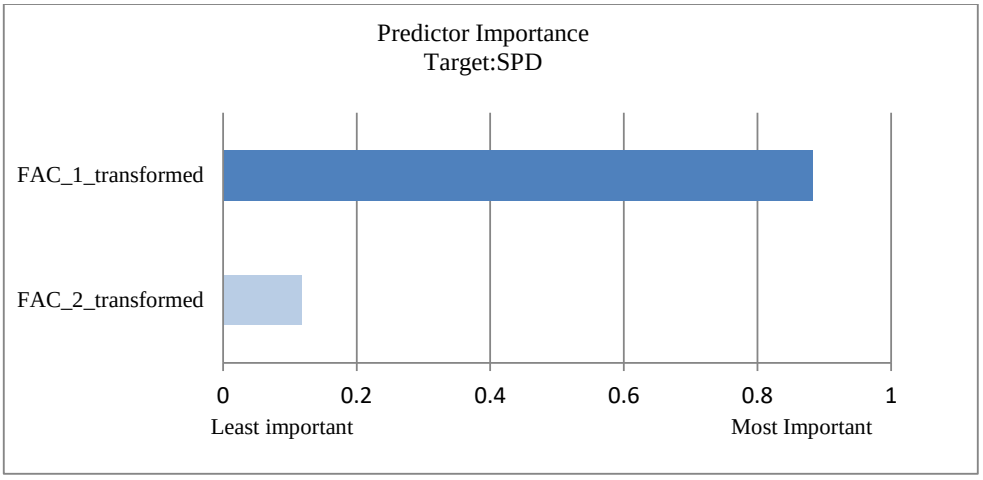

Figure 1. Predictor Importance

Overall, analysis (Figure 1) indicates the importance of technological factors which can be regarded as critical dimension for SPD. It is expected that from industry 4.0 perspective, IoT could have capability to offer transformational solutions for solving the complex digital issues in complex digital environment. In our opinion smart India in future would add value to realisation of industry 4.0 by deploying cloud manufacturing / manufacturing-as –a- service (Maas) which is gaining importance in manufacturing industry. Cyber-physical systems resemble a significant technological enabler for smart product development.

Findings and Discussions

The stepwise regression analysis reveals that attributes like technology and innovation (TI), system integration (SI) and collaborative engineering (CE) have significant positive impact on SPD whereas attributes like lean systems (LS) and sustainability (SUS) have insignificant impact on SPD. The impact analysis of technological innovation indicates that Indian industries are moving towards digital manufacturing where product development process will be executed through organised application of scientific knowledge and is consistent with Hecker (2005). With intervention of advanced technologies it is also likely that developmental process is driven by innovations that add value to the products which facilitates market demand. Here, SI resembles critical significance of cyber physical systems (CPS) where organizations would be able to generate large chunks of production data for real time analysis and decision making. Perception of respondent's towards SI also confirms the rapid move of manufacturing organizations to adopt IoT (internet of things) based approach where objects/ entities are virtually interconnected with lots of data being generated. CE approach also shows the significance of concurrent engineering management on the developmental process of SPD. As SPD from industry 4.0 perspectives is in its stage of infancy thus it would take some time to apply lean systems management and to develop a sustainable framework. Although TI, SI and CE models have been found to be statistically significant however impact of TI, SI found to be strong and CE to be moderate. This shows the lack of prominence in teamwork and human resource

practices. Exploratory factor analysis extracted two factor dimensions which are referred to as constructs namely“technological” and “strategic” factors respectively. Based on analysis performed, automatic linear modelling shows that both technological and strategic factors have significant impact on SPD which is interesting and thus exhibits paradox. The paradox itself gives an impression that strategic factor alone could not significantly impact SPD when acting alone but can significantly influence when combined effect of each technological attributes (TI, SI and CE) is deployed which shows complementarity effect with other resources. The results indicate that Indian industries with respect to Industry 4.0 anticipate better digital adoption with reduced operational costs and productivity improvement. The significant influence of strategic factor indicates the importance of triple bottom line (3BL) with lean initiatives as critical strategic components towards successful SPD initiatives. The perceptual measures from technological perspective expected to exhibit digital automation with integrated sensor systems as one of the most implemented technologies. The results obtained based on analysis gives an overall impression that increasing quality of industry 4.0 can be accomplished with proper integration of technologies and strategy. The integrated application of technological and strategic factor dimensions indicates that when products embed with advanced technology it increase intelligence and play strategic role. From lean initiatives the results indicate the possible dominance of design engineers to hide unwanted and irrelevant features and reduce environmental impact of product. Findings exhibit an overall impression that strategic/ intelligent product information is likely to be utilized as part of user-centered design process, where industrial designers can take advantage of smart product’s life cycle management. Overall the perception based findings show that advances in semantic and sensing technology can change approach of user interaction with products which eventually leads to product development success.

Contribution of the Study

In this study attempt has been made to analyze the perception of Indian organizations which are involved in product development in order to measure the impact of factor dimensions on SPD in terms of expected implementation benefits. Since the concept of smart product development from industry 4.0 in Indian context is in its stage of infancy and the scarcity of literature available in the said context clearly shows the prominence of the present study and its contribution. Results demonstrate the emergence of two constructs (technological and strategic) which are positively associated to expected benefits in terms of SPD success. The main contribution of this paper is identification of emerging constructs (herein referred to as factor dimensions) of SPD and how these factor dimensions are seen in emerging economy context like India, since most of the studies have been done from developed nations perspective. In this regard the present study showed how technological and strategic factor dimensions are associated with projected benefits of SPD. The designated approach using quantitative model for industries 4.0 gives industries the opportunity to learn regarding solutions from techno-strategic aspect which may be deemed to be a novel contribution from Indian context since Industry 4.0 is still in concept development phase.

Conclusions

In this paper the current industrial development on smart products from industry 4.0 in Indian context has been represented. The attributes and factor dimensions influencing SPD gives a preliminary overview regarding developmental process based approach for smart products. SPD from industry 4.0 perspective in Indian context being relatively new thus there is always a possibility of high degree of uncertainty and technological know-how for real time implementation. Hence, present study would be beneficial for its application based findings which could be taken up by the industries as partial guidelines to undertake implementation procedures from both technology and strategic perspectives.

Practical Implications

Results derived from this study can be beneficial to operations manager and industry policy makers to execute decisions at all levels from strategic, tactical and operational aspects. From operational perspective the results exhibit which attributes are critical for successful implementation of SPD. Considering the present industrial scenario the results would provide partial guidelines to the industries who wish to adopt the strategy of industry 4.0 and think which attributes should be considered. Accordingly based on competitive priorities industries can develop and design their implementation strategies. On other hand industrial policy makers can use the findings of this study to initiate policy level decisions as to what technology and strategic dimensions need to be considered during developmental phases of smart products in order to achieve competitive advantage. For example technological attributes like TI, SI and CE could be strong trending patterns followed by strategic attributes like lean systems and sustainability. Results and findings derived from this study can be beneficial to operations manager and decision makers to design their implementation strategies.

Limitations and Future Scope

In this study five critical attributes of SPD have been considered and there is a scope to explore more number of attributes from industry 4.0 perspective. From statistical perspective the study has some limitations since we considered perceptual measures based on respondent's opinion from industry 4.0 context, thus there may be possibility of respondent's bias. Secondly, there is a scope to increase number of respondents to generalise the findings. Future research can incorporate multiple variables and attributes along with control variables for advanced statistical learning. Furthermore, advanced prediction modelling could be initiated in future to investigate the role of contextual variables. Researchers can even think of bringing design management aspects into the entire process flow methodology to make smart products highly flexible and quality oriented.

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Digital Machines, Space, Time: a Sociomateriality Exploration in Motorsport Manufacturing

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Abstract

The diffusion of digital additive technologies has enhanced manufacturing flexibility but also opened questions on how such technologies could affect practices in the production space. Addressing these timely questions, we adopt a sociomateriality perspective and comparatively explore how different digital manufacturing machines—characterized by increasing degrees of manufacturing—affect the use of space and time. We qualitatively observe and compare 45 digital manufacturing machines sampled across 4 types and 14 companies in two countries (UK and Italy) within the motorsport industry. A model emerges where the imbrication between machine time and space mediates the relationship between machine flexibility and performance.

Keywords: Digital Manufacturing; Sociomateriality; Flexible manufacturing.

Introduction

The recent paradigmatic shifts towards digital manufacturing—represented by the disruptive diffusion of additive manufacturing machines (AM)—are dramatically changing business and innovation models, shrinking supply chains, and altering the global economy (d'Aveni, 2015; Holmström et al., 2017; Khorram Niaki and Nonino, 2017), thus representing a pivotal phenomenon within the so-called "Third Industrial Revolution" (Anderson, 2012; Rifkin, 2008).

Research in operations management has been thoroughly investigating the evolution and innovation of manufacturing technologies (Holmström and Romme, 2012; Jiang et al., 2017; Mellor et al., 2014; Reeves et al., 2011; Wagner and Walton, 2016). Extensive research on flexible manufacturing systems and advanced manufacturing technologies has shed light on several compelling effects, especially in terms of influence on organizational, operational, and economic performance, as well as their overall linkage

to operations strategy (Cagliano and Spina, 2000; Swink and Nair, 2007). In this vein, the adoption of new digital technologies in manufacturing—which are able to provide additional degrees of manufacturing (Eyers et al., 2018)—is currently attracting increasing scholarly attention, thus creating a sort of "hype" regarding its potential advantages. However, both in the literature and in the practice, it is still unclear what are the rising complexities and potential pitfalls associated with the implementation of such technologies. For instance, new technologies are often wrongly considered as "plug-and-play", while executives and managers tend to underplay the complexity of additional factors influencing their effective implementation—see among others Adidas' efforts to scale-up its 3D-printed soles to mass production (Tepper, 2017).

Despite scholars are developing novel frameworks to understand and implement digital technologies in manufacturing (see for instance Mellor et al., 2014), when investigating the concept of manufacturing in the production floor, the operations management literature has mainly adopted an "Euclidean perspective": a positivist approach where time and space are conceptualized as finite, tangible, and objectively measurable resources. This specific view has overlooked the more subjective and relational aspects of human agency, as well as the critical interaction between humans and machines/technologies, which are more often than not influencing business performance (Leonardi and Barley, 2008). The relation between human and material agencies within organizations and across organizational boundaries has recently been gaining increasing attention (Balogun et al., 2014; Carlile et al., 2013), especially in management and information systems literature (Boudreau and Robey, 2005; Cecez-Kecmanovic et al., 2014; Leonardi, 2012; Orlikowski, 2000, 2005). Recently, the interdependence between individuals and technologies—which shape each other's development, affecting organizational social space, and actions over time (Leonardi, 2013; Pentland and Rueter, 1994)—has been overall defined as imbrication. From this perspective, technologies and human agents become mutually intertwined, embedded (Barad, 2003; Leonardi, 2012), thus mutually influencing and jointly enabling the development of organizational practices (Leonardi and Bailey, 2008). The constitutive imbrication of technologies on individuals' actions gives the resulting practice a social character, which has been analyzed using the so-called "sociomaterial perspective", or in short "sociomateriality" (Leonardi, 2012; Suchman, 2007). To date, and despite the pivotal importance of human and material agency in their conversation, operation management and innovation management scholars have seldom considered sociomateriality and its paramount implications. This would be particularly compelling when considering the evolution of manufacturing technologies and introduction of new digital technologies (such as AM) within the innovation process—see for example the consideration on the importance of adopting a "socio-cognitive sensemaking" in Nambisan et al. (2017: 228). The operations management literature has investigated the relationship linking technology adoption with manufacturing, in turn influencing firm performance; however, it has massively overlooked the role played by the "imbrication" between the agency of the machine and the human operators, which involves key dimensions such as space and time.

We believe the adoption of this new scholarly perspective would help understand why organizations that are currently implementing new, high-potential, flexible technologies are still facing challenges in effectively integrating these technologies and in turn failing to obtain superior business performance and a sustainable competitive advantage. In our study we purposefully aim to develop a first attempt at opening the "black box" of innovation relative to the relation between varying levels of manufacturing of (digital) manufacturing machines and the "subjective" dimensions of human agency related to

time and space in the production floor. Hence, we address the following question: *"How do flexible (digital) manufacturing machines influence organizational manufacturing practices in terms of space and time?"*. We respond by extensively collecting and analyzing qualitative data from the British and Italian motorsport industry, an innovation-driven empirical setting where firms have extensively adopted a broad range of (digital) manufacturing technologies—including AM.

With this study, and in line with the sociomateriality perspective, we extend the boundary conditions of the sociomaterial perspective from IT technologies to flexible machineries and investigate how those also affect the space and time within organizations, and ultimately performance. In addition, we show how different degrees of technological flexibility enable their adaptation in different spatial contexts and through time, shaping the development and evolution of different organizational practices. Ultimately, we advance an overarching model connecting technological adoption of digital machines to manufacturing, imbrication, and firm performance. In this model, great exposure and reflection is given to digital transformation as enabler of flexibility and moderator of the relationship between flexibility and imbrication.

Theoretical background

Manufacturing flexibility and the dimensions of space and time

Manufacturing flexibility has been considered as one of the major competitive levers for manufacturing firms operating in increasingly uncertain environments and turbulent markets (Gerwin, 1993; Sethi and Sethi, 1990; Slack, 1983; Upton, 1994). Such flexibility allows to rapidly change production outputs, to develop new products more quickly and more frequently, as well as to respond more rapidly to competitive threats (De Toni and Tonchia, 1998; Oke, 2005). In their literature review Jain et al. (2013) underline its complex and multi-dimensional nature: on the one hand, manufacturing flexibility represents a general ability to adapt/change, while on the other hand, the proactive adoption of flexible solutions can support the organization in gaining competitive edge, by raising customer expectations and putting competitors under pressure. Therefore, the role of flexibility of production systems has heavily attracted operations and innovation scholars' attention throughout the last 30 years (Browne et al., 1984; Buzacott and Yao, 1986; Cagliano and Spina, 2000; MacDuffie, 1995; Myint and Tabucanon, 1994; Slack, 1987).

To date, research on the evolution of manufacturing technologies has mainly focused on flexible manufacturing systems and advanced manufacturing technologies (Kotha and Swamidass, 2000; Swink and Nair, 2007). Such literature has traditionally identified and analyzed compelling implications for supply chains (Slack, 1983), operation strategy (Gerwin, 1993; Upton, 1994)—such as opportunities for mass customization (Da Silveira et al., 2001)—and wider influence on performance at different levels (Gupta and Somers, 1996; Swamidass and Newell, 1987)—i.e., from operational to organizational. One key insight emerging from the literature is that it is impossible to obtain disruptive results from the stand-alone adoption of flexible technologies, without the support of design-manufacturing integration (Swink and Nair, 2007), and the appropriate combination of "soft" elements and strategic orientation (Cagliano and Spina, 2000; Nambisan et al., 2017). This is paired with the relatively scant understanding on the relationship between manufacturing flexibility and another key competitive criterion: innovation (Bolwijn and Kumpe, 1990; Oke, 2013). In fact, due to its possible limitations and pitfalls on organizational performances, it has been argued that companies pursuing manufacturing flexibility should develop the specific innovation capabilities that enable them to enjoy a significant improvement in organizational performance (Camisón and Villar López,

2010). Yet, it is still not clear yet what are the microfoundations (i.e., interactions, routines, co-creation opportunities) which favor the emergence of such key capabilities.

Furthermore, and perhaps more importantly, when considering a specific manufacturing configuration (e.g., the adoption of a series of new production machines), the literature has underlined the importance to understand the right context of application and its related flexibility features. The classic "product-process" matrix developed by Hayes and Wheelwright (1979, 1984) provides useful guidelines to position different technologies along several degrees of flexibility, ranging from production lines (characterized by a standardized structure with high volume, low variety, and high rigidity), cellular-based manufacturing (where flexible systems play a key role), to job shops and individual projects (featuring higher adaptability and opportunities for customization, but limited efficiency). Recent reviews on manufacturing flexibility (Jain et al., 2013; Mishra et al., 2014), underline a common orientation in the field towards a positivist, number-driven, engineering-oriented approach (i.e., often supported with granular quantitative analyses and measurement) to identify critical holdups and suggest changes for sizeable process optimizations. Taking this approach, scholars investigating manufacturing have mainly focused on "space" and "time" dimensions by adopting a Euclidean perspective (i.e., where time and space are conceptualized as finite, tangible, measurable, objective resources), and have treated them as mere operational factors that characterize a manufacturing/service process and its performance implications.

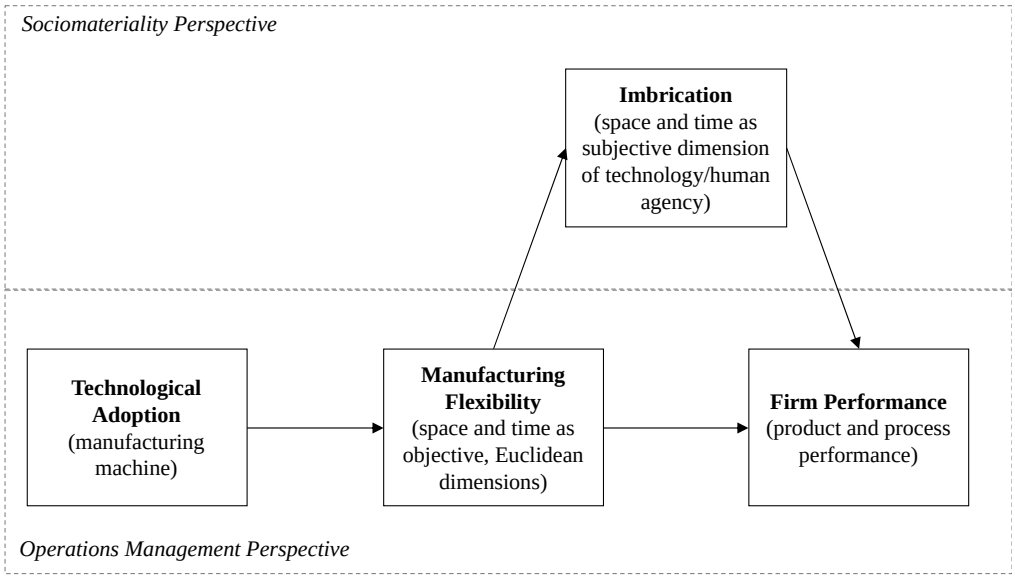

Figure 1 – Conceptual model emerging from the literature review

However, we argue that the traditional quantitative approach has so far foregone the opportunity to develop a more complete understanding of how manufacturing tools and machines can influence the use and cognitive understanding that agents hold of time in a more subjective, intangible, and nuanced fashion. In fact, "softer" dimensions are hardly considered in the main frameworks available in the literature (Jain et al., 2013; Mishra et al., 2014).

This has affected our understanding in two inter-linked ways. First, instead of passive tools and assets, manufacturing technologies (particularly the digital ones) can play an "active" role and influence space, time, and human interactions (Nambisan et al., 2017). Second, routines—intended as repetitive patterns of interdependent organizational

processes or actions that utilize resources to achieve outcomes (Pagell et al., 2015; Parmigiani and Howard-Grenville, 2011)—have been merely considered in terms of performance implications, rather than a substantiation of human-machine interaction, due to the lack in the operations management literature, of a behavioral and socio-cognitive understanding of individual actions. In the case of manufacturing flexibility, scholars have long searched a deeper understanding of how machines influence the creation of new routines in the shop floor, not only considering in their flexibility as an operational feature, but also as a socio-cognitive quality connected to the human-machine interaction (Feldman and Pentland, 2003; Howard-Grenville, 2005; Patel, 2011). Responding to a recent call by Pagell et al. (2015) to follow researchers in other fields and begin to explore routines from a more "micro" (Felin et al., 2012; Teece, 2007) and behavioral (Gavetti, 2005; Gino and Pisano, 2008) perspective, the sociomateriality perspective has recently opened new avenues for investigating this influence and offers a lens to observe and comprehend the interactions between human agents, and machines.

Methodology

To answer this question, we collect and analyze qualitative data from the motorsport industry, a cutting-edge empirical setting where firms have traditionally experimented with a broad range of manufacturing technologies, and have an advanced experience, compared to other industries, in innovative machines such as AM. Our study adopts a qualitative methodology (Gioia et al., 2013) that is well suited for our study's exploratory scope and fully consistent with the sociomateriality perspective. We qualitatively analyze and compare 45 digital manufacturing machines sampled across 4 types and 14 companies in the iconic motorsport industry in two countries (UK and Italy), by conducting semi-structured interviews with relevant actors in each company. Reliability of data has been assured through triangulation and use of additional archival materials.

Findings

Space-machine imbrication

Despite traditional manufacturing and innovation literature often considers machines as passive set of tools or—more in general—assets that human agents leverage and manipulate for their goal, the collected evidence suggests instead that all manufacturing machines play an active role in shaping the operational space where innovation and manufacturing takes place. Our first order-constructs point to a reshaping of the interactive space around the machine. For the observed projects, we noticed that when a new machine entered the production space, the adoption was associated with the (re)design of a specific layout of operational space where human agents were involved to optimize routines and collective procedures. This interactive space represented not only an intangible discourse between human agents, but often translated—particularly for more flexible machines such as AM—into an opportunity for setting up dedicated areas, such as R&D labs, customer trial rooms, and other spaces for idea generations via multiple actors' interacting with the machine). The use of space revolved around the work of the technological equipment that—when possible; the experimentation with the machine was aimed at gathering new knowledge via processes of search, trials-and-errors. In such instances, it was common to even see either some of the design activities to be moved to the production floor where the experimenting machines were located or—when size of the machine allowed—the positioning of a flexible, digital machine to be placed in the offices dedicated to design.

Evidence showed that custom-made product-specific machines were clearly less associated with these types of initiatives. Interviewees suggested that this was due to the manufacturing rigidity of such machines (e.g., lines for specific products).

Instead, flexible machines tended to play a more dynamic role in shaping the virtual and physical space around them, thus creating opportunities for interaction, knowledge exchange, and experimentation. This was systematically associated to the co-presence of partners and customers within the interaction space, thus making the production plant where the machine operated a connection point between the production facilities of multiple stakeholders involved in the co-development project. As CNC machines and AM offered a broad and not fully understood range of possibilities, companies that used such technologies enjoyed the opportunity to upgrade the understanding of their functioning, and thus enlarged their types of manufacturing applications. Among other less notable aspects, the space was specifically designed (or modified) to facilitate the access and exit of customers and partners, in order to maintain a good level of discretion about their involvement, particularly towards other customers and partners which could be competitors. By showing careful attention to such space design, the focal company aimed at obtaining a high level of trust from each partner.

Evidence suggests that machine adoption also corresponds to a shift in the innovation practices performed around the machine space. In advancing this observation it is necessary to include two additional reflections. First, the increasing level of flexibility (usually associated with more digitized machines) corresponded to more significant changes in such practices—this, however, might be related to the fact that newer tools embedded possibilities and features that by definition disrupted those formerly established by the adoption older machines. Second, and perhaps more importantly, the emergence of new practices was associated with a different perception of space, where the spatial areas bent to incoming needs of flexibility to embrace more fluid and unstructured experimentation activities. Our observations started with affirming that a space of active experimentation called for the needs of partners being present in the same area to conduct their co-development activities. Simultaneous presence transformed the space in co-working spaces, with desks and/or working tables that were used for meetings and experimentation between workers and with business partners. In such areas it was often possible to retrieve artefacts of such practices and interactions: sketches, blueprints, guideline documents, and instructions. Such material artefacts had both a functional utility insofar they indicated ways of utilizing the machine to more unaware users. Yet, they also demonstrated, with their visible and tangible presence, the amount of reasoning and thinking that had been going into the engagement with the machine. Another key element that was common to find in the proximity of the machine was advanced manufacturing samples. These were usually purposefully left to impress possible visitors or (perhaps narcissistically) showcase the potential of the machine. Such elements, however, had also a more profound function. As increasing level of manufacturing allowed potentially an infinite number of applications and operations, such artefacts were used to demonstrate through material evidence the firm's creative capability and its skills in exploiting and exploring the machine potential.

AM machines were in most cases placed at the center of the room, or in a highly visible position where it is impossible not to notice them once inside the space—they represented a sort of "totem" within the manufacturing space, an object which was regarded with a sort of admiration, respect, and curiosity (probably due to their untapped potential). Such machines could be observed from all sides, by simply walking around them. Visiting the machine with new partners often followed patterned rituals, where the problem-solving value of the machine was described by using a specific narrative of time.

Time-machine imbrication

Beside space, time-machine imbrication emerged as another prominent element from our observation. Within this domain, time was conceived not only—in a more objective and positivist form—as a measurable and systematic repartition of human activities, but also as a subjective, cognitive construct which resided in the human agents' mind, took different forms, lead to different understandings, and consequently affected the practices on the shop floor in different ways.

We identified a set of ways in which time (e.g., sequencing, length) was reshaped within practices involving the machine. To gather a more precise understanding of the machine usage, we asked our informants a series of question aimed at understanding (1) how many hours of work actors dedicated to the design and first set-up of the new machine; and (2) how many hours they spent to understand its functioning and exploring its possibilities before considering the machine as fully integrated in the manufacturing processes.

This distinction was critical to identify whether the imbrication was concentrated in the planning or in the execution of the manufacturing process, or both. In addition, as imbrication with these machines might involve human agents from different organizations, inquiring into such aspects also provided insights about the temporal evolution of the relations between the human agents and the machine. Specifically, we asked our interviewees to quantify the hours spent in interaction with other members of the organization, or other partners such as the equipment suppliers or the customers. We collected values for each machine and averaged them across machine types. Then we asked executives and operators to provide narratives of such phases. Our data collection highlighted that the intensity of human interaction with the machine was strongly influenced by the machine's degree of manufacturing. Throughout all our observations interviewees consistently affirmed that for machine that were intrinsically more flexible, human intervention was higher in the phases that did not strictly follow defined procedures or routines.

As custom-made, product-specific machines and machines for standard 'off-the-shelf' products did not offer any major opportunity for significant variation within the manufacturing process—unless the machine underwent a structural re-engineering—they required instead an intense human intervention while designing the machine itself, as the equipment came with a high level of customization.

Instead, evidence pointed to a quite different scenario for the application of more flexible machines (i.e., milling machines and 3D printers), as this latter equipment came in rather standard models, but provided higher space for flexible applications. Hence, while the design phase was relatively standardized, and left little space to customization, once the machine was set up the possibilities of experimentation benefitted from an experienced and continuous interaction with the machine.

All in all, we notice how the different levels of machinery flexibility corresponded to different timings in the interaction process with the equipment. While customized, task-specific machines (i.e., machines for standard, 'off-the-shelf' products and custom-made, product-specific machines) led to more intense interaction in the machine design and set-up phase, standard flexible machines (i.e., CNC milling machines and AM machines) required a more intense interaction later-on in the testing and operational phase. Practices enabled by highly flexible machines were often described as more "fragile" and prone to hold-ups. Hence, and despite such devices allowed a certain level of automation, human agents felt compelled in monitoring more often their activity.

The overall refocusing on the experimentation phase created a relevant shift in the timing of the innovation development, as the machine constraints and utilization paced

the project timing and deadlines. However, as such machines were used as collaborative devices in multi-partner experimentation, the alignment of the partners was also constrained by the timing of the machine. In other words, the firm that deployed the machine ended up indirectly influencing the timing of the third parties involved.

Ultimately, the time-machine imbrication carried significant implications on a more subjective and cognitive level. The adoption of more flexible and technologically sophisticated machine corresponded to the adoption of new narratives of time within the organization. Concepts like "speed," "responsiveness," "reaction time," became part of the core value proposition that the companies' embraced, particularly when proposing their services or potential collaborations to third parties. This is overall not surprising, as technological adoptions are often justified with aspirational upgrades in efficiency and effectiveness, particularly in innovation-focused domains. However, in our cases such types of narratives held substantial implications in the way time was envisioned and activities were scheduled. Despite (as we reported) more flexible machines entailed the systematic extension of the experimentation phase (due to extensive set-up time, integration or multiple actors, and exploration of diverse operational possibilities), this narrative of time and "speed" was associated with an average reduction of estimated experimentation time in a range between -10% and -20%. This means, for example, that a new design project that formerly was expected to last around 10 weeks with prior machines and technology before was now expected to take between 8 and 9 weeks. Still, such estimates often fell short to deliver on the original planning. This was not necessarily a negative thing in terms of quality of the output, as products developed with superior manufacturing flexibility did embed an added value in terms of innovation and performance, but timing remained an unfulfilled promise in the relation with third parties. Yet, the partners' direct involvement in the collaborative project allowed them to better appreciate the nuances of the process and the superior returns that an extended experimentation entailed, and thus reasonable delays were seldom considered an issue, and they hardly terminated the partnership in future instances.

Furthermore, and perhaps more interestingly, particularly with AM machines the design and engineering of a component became a key element of each project. More recently, with the advent of hard-materials in AM (e.g., through metal, graphene powders) the companies were able to manufacture more and more "functional prototypes," These are components which, despite their prototypical nature can be deployed (within certain limits) in finished products such as race cars, rather than just being used for mock-ups and wind-tunnel models. The diffusion of functional prototypes blurred the boundaries between experimentation and production phases, and actors involved in the process struggled to more objectively divide the two. This reconceptualization of time and project sequencing made former project development and current ones less comparable, thus contributing to interpreting the adoption of new machines as a paradigmatic shift in the manufacturing operations.

Discussion of findings

Moving from the original empirical model, we advanced in our theory section, Figure 2 provides an elaboration of how our empirical investigation unpacks the role of imbrication in the relation between manufacturing and firm performance (in our case considered as product and process performance, given the nature of our inquiry). While the literature gives extensive explanation of the relation between manufacturing and performance (Grawe et al., 2011; Youndt et al., 1996), as well as sociomateriality and performance (see Orlikowski and Scott, 2008b for a review), little is known on the

imbrication between digital manufacturing machines (i.e. flexible machines) and social practices.

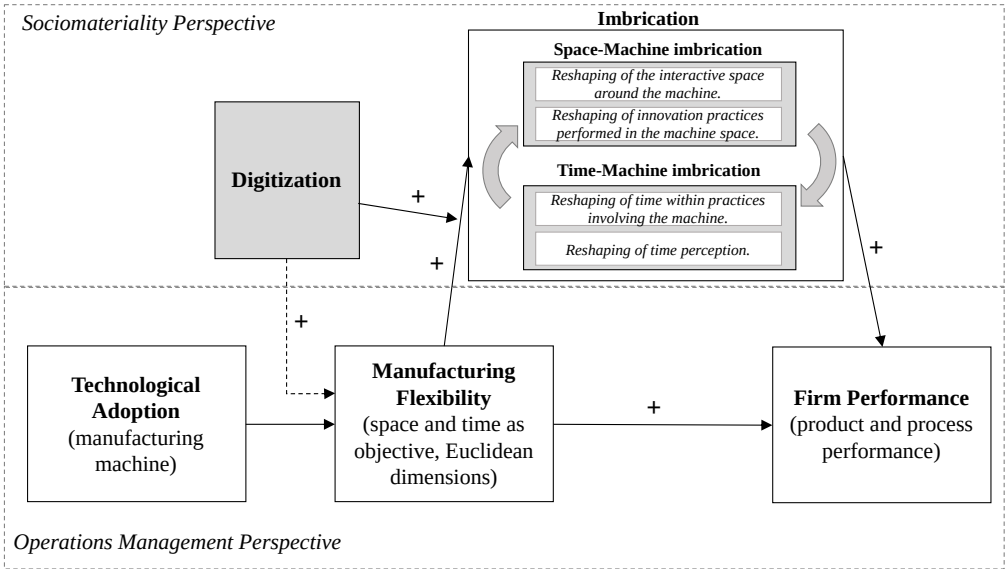

Figure 2 – Final model based on empirical evidence

In our model the concept of imbrication, which is traditionally ascribed to sociomateriality (Leonardi, 2012), acts as a mediation between manufacturing flexibility and firm performance, thus leading to a mediation model. The level of manufacturing flexibility increases the level of imbrication across multiple dimensions, such as space and time. In terms of space, we showed how more flexible machines trigger a reshaping of the interactive space around said machines, as for example, the undertaking of a more radical change in the layout of a shop-floor, the inclusion of experimentation spaces, or the creation of show-rooms dedicated to the creation and display of related artefacts (notes, instructions, advanced samples). At the same time, more flexible machines re-shape innovation practices in the machine space by calling for a co-present involvement of multiple actors, and a new set of interactions and routines in relation to the machine itself. Increasingly, manufacturing flexibility has also an effect on innovate practices over time. Not only the time of the practices involving the machine undergo a significant reshaping (e.g., superior experimentation and monitoring; all partners align to the time constraints of the machine), but also there are significant cognitive implications. Specifically, a new narrative of "speed" and "responsiveness" is embraced by all the actors that utilize more flexible, and ultimately more efficient and better performing, machines. although the systematic underestimation of the temporal variable by previous studies, the positive effects of the adoption of flexible machines and the development of dynamic social practices can be seen in the increasing average quality of the product/process, thanks to iterative activities with third parties, but it can also be undermined by the necessary increasing experimentation phase in the producing process.

This brings systematic underestimation of the development time, but at the same time by involving the third parties in extensive experimentation phases, the average quality of the product/process increases insofar partners see possible delays as necessary costs to achieve superior outcomes. Ultimately, this strengthens (rather than foregoes) partnerships. Further, functional prototypes make it harder to distinguish experimentation from production (thus requiring a new way to reconsider project time and compare them

to older ones). Still, the possibility to apply components born in prototyping processes to final products reduces the complexity of the production process by eliminating the intermedia production phase that create final parts from prototyped ones, thus ultimately enhancing product and process performances altogether.

The digital component plays, by any mean, a key role in our model. As a first premise, it is important to acknowledge that the great majority of modern manufacturing machines (no matter how operationally flexible) embed a digital component, such as data transmission systems for digital commands through project specs. Arguably, the digital technology can be, thus, considered endogenous to (and embedded in) the technological adoption, and one of the very enablers of manufacturing (see dotted arrow in Figure 2). This said, it is also important to notice that the level of digitization can also present significant variations across firms, and it might depend on the firms' engagement with the digital technologies—e.g., the level of digitization of each machine (different machines can have a more or less prominent digital component) and, perhaps more importantly, the level of digital transformation that each firm has embraced in its productive process and complementary/supporting technologies. In these regards the digital component play a pivotal role to positively moderate (and thus enhance) the relation between manufacturing and imbrication.

Digital solutions are based on strings of data which are—by definition—mode loosely coupled and modular than physical artefacts (Baldwin and Clark, 2000; Ulrich, 1994). Digital interface can be more easily aligned common standards and it is therefore easier and more efficient to recombine the layout of a manufacturing space, if the different machines can be easily connected to common data protocols. Digital solutions allow superior level of process flexibility, thus becoming an enabler of time reshaping across projects. In addition, Digital solutions, despite powerful and influential, are naturally intangible and immaterial. This intangible nature makes them more apt to be imbricated—and it is not by chance that such phenomenon was first of all observed in the domain of information systems, where the digital (often online) component is largely predominant (Leonardi and Barley, 2008).

Finally, digital component of manufacturing machines is an enabler of manufacturing and at the same time a moderator of the relation between such flexibility and opportunities for imbrication. Jointly, despite the role of manufacturing flexibility as a key aspect to enhance firm performance in terms of product and process innovation is beyond the scope of our study, we believe that scholars and practitioners should also consider the mediation effect of imbrication across time and space in the domain of innovation and manufacturing in affecting said relation.

Conclusions

Our study attempts to adopt sociomaterality in operations management and innovation management studies. This endeavour complements the traditional Euclidean aspects of manufacturing (offered by different types of manufacturing technologies) with the novel sociomaterial dimensions of imbrication of space and time—two facets of process and product innovations which carry relevant implications for firm performance. In addition, our research contributes to the broader conversation on sociomateriality by providing insights on dynamics happening in the (more) physical context of manufacturing, where current technological disruption is underpinning non-trivial dynamics between digital and manufacturing innovations.

References are available upon request

Digital transformation in apparel SMEs: Brazilian multiple case study.

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Abstract

The main objective of this article is to evaluate the motivational factors that induce and those that block the adoption, use and appropriation of digitalization in Brazilian apparel SMEs. It is considered of interest to focus the study on the technologies of the so-called "Industry 4.0". The methodological approach is based on a multiple case study. In this sense, 5 Brazilian apparel SMEs were selected and a semi-structured questionnaire was applied. In general, it can be said these are still in the early stages of the digital transformation process.

Key words: Digital transformations, Brazilian apparel SMEs.

Introduction

The technologies that were previously considered novels, such as computers, internet, mobile devices, and even social networks, now they could be considered mature technologies, that is to say, they have already established themselves and become essential in the vast majority of the companies. It is considered of interest to focus the study on the technologies of the so-called "Industry 4.0", such as artificial intelligence, cloud computing, big data analytics, production internet, among others. A characteristic of these new technologies is that they have found a place in the entire value chain of the enterprise and, by generating disruptions, open the way to the incorporation of new products, services and business models.

Based on extensive interviews and analysis Berman & Marshall (2014) try to explain how the next digital transformation will result in a paradigm shift from one that is customer-centricity to an everyone-to-everyone (E2E) economy. For these authors "E2E is characterized by hyper-connectedness and collaboration of consumers and organizations across the gamut of value chain activities: co-design, co-creation, co-production, co-marketing, co-distribution and co-funding". They conclud that the next

future, all organizations that will survive in their marketplace will operate in ecosystems of converging products, services and industries.

The main objective of this article is to evaluate the main motivational factors that induce and those that block the adoption, use and appropriation of digitalization in SMEs.

Some of these new technologies are presented next: Computer-aided manufacturing projects CAD/CAM; Integrated engineering systems for product development and product manufacturing; Digital automation without sensors; Digital automation with process control sensors; Digital automation with sensors for product and operating conditions identification, flexible lines; Remote monitoring and control of production through systems such as MES and SCADA; Simulations/analysis of virtual models (Finite Element, Computational Fluid Dynamic, etc.) for design and commissioning; Collection, processing and analysis of large quantities of data (big data); Incorporation of digital services into products ("Internet of Things" or Product Service Systems); Additive manufacturing, rapid prototyping or 3D printing; Use of cloud services associated with the product.

Among the obstacles that companies face when adopting or using new technologies, it is possible to verify the internal obstacles, such as lack of knowledge or interest, lack of financing and lack of qualified human resources; within the external obstacles, it is noticeable the lack of infrastructure or of suppliers of technological products and services, little mature technology, and an insufficient training system. Also, when measuring the levels of adoption, the use and appropriation of the benefits of new technologies, technological convergence (such as digitization of most areas of a company) add a degree of complexity to this analysis.

The adoption of these emerging technologies in Latin America, and particularly in SMEs, is low. Given this scenario, a study is proposed about the process and the motivations of those that have adopted these new mechanics.

To this end, a survey will be carried out for a total of 20/30 Argentine companies. This survey will be semi-structured interviews with open and closed questions, and the companies will have to focus on a set of new technologies that will be previous decided. The definition of the sample will be non-probabilistic, because SMEs will be selected from which they will know a priori that they have already incorporated, are in process, or are in a position to incorporate some of the new digital technologies. It is estimated that companies in the manufacturing sector are the most likely to meet the required conditions. Likewise, knowing that all new digital technologies have the potential to affect all the links of the company's value chain, it is proposed to focus on the following areas: innovation and product design, production, logistics of entry and relationship with suppliers, marketing and relationship with customers.

The present project will be carried out simultaneously among different Latin American countries, in order to later elaborate a comparative study among them. The final objective of the work is the generation of policy proposals for the incorporation of digital technologies in SMEs.

Small and medium-sized companies in the Brazilin textile / clothing (T&C) chain

Small and medium-sized enterprises represent 99% of establishments in Brazil (6.4 million), which account for 52% of formal jobs (SEBRAE, 2017).

The textile industry can be divided into three main segments: production of chemical fibers, production of basic textiles (yarns, fabrics and knitwear) and production of ready-made articles (clothing, home and technical-industrial articles), it is included in the industrial stages of the sector the production of natural fibers, which are of agricultural or agricultural origin (IEMI, 2017).

The textile and clothing industry is particularly important in Brazil because of its breadth, relevance of the value of production and its ability to generate jobs. There are 33 thousand companies that together totaled R$ 120 billion in 2016, equivalent to approximately 5% of the manufacturing industry and they also generated 1.62 million jobs, corresponding to 10.6% of the total industrial and the generation of US$ 473 million in wages. That is to say, it is a sector with a strong social impact (IEMI, 2017).

In addition to that, concerning the textile and clothing industry, they are the 2nd largest employer in the manufacturing industry; 2nd largest generator of the first job; 4th largest manufacturing park in the world; 5th largest textile producer in the world; 2nd largest producer and third largest consumer of denim in the world; the fashion week, which is considered one of the five largest in the world, is proving how decisive the sector is for the Brazilian economy and is increasingly strengthening the competitiveness of this industry (IEMI, 2017).

The T&C chain in Brazil is pulverized; as the number of employees is measured, the number of personnel employed, the production volumes and revenues obtained, are increasing. However, by examining the average per company, as the final link is taken, the indicators of generated jobs, volumes produced and revenues obtained per company fall, which, according to the IEMI (2017), shows the reduction in the average producing companies with respect to yarn and fabric producers.

It is possible to visualize the structure of the textile and clothing chain in Brazil. In addition, some companies can present a vertical structure, having more than one link in the chain, such as weavings that have finishing functions (dyeing, stamping or laundry) and confections that also have wholesale and retail stores.

Textile and / or apparel companies are present in all Brazilian states. In the Southeast region there are 49% of the personnel employed, followed by the South region with 29%, the Northeast region with 17%; Central West region 4% and the North region with only 1% (IEMI, 2017). Based on the analysis of occupations available in the RAIS (Annual Social Information Report) of the Ministry of Labor and Employment, it is indicated that between 1997 and 2005 there was an increase of approximately 12% in the total number of employees in the sector. Although there is an increase in the number of male employees, the workforce in the sector is female, of which 75% are financially responsible for the whole family (IEMI, 2017).

Methodology

The methodological approach is based on a multiple case study. According to Yin (1998), the main characteristic of this case study method lies in the fact of its being generalized to theoretical propositions, and not to populations and universes. The generalization to theoretical proposition is exactly the subject intended by this work, which makes of the case study the ideal instrument to attain the goal. In this sense, 5 (six) Brazilian apparel SMEs were selected, due to their outstanding importance in this industrial segment. A semi-structured questionnaire was elaborated and applied to the main executives of the industrial area of the companies.

Main questions

The main questions that are guiding this research are the following:

- What are the different projects, investments or contracted services related to new digital technologies?
- Is it possible to identify the most common technologies to the company that would fit the concept of new digital technologies and the main functions of the value chain of the company that are of interest for the impact of the new digital technologies?
- Has the company implemented any project or hired any service among the following new digital technologies?
- What are the main motivations to implement the project / investment or hire the technology service?
- What are the relevant elements on how the decision was made to invest or contract services in new digital technologies?
- How was the implementation process? What were the main problems or obstacles that should have been overcome?
- How were the projects funded? Did they use external funding sources? (Assess availability and ease of access to external sources of funding).
- What were the main benefits so far? Is your company evaluating or planning to implement any project or contract any service on any of the new digital technologies in the near future?
- How much has your company spent with resources to implement the new project or make use of the services that are contracted? What are the problems or obstacles you face?
- Is the company receiving or expecting to receive any kind of public or private support for the evaluation, design or implementation of the project / investment?

Our main hypotheses that support this research are the following:

- In general, SMEs are in the stage of adoption of some technologies regarding the third industrial revolution (computing, automation, consumer Internet, etc.);
- A low adoption or preparation for the deployment of the new technologies of Industry 4.0;

On the other hand, we can point out some implications of these hypotheses:

- Finish measuring what you already know
- Measure only opinions about industry 4.0;
- Increase complexity if it is necessary to evaluate the automation and use of digital (traditional) technologies across all areas of the company.

Barriers / Obstacles to the adoption and use of new technology:

Internal to the company:

- Lack of knowledge;
- Lack of interest;
- Lack of funding;
- Lack of qualified HR;

External to the company:

- Lack of infrastructure;
- Little mature technology;
- Small number of Technological products and services suppliers;
- Insufficient training system;

Case study

Company A

Company A is a medium-sized company (with 178 employees and annual revenues of US $ 2 millions , producing lingerie items (bras and panties).

From the point of view of new digital technologies, the company stands out because it has already made significant investments in the purchase of sensors and applications to monitor the notes in real time, directly from the smartphone, aiming at greater production efficiency, production predictability and operations history in the factory floor. Such investments include consulting services (*Senai Cetiqt*) software and hardware. Also in the sphere of product design the company hired a supplier specialized in 3D tool that streamlines the process of creation and design.

The main motivations that led company A to invest in these,, new technologies are basically summarized as follows: 1.) Search for improvements in the efficiency of a function or process; 2. Cost savings; 3. Facilitating the development of new products.

Regarding the main barriers, the company stands out: 1.) Difficulties of the operators in the use of these new technologies. For example, many seamstresses had the treadmill, even without sewing equipment (need for training in these technologies and breakdowns with "cultural barriers" in the company); 2. Problems in communication infrastructure (WIFI).

Company B

Company B can be considered a small company (52 employees and revenues, under US $ 2 millions , / year) that operates in the segment of knitting and printing.

In terms of new digital technologies the company has already invested in an application to program and select prints of the fabrics and devices to implement the digital stamping operation. In addition, he had already invested in digital marketing (e-commerce).
As to the reasons for such investments, the company stated that the main reason was the pursuit of higher productivity (higher costs and better production processes) in its factory operations. In addition, the companies also sought to improve the relationship and minimize customer response time ("being able to serve customers 24 hours a day").

The main problems faced are the difficulty of adjusting the calibration of the robot in the factory operation to obtain better results in comparison to the manual activities.
In terms of new investments in the near future Company B is evaluating the possibility of investing in "virtual and augmented reality".

Company C

Company C is medium-sized (122 employees and revenues of about US $ 3,800 thousand / year) and produces lingerie articles (panties and bras). Regarding the incorporation of digital technology, the company invested basically in the following freights: 1.) Digital marketing with actions of e-commerce; 2.) Integrated management software and ("*ERP Sistextl*") electronic data exchange (EDI); 3.) Software for automation in the cutting operation.

The main digital transformation projects currently being conducted by the company are as follows:
1.) Cloud Computing (“Sistextil” application); 2.) Printing 3D. (this is in negotiation with software supplier yet) .

Regarding the main factors that motivated the company to adopt such innovations, the following stand out: 1.) Speed in customer service; 2.) Scale gains in production;
3.) Monitoring market trends for (increased use of the Internet and social media). According to its leaders "the company must be prepared for these changes ...".

On the other hand, the following difficulties were identified for the adoption of other innovations of digital transformation: 1.) Infrastructure of information and communication weak or insufficient. 2.) Suppliers of technological products or services missing.

Company D

Company D is a company that produces articles of feminine, masculine fashion and accessories for clothes. It is a medium-sized company with gross annual sales of US $ 10 millions , employing 76 people. As for the recent investments in innovations, we highlight the implementation of a Customer Relationship Management (CRM) system.

Regarding the motivations that led the company to invest in the new technologies stand out the search for greater agility in its operations and reduction of expenses in the allocation of the logistics warehouse. In this sense, the company achieved a significant efficiency gain reflected in the reduction of the warehouse's operating cycle from 8 to 5 days.

On the other hand talking about the difficulties or main obstacles to the implementation of these new technologies, the company highlights the lack of greater knowledge of the technology itself, besides the lack of qualified human resources for its implementation.

Company E

Company E is a large company with 500 employees and gross sales in the order of US $ 53 millions / Year. It operates in the textile segment - Knitwear (Dyeing and Dyeing) and its main product are fabric rolls.

The company's main investment in the digital transformation process is a Company Loom Monitoring System. The main motivation for this investment was to monitor the efficiency of the Company's production machinery (looms). In addition, the company also stated that other factors were important in deciding this investment: 1.) Improve the efficiency of a productive function or process and 2.) Improve the relationship with the customer.

On the other hand, regarding the factors that made the implementation of technology difficult, it is important to mention the weak and insufficient information and communication infrastructure.

Some Conclusive Remarks

The digital transformation in emerging economies as the Brazilian one is not so easy, nor is it a rapid process. Specially talking about Brazilian apparel SMEs this phenomenon must be considered in a medium/long term perspective.

The requirements to develop a digital transformation in this case depend on how well the barriers regarding enterprise culture, legal policies, technological infrastructure and information technologies are jointly tackled among government, scholars and companies.

In fact SMEs can leverage their business significantly if they invest in the new technologies required by the digital transformation process. The gains relate both to increasing operational efficiency and to expanding its markets.

It is known that traditionally larger firms are at a higher level of competitiveness both on the domestic and international market. The clear differences in terms of the evaluation of competitiveness in favor of larger firms appears through the emphasis on determining factors such as production technology, the quality of the management staff, financial possibilities, effective marketing, research and development. Such discrepancies between large firms and SMEs suggest that there a great gap in

competitiveness as between the SME sector and large companies. One potential way of overcoming the lack of competitiveness of small and medium-sized enterprises is to create the conditions for SMEs to invest properly in new digital technologies.

In general, it can be said that SMEs in the textile / clothing sector in Brazil are still in the early stages of the digital transformation process. The innovations carried out by most of the SMEs analyzed in this study concentrate their investments in the relationship with the customer and in digital marketing. Some exceptions occur in companies that also invest in product design and design using the capabilities of new digital technologies.

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Teaching and Learning in Operations Management (incl. Cases, Games and Simulations)

Classroom Simulations for Customization: Teaching Production Control in Non-repetitive Contexts

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Abstract

When introducing production control solutions, most textbooks focus on a to-stock, repetitive context. In response, we extend the classical match and dice game, which focusses on a repetitive context, in order to teach complexities that emerge in a non-repetitive context, such as the emergence of direct and indirect load, and to introduce appropriate production control solutions (e.g. ConWIP and COBACABANA). A field test is used to prove the playability of our game and assess its teaching effectiveness using post-game scores and self-assessment. Both give support to our game and highlight that it helps specifically average students to understand complex knowledge.

Keywords: Match and Dice Game, Customization, Kanban

Introduction

The complexity of Operations Management (OM) does not rest upon individual operational issues themselves, rather it is a result of their interrelationship; and this inter-connectedness of phenomena must be manifest in the material that is taught to students of the discipline (Hill, 1987). For example, the success of production control methods is contingent on the environment to which they are applied (Jonsson & Mattsson, 2003; Sousa & Voss, 2008; Tenhiälä, 2011). Consequently, production control techniques, such as Kanban, should not be abstractly taught in themselves but grounded within the context from which they derive, since this determines their applicability (Hill, 1987; Thürer *et al*., 2016). A major contingency factor used in the production control literature is the position of the so-called Customer Order Decoupling Point (CODP; Hoekstra & Romme, 1992),

also referred to as the inventory/order separation point (Hopp & Spearman, 2001) or the order penetration point (Olhager, 2003). The CODP marks the border between to-stock and to-order production. It also marks the degree of customization that can be realized (Amaro *et al*., 1999; Stevenson *et al*., 2005) since highly customized orders are typically not repeated and thus cannot be kept in stock. Most textbooks teach some content on the CODP and the different production modes it creates. However, when production control solutions are introduced most textbooks remain in a to-stock, repetitive context. Yet production control techniques for this context, such as the use of Kanban containers for inventory control, cannot be directly applied to shops that produce a high variety of products, such as small and medium-sized make-to-order companies (e.g. Hines *et al*. 2004, Thürer *et al*., 2012, 2014a). While contingency factors are introduced, how to solve these contingencies is neglected.

For over 20 years, it has been accepted in the academic literature that if a Kanban system produces orders that are not interchangeable, then a card acquisition process takes place (Chang & Yih, 1994a,1994b; Bonvik *et al*. 1997) that makes it necessary to allow for more cards at downstream stations compared to upstream stations (Gstettner & Kuhn, 1996). But is this really taught to students? Surprisingly, while there exists a large body of theory and alternative solutions (see e.g. Thürer *et al*. (2016) for a review of alternative card-based control systems), there is no evidence that this is routinely taught to students. This means students remain ill-prepared for practice since a significant portion of firms in practice are actually small and medium sized make-to-order companies and since customization plays a significant role in firm success (Spring & Dalrymple, 2000).

We have found that most textbooks do not discuss complexities that arise if systems such as Kanban are used in non-repetitive contexts. One reason for this may be the complexity of the emerging phenomena itself. Appropriate methods to teach complex phenomena are simulation and experiential learning. While experiential learning allows students to make sense of real-world phenomena by reflecting on experience (Itin, 1999; Moon, 2013; Beard & Wilson, 2018) and transforming this experience (Kolb, 1984), simulation allows the teacher to act as a sense-giver (Weick, 1995) controlling the experience of the students.

While the largest group among OM games arguably focuses on production control in manufacturing (Lewis & Maylor, 2007), all of the simulations for teaching production control systems that we could identify assume a repetitive context (e.g. Cox III & Walker, 2004 and 2005; Ashenbaum, 2010; Lambrecht *et al*., 2012; Manikas *et al*. 2015; Heikkilä *et al*., 2016; Hübl & Fischer, 2017; Rachman & Ratnayake, 2017 and Wake & Urquhart, 2018); i.e. the same product is produced over and over again. In fact, most follow the classical match and dice game originally introduced by Goldratt & Cox (1984, see chapters 13 and 14). The match and dice game models a production line in which each upstream station replenishes the inventory at its downstream station whereby the output of each station is dependent on a random event (a dice throw). While this illustrates the effect of variability and dependent events, the proper working of the game relies on the assumption that matches are interchangeable. But this assumption is rarely discussed, nor are the consequences of violating this assumption. So, the question remains: *How can we teach the complex phenomena that emerge when production control systems are used in non-repetitive contexts*? In response, we extend the classical match and dice game and assess the performance of our newly designed simulation in teaching practice.

Theoretical Background

Gamification has been used to teach managers and students for approximately 100 years (see, e.g. Cohen & Rhenman, 1961; Robinson & Robinson, 1994). A summary of

different forms of gamification is provided in Lewis & Maylor (2007). In this study, we focus on a physical simulation, which means that we seek to construct a small, simplified version of a complex real-life problem – the so called 'game' – to help students (or managers) to understand its complexities (Fripp, 1993). As a basis for our development, we first outline the content to be taught and summarize our expected learning objectives. The content are two complexities and two alternative solutions.

Complexity I – Customized Products Prohibit Producing in Advance of Demand
If the same item(s) are always produced, then these items can be stored in an inventory decoupling point, typically referred to as a 'supermarket' in the Kanban literature (Ohno, 1988). This allows demand to be satisfied instantaneously; the Kanban system functions as an inventory replenishment system signaling via Kanban cards that 'an item X **was used**, please replenish it'. But when each item differs, items cannot always be stored in advance and simply withdrawn from the supermarket to satisfy demand (Amaro *et al*., 1999).

Complexity II – Card acquisition leads to Indirect and Direct Load
When each item differs, the need for the item must first be propagated upstream from station to station until it reaches the first station where the need can be met – the CODP. In other words, a job must acquire a card from each station downstream from the CODP, and only then can processing of the job start. Acquiring means that a Kanban card is associated to this and only this specific order until the order is complete (Chang & Yih, 1994a and 1994b). During this card acquisition process, the *kanban* card signals 'an item X **will be used**, please create it'. Once a job has acquired a card for all operations in its routing, the actual processing of the order can start. The order is released, and the job moves downstream from station to station, being processed at each one in turn. After job completion at a station, the corresponding Kanban card can be used for a different order. So, a Kanban card remains associated with an order from release to the first station in the routing until completion at the corresponding station. But only when the order has arrived at a station does the corresponding Kanban card represent *direct* load. Before this point the card represents *indirect* load, which is the load associated to a station that is yet to arrive at this station. Since the indirect load increases the further downstream a station is positioned in the typical routing of jobs, downstream stations require looser or slacker limits on the number of Kanban cards (Gstettner & Kuhn, 1996; Oosterman *et al*., 2000).

Alternative Solutions – Kanban's Decentralized Card Acquisition can be Centralized
The decentralized card acquisition process executed when using standard Kanban without adaptation may lead to severe blocking in the material and information flow (Bonvik *et al*., 1997; Thürer *et al*., 2018). It also complicates control of the system, since: (i) the last station, which has the loosest limit exercises the control; and, (ii) order prioritization is decentralized. Both can be resolved by centralizing Kanban's card-acquisition process; for example, by combining Kanban with Constant Work-In-Process (ConWIP; see e.g. Spearman *et al*., 1990; Hopp & Spearman, 2001) as in Bonvik *et al*. (1997) or through Control of Balance by Card Based Navigation (COBACABANA; see e.g. Land, 2009; Thürer *et al*., 2014b), which centralizes the whole card acquisition process.

Expected Learning Objectives
Our analysis suggests two main complexities that arise when Kanban systems are used in a non-repetitive context. These complexities are neglected in most standard textbooks. The same holds for the solutions. Most textbooks only cover simple push methods, with

infinite work station loading being the main control exercised by local priority rules. While ConWIP is sometimes taught, this is mainly due to it arguably being simpler than Kanban. Meanwhile, COBACABANA is widely neglected although it has the potential to significantly improve performance compared to ConWIP and Kanban (Thürer *et al*., 2014b). Within Bloom's (1956) taxonomy we mainly focus on the cognitive domain, specifically comprehension. Table 1 summarizes the expected learning objectives.

Table 1 – Learning Objectives

	Learning objective – Students can:
Complexity I: Customized products prohibit producing in advance of demand	1. Explain why customized products cannot rely on traditional Kanban;
Complexity II: Card acquisition leads to indirect and direct load	2. Describe the card-acquisition process; 3. Explain what is meant by direct and indirect load; 4. Recognize the consequences for the workload limits;
Alternative Solutions: Kanban's Decentralized Card Acquisition can be Centralized	5. Utilize ConWIP and COBACABANA.

Design of the Game

Required Materials and Set-Up

The basic infrastructure of our new game follows the match and dice game. We model simple production lines where each line consists of 4-6 players. Sheets of paper are used to represent the output buffer of a player, the products and the Kanban cards. The Kanban cards should be of a size such that five fit on the planning board described below. This planning board can be a simple A4 sheet of paper. Note that the use of sheets of paper is arbitrary and any other material (e.g. bowls and matches) could equally be used. Finally, we do not use a die so as to exclude the effect of variability in the output rate and to isolate the effect of customized products. Hence, the output rate and processing time are fixed. The game takes approximately 45 minutes for one modelled line.

Execution

There are three primary learning styles: visual, auditory and kinesthetic (Protzman *et al*., 2016). Visual learners prefer pictures with written materials. They also prefer lists and make mental maps of activities and tasks. Auditory learners prefer to talk out loud and repeat things to themselves. They prefer to discuss ideas that they do not understand in a group. Kinesthetic learners learn from experience. They can remember how to do things they have only done once. They need practical, participatory experiences where they can handle materials. All three types need to be considered when executing the game. First, the visual learning style is supported by use of a Powerpoint presentation synchronized with the execution of the game. The presentation summarizes the simulation, the structure of the production control methods and the results step-by-step. Second, the auditory learning style is supported by letting students discuss the results, guiding the discussion through a set of open-ended questions. Third, the kinesthetic learning style is supported by the simulation; all students actively participate in the simulation. In total, three experiments will be executed.

As a baseline, we start with a 'classical' Kanban system, as illustrated for five stations in Figure 1, and the scenario where all products are interchangeable (Experiment 1). There are arbitrarily five Kanban cards allowed in each Kanban loop. The teacher takes products

from the output buffer of the last station (finished goods), which frees up Kanban cards. The player at the last station (Station E) then goes to the previous station (Station D) and takes products from the output buffer before finishing the products and putting them in his/her output buffer. The Kanban cards of the previous station are freed when the player at the last station takes parts from the previous station and attaches his/her Kanban cards. This triggers production, and so on.

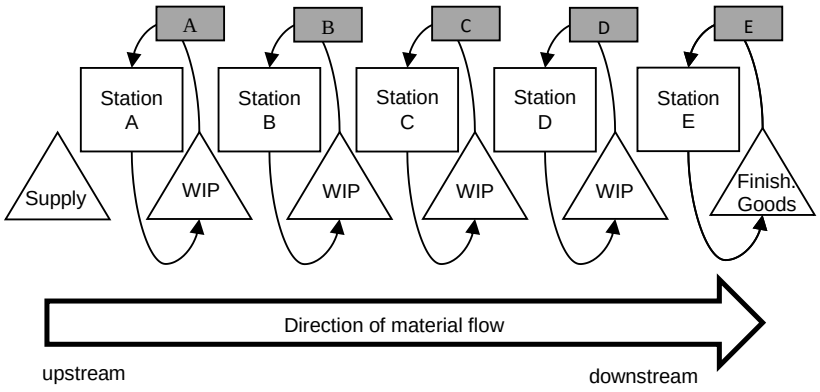

Figure 1 – Baseline Kanban System

Complexity I: Customized Products Prohibit Producing in Advance of Demand
We then change the scenario, stating that we now produce highly customized products (Experiment 2). This means products are now no longer interchangeable. We ask the students to set up the simulation as for the baseline experiment, but they should soon recognize that customized orders cannot be held in stock. Students learn that if orders are highly customized one must shift the CODP and always wait for demand before the production process can occur. This addresses our first learning objective – students can explain why customized products cannot rely on traditional Kanban.

Complexity II: Card Acquisition Leads to Indirect and Direct load
We now trigger the first customer order. Students discover that a card must be acquired at each station until the order reaches the first station, since demand created downstream cannot be fulfilled instantaneously or directly from stock. This addresses our second learning objective – students can describe the card-acquisition process. To facilitate this card-acquisition process, we ask the students to put all Kanban cards on a centralized planning board. Thus, instead of each student independently deciding which order to process, we introduce a centralized release function executed by the first player in the line. Kanban cards no longer remain in the loop of the station, rather they are attached to the order at release and move with the order until completion at each station. This establishes a centralized loop between each station and the first/gateway station.

It is important that production at each stage is synchronized. This means each station completes its order, detaches the card sending it back to the planning board and moves the order at the same time. After four rounds the first order reaches Station E with one card (from Station E) attached to it and the steady state is reached. At the steady state, four cards are taken from the planning board and attached to the order, and four cards are received (one from each station) from the shop floor and put on the planning board. We now let students continue for some rounds until they have internalized the feedback loops. We then stop and ask them to observe the distribution of available cards on the planning board and assigned Kanban cards on the shop floor. This is illustrated in Figure 2.

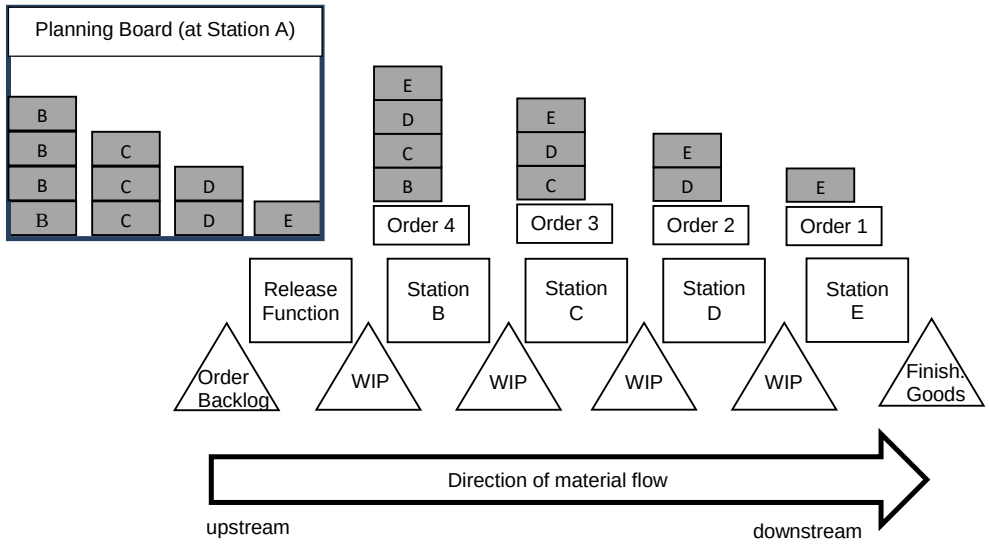

Figure 2 – Available and Assigned Kanban Cards: The Effect of Direct and Indirect Load

As an example, take Station E: Where are all of the cards of Station E? We explain to students the difference between direct load, represented by the card directly queuing at the station, and indirect load, represented by the cards at the three upstream stations. It arises since it takes longer for cards from station E to actually reach Station E than, for example, for cards from Station B to reach Station B. This addresses our third learning objective – students can explain what is meant by direct and indirect load.

We next ask whether we can release more than one order. Students will observe that this is not possible since there is only one card from Station E on the planning board. Hence, Station E imposes the limit for the whole system, although we designed the system to have five orders at each station. As a result, the limit on the number of cards should increase the further downstream a station is positioned to ensure that the direct load at each station remains at five orders. This addresses our fourth learning objective – students recognize the consequences for the workload limits.

Alternative Solutions: Kanban's Decentralized Card Acquisition can be Centralized

We now explain to the students that the centralized Kanban system represents the COBACABANA system as outlined in Land (2009). We then ask: is there a simpler solution to control the number of jobs in the system? A single card loop from the customer to the first station of the line (the release function) could be used. We explain that this is ConWIP, which neglects direct and indirect load. We ask about the minimum number of ConWIP cards in the system, which is equal to the number of stations, and let students simulate the ConWIP system (Experiment 3). While students will find the execution of the ConWIP system easier, they should also observe that only 1 or 2 players are actually processing orders while the remainder watch. We now explain that ConWIP cannot be applied if processing time variability or routing variability is high, since it does not control stations. Moreover, the routing length is restricted since the number of ConWIP cards increases with the routing length. This addresses our fifth and final learning objective – students can utilize ConWIP and COBACABANA.

Field Test Results

Different assessment methods could be identified in the literature; for example, the use of self-reported data on whether learning outcomes improved, either directly from

students themselves (Arenas-Márquez *et al*., 2012; Costa Santos *et al*., 2012; Piercy *et al*., 2012; Yalabik *et al*., (2012); Scholten & Dubois, 2017) and/or from teachers (Léger *et al*., 2012; Scholten & Dubois, 2017), and final test scores (e.g. Arenas-Márquez *et al*., 2012) or pre/post implementation scores (e.g. Manikas *et al*., 2015). In this study we use both self-assessment and test scores. However, our game teaches new knowledge which is not part of an existing curriculum. So, we cannot assess pre/post implementation scores but only assess post implementation scores. We can also not use a problem-based assessment (see, e.g. Bamford *et al*., 2012) since it focusses on an uncontrolled environment where a basic requirement is that the problem is not fully defined. In contrast, our simulation provides a controlled learning environment.

The game was conducted in December of 2018 in a class in China as part of an introductory course on production control systems. A total of 41 students participated in the game and 10 production lines were simulated. Lines consisted of either 4 or 5 students on a team. The differing line sizes were necessary due to the layout of the teaching facility. After the game a questionnaire was given to each student. All questions were in both English and Chinese. Students were free to answer in any of these two languages.

Assessment & Self-Assessment of Teaching Effectiveness

Table 2 summarizes the questions used to assess whether learning objectives were met together with the percentage of given right answers. The percentage of right answers compares favorably with those obtained in post-tests in other studies in repetitive contexts (e.g. Manikas *et al*., 2015). A major issue is the low score observed for drawing a ConWIP system. It may originate from a confusion of terms, since students assume ConWIP cards to be Kanban cards. In fact, 8 students drew a Kanban system.

Table 2 – Assessment of Learning Objectives

Learning Objective	Test Question	
1. Explain why customized products cannot rely on traditional Kanban	Traditional Kanban systems are not utilized to produce customized products because:…	85%
2. Describe the card-acquisition process	When utilizing a Kanban system to produce customized products:…	85%
	Number the following 5 activities in the order they would occur when using Kanban to satisfy customized orders:…	68%
3. Explain what is meant by direct and indirect load	Which of the following best describes a work station's direct workload?...	58%
	Which of the following best describes a work station's indirect load?...	68%
	Indirect load arises at a work station when producing customized goods because:…	71%
4. Recognize the consequences for the workload limits	If a production system for customized orders has six work stations and a limit of 7 Kanban cards at the first station, what will be the actually imposed limit at the last station?...	90%
5. Utilize ConWIP and COBACABANA	Can you outline the loop structure of a ConWIP system?...	46%
	When utilizing a COBACABANA system:…	78%

A seven-point Likert scale was used for student self-assessment. Table 3 summarizes the questions and the average score. Our third learning objective – explain what is meant

by direct and indirect load – received the lowest score, which overlaps with the test results given in Table 2 above. Still, we considered it adequate since direct and indirect load are highly complex conceptualizations. So, to a certain extent the low score was expected. For practice it is important that most of the students were aware of its consequences in terms of workload limit applied. The high score for our fifth teaching objective - utilize the ConWIP and COBACABANA alternatives to Kanban – supports our conjecture that the low score for the ConWIP related question in Table 2 is due to a confusion of terms.

Table 3 – Student Self-Assessment of Learning Objectives

Utilizing a seven-point scale, please describe your view of the game:	
This game prepared me to explain why customized products cannot rely on traditional Kanban approaches that produce components in advance of customer demand?	5.05
This game prepared me to describe the card acquisition process required to facilitate customized products?	5.59
This game prepared me to explain what is meant by direct and indirect load and why these arise in the card-acquisition process?	4.07
This game helped me to recognize the consequences of direct and indirect load for the workload/card limits applied?	4.41
This game prepared me for opportunities to utilize ConWIP and COBACABANA?	5.56

Engagement, Comments and Discussions

The questionnaire also contained general questions: Can you think of more effective ways to learn the material you acquired with this game? Did you enjoy the game? To what extent? Do you think the game can be improved? If yes, how would you improve the game? And, Any further comments?

In terms of more effective ways, two students mentioned the inclusion of practical examples and one student suggested a better link to the course textbook. All answers would better fit under improvements. Meanwhile, 34 out of 41 students enjoyed the game, ranging from “so, so” to “normally” and “very much”. The majority of the students actively participated in the game, but a major problem was the large number of lines used in class (10 production lines) which led to students waiting while we were explaining the game to the students at other lines. Overcoming this issue was one of the major suggestions to improve the game. Students suggested the use of videos or letting students teach each other. The latter would also help to overcome the language barrier, given that the course is taught in English to a native Chinese audience. Developing strategies to more rapidly teach the game in different linguistic contexts is one of the main future research issues.

Conclusion

A major contingency factor that determines the applicability of production control techniques is the position of the so-called Customer Order Decoupling Point (CODP). While this is widely recognized in the literature and most textbooks teach some content on the CODP and the different production modes it creates, most textbooks remain in a to-stock, repetitive context when introducing production control solutions. However, production control techniques for this context, such as the use of Kanban containers for inventory control, cannot be directly applied to shops that produce a high variety of products, such as small and medium-sized make-to-order companies. While contingency factors are introduced, how to solve these contingencies is neglected. We therefore asked: *How can we teach the complex phenomena that emerge when production control systems*

are used in non-repetitive contexts? In response, we extended the classical match and dice game, which focusses on a repetitive context, and integrated a strategy to teach two complexities (i.e. customized products prohibit producing in advance of demand and card acquisition leads to indirect and direct load) and two solutions (ConWIP and COBACABANA). We then used a field test to prove the playability of our game and assess its teaching effectiveness. We used two different approaches: post-game scores and self-assessment. Both give support to our game and highlight that it helps specifically average students.

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Using Virtual Reality to teach warehousing operations: the Leclerc Drive Case

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Abstract

While increasing volumes of knowledge are becoming available on the Internet, the challenge remains of providing students with unique experiences in the classroom through experiential teaching methods. The stakes are all the greater since student numbers are growing with the massification of higher education. One way to provide experiential learning for large numbers of students is to use Immersive Virtual Reality technology. The paper provides feedback on a virtual reality application developed at NEOMA Business School that enables students to visit a logistics warehouse owned by the retailer Leclerc while remaining in the classroom.

Keywords: experiential, virtual reality, warehousing

Introduction

Since Freud made his celebrated statement, people often describe teaching as an "impossible profession." However, recent upheavals in the educational system mean that the statement has doubtless never been as true as it is now, and for two major reasons. First, all knowledge is immediately available: everything that is said can instantly be verified. Thus, there is every chance that when a teacher makes a mistake in the classroom, one of the students will point it out after checking on Google. Second, it is increasingly impossible for teachers to keep their students' attention for any length of time. When a teacher speaks in the classroom, many students are no longer able to concentrate for more than a few minutes…

How can teachers overcome these two new disruptions? The answer lies in pedagogical innovation. One challenge is to develop educational strategies that provide less theoretical, lecture-based, "experiential" learning (Kolb, 2014). According to Legendre (2007), experiential learning is *"a learning model that advocates participation in activities set in contexts as close as possible to the knowledge to be acquired, the skills to be developed, and the attitudes to shape or modify."*

Experiential learning encourages knowledge retention and involves students more actively in the learning process. It enables a learning process involving, to use Schön's (1984) expression, a dual reflection: *"reflection during the action and reflection about what is put into action."* Experiential learning takes place during class time, using practical work, advanced learning sessions, questioning, the application of content worked on beforehand via distance learning, simulations or business games, group work, traditional case studies, exercises, virtual or actual projects, professional experience (internships or voluntary work), etc.

The benefits of virtual immersive reality in experiential learning

While a range of tools is available, one recent technology is particularly appropriate for experiential learning: virtual immersive reality. Virtual immersive reality consists of photographic or video images of professional or entertaining scenes. These images are

used to create a 360° digital reconstruction of the scene, in which users, equipped with a headset, feel immersed, included in the photo in the middle of those being photographed, or standing next to the people in the video who are speaking to them. Virtual immersive reality can thus enable students to visit a location (even if it is small, dangerous, or inaccessible) while remaining in the classroom, to experience a learning situation, or to be immersed in an environment relating to the discipline being studied. Using a smartphone and a passive virtual reality headset, students can be propelled into a 360° environment chosen by the teacher. Learners will use their critical skills in the environment to analyse the context and take decisions as appropriate for the exercise.

In 2016-2017, NEOMA Business School initiated its Learning Experience approach. This is part of the school's pedagogical approach, focused on experiential learning and action learning. The School's first initiative in this area was to use immersive virtual reality to develop an application that immerses our students in a retail store. The approach, designed to improve marketing courses covering sales outlets (merchandising, organization, etc.) has been proposed to over 2,000 students since 2016.

We developed our second virtual immersive reality application for our operations and supply chain management courses. Ultimately, NEOMA's aim is to produce a library of teaching content that will immerse students in a wide range of organizations to work on their agility and "critical awareness". Our library of immersive content will enable students to benefit from a variety of educational experiences and to make connections between these experiences. It will also provide learners with a variety of contexts that would not otherwise be possible due to the temporal, spatial or organisational constraints of their curriculum. Finally, the system will enhance the value of the teacher, who must provide learners with the means to go back and forth between theory a.

The Leclerc Drive case study: an application to a logistics warehouse tour

The application immerses students in a logistics warehouse: a drive-through warehouse operated by the supermarket chain Leclerc. Drive-through stores are a retail format that appeared in France in the year 2000, and which are both stores and logistics warehouses. Their development has been remarkable, and in 2017, there were more than 4000 drive-through stores in France. Unlike a supermarket, where customers choose their purchases in the store, in a drive-through store, customers order their shopping on Internet, and then drive to the store, where the shopping is loaded into their car boot, after being prepared by the staff.

The case plunges students into the largest drive-through store in France (in 2018): the Leclerc store in Saint-Brice Courcelles, near Reims. As a logistics and supply chain management (SCM) consultant, the students' mission is to discover how the Drive operates, and then to provide Leclerc senior management with recommendations to help the store absorb the rapid increase in customer orders. Specifically, the students:

1. Visit Leclerc Drive in Saint-Brice Courcelles, either in immersion (ideally) or in 360°
2. Model the physical and information flows through the Drive, in groups. To do this, the students:
    - a- Draw the store building with its different areas
    - b- Locate the drive-through store within its upstream and downstream supply chain environments (suppliers and customers respectively)
    - c- Draw a diagram of the physical and information flows through the Drive from supplier to customer

3. Prepare a critical analysis of the drive-through store with their group. The students analyse the marketing and logistics choices made when designing the Drive, and then imagine how the store could be rethought to cope with the increase in customer orders.
4. Present their analysis using a five-minute slideshow, including the key issues identified and proposed improvements for each of the key issues they have identified (objectives, means, expected results, budget required).

Case study design

We designed the case study in partnership with the retailer Leclerc. The project took almost 18 months, divided into 5 phases. The first phase of the project was to define the learning objectives. In the case of the application, four objectives were defined, classified according to the Bloom taxonomy. Specifically, the goal was that after the case study, students would be able to:

- Schematize the logistic process of a drive;
- Explain the link between physical flows and information flows;
- Analyse the decisions taken with regard to marketing and logistics;
- Design a Drive according to different constraints from those of Leclerc.

The second phase of the project was to define a script for the application (figure 1). The script identifies the different areas of the Drive that the students would see in the application, and in particular where they would watch videos of employees working (V1, V2, etc.) and where they would watch 360 panoramic pictures (P1, P2, etc.). During this phase, we wrote the text that each Drive employee would say during each video, to help students reach their learning objectives.

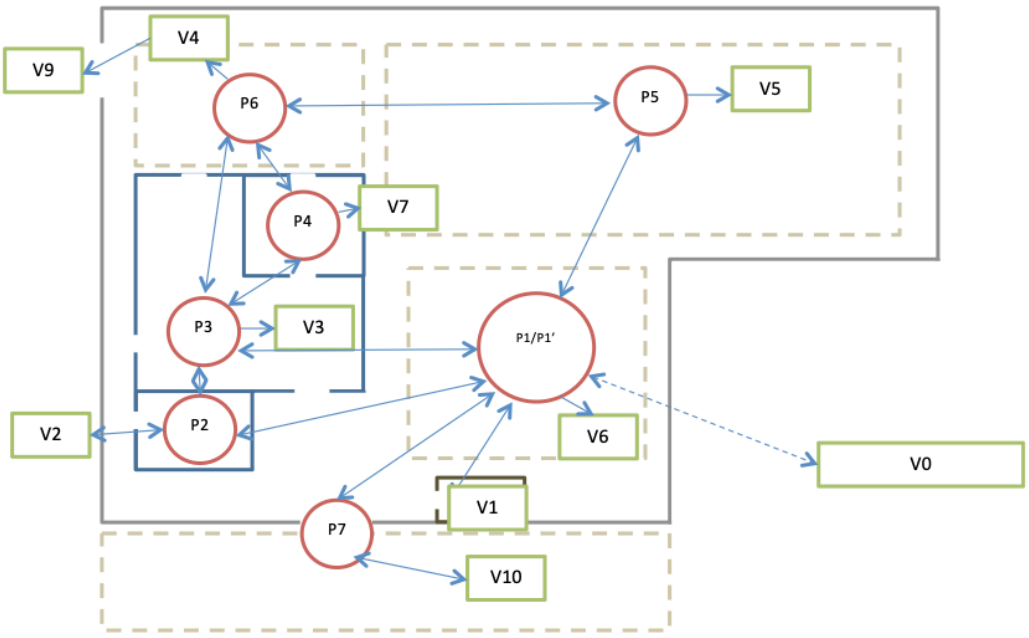

Figure 1: Script of the VR Application

The third phase consisted in shooting the application at the Leclerc Drive. During this phase, the Drive employees rehearsed what they would say and do. After the rehearsal, 3 days of shooting were organised at the Drive, using a 360° camera (see figure 2).

Figure 2: 360° camera used to shoot the application

The fourth step of the project consisted in developing the smartphone application. During this phase, the application was tested technically, debugged, and several versions were released. In parallel, the videos, which had been shot in French, were translated into English, to enable the application to be used with a larger audience. During this technical phase, we designed a first draft of the teaching material (teaching scenario, slides, etc.).

Finally, we tested the application with two classes. Using their feedback, we made improvements to the application and the teaching scenario. Finally, we launched the case study in September 2018, since when it has been used by more than 600 students in three-hour classes.

Learning from the case study

The results of this initiative have been extremely positive. First, the students learn fast. They feel more involved and quickly learn the concepts associated with managing physical flows in warehouses. This is mainly because they are not on their smartphone, but in their smartphones when they use the application! Second, they appear to retain what they learn. As the experience is new and unfamiliar, they do not forget the concepts studied. In addition, their understanding is more complete. In this nonlinear, immersive approach, they learn about the system as they would in real life. Finally, the students are captivated by using the very latest technology. In this "attention economy," the system benefits the teacher while making the learning process enjoyable: the era of edutainment (educational entertainment) has begun.

Using virtual reality, however, requires care. Indeed, using any technology involves paying particular attention to the UX (user experience). In the case of immersive virtual

reality (IVR), the brain is subjected to a unique exercise and needs to be provided with an environment of the highest quality: the brain will see and hear an experience that the other senses do not perceive directly. In rare cases, either because of the poor quality of the immersive environment, or because of the student's personal reaction to this type of experience (as with forms of transport sickness), a few students may feel the effects of motion sickness during virtual immersion. According to a US Navy study in 2015, up to 40% of users may feel motion sickness when using VR. This phenomenon is of course directly related to the type of experiment and the user's profile.

In the case of immersive virtual reality, particular attention must be paid to:

- the quality of "navigation" during the IVR experience, avoiding complex or unnecessary movements,
- short immersion times to limit exposure to the smartphone screen's light and visual accommodation effort time,
- the quality of the images, to avoid tiring the user with blurred or poorly edited images.

Figure 3: Students using the VR application in class

Proposal for the EUROMA session

During the EUROMA session, we will present in more detail the case study's design and use in the classroom. We will also give participants the opportunity to use the application and experience the Drive-through immersion as the students do (see figure 3). We will supply Homido headsets for participants to test the application using their own smartphone. Finally, we will stress that the interest lies not in the technology but in its educational uses. Without a thoughtful pedagogical approach, finely crafted goals, and a carefully constructed scenario, immersive virtual reality will simply become a passing fad. Moreover, as highlighted by Figure 4, we use the technology coupled with traditional techniques: a marker and flipchart sheet to draw the warehouse. Such

techniques keep the students focused on reality and help them really work together, which is crucial.

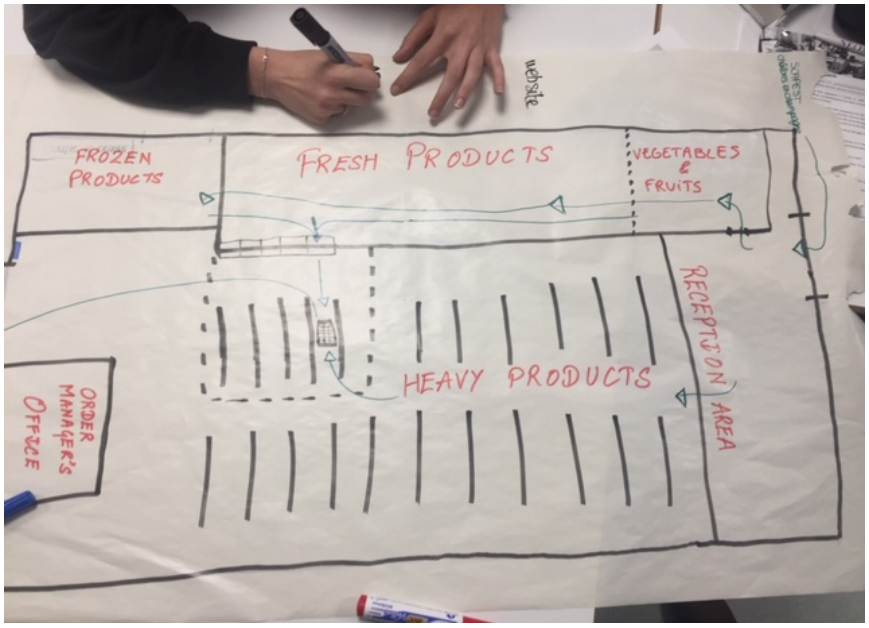

Figure 4: Students drawing the Drive warehouse with a marker and a flipchart sheet

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A feasibility study into how a synthetic digital environment can help people with less visible impairments use rail more easily.

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Abstract

The UK government's objective to increase accessibility to the rail system for users presents challenges for the management of day-to-day operations. This research reports on the development of a virtual-reality-based learning tool (game) to facilitate continuous improvement of rail service management in respect of accessibility. Application is via two modes, a journey planning tool for users and a training tool for customer-facing rail staff. The tool aims to identify issues pertinent to the management of rail operations and promote the staff discussion of accessibility management. Provisional results and demonstrator will be presented at conference.

Keywords: Service Improvement, Virtual Reality, Learning

Introduction

One aim of the Department of Transportation's Accessibility Action Plan Consultation (Department for Transport, 2017) is to improve railway accessibility for individuals with Less Visible Impairments (LVIs). In context LVIs are conditions that limit an individual's ability to utilize rail services that are not immediately visible (or obvious) to the casual observer, for instance, developmental conditions such as Autistic Spectrum Disorder (ASD). Furthermore, with aging populations the number of potential rail users with LVIs such as mild cognitive impairment is likely to increase and they in particular will require modification to service provision. This is an issue for standardized high volume, low variety, operations management where operations are normally geared toward the majority of users (without LVIs) and there is currently little academic research on how this can be achieved. Facilitating rail access for individuals with LVIs would enable them to take a more active role.

This research involves the Rail Safety and Standards Board (sponsors), technology and operations management academics, LVI experts, and a Train Operating Company (TOC) with the aim of improving access for those with LVIs through two routes:

- enabling users to prepare for, and be better supported during, rail journeys
- developing a learning capability for customer-facing rail staff to improve their ability to provide appropriate customer service for users with LVIs.

The project will assess the effectiveness of Virtual Reality (VR) technologies and gamification to improve the quality of service and travel experience for users with LVIs, and the ability of customer-facing staff to manage operations in respect to those with LVIs. The research focuses on two specific LVIs, mild cognitive impairment (MCI) / Pre-Dementia and ASD, where the use of VR technologies and gamification as a therapeutic aid has provided superior results over traditional methods (Mesa-Gresa et al., 2018; Fleming et al., 2017).

It is envisioned that a gamified VR environment will aid MCI and ASD users to plan, practice, and thereby more effectively execute rail journeys and facilitate improvement of staff/LVI interactions, accessibility, and customer service.

Literature Review

Gamification remains a nascent area of research and, as such, has not been definitively characterized. An oft quoted definition is that of Deterding et al. (2011) which focused on the use of game elements, such as badges and missions, in non-game contexts. Other authors e.g. Mora et al. (2017) go beyond this to include factors that are aimed at changing behaviour, levels of motivation, or engagement in organizational initiatives and the improvement of users' experiences. It is within these broad approaches that the application of gamification in this research resides, where the virtual environment will include gamified elements in order to motivate users to engage with the process of journey planning.

Authors argue that to achieve a successful gamified outcome requires a process perspective in order to enhance behaviour through a persuasive design approach (Werbach 2014). Persuasive design itself can be characterized in three elements which can achieve the targeted behaviour (Fogg, 2009). The design must provide the user with sufficient motivation, they must have sufficient ability to complete the tasks required, and there must be an effective trigger which motivates the desire to achieve the behaviour. Thus the use of gamification should consider what behaviours are desirable and therefore should be rewarded in some context. Importantly for this to be achieved the process to be gamified must have some intrinsic value to the user, without this the use will have no motivation to engage or further deepen that engagement through gamification. As such gamification can be considered a potential motivational design solution (Deterding,

2012). Therefore to achieve behavioural changes design should attempt to 'provide the user with arguments for specific behaviour and suggest actions' for the users as part of gameplay (Tromp et al. 2011). In the context of this research the gamified approach should encompass game elements that influence users towards explicit goals; where both the behaviour and explicit goals are apparent to the user. In more specific terms, gamification should motivate and enable potential rail users to plan for their journey (something that is not straightforward for those with ASD or MCI) and provide customer-facing rail staff with a mechanism to gain insight into, discuss, and develop service improvements. In broad terms design should consider functional and practical requirements, constraints, and non-functional requirements. These include primary tasks that provide meaningful content for the user, computer-human interaction which moves the user toward the goal or behaviour through feedback, a credible system that is persuasive in terms of the desired behaviour, and social support which can influence the user's progress towards the desired behaviour (Oinas-Kukkonen and Harjumaa, 2009).

Examples of serious games and gamification to promote knowledge sharing are becoming more common as gamification becomes recognized as, "…a process of making activities more game-like…" and, "… focus[ing] on the crucial space between the components that make up games and the holistic experience of gamefulness" (Werbach 2014). It is the aim of this research to apply the learning capability as a serious game to promote discussion and knowledge sharing between customer-facing staff through the lens of the requirements of rail users with LVIs. In the context of this study it is important to make the distinction between the use of a serious game and the gamification of the process of improvement. Deterding et al. (2011) developed a 2x2 matrix where gamification involves the use of game elements in parts of a designed process whereas a serious game involves the use of a game without necessarily including it in a wider process. This research combines this design thinking to use a serious game, as an intrinsic, explicit and critical part of the process improvement process. Hence the process improvement process is gamified through the use of a serious game. This approach is an example of gamification because it is possible to be engaged in both game design and gamification, "without conflating the two" (Werbach, 2014).

VR is broadly defined as an experience that gives a person a sense of reality and a feeling of presence in a synthetic environment that is normally computer generated and different from one's surroundings in reality (Steuer, 1992). Due to advancement in optics and tracking, there is a variety of affordable Head Mounted Displays (HMDs) which allow the users to be fully immersed in a VR environments (Liagkou et al. 2019). Typical examples are the Oculus Rift, the HTC Vive, and Playstation VR. Oculus and HTC HMDs offers 1080 by 1200 pixels and a refresh rate of 90 Hz and both of the devices offer controllers and their one implementation for tracking, PSVR is a cheaper alternative but is broadly widely used due to the integration with the Playstation 4. Other cheaper alternatives include the Google CardBoard VR, and Samsung Gear VR which are heavily dependent on the user' mobile phone.

Previous research has shown promising results in terms of the use and effectiveness of VR as a therapy tool for people with different LVIs such as Autism Spectrum Disorder (ASD) (Bernardes et al., 2015). VR also offers several advantages over traditional therapy and staff training methods, namely that VR offers a risk free environment, the ability to easily customize and develop highly controlled experiments (Maples-Keller et al., 2017) while having high ecological validity, meaning that the skills acquired during VR interventions could potentially be transferred to real life (Mesa-Gresa et al., 2018).

Theoretical Framework

The theoretical basis of the research is that the use of the gamified learning environment can facilitate the elements of the SECI framework.

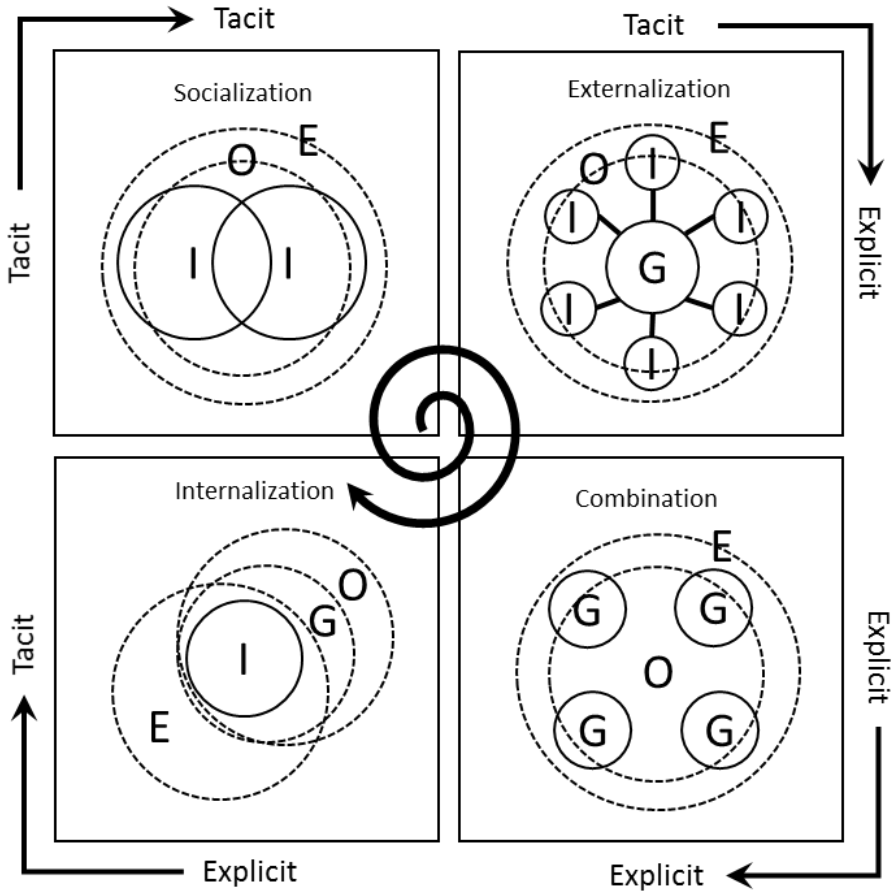

Figure 1: SECI Framework (adapted from Nonaka and Toyama, 2003)

The provision of customer service for those with LVIs requires an understanding of their particular needs, this however is not a straightforward proposition due to the individual nature of their requirements. Consequently it is necessary to have some means of capturing their needs and communicating them to the organization as a whole. The development of organizational knowledge is characterized by the SECI framework (Nonaka and Toyama, 2003), *Figure 1*. In this context it is necessary to transfer the knowledge of individual requirements to the organizational context and then to transfer that knowledge within the organization itself.

The gamified VR environment aims to enable customer-facing staff to better understand the requirements of those with LVIs and stimulate discussions on how customer service can be improved. It is argued that the game and its feedback will allow those with LVIs to plan their journey and particularly highlight the elements of their decision process that will affect it. In this sense, under the SECI framework, individuals with LVIs can to some extent socialize their individual knowledge which can then be absorbed as individual knowledge by customer-facing staff. This knowledge can then be externalized by promoting discussion between customer-facing staff who have undergone the training and other individuals in the organization. In this way the initial learning and

knowledge can be spread within the organization. Subsequently customer-facing staff would combine their individual knowledge, and experience with customers with LVIs, to identify customer-service improvements and standardized approaches (where appropriate) that can be used across the organization as a whole. This is particularly important in the context of rail operations which are geographically dispersed and staff do not necessarily have significant contact between different geographic locations. Individuals at different locations, who had undergone the training, would then internalize what they had learned, apply it in practice, and then begin the cycle again (socialization) by sharing their individual experience. It is the approach of this research to test whether this process can be facilitated by the use of a learning game.

In summary gamification and games can be used to create learning environments and motivate users to participate in that learning. This learning can be facilitated in the subject group, those with LVIs, by the application of VR technologies. Further it is argued that such an approach can be used to educate customer-facing staff and subsequently begin a cycle of organizational learning, the ultimate outcome of this research.

Methodology

Gamification utilizes gaming associated elements in non-game contexts (Deterding et al., 2011). This research will develop a gamified learning environment to help engage users with LVIs and customer-facing staff in planning, practice, execution and discussion of such customers' journeys. A generic new product development methodology (Tidd and Bessant, 2013) was used and modified using the recommendations of other educational game developers (Fripp, 1993), see Figures 2 and 3.

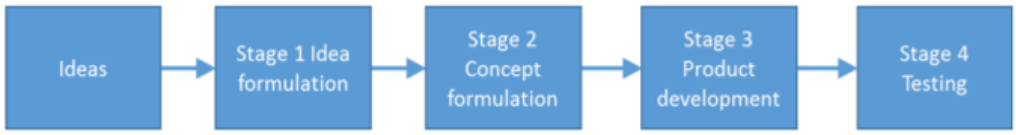

Figure 2: Generic new product development methodology adapted from Tidd and Bessant (2013)

Figure 3: Game development methodology applied in this research

Stage 1, Prototype definition: requirements gathering interviews and focus groups were conducted with experts in ASD, MCI, and customer-facing TOC staff identifying areas which affect the planning and execution of journeys for people with LVIs.

Table 1: Experts consulted as part of requirements gathering and initial design testing.

Area	Number	Experience / Expertise
ASD	1	Academic: Prof. Cognitive Neuroscience
ASD	1	Academic: Psychology (PhD).
ASD	1	Educational professional ASD focused: service support manager (communication and technology)
ASD	1	Speech and Language Therapist: ASD focused.
ASD	1	Occupational Therapist and Sensory Specialist: ASD focused.

ASD	5	Educational professionals ASD focused: members of the Mobility and Travel Training Team.
ASD	3	ASD focused charity management: Head of Research, Head of Campaigns, Trainer and Consultant.
ASD	1	Individual with ASD who is affiliated with the ASD focused charity.
MCI	1	Prof. Dementia & Psychiatry and Consultant in Old Age Liaison Psychiatry.
MCI	1	Consultant Psychiatrist, Clinical Director Psychiatric Specialties & Dementia Frailty
MCI	1	Consultant in Old Age Psychiatry
MCI	1	Director of Aston Centre for Healthy Aging
MCI	1	Consultant Geriatrician
TOC	1	Area Station Manager, experienced with ASD customers
TOC	7	Customer-facing station staff with experience of ASD customers
		People who played the game during development
ASD	7	Researchers and PhD students at the ALIVE Lab, Aston University
ASD	6	Educational Professionals ASD focused: Travel Trainer x3, Speech and Language Therapist x2, Student Support Manager.
TOC	TBC	Area Station Manager & Customer-facing Station Staff

Stage 2, Conceptual design: a VR environment, based on a medium-sized UK railway station, was developed incorporating desirable game elements identified through literature review and consultation with a professional game developer. The design was reviewed by experts in the needs of those with LVIs on an iterative basis.

Stage 3, Prototype and Pilot: the prototype is under development at the time of writing. Development will involve periodic review by subject matter experts. Pilot studies will constitute live testing of the gamified VR environment with individuals with LVIs, including standardized pre- and post- test questionnaires designed to evaluate usability, game experience, workload, and presence, and individual feedback on the perceived system usefulness. Every questionnaire is aimed at subjectively measuring a different aspect of the developed prototype, where the System Usability Scale questionnaire (SUS) (Brooke, 1996) will measure the overall usability of the prototype, the Game Engagement Questionnaire (GEQ) (Brockmyer et al., 2009) will measure user engagement in the gamified aspects of the prototype, the Presence Questionnaire (PQ) (Witmer and Singer, 1998) will measure how immersed users felt in the VR environment developed for this prototype (i.e. VR train station) and finally the NASA-TLX Questionnaire (Hart and Staveland, 1998) is used to measure the mental and physical workload experienced by users during their use of the prototype. User responses in these questionnaires will be important to further refine the VR game in Stage 4. In addition to questionnaires, objective in game user performance metrics will be recorded such as task completion times, head movements (i.e. where a user is looking in the VR train station in a given task) and in game choices (e.g. answers given by users to challenges in the VR game, avatar choice, number of attempts in completing a given task). This data will be used to further improve the prototype and measure its effectiveness in quantifiable measures when used as a training tool by users with LVIs. Objective and subjective measures will potentially highlight common user preferences and behaviors when faced with different problems in a VR train station. These findings will be particularly important for staff training. Staff testing will involve a debriefing session assessing perceived system

usefulness and identifying system, service, and training improvements in order to meet the needs of users with LVIs.

Stage 4: Refine, rework and review: production of the final design based upon user feedback, and methods for commercialization, implementation in the participating TOC, and making the prototype publicly available. This may include distribution of the game as an Android App on the Google Play Store, where more in game objective data will be collected in order to continuously improve the prototype.

Brief Overview of game environment

The learning capability will have gamified features so that it becomes an engaging and fun experience for passengers and frontline staff to use. The learning capability will also focus on the movement of passengers with LVIs through railway stations, and their interactions with augmented information (i.e. using Augmented Reality (AR)) to provide passengers with additional information that is not necessarily available in the physical space of rail stations to benefit future designers of such spaces.

Based on the user requirements outlined by experts, a gamified VR system will then highlight how the physical environment (i.e. rail station) presents difficult challenges to people with LVIs. Unlike people who have physical impairments that are visible, and readily evident to others, people considered by this project have impairments not readily visible. Therefore difficulties they have in being in environments (i.e. rail station) – normally geared toward the majority who do not have such impairments – are not readily understood (Smith, 2009).

In designing the game, a number of design considerations for users with the two LVIs that this research focuses on were taken into account, including presenting users with a choice from different avatars which can be motivating for users (Silton, 2014; Bejan et al., 2018) (see Figure 4), use of animations and encouraging language that were found to help attract user attention (Bozgeyikli et al., 2016), use of bright and contrasting colors in the user interface of the game to increase usability for elderly users (Siriaraya and Ang, 2014) and due to previously reported difficulties that ASD users face when dark colors are used in VR systems (Bozgeyikli et al., 2017), finally short and literal instructions were used throughout the game to avoid any user confusion especially due to the fact that difficulties in language processing are kin to the LVIs addressed in this research (Faria et al., 2016; Bozgeyikli et al., 2016).

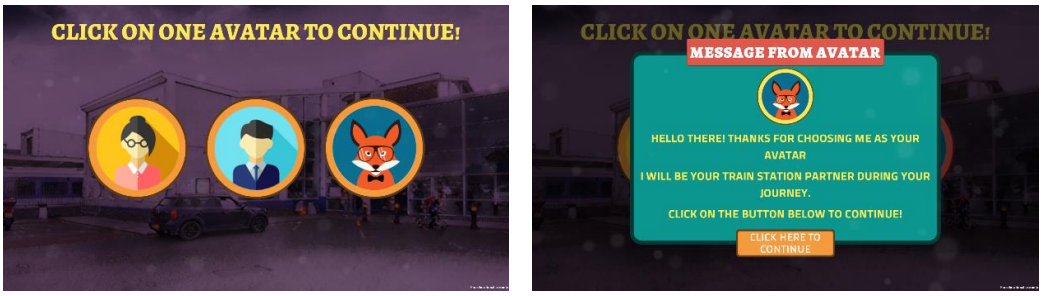

Figure 4: In-game avatars

The game consists of three different levels, where level 1 acts as a training level for users to become more familiar with the gameplay, interface and devices used in the game. This first level allows users to look and move around the train station from the point of entrance up until boarding the train without facing any challenges (Figures 4 and 5).

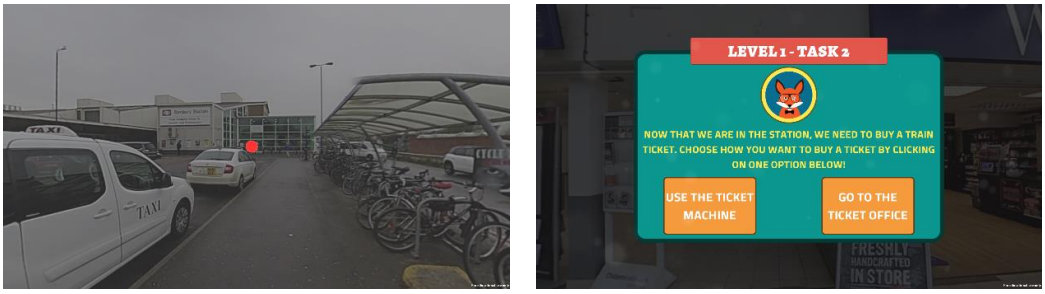

Figure 5: Screenshots

Level 2 then presents one challenge per task, where challenges address potential problems that users with ASD or MCI can face during journey planning in a train station, e.g. tickets machine is broken, the stairs are busy (Figure 6).

Level 3 finally presents a repetition of the challenges in level 2, as task repetition in VR environments is considered to be beneficial for users with ASD and MCI given its potential in honing brain skills (Hamadani et al., 2018). Additional challenges are also presented in this final level in the game, that in some cases require users to solve problems that are normally stressful in real environments and may require a lot of movement in a train station in order to be solved (e.g. sudden changes in train platforms, train delays).

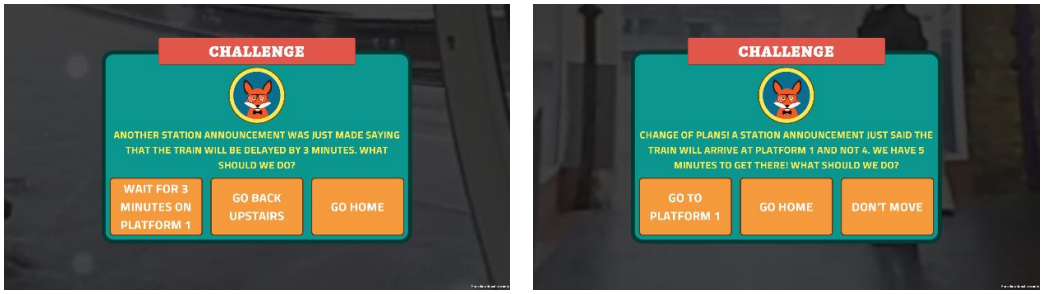

Figure 6: In-game challenges

Following the completion of all three levels of the game, users are then able to play any of the three levels again in no specific order, along with an option that allows users to freely explore the VR train station without any tasks or challenges.

Contribution

In addition to addressing the agenda set by government (Department for Transport, 2017), that highlights lack of confidence to travel as a major issue for people with LVIs, this project will present a novel approach to continuous improvement through increasing the understanding of supported rail passenger journeys in a high volume environment, a topic that is currently largely unexplored. It is also expected that assessing the feasibility of supported approaches to achieve improved access to rail services and the use of VR environments as training for customer service and accessibility will represent a shift from the current focus on simulating symptoms to the facilitation of improved coping mechanisms for users.

For frontline staff, VR gamification will offer a novel approach to continuous improvement. The approach will use interactive VR (e.g. video with questions, information, tasks and challenges relating to LVIs). This will enable frontline staff to better understand and empathise with people with LVIs and be more able to identify and

develop innovative solutions to LVI accessibility problems, without necessarily having direct contact with people with LVIs. This proactive and asynchronous approach has the potential to encourage LVI related improvements more quickly and effectively if compared to traditional methods (e.g. questionnaires, focus groups). Currently there are limited uses of virtual tours of this kind for passengers and limited feedback from LVI passengers, or potential LVI passengers, regarding their concerns about travel which makes this approach novel; it has the potential for the remote identification of improvements directly from passengers without the need for them to physically travel and will directly identify ways in which LVI passengers' experience can be improved. In addition built environment engineers will be able to use the resulting dataset to improve ergonomics and journey experiences for such rail users.

A demonstration of the VR game and preliminary results will be given at the conference.

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Bridging teaching, learning and industry practice – A co-learning approach

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Abstract

The paper studies a case teaching method that tackles companies' actual business problems of their current environment. The Real-life case method allows students to devise solutions novel to the case company, guided by their instructor and a company representative (the protagonist) in a live case setting. The method is also compared with traditional Harvard cases. The Real-life case method is evaluated by a survey and identified to bring additional value particularly in increasing students readiness to face real business problems in the field, understand the concepts of the course and becoming more confident with the taught subject in general.

Key words: Live case study, industry collaboration, learning-by-doing

Introduction

What makes high performing companies share their core business-critical information with a group of undergraduates? Why do the same companies keep paying for this year after year? These questions manifest the uniqueness of the teaching method under investigation. The paper will study an application of case-based teaching developed in the focal university, which is titled here *Real-life case.* This method builds on actual business problems that real companies face in their current environment and allows students to devise solutions that may be – and often are – novel to the case company itself. The students are guided by their instructor in a live case setting where they interact with relevant stakeholders to analyse and develop future scenarios together with the protagonist (focal character from the case company). The case method gives students the opportunity to attain managerial competences in a "real-world" setting including interaction with stakeholders This approach has gained popularity in the focal university in the form of "real-life challenges" and is also used as "Real-life" cases globally in business schools. The method is compared with the Harvard case teaching method that builds on Socratic principles to stimulate discussion, debate and critical thinking through

using descriptions of decision-making problems faced by an organization/individual. One of the goals of the case method, in general, is to bridge university education with practice through building students' skills that will be relevant when working on complex real-world phenomena after graduation (Steiner and Laws, 2006). The research aims to study Real-life case as a possibly effective method to reach these goals.

Harvard case method has become a commonly approved way of delivering parts of standard business curricula. Despite being useful in many settings, it has shortcomings particularly in terms of how effectively a carefully prepared written report can simulate an actual business problem within a company. Live cases are an application of case teaching, which aim to provide even better resemblance of real-life circumstances in actual organizations and stakeholder groups' perspectives (e.g. Roth and Smith, 2009; Steiner and Laws, 2006). They should provide a more thorough representation of the dynamics intertwined within companies' decision-making processes. In live teaching cases, students have even more freedom to develop the case, construct a problem and devise a solution (Steiner and Laws, 2006). The Real-life case studied here take these ideas even further through deeper co-learning among the students, the focal company and the instructor.

This study aims to analyse Real-life case as a way to deliver engaging, high impact education that is tightly linked to company practice. A key goal is to capture the essence of this method to enable other educators to replicate it in suitable contexts. One of the core aspects is to define the roles of parties participating in delivering Real-life cases, because these differ considerably from many other forms of case teaching. Further an explicit comparison of Harvard, instructor-led live case and Real-life case will be carried out to identify the value that these methods can bring to the participants.

The research questions (RQs) are:

RQ1: *What kinds of roles do parties play throughout co-teaching Real-life cases?*

RQ2: *What kind of value do Real-life cases deliver to each party, and how does this compare with the Harvard case method and author-led written case?*

Literature background

Different case methods in business school education

Business school education faces a challenge by the ever-changing managerial requirements in work-life. Accordingly, instructors need to provide education relevant for work-life, which often means a rich use of various teaching cases (e.g. Miller and Maellaro, 2016). Variety in both case content and teaching style provides students with a broader perspective on ways to apply knowledge in different real-life scenarios (Druckman and Ebner, 2018). The value of teaching cases is traditionally seen in the decision-making process, although the case method can offer a multitude of value to different participants when the delivery is amended. Concepts behind case methods vary and can be interpreted in many ways depending on the instructor, but the categorization used in this study is based on the following: strategic orientation, structure, relevance for the case itself, participation role of the student (Steiner and Laws, 2006), complemented by the role of the protagonist.

This paper focuses on three case study approaches: (1) Harvard case, (2) author-led written case and (3) Real-life case (see Table 1). In the second method, the instructor provides a written case in the classroom with all the information relevant to the case, similar to the written case description in the Harvard method. In the third method, students are guided into a live case setting where they interact with relevant stakeholders to analyse and develop future scenarios together with the protagonist who is a practitioner.

Table 1 – Three case study methods categorized (applied from Steiner and Laws, 2006).

	Strategic orientation	**Structure**	**Relevance for the case itself**	**Participation of students**	**Protagonist**
1. Harvard case	Education	Written	Historical	Classroom	Ulterior to students
2. Author-led written case	Education	Written	Historical	Classroom	Author/ instructor
3. Real-life case	Education	Live	Real-life	Interaction	Company contact

Live case method as a way of delivering experiential learning

Business school education should be influenced by the epistemology of the field: rather than simply allowing students to acquire knowledge, they should be engaged in a process that transforms some of their beliefs, values and ways of working (see Kolb, 2014). Fulfilling this likely requires a thorough learning process, where students are exposed to real-life business situations where they interact with relevant stakeholders and construct knowledge from this process (Yardley et al., 2012). Learning and knowledge creation requires reflection on the experience and conceptualization of key events (Kolb and Kolb, 2009), where the instructor's help is crucial.

Live case teaching is a method that can help students acquire several types of work-life skills required in future practice. This is achieved in closer partnerships among universities, companies and university students (Roth and Smith, 2009), which requires different types of course designs but also new roles from the instructor, students and partner companies. Live teaching cases (Cameron *et* al., 2012) amend live cases by introducing a practitioner/protagonist to deliver the case description in-person in the classroom. This requires the development of close relationships between the university and companies as well as between the instructor and practitioner. However, the learning results that the students can reach from this experiential learning approach are more relevant to practice but also more durable (Elam and Spotts, 2004; Miller and Maellaro, 2016; Druckman and Ebner, 2018).

Research methods

The original purpose of the case method is to enhance learning by fostering better thinking (Lundberg et al, 2001). We argue that offering case variety, especially in case teaching methods, is important for developing students' managerial competences. The Real-life case method offers an extension to the more traditional Harvard style case, which focuses strongly on decision-making whilst the Real-life case focuses on a larger spectrum of outcomes, such as managerial recommendations, insights into business operations and interaction with the protagonist. The Real-life case method gives students the opportunity to attain managerial competences in a "real-world" setting including interaction with stakeholders. This approach has gained popularity in the focal university in the form of "real-life challenges".

For this study, an undergraduate course was analysed in a Northern European global top-50 Business School (ranking based on 2018 Shanghai Ranking in Management). Three teaching methods with similar goals were compared on the course: a collaborative Real-life case, instructor-led written case and a traditional Harvard case called "Leitax (a)". The Real-life case aimed to improve participants' interaction with the learning materials and context, in a co-learning setting.

The data set considers both qualitative and quantitative data from a questionnaire with students (23 individuals) responding to questions concerning the three case methods. It focuses on how useful the case methods are for learning to apply concepts to a real-life situation. The data was analysed primarily through content analysis methods (Miles *et al*., 2014) and comparison of variances.

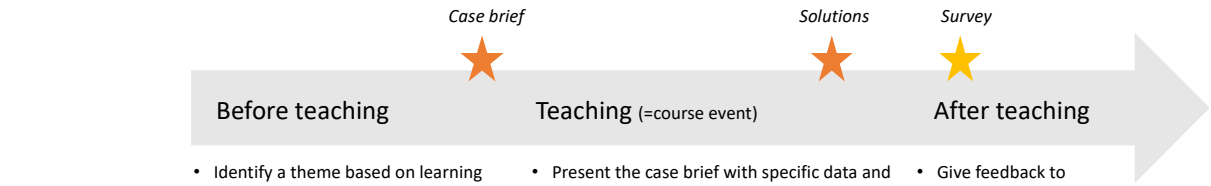
Findings

The findings of the study centre on the roles and value of the *Real-life case* method. Figure 1 provides a summary of the roles in different phases of the process. From the instructor's viewpoint, significantly more time in the preparation phase is needed because the case company and protagonist must be engaged early enough to allow content creation and preparation and secure availability during the lecturing times. In Real-life case, the instructor is also expected to take new roles such as coaching the protagonist in their preparations, facilitating classroom interaction not only with students but with students and protagonist and between them. The approach calls for flexibility, good communication and facilitation skills, not forgetting an ability and willingness to direct and lead the conversation when needed.

Roles of participants in the Real-life case compared to those in other case teaching

Table 2 assesses the three studied case study approaches through the different participating roles: (1) Student, (2) Protagonist, and (3) Instructor. University graduates need to possess a broad set of managerial competences that include: personal (i.e. self-regulating work, ability to develop oneself), interpersonal (i.e. working within interdisciplinary teams), informational (i.e. critical thinking, analysing information) and actional competences (i.e. decision-making, making things happen). Emphasis on decision-orientated cases, such as the traditional Harvard case, limits the development of students' managerial competences. In the author-led written case, the student can gain considerable experience in knowledge and secondary experience. Harvard methods allow students to act in a classroom setting without the real-world challenge and stakeholders, which makes the learning experience somewhat scarce in actual business dynamics. In practice, real-world challenges do not take place in an isolated setting. Finding solutions to real-world challenges requires a broader set of managerial competences than traditional written format cases can offer. To create value through learning, student interaction with the case context and reflection on the experience are required.

Figure 1 – Key activities in the Real-life case process from the viewpoint of Instructor, Protagonist and Student.



	Before teaching	Teaching (=course event)	After teaching
Instructor	• Identify a theme based on learning goals and scope of the course • Identify and engage a company • Prepare a written and/or verbal case brief with protagonist • Build a clear architecture for participation (e.g. structure of student teams, check-points with protagonist and instructions for deliverables)	• Present the case brief with specific data and insights to students and address all questions • Encourage independent, critical and creative thinking • Challenge when needed • Observe the process and learning interaction	• Give feedback to students • Grade • Reflect the process and summarize lessons learned
Case company protagonist	• Work with the instructor to isolate and define a relevant business problem • Plan engagement of relevant case company resources • Consolidate information/data for the case brief • Plan interaction with students and deliver the case brief to students	• Clarify expectations (e.g. details related to expected recommendations and documentation) • Help students to build connections between course theories and the case • Challenge when needed • Observe students at work, if possible	• Reflect the process • Give feedback • Apply recommendations in practice • Disseminate ideas inside the case company
Student	• Research the written case brief, if available • Search for out-of-the-box insights proactively	• Participate actively to understand the real situation • Present recommendations • Seek feedback from both protagonist and instructor	• Digest feedback • Reflect the process • Give feedback

Table 2 – Roles of participants in the three tested cases.

Case	Student	Protagonist	Instructor
Leitax (Harvard) – "decision-orientated" case	Students' investigation of the case is limited to classroom work. Learning outcome focuses on gaining theoretical knowledge and applying possible outcomes of the case.	The perspective of a specific "case protagonist" provided by a written case. Level of information is non-variable.	Making the case available to students without direct interaction with the case or its stakeholders. Provide students with insights based on a Teaching Note.
JEQ (Author-led written) – "decision-orientated" case	Reflecting on the role of the "case protagonist" through the instructor's account on experience. Learning outcome focuses on gaining theoretical knowledge and applying alternative outcomes of the case.	The perspective of an instructor-protagonist. Level of information is based on the instructor's experience.	Making the case available to students through a self-written description of the event in the case. Provide students with the actualised outcome of the case event.
Posti (Real-life) – "live" case	Immerse in the role of the protagonist through experiential learning. Learning outcome focuses on the application of course theories in the real-life business context. Consider alternative solutions and present recommendations to the protagonist in class. A new problem-solving approach gained, managerial competences developed and networking possibilities with a potential employer.	The perspective of a real-life protagonist. Level of information disclosed may vary from high to moderate based on company policies. Increased understanding of a selected business problem, access to (latest) theories useful to the problem and new ideas for possible solutions. Increased employer visibility.	Identify a case company and work with the protagonist on the assignment questions and material. Support the protagonist in the classroom (e.g. aligning terms, clarifying student viewpoints). Provide students with guidance and feedback to formulate new business outcomes. Better knowledge of current real-life business trends gained and possible identification of research questions especially for design science-based research. Nurturing academia-industry relationships and case examples for research.

Testing the approach: Value of Real-life cases compared to other types of cases
Data were collected from course participants immediately after completion of each case study and before starting the following case study. The data consisted of scores of the questionnaire described in the research methods section, with a 5-point Likert scale (1=strongly disagree, 5=strongly agree) being utilised for all items. Table 3 presents the analysis of participating students' perceived value of the different case methods used in teaching during a course.

Table 3 – Mean (and standard deviation) of students' perceived value of case methods post case study.

	The case is intellectually stimulating	**I participated actively in the class discussion**	**I feel now more confident with the subject in general, as a result of the case**	**The case helped me understand the key concepts of the course**	**As a result of the case, I feel confident in tackling related real-life problems**	**Overall, I am satisfied with the case**
Leitax (Harvard) – "decision-orientated" case	3,85 (0,53)	3,04 (0,85)	3,88 (0,64)	3,88 (0,64)	3,35 (0,73)	3,73 (0,65)
JEQ (author-led written) – "decision-orientated" case	4,04 (0,79)	2,83 (0,85)	3,83 (0,69)	4,04 (0,68)	3,38 (0,90)	4,00 (0,71)
Posti (real-life) – "live" case	4,04 (0,55)	3,04 (1,04)	4,04 (0,75)	4,22 (0,51)	3,74 (0,90)	3,96 (0,55)

Note: (1=strongly disagree, 5=strongly agree)

The Real-life case method is associated with feeling more confident with the subject in general as a result of the case, the case helping students understand key concepts of the course and feeling confident in tackling related real-life problems. Overall, the Real-life case was considered more value adding by the participating students. Although there were some exceptions, the author-led JEQ case was considered overall as the most satisfying case and was thought of as equally intellectually stimulating as the Real-life case.

Based on our experiences, critical differences between real-life case and other forms of case teaching relate to preparation time, level of uncertainty and learning experience (Table 4).

Table 4 – Differences of Real-life case compared to Harvard method, from the instructor's perspective?

Changes compared to Harvard case method	Reasoning
Instructor's preparation time increases	Identify a fitting case company and protagonist. Plan schedule and get solid commitment from the protagonist. Agree on the scope of the case and student assignment. Support protagonist's preparation e.g. writing the case brief by giving guidance and feedback (often iterative).
Uncertainty increases	Protagonist: depth of business knowledge, presentation skills, ability to answer questions, willingness and courage to share the (ugly) truth. Case design: estimation of student workload during the scoping phase, ease of applying course theories, students' ability to relate (vs. instructor's ability to understand the problem). Teaching/learning interaction: time usage in class both during the brief and student presentations, role of instructor vs. protagonist in giving feedback.
Learning experience increase	Unique case with no predefined right answer, i.e. honest opportunity to invent something novel. An appropriate amount of pressure due to the real client. Opportunity to experience how complex and messy situations are in real-life; problem definition alone can be tricky.

It is particularly intriguing to evaluate the value of the proposed Real-life case approach. There are several factors which may help explain why the Real-life case method is an excellent case study approach for participants' to gain value as learning and other value. First, a Real-life case involves the participation of a partner company, with a real-life challenge, changing variables and a deadline to meet. The challenge is not hypothetical, and students receive information directly from the real-life protagonist, rather than reading past accounts. From a students' point of view:

> *I would choose [real-life] case studies instead of theoretical approach, because cases make it easier to understand concepts and real-life examples are more interesting than plain theoretical frameworks. Also, cases help you to remember learnings.* (Student N.N. of the studied course)

Second, the dimension of the Real-life case as a learning experience is much deeper with the potential access to a large amount of real-life information from the partner company. From a student's point of view:

> *Case studies are one of the best ways to support active learning by motivating students to implement their prior knowledge with the course material more deeply. I personally prefer this style of learning than just memorizing the materials to the exam. Case studies are real and broad enough to test students problem-solving skills.* (Student M.*M.* of the studied course)

On a downside, it is equally possible that the partner company is not willing to disclose enough information for a successful case. In some cases it is difficult to check whether the protagonist is willing to share all relevant data and prior checks and promises might not realize in the classroom for a variety of reasons. Therefore, it might be reasonable to consider formal contracts and Non-Disclosure Agreements. Third, the Real-life case takes a different form every time it is taught, depending on the partner company, their challenge at hand and the current business environment in general. This way students do not get familiar with certain case types and generally accepted outcomes and decisions for the cases. Finally, a Real-life case scenario requires all the participants to get involved in addressing the challenge provided by the partner company. The sense of commitment towards the case is much higher when real-life stakeholders are involved and regular opportunities for face-to-face engagement are organised.

While it is important to note the relatively small sample size and focus only on a one-time teaching setting, the results of this study indicate that the use of a Real-life case contributes positively to increase the spectrum of case teaching methods and offers participants added value through real-life interaction.

Discussion

Contributions

The paper contributes primarily to the body of knowledge of teaching innovations in general and case method in particular. It offers novel insights on how case study teaching can be made more relevant to students and yield additional benefits to the case company in addition to the students and the instructor. The Real-life case builds on the live (teaching) case method (e.g. Elam and Spotts, 2004; Roth and Smith, 2009; Steiner and Laws, 2006) taking it even further to provide experiential learning that closely resembles real-life circumstances in companies. The method enables students to acquire capabilities around critical thinking, self-regulated working, project management, collaboration and other highly relevant work-life skills that the Harvard case method may not fully support. The paper is an initial attempt to explicate the roles and additional value of Real-life case method and is limited to the context and data set of the study. Future research is encouraged to explore how the method could be applied in other contexts and to compare it with alternative teaching methods.

Limitations of Real-life case method

It is important to identify possible shortcomings and risks related to Real-life cases, in addition to the many opportunities. First, the context of education should be considered carefully before the possible application of the method. Real-life cases require skills in scoping and designing the education process from the instructor, while students need skills in tackling difficult challenges and fuzzy problems. Further, first-year undergraduates may struggle due to having little understanding of the field or in case if lacking the motivation to engage in a somewhat challenging learning experience. Second, there are additional risks in relying on a company protagonist to deliver the case live in class, particularly related to reduced possibilities for the instructor to control delivery. As

a result, some company protagonists may take more time in delivering the case or experience other challenges due to a lack of teaching experience. Accordingly, the authors suggest selecting the protagonist carefully and prefer a person with whom the instructor has prior experience. On the positive side, a Real-life case is always delivered for the first time and has good chances of success through thorough preparations. On the other hand, the Harvard case method seems to require experience of delivering the particular case several times to realize the full value potential.

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Towards the next industrial revolution: a board game for teaching I4.0 principles

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Abstract

This paper presents the development and pilot testing of a board game for education and training in Industry 4.0. The game main goals are to improve participants understanding of I4.0 design principles, of the relationships among technologies-equipment-departments and to enable them to experience the transition process towards I4.0. Three pilot tests of the board game were carried out. Participants indicated the game is successful in improving their understanding of the link between I4.0 principles and company's objectives as well as of the I4.0-related technologies. Overall, the board game was a suitable learning tool to foster I4.0 education.

Keywords: Industry 4.0, Gamification, Education.

Introduction

The recent disruptive technological advancements and their industrial applications such as factory digitalization, smart objects lead to the expectation of an unfolding fourth industrial revolution, coined as Industry 4.0 – I4.0 (Lasi *et al.*, 2014). In this context, researchers have been discussing education and training requirements for this new paradigm (Abele *et al.*, 2015; Paravizo *et al.*, 2018). To address this need, we developed a board game connecting key concepts and technologies related to the transition process towards I4.0. As such, we had to integrate a conceptual body of knowledge in I4.0, define a learning strategy and develop a learning tool.

Many researchers have discussed the core characteristics of I4.0 and what if can mean for the development of industry (Kagermann, Wolf-Dieter and Wolfgang, 2011; Hermann, Pentek and Otto, 2016; Qin, Liu and Grosvenor, 2016; Roblek, Meško and Krapež, 2016). One proposition by Hermann, Pentek and Otto (2016) claims that designing and developing factories towards I4.0 depends on 6 design principles to succeed. They provide a systematization of knowledge, aid the understanding of what should constitute I4.0, support practitioners in developing solutions and, in an academic perspective, are the foundation of the design theory. Within the context of this paper (and more broadly the research project conducted by the authors) we have adopted Hermann, Pentek and Otto (2016) propostion of six design principles: interoperability, decentralization, virtualization, real-time capability, modularity and service orientation.

In line with (Qin, Liu and Grosvenor, 2016) we consider interoperability as the ability to employ different machines and equipment to perform the same task (even if they are from different vendors), fostering the creation of intercommunication and trusted networks which enable I4.0 development. Decentralization is related to the capacitation of local actors (companies, professionals or machines) to make decisions with more flexibility, employing specialized knowledge, aiming to achieve a decentralized self-organization (Roblek, Meško and Krapež, 2016). The virtualization principle is highly related to the achievement of a virtual twin that gathers the data collected across the factory to virtual plant model, supporting operations' control, simulation and optimization (Schuh *et al.*, 2011). Real-time capability is linked to the responsiveness of companies' operations which is enabled by the continuous data flow and analysis leading to impact throughout the company roles and functions (Verrière and Quenedey, 2012). Modularity is related to the development of modular, flexible systems, that are able to adapt to changing factors by incorporating or replacing production modules, which could also benefit from an interoperability standpoint (Qin, Liu and Grosvenor, 2016). The service orientation principle is enabled by I4.0 ability to collect and analyze large amounts of data, in real-time, which facilitates the provision of product-service systems (Demirkan and Spohrer, 2016).

After selecting the six principles as a basis, an ongoing literature review pointed towards other key concepts associated to I4.0, Internet of Things (IoT) and Cyber-Physical systems (CPS). The former being considered as a key enabler of I4.0 through the multitude of sensors and communication routines possible (Kagermann, Wahlster and Helbig, 2013) and the latter regarded as the integration between physical process and computations interacting in closed feedback loops (Lee, 2008).

As the design principles were made to achieve the full potential of I4.0, the lack of knowledge on how to work within this new context can lead to unnecessary risks and worse results, be it on the economic, environmental or social spheres. From these design principles, we can derive that the increased integration of technology will lead to a decrease in direct control for the leadership, and, as proposed by the authors (Hermann, Pentek and Otto, 2016), this is a positive effect directly related to decentralization and real time capability, which can contrast with traditional thinking.

Regarding the learning strategy, among the many developments and innovative approaches designed for improving teaching and learning of many subjects, the use of games – both virtual and physical – is increasingly popular (Connolly *et al.*, 2012; Qian and Clark, 2016). As key advantages, games have a positive effect on motivation and place the learner in a more active role, in comparison to more traditional methods, and have been increasingly used as learning tools (Qian and Clark, 2016). Regarding topics on sustainability and circular economy researchers have employed both digital learning environments and board games (Despeisse, 2018; Whalen *et al.*, 2018). Furthermore, the

benefits of educational games in industrial engineering education have also been discussed (Braghirolli *et al.*, 2016).

Considering the lack of active tools to facilitate the learning of I4.0, this paper reports the development and initial tests of a board game for I4.0 developed to bridge this gap. In the next sessions, we summarize the methodology, detail the board game (BG i4.0) development process; the preliminary tests performed and conclude highlighting the potential benefits and shortcomings of this board game.

Methodology

The development of the board game can be divided into three steps: content, game development and testing.

The first step was building a body of knowledge and identifying the most important concepts about I4.0. After the evaluation of the most cited articles, we have selected the six design principles proposed by Hermann, Pentek and Otto (2016) for their scientific impact and practicality, since these principles can be translated into industrial decisions. The rest of the literature was not discarded, with many other articles being used to select key technologies, understand their relation and enhance the concepts present in the game.

After the definition of an initial body of knowledge, the main learning goals of the BG i4.0 were defined as:

- Understanding the design principles of I4.0 that enable achieving its potential;
- Understanding the relationships among the I4.0 design principles and industrial developments. These developments represent technologies, machines, production methods and industrial departments;
- Enabling participants to experience the transition process towards I4.0 (i.e. I4.0 is not something that is simply bought and installed in the company).

The second step was realizing the development of the board game, following game design and gamification theories (Werbach and Hunter, 2012; Schell, 2014). A board game was chosen as the medium for such educational resource due to its tangible and social aspect. An initial analysis of several commercial games of wide renown (e.g. Settlers of Catan, 7 Wonders, Puerto Rico, Project Gaia) served as inspiration to the BG I4.0 design process especially due to their gameplay mechanics, such as resource management, and aesthetics.

The third step was testing the game and collecting feedback for further improvements. These tests have been divided into two types: workshops – focusing on the development of the game; pilot test – for testing of the current prototype. The workshop and pilot test and their results are further discussed in their own section.

The tests results are then used to review both the game content and the mechanics. This interactive approach during the workshops allowed for direct input from the participants while the iterative approach between pilot tests allowed to infer on the current functioning of the presented prototypes and external feedback.

Selection of game and gamification elements

Following the game element hierarchy for gamification devised by Werbach and Hunter (2012), the main dynamics (high-level, abstract elements of the game) of the BG I4.0 are related to constraints (resolving trade-offs and facing limitations) and progression (players strive to grow and develop their companies). Regarding the mechanics (basic processes of the game) of the BG I4.0, the main ones are related to resource acquisition, turns, challenges, competition and win states. The components (specific implementations of game mechanics and dynamics) of the BG I4.0, that were devised to enable the learning goals are detailed on Table 1.

Table 1 – Game components and their relationship to the learning goals of the BG I4.0

Component	Description	Link to learning goals
Objectives	Results and improvements that the company would like to achieve through I4.0.	To achieve the objectives, teams need to discuss and decide which advances (I4.0 design principles) to pursue, thus contextualizing abstract definitions to practical settings.
Advances	Excellence level in the implementation of the design principles related to I4.0.	To get an advance, teams must fulfil a series of prerequisites in terms of developments, workers and competencies tracks level, thus understanding the relationships among these elements.
Developments	Set of technologies, machines and equipment implemented in the company which lead to results and enabled the achievement of **advances**.	The developments are pre-requisites among themselves and other elements; the more advanced the machine/technology the more VPs it awards.
Competencies development tracks	Level of the company's competencies in technology, operations and people management.	The competencies development tracks (human resources management, technology management and operations management) are a proxy for the organizational readiness level (in terms of procedures, practices, culture, etc.) for I4.0.
Workers	Workers are necessary for manning **developments** and overall functioning of the company.	The workers of different specialization levels (from technical to specialist) highlight the importance of workers within the I4.0 paradigm, especially focusing on their competencies.
Sectors	Different sectors and departments that are required for the company to work and to achieve **advances**.	The sectors and departments highlight the need to develop other areas of the company (such as quality, customer relationship management and legal departments) to transition toward I4.0.
Money	Limited amount of cash players gets throughout the game used to pay costs and do investments.	In the end of the game, the money teams have translate how well they balanced the current phases (producing and selling goods) with the investments towards I4.0.
Resources	Requirements for the **developments**.	Players must match the available resources with the right development thus needing to think and discuss what each technology/machine demands.
Teams	Participants play the game in teams	Playing the game in teams enable discussions on the topics of I4.0 covered by the game, which further helps in the learning process.
Event cards	Random events that occur twice at each phase and affect all teams.	These events mimic external aspects (laws, market fluctuations, unforeseen issues, etc.) that further contextualize the importance of I4.0 principles in tackling these issues.
Support website	A support website accessible via QR code	The website contains the definitions and descriptions of all cards (advances, developments and resources).

Overview of the BG I4.0 gameplay

The BG i4.0 is played in teams (usually two people per team) which are in charge of an existing factory with basic equipment, technology and departments. At the beginning of the game each team receive two random objective cards that mimic strategic planning directions which they should strive to achieve by the end of the 3 rounds of the game.

During each round, players can use resources and money to buy developments (machines, equipment and technologies), hire workers or advance in competencies development tracks. By the end of each round, players produce goods (based on the productive capacity of their factories) and thus earn money to subsidize the next round of investments. After the third round, players count how many Victory Points (VP) they got

which depends on the goals they achieved, the developments and design principles, the number of workers they have, how far along the competencies track they got and their money.

Victory points attempt to reward players for achieving improving their factory results according to their objectives, these points emulate predicted success factors in I4.0. They reinforce the idea of not implementing technology for its own sake, but according to the company's strategic objectives. At the end of the game, the team with the most VPs wins.

After finishing the game session, a collective discussion of the underlying concepts of I4.0 and their application in the game is conducted to deepen participants understanding of I4.0 and clarify any doubts and questions they may have. During this discussion, facilitators emphasize that the VPs are not the end goal (since they try to translate a set of complex, intertwined decisions in a simplified way), so the main takeaway are the discussions and learning had throughout the game.

Validation Workshops

In the course of developing the BG i4.0, we conducted several internal and external tests and workshops. The internal workshops focused on the game design, discussing content, mechanics and overall experience to improve and refine the game. The external tests focused on pilot testing the most current version of the game to gather insight from participants and assessing gameplay performance and participants' learning. Table 2 provides an overview of the workshops and pilot tests and Figure 1 shows these workshops.

The final list of components that are part of the current prototype includes individual (teams) game boards, a central board (market), workers' pawns, objective cards, developments (machines/technologies) cards, money tokens, rules leaflet, events cards, a competencies development tracks board and a website with the additional resources for participants.

Table 2 – Workshops and pilot tests description

Events	Overview	Participants
Workshop 1 Jul/2018	Initial concept of the BG I4.0 was discussed, it's main goals and learning objectives. Discussion on the possibility of using 3D printed scale models and other game components (Fig. 1A).	5 project members.
Workshop 2 Aug/2018	Discussion of the core mechanics and how the game components supported them (e.g. worker allocation using cards for workers was not optimal) (Fig. 1B).	11 project members.
Workshop 3 Nov/2018	First complete playthrough of the game, already using pawns and tokens bought and designed specifically for the game (Fig. 1C).	12 project members.
Workshop 4 Dec/2018	Improved rules (e.g. participants play in teams) and added additional elements/mechanics (e.g. events cards - simulating external factors that affect all teams) (Fig. 1D).	8 project members.
Pilot Test 1 Feb/2019	Pilot test with students. Complete playthrough of the current prototype (Fig. 1E).	8 playing (3 undergrad and 4 graduate students, 1 professional game designer) / 7 project members.
Pilot Test 2 Feb/2019	Pilot test at Consulting Company A. Complete playthrough of the current prototype (Fig. 1F).	8 playing (4 consultants, 4 project members) / 8 project members.

Pilot Test 3 Mar/2019	Pilot test at Consulting Company B. Complete playthrough of the current prototype (Fig. 1G).	8 playing (6 consultants, 2 project members) / 7 project members.

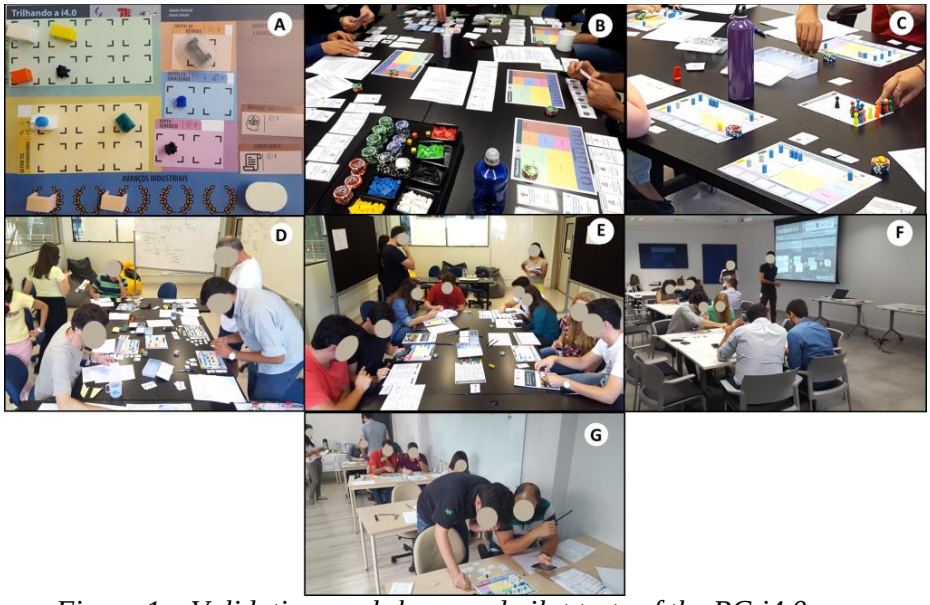

Figure 1 – Validation workshops and pilot tests of the BG i4.0

Pilot Tests

The pilot tests were structured in such a way that participants answered a brief questionnaire before the session and another afterwards. The first questionnaire aimed to get an overall understanding of participants perception of their own knowledge of I4.0 and its related concepts. The second questionnaire inquired participants of their background, if they felt the game helped them in achieving a better understanding of I4.0 and related concepts, as well as usability aspects, their familiarity with boardgames in general and had an open-ended question so participants could freely comment on their overall experience. All participants consented to take part in the study.

In this section, we are going to present results from the pilot tests (in terms of teams' performance) and responses from the feedback questionnaire. Figure 2 shows the evolution of money (revenue) accrued by teams in each phase of the game, in the three pilot tests (PT). Figure 3 shows the distribution of the VP each team got in the three PTs.

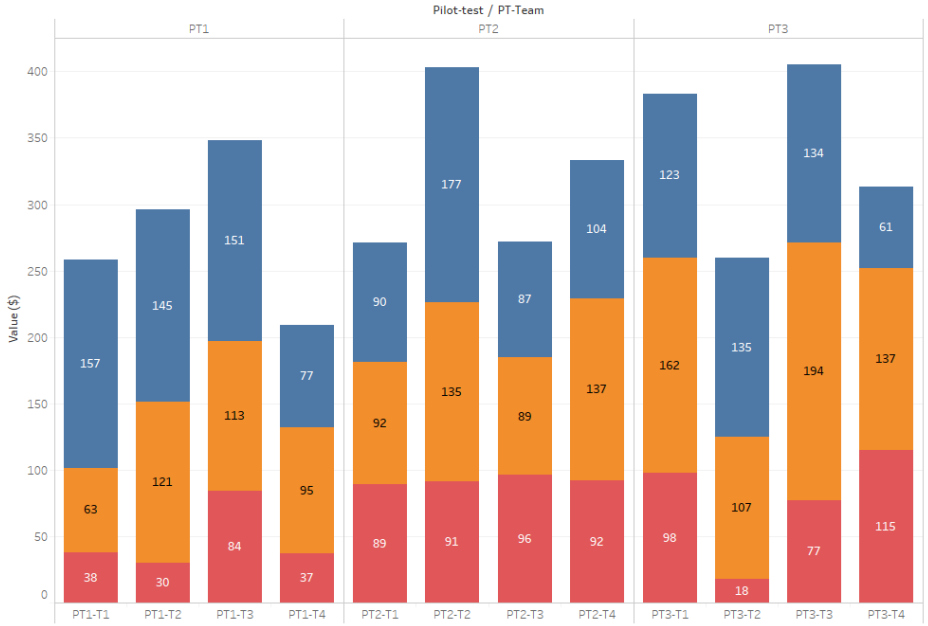

Figure 2 – Evolution of the money received by each team throughout the phases of the pilot tests. Pink – Phase 1, Orange – Phase 2, Blue – Phase 3.

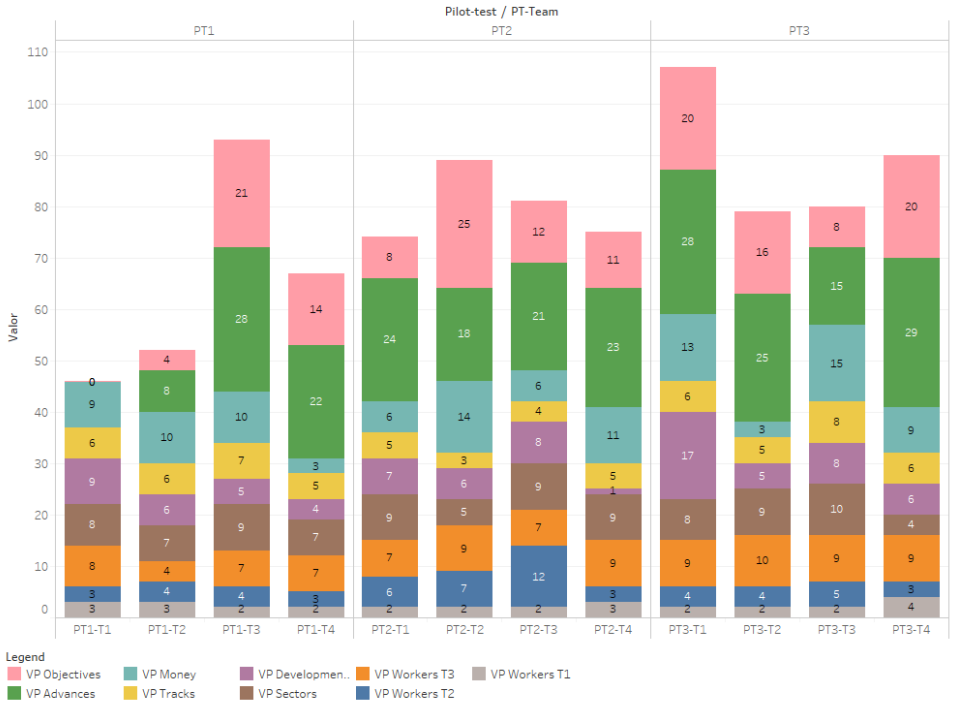

Figure 3 – Validation workshops and pilot tests of the BG i4.0

In total, in the 3 pilot tests held, 18 unique participants took part in the BG I4.0. One of the participants of the pilot test three did not answer the pre-questionnaire and was taken out of the response pool. Thus, the final respondents' sample is 17. In the post-pilot test questionnaire, participants were asked about their perception on the learning of the I4.0 topic they experienced through the game. The questions were presented as 5-point

Likert scale, ranging from "Completely agree" to "Completely disagree". An overview of the answers for this question is shown in Figure 4.

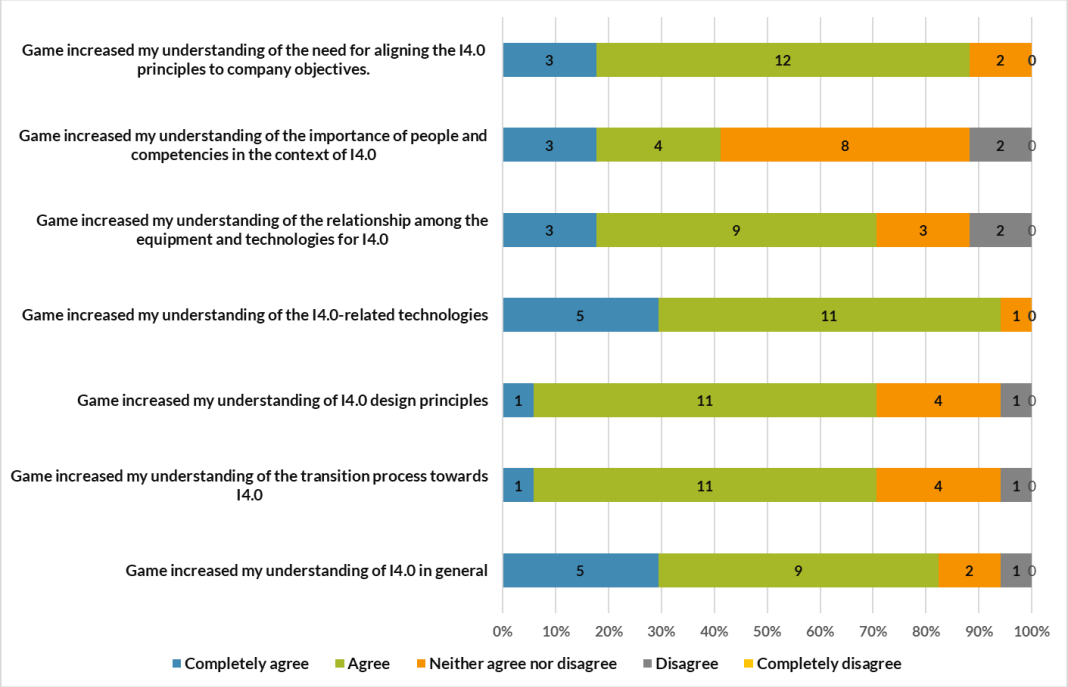

Figure 4 – Participants answers for the I4.0 understanding questions.

In the feedback questionnaire answered after the pilot test session, participants were prompted to comment on the positive aspects of the game and the areas in which it could be improved. These comments were analysed following the general inductive approach for qualitative data analysis (Thomas, 2006). Out of the 17 comments written by the participants a total of 57 segments were coded to 1 of 20 codes which were divided in two main categories (positive and "can improve" aspects). An overview of the 8 most recurrent codes (accounting for 71% of the segments coded) is provided on Table 3.

Table 3 –Participants' comments analysis overview

Category	**Code**	**Count**	**% Codes**
Positive	Overall positive impression of the game	9	17,31%
Positive	Understanding I4.0 aspects	7	13,46%
Can improve	Lack of time	5	9,62%
Can improve	Needs more theoretical background of I4.0 beforehand	4	7,69%
Positive	Game mechanics	3	5,77%
Can improve	Better explanation of the rules	3	5,77%
Can improve	Theoretical background for game components relationship unclear	3	5,77%
Can improve	Game too complex	3	5,77%
	Total	**37**	**71,15%**

Discussion

Regarding team's performance shown in Figures 2 and 3, it is possible to see that their income at the end of each game phase can vary significantly. Despite being a strong factor influencing teams' performance, money is not the only factor for winning the game. For

instance, in the pilot test 3, the winner team was not the richest. Additionally, the money received in the third phase of the game, for 7 out of the 12 teams, counterintuitively, decreased. This could be due to teams' increased investments that enable future higher incomes or technological infrastructure, but not in production elements that use that infrastructure. The VPs distribution shows, on average, that roughly 53% of teams' VPs were obtained for achieving objectives, advances and for the money left at the end of the game, which is in line with the learning goals of the BG I4.0.

As shown in Figure 4, the most undisputed questions are those related to the "understanding the need for aligning the I4.0 principles to company objectives" and "increased understanding of the I4.0-related technologies", with 88% and 94% of the participants indicating they agree or completely agree, respectively.

Furthermore, from participants comments, the most recurrent topics highlighted were related to an overall good impression of the game (17,3%), to the understanding of general I4.0 aspects (13,4%). Some areas of improvement indicated in participants' comments were related to the duration of the workshop (9,6%), too short for the game as it is, and the need for an overview of I4.0 concepts before the game (7,6%). Some examples of participants' comments in these categories are: "The evolution structure is very good; the game is thrilling and fulfils the goal to increase learning" – Pilot Test 2 participant; "I loved the depth on the theme that the game had" – Pilot Test 1 participant. "Maybe the duration of the game didn't allow a deeper discussion of the correlation between the objectives, advances, developments and resources" – Pilot Test 3 participant; "Concepts need to be presented for longer time for them to be completely absorbed".

Conclusion

Novel approaches for education and training in the field of operations management and engineering are increasingly popular. We report the development of a board game for teaching the design principles of I4.0. Throughout the design workshops the board game evolved significantly. The inputs received in the pilot tests are the last input for guiding the final improvements of the BG I4.0 that are already underway. The final version will be available for being used in a variety of contexts.

The iterative and interactive development of the board game for I4.0 education enabled the research team to identify and address a series of issues in terms of gameplay and mechanics. Overall, in the pilot tests, the game achieved its main learning goals of improving participants understanding of I4.0 principles, the relationships among the technologies, machines and departments and the transition process of I4.0.

Future applications of the final BG I4.0 in different contexts (technical courses, universities and companies) will be necessary to validate the final version of the game and provide further insight in the Industry 4.0 education particularities.

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Enabling problem-based education in collaboration with manufacturing companies

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Abstract

A focus on problem-based education is crucial as students need to complement academic knowledge with real-life projects. Several concepts in problem-based education have been tried over the years with focus on preparing students for working life. This paper aims at creating a list of recommendation on how to enable learning in problem-based education. To do so, we collect data in a problem-based course at Mälardalen University in Sweden. The resulting list of recommendations contributes with guidelines on what to do, and what to avid to successfully enable learning in problem-based education.

Keywords: Problem-based Learning, Production System Development, Education

Introduction

Problem-based courses has been on the agenda as an opportunity for real-life situated learning for many years (Brown Sr. and Brown Jr., 1997). Literature claims that problem-based learning is an important enabler of the way Operation Management (OM) students transition to working life, yet executing this type of courses places strains on actors compared to traditional courses at universities (Brown Sr. and Brown Jr., 1997; Nielsen, 2004; Bennis and O'Toole, 2005; Bak and Boulocher-Passet, 2013; Gorman, 2018). Therefore, *the purpose of this paper is to present a list of recommendation to enable learning in problem-based education with real-life manufacturing company student projects.* This paper analyses problem-based education from the perspective of three actors, students, companies and facilitators in an OM university course for engineering students. To reach this, we formulate the following research question: *how can challenges in problem-based education be approached to enable learning in OM course?* For the purpose of this paper, problem-based education means that students gain professional experience in a real-life setting to improve abilities to solve complex interdisciplinary problems and to learn how to communicate and collaborate with companies (Brown Sr. and Brown Jr., 1997; Nielsen, 2004). Teachers in problem-based courses has a facilitating role rather than exclusively giving lectures (Gorman, 2018), subsequently teachers are referred to as facilitators in this paper.

In problem-based courses, facilitators and companies experience challenges in time-consuming preparations starting months before the course starts, including the demanding phase of defining and scoping student projects, and setting up schedules (Gorman, 2010,

2011; Bak and Boulocher-Passet, 2013; Gorman, 2018). The actors, having intense interactions throughout the student project, are interdependent which requires the facilitator to manage the collaboration between companies and during the course (Nielsen, 2004; Bak and Boulocher-Passet, 2013; Gorman, 2018). Assessing the problems and challenges associated with problem-based leaning is an open issue in preparing students for working life (Bak and Boulocher-Passet, 2013). Contributing to existing problem-based literature, this paper presents three novel contributions by a list of recommendations providing, firstly approaches to managing problem-based courses, secondly present what to avoid in problem-based courses. Finally, the contributions are based on data collected from a course in OM.

Problem-based education in literature

In the review of problem-based education by Gorman (2018) indicate that the facilitators require a longer period of preparations for the course, for instance by undertaking a solicitation phase. Finding challenging and new student projects requires redoing the solicitation phase each year which is time-consuming compared to standardised lectures in other courses (Gorman, 2018; Konrad, 2018). Several contacts with companies need to be established, especially as the rate of accepted student projects from companies can be as low as 60% (Gorman, 2018). However, well-established industrial contacts are likely to come back for several years with new student projects easing up the workload for the facilitator. The student projects are scoped to include both the industrial partner's criteria, academic requirements and to make sure that the student projects are attainable for the time given in the course. Preparations are also made to ensure that student groups are formed and assigned to a case (Bak and Boulocher-Passet, 2013; Gorman, 2018).

According to Gorman (2018), the actors involved in a field-based course, students, company and facilitators experience challenges and benefits from participating in courses with real-life student projects. Companies that are unable to sustain the level of involvement and support required for the student project is risking the student project to miss the intended project or learning goals (Bak and Boulocher-Passet, 2013). Nevertheless, the learning experience from a student and academic perspective is still valuable (Gorman, 2018). The student projects ambiguity is considered to be a risk in that students can experience that the project is overwhelming and require more time than the course stipulates (Bak and Boulocher-Passet, 2013). A rigours project selection process done by the facilitator give the students direction on how to approach the student project. With further guidance on standardised documentation, grading and continuous facilitation, these risks can be limited. Facilitation can include supporting student groups to narrow the scope and clarify goals of the project (Gorman, 2018).

In problem-based education, the facilitator experience a risk in student projects as course ambiguity can results in an intense level of student group supervision, resulting in time-consuming activates (Bak and Boulocher-Passet, 2013). A release of time and resource of the facilitator can be achieved when student projects are self-managed and supported by the facilitator. Thereby being a learning opportunity in project management (Gorman, 2018). Furthermore, facilitators perform a tedious company solicitation and promotion, which requires business area acquaintance and contacts (Bak and Boulocher-Passet, 2013). Approaching companies on-site and creating groups of industrial partners as a long-term strategy can minimise the risks involved with solicitation. Indeed, resource shortage in the course can be addressed by increasing the credit scope of the course (Gorman, 2018). Finally, from a company perspective, there are risks associated with course participation as the resources required are challenging to estimate, especially in regards to the requirements of academic courses and expectations of student skills (Bak

and Boulocher-Passet, 2013). Generating a schedule and assigning supervisors, often experts, is challenging in a problem-based student project. The facilitator carefully communicating expectations to the company, such as course outline and schedule, can limit the aforementioned risks (Gorman, 2018).

Methodology

The purpose of this paper was fulfilled by analysing course evaluations and performing observations before, during and after a problem-based course. Initially, a literature review was conducted by searching databases such as Scopus and Emerald Insight with keywords like; 'teachings and learnings AND organisational management', 'Field-based education' and 'problem-based education AND organisational management'. Data was collected from problem-based course industrial excellence at Mälardalen University (MDH) in Sweden from year 2018 by observations, investigating course evaluations, facilitator's self-evaluation as well as conducting field studies by writing notes when visiting companies. The data was analysed in a seven-step process including both individual analysis as well as joint analysis sessions, see Figure 1. The purpose of step one through three was for the authors to individually analyse the data in terms of categories, perceived course dynamic based on the categories and to identify interrelationships of the aforementioned. Finally, in step four through six the authors compared results, presented an initial set of recommendation and supported findings with literature. The analysis was scrutinised iteratively to ensure reliability in the list of recommendation.

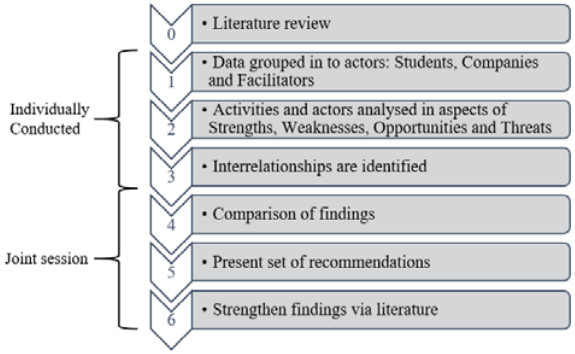

Figure 1 - Analysis Process

Mälardalen University

MDH is a public university college in Sweden, located in the cities of Eskilstuna and Västerås. MDH has a student body of 16 000 students in undergraduate programs ranging from two to five years of education. In the field of OM, MDH is concerned with education and research necessary for developing new products, services and production systems in a technically leading, economically viable, and environmentally sustainable way. MDH offers its production engineering students problem-base courses related to the development of production systems. In addition, students of this program take OM courses that help contextualise the development of production systems during their education. This program requires all production engineering students to pass the problem-based course industrial excellence. In this course, students meet twice a week for three-hour sessions during 16 weeks. On average 20 students, in their fourth or fifth year of education, attend the course every year. Student composition includes diverse nationalities with about a third of students from abroad and students with different background (product or production specialisation). Course industrial excellence has been

offered for five years in its current form.

Problem-based education at Mälardalen University

The problem-based course industrial excellence includes collaboration with five to six companies ranging in size from small to large manufacturing companies. The aim of this course is to give students a deeper understanding of how to apply knowledge from the field of OM and improve industrial processes. The course includes three tasks: understanding the competitive priorities reflected in a production system, analysing the steps involved in the development of a production system, and proposing an improvement to a production system based on Discrete Event Simulation. In addition, students analyse literature in areas manufacturing strategy, production system development and discrete event simulation in OM individually, and participate in a four student project during the course. Company representatives and course facilitators select and define a project and a schedule of at least three on-site student meetings is decided. In this project, student teams visit a company on at least three occasions to understand the problem, collect data and clarify or present partial results.

During the execution of the course, course facilitators provide lectures, supervisions, and feedback supporting students in their project. Students visit the company continuously and the companies are expected to support the students throughout the course. Furthermore, the facilitator require the students to present project status in set milestones as well as facilitating the projects and company collaboration.

At the end of the course, student teams submit an academic report to course facilitators and companies, and present their results to other student teams and companies. Collaboration with companies occurs in three phases including preparation, execution, and follow up. These phases occur prior, during, and after course industrial excellence respectively, and include different activities for each of the actors involved in the course (i.e. students, companies, and facilitators).

Analysis of problem-based education

This section describes the activities of the three actors in course industrial excellence (i.e. students, course facilitators, and companies) during the preparation, execution, and follow-up phases. In addition, this section presents a classification of strengths, weaknesses, opportunities, and strengths as perceived by students, course facilitators, and company representatives according to Osita et al. (2014). Correspondingly, strengths are characteristics of the course that gives it advantages over other courses to prepare engineering students for real life problems. Weaknesses are characteristics of the course that places the course at a disadvantage relative in preparing engineering students for real life problems. Opportunities means elements in the environment that the course could exploit to its advantage in preparing engineering students for real life problems. Finally, Threats are elements in the environment that the course could cause trouble in preparing engineering students for real life problems. In Table 1 - 3, the SWOT's are presented by abbreviations, thus only S, W, O and T are seen in the table. Each activity can contain one or all of the SWOT's depending on its analysed impact on the course.

Preparation phase

For the facilitators, the preparation phase consumes a generous amount of time and effort, similar to that of companies. Initially, visiting companies to find projects entails several meetings with company representatives that are either known by the facilitator, or new companies. As some visits ends without a project being formulated, this activity requires several iterations. However, time spent on visits ensure that the students projects are

tailored to the course and that the projects are indeed a real issue for the companies. Facilitators and company representatives analyze that these projects may be achieved within the duration of the course. Evaluation of student projects is a time-consuming, but the benefits are front-loaded activates and, the companies are able to see the project from a new angle by iterating cooperatively with the facilitator. The activities in the preparation phase are on the other hand, experienced as demanding and time-consuming. For instance, taking time off daily operations to define a student project, collect data, and later supervise students and evaluate results of the student project. Time spent on the preparation activities ensure clearer problem definition, purposefulness of visits and a manageable student project as well as student in-depth problem solving. Additionally, the iterative approach of defining the problem together with the facilitators is a learning experience regarding the company's ability to form student projects, see Table 1.

Table 1 – analysis of Preparation phase in problem-based education

	Activity (Preperation)	***SWOT***
Facilitators	Visit companies	S – Tailored project, that is a real issue for the company (also Gorman, 2018) W – Time consuming task (also Gorman, 2018) O – Allow students to experience real life situation, continuous collaboration opportunity T – Problem to find the right fit between company and student needs (knock on many doors before getting a yes) (also Gorman, 2018)
	Evaluate student project	S – Introduces an academic perspective to projects (also Gorman, 2018), (PSD, MS, DES) T – Scoping student project can be time-consuming and require several iterations (also Gorman, 2018)
	Help company collect data	S – Ensures that correct data is collected W – Defining suitable data can be challenging and companies may not know how to do it or may not have the resources O – To get to know the company for future editions of the same course T – Company can be reluctant to give data
	Manage company drop-outs	T – Drop-outs can cause last-minute projects that are not fully defined
	Define problem of interest by iteration	S - Front load activities and allow students to focus on learning and not scoping W – Time consuming O – Gain awareness of the type of competence required by industry T – As a result of a lack of time, facilitators may not be able to help companies scope problems to the right fit
	Divide students into homogenous groups	S – Groups are evenly distributed based on background, grades, and gender; Provides a diverse work environment W – Limited information on student skills O – Evaluation of students is simplified T – The respective problem-based projects requires well performing groups
	Define subjects of individual assignments	S – Make sure that there is a synergy between academic knowledge and a practical problem W – Time needed to collect relevant articles O – Give student groups insight on various topics
Companies	Find suitable student project	S – Tailored project, that is a real issue for the company (also Gorman, 2018) W – Time-consuming task (also Gorman, 2018) O – Allow students to experience real life project (also Gorman, 2018) , gain outside perspective on production issues, continuous collaboration opportunity (also Gorman, 2018) T – Can be challenging to find a project that meets the competence of students, time frame for the course, and not overly complex (also Gorman, 2018)
	Assign a supervisor	S – An assigned supervisor can support student projects (also Gorman, 2018) W – Time needed to put in to project (also Gorman, 2018) O – Evaluate and meet students as candidates for thesis and future work T – May not have sufficient time to supervise (also Gorman, 2018)
	Initial data collection	S – Support to get better end results and reduces the time students may otherwise spend collecting data O – Ensure usability of results and help scope the project T - Can be time-consuming
	Define problem of interest	S – Company can revise project with facilitator to find appropriate level W – The companies may oversimplify the problem O – New insights gained on own project T – In dynamic environments and highly dynamic projects there is a threat that the problem scoped in the beginning is no longer relevant, and therefore under-prioritized
	Develop a schedule for student visits	S – Companies have control of time spent and ability to schedule activates (also Gorman, 2018) W –Might vary between companies to a large extent in terms of accessibility O – Visits by students are planned and purposeful
Students	Ask for course references from former students	S – Former students with positive experience support new student to apply for course T - Student experience might be negative (due to high workload in course) thus projecting a negative view of course.

Execution phase

The role of the facilitator comes with challenges in managing the diversity in student

projects as well as addressing company-student collaboration issues. Time spent on this effort have benefits in academic results, solution fit to companies as well as in evaluating students. A set of course milestones support facilitating the student projects in a structured and controlled manner. Preparing students for the project creates a common view of the project, and how to approach the problem but also how to communicate with companies. Preparation by lectures and, especially, the individual assignment give the student a preconception of the topic at hand. The individual assignment, being a literature review on a topic related to the project, is demanding but the knowledge is useful for both project execution and report writing, see Table 2.

Students report that course industrial excellence is challenging and time-consuming when compared to courses that do not include a problem-based approach. For instance, *"the workload was very high"*, and *"[the course is] tough, but the experience could not be provided anywhere else"*. In addition, students report that the course is worthwhile as it leads insights about problems faced by manufacturing companies, and collaboration with companies in solving problems. Working closely with the companies is identified as an opportunity to learn about problem-based projects and how to manage, re-define, and execute the projects at companies. However, contact persons at the companies can be difficult to contact due to hectic schedules Presenting results to a company provide students with communications skills and students *"have learned how to communicate results directly to a company […]"*. Companies can however, fail to attend the university presentations and focus on on-site presentation at the company. Student report benefits in learning self-management and group work, *"You learned to plan and work on your own and in a group"* and to manage project setbacks, *"I learned how to make the best out of a situation"*. Furthermore, defining and adjusting the problem is a challenging task for students, but it is nonetheless an opportunity to learn about how production system-related problems are managed in real-life. Additionally, the opportunity to meet and learn about future employers is expressed as a strengths of the course, for instance, *"I would recommend it [the course] for learning about simulation and get company contacts"*, as one student said. Finally, students express that *"the teachers [facilitators] helpt us a lot*" and *"the course was structured and planned"* giving the students an opportunity to focus on project delivery.

From an academic perspective, students found that the assignments in the course add to the demand and time limitations of the course. However, improvement in writing and presenting complex problems in an academic way are identified as important learnings from the course. For instance, *"I learned a lot about manufacturing strategy, production system development and discrete event simulation. […] I learned to manage my time better and where my flaws are when delivering and finishing assignments, that is very valuable to me"*. Additionally, thesis preparation and managing a project are perceived as major learning outcomes. Student's experiences show that there is *"a lot of time spent on writing"* in the course, but the assignments contributed to the student's *"improvement on writing a literature review and connecting it to analysis"* and to *"learn how to write a report and prepare for thesis*". The assignments furthermore contributed to learning by *"[…] discussions among the group and teachers [facilitators] to get insight and perspective"*. For details, see Table 2.

The company's participation is planned to minimise the companies time in the course by only having three mandatory student meetings. This does however require the companies to make preparations prior to the meetings. Companies experience that the planned meetings are controllable, but some projects require adjustments and, the supervisor need to add more time to the project. On the other hand, the opportunity to evaluate students as future employees or potential thesis workers is seen as a major benefit

when collaborating continuously with students in several course activates. As a result, master theses can be developed as a continuum on the student's project, allowing the company to continue working with the students that performed satisfactorily. Finally, the execution phase provide the company with insights on student ability to understand and solve complex production system problems, see Table 2 for details.

Table 2 – Analysis of Execution phase in problem-based education

	Activity	***SWOT***
Facilitators	Confirm student projects with companies	S – Securing final projects and ensure that resources are in place W – Time-consuming task due to many projects O - Increase collaboration with companies, companies learn about academic viewpoint in project (also Gorman, 2018)
	Act as student project facilitator	S – Quality in student project execution is increased W – Many issues have to be addressed in project groups (also Gorman, 2018) O – Gain insight on student project management and ability to adjust projects that are off-track (also Gorman, 2018) T – Time-consuming task
	Supervision for individual and group assignments	S – Set deadlines facilitates report and assignment deliveries, progress can be monitored O – Support students in project execution T- Due to many project, each student project have specific challenges and prerequisites that need consideration/support.
	Solve student project group dynamic issues	S – Ability to combat issues hands-on as they arise W – Time-consuming, each student project is different O – Learn from issues to develop course/project outline
	Solve issues related to company-student collaboration	S – Issues can be manages instantly – adjusting project etc. W – Time-consuming (also Gorman, 2018) O – Show companies and students that they are supported T – Issues can be difficult to manage
	Grading of individual assignment and student project	S – Teach students how to write and read articles – preparation for report and thesis W – Each project is unique, hence a common grading system is not entirely possible O – Identify good students for future thesis or PhD positions
Companies	Meet students 3 times for: Workshop, interviews and complementary data collection	S – Time spent is limited and controlled, little time needed for supervision W – In some projects, more time is needed to form and support student project O – To get to know students and evaluate them T – Supervisor might become unavailable on predetermined times due to daily operations
	Provide feedback to students • Support students • Provide feedback on progress • Provide feedback on findings	S - To follow student project and address issues, gain insight on student project O - Learn how students work and perform, gain insight on novel student project solutions T - Might be considered time-consuming (also Gorman, 2018)
	Adjust problem for student project	S – Collaboration with students, self-evaluation of project W – Academic requirements can be challenging to interpret O – Gain insight on student ability to understand complex projects T – Active participation required, not just handing over a project (also Gorman, 2018)
	Provide additional data for student project	S – Support project for better execution and results W – Can be time-consuming, expertise might be needed T- Time and experienced personnel might not be available for a one-case problem-based courses
	Participate in final presentation of student project	S – Gain insight on project results, gain novel knowledge on current issues W – Can be challenging to interpret academic results O – Find potential candidates for employment – based in project execution T – results might not reach expectations, or be too far from initial problem statement
Students	Active participation in student project	S – Effective groups, collaborative learning experience, learn self-management W – Can be time-consuming due to group meetings and company visits O – Learn how to work with problem-based project on academic and company approach (also Gorman, 2018)
	Deliverables for Supervision and milestones	S – Deliverables ensure that sub-targets are met, and finally the report W – Students feel pressured to deliver continuously throughout the course O – Learn about problem-based project, and managing deadlines T – Students might skip supervisions due to high workload, thus lose learning opportunities
	Write an individual assignment on provided subject (in PSD)	S – Learn about topics relevant for project W – A lot of reading and writing is expected O – Become a better academic writer, preparation for full report T – Students can experience high demands for a passing grade (also Gorman 2018)
	Adjust problem for student project	S – Opportunity to collaborate with companies and gain insight on how to limit and adjust projects (also Gorman, 2018) W – Challenging to balance academic and industry expectations (also Gorman, 2018) O – Learn much about production system projects and problem-based projects in production companies T – Overwhelming amount of information can complicate this task
	Deliver individual assignment and student project	S – Learn to present results in a scientific way, preparation for thesis W – Companies can view report to be "too academic". O – Learn from feedback from company and facilitator on how to improve on writing and problem-based investigation T -Students can experience these tasks to be demanding and time-consuming
	Present findings to class and company	S – Learn how to present, and communicate, complex project results to both companies and academia (also Gorman, 2018) W –Academic presentations can be considered too stiff and complicated for companies O – To get feedback from both academia and companies on project management T - Students can experience company presentation as a daunting undertaking

Follow-up phase

Taking time in the follow-up phase to speak with participating companies give valuable feedback to the facilitator in regards to updating the course curriculum as well as to form closer relationships with the companies in both research opportunities and in preparation for next year's edition of the course. Feedback from companies is a valuable contribution on how to manage the partnering companies, student-company relationships and future versions of the course structure. Corse evaluation from companies and students are indeed of high value in problem-based courses, as the learning environment need to be improved each year to enable students to focus on learning and collaboration rather than surrounding issues. Companies add current industrial issues to the curriculum, but also gain up-to date knowledge on ongoing research in related areas. The final report and results contributes to the company with an outside perspective on the defined problem. However, as there are only a few points in time for collaboration, the companies might experience that the results does not match the initial student project. Nevertheless, continuous collaboration with the university and learnings from earlier student's projects can increase the possibility of valuable end-results from the project when planning for next year's student project. Additionally, student theses can spring from close collaboration. Details of the analysis can be seen in Table 3.

Table 3 – analysis of Follow-up phase in problem-based education

	Activity	***SWOT***
Facilitator	Contact companies to gain feedback on student projects	S – Continuous contact emphasises collaboration W – Can be time-consuming O – Increase collaboration and gain insight on student project execution T – Companies might be difficult to get in to contact with
	Re-evaluate/update course based on course evaluations	S – Insights from students and companies emphasise continuous improvement of course
	Submit grades	O – Teach students how to write thesis and work with company projects
	Grade re-examinations	W – No opportunity to change project outline for re-examination due to the nature of the project
Companies	Provide feedback to facilitators	S – Companies can contribute to course, thus adjusting course to company needs. O – To present concerns and improvement suggestions on student project and course
	Provide feedback to students	S - Can support students as future employees in self-development and project skills
	Evaluate findings from case	S – Gain insight on students approach to solve problems, learn about state-of-the-art in academia. W – Some project may not have come to the expected results O – Insights on own production from an outside perspective T – Report can be highly academic
	Consider participating in next year's course	S – Able to identify projects in advance and adjust well in time O – Continuous collaboration with university in research and student projects
	Follow-up on case contributions	S – Students can continue their project as employees or thesis workers. O – Can be an opportunity for an in-depth project based on student project
Students	Evaluate course	O – To express concerns about course structure and to give improvement suggestions for future versions of course
	Receive grade	S – Gain knowledge and feedback on what is expected from thesis work

Contributions and Discussion

This study contributes to previous research by providing a list of recommendations on how to enable a problem-based course, to do so we focus on three distinct points in time, preparation, execution and follow-up. This paper provide insight on outstanding challenges that hinders problem-based education. Furthermore, actions have been identified that can be taken to avoid the aforementioned challenges.

A novel contribution presented in the paper shows that the preparation phase in general is a prerequisite for successfully enable learning in problem-based education (Bak and Boulocher-Passet, 2013; Gorman, 2018). Efforts in this phase ensure that students can focus on problem solving, problem solving and achieving academic goals. Gorman (2018) suggested that this phase should be in focus, however, we present the novel finding

that company data collection is necessary to ensure that the student projects can get a short start-up and focus on problem solving. We presented that the individual assignment in course industrial excellence support the students in learning about subjects related to OM in general, but manufacturing strategy, production system development and discrete event simulation specifically. Additionally, the individual assignment prepare the students understanding of the company's context, which contribute to their ability to understand the current challenges. This paper suggest that the companies should be presented with a clear understanding of the course schedule and curriculum (Nielsen, 2004; Bak and Boulocher-Passet, 2013; Gorman, 2018) but going further, we suggest that a predefined set of student company visits should be decided. Three company visits during the course have been proven as a success factor for enabling students to focus on learning and problem solving and the companies to be able to manage the timeframe for the project. Finally, we contribute with a course structure consisting of a set of milestones throughout the course. The milestones gives the facilitator an opportunity to determine student project status and address issues in student group or student-company collaboration, whereas students have clear deadlines and can get support from the facilitator. In Table 4, a complete list of recommendations and what to avoid is presented, thereby answering the RQ; *how can challenges in problem-based education be approached to enable learning in OM course?*. The list contains all actors, but the focus is on what approaches are required from a facilitator's perspective in relation to the course actors.

Table 4 – List of recommendations on how to manage challenges in problem-based education

Challenges	**Recommendations**
Focus on long-term collaboration with companies	Keeping the company satisfied with student group performance, in delivered results and overall student and facilitator collaboration experience
Iterative project scoping process	Ensure project fit to company and academic requirements
Homogenous groups	Ensure student groups are multidisciplinary and group performance is higher as student levels are harmonised.
Data collection in the preparation phase	Students can focus on learning and project execution
Scheduled company visits	Students can focus on project, easy to manage by companies
Course milestones	Enables learning and student project execution
Student project iterations	Allow students to focus on student project execution
Individual assignment	Preparing students for project by gaining knowledge on subjects related to student project
	What to Avoid
Giving companies leeway on timeframe	Companies can ignore students and prioritise daily operations
One time company projects	Companies on long-term collaboration learn how to scope projects and knows how to priorities project and reap benefits, simplifying the solicitation process.
Using last-minute project	Usually ill-defined, poorly scoped and companies have not realised the required time needed for project execution
Company secrecy	Students cannot use or present results in the course
Letting students create groups	Can have a negative effect on company-university collaboration due to low performing groups

Conclusions

The purpose of this paper was to present a list of recommendation to enable learning in problem-based education with real-life student projects. This have been achieved by a list of recommendations and what to avoid in problem-based education stemming from a thorough analysis of course industrial excellence at MDH. Indeed, the preparation phase was identified as the most challenging for company and facilitator, but the reword in learning outcome and manageable student projects for all actors is worth the time of preparations. This paper would have benefited additionally by collecting data on how companies prepare the student project to understand the underlying reasons for engaging

in problem-based education. Additionally, an investigation of other courses in problem-based education, outside the production system development area, would have given an opportunity to compare data and verify results to strengthen our findings. For future research, we recommend additional courses in problem-based education to be investigate, and that companies should be more thoroughly investigated in order to understand how to engage them in problem-based education.

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Enhancing Operations Management Learning Environment Through an Educational Big Data Analytic

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Abstract

The teaching and learning modularity in the higher education environment of business and management studies are of the view that there has to be a linkage between institutional work-experience and classroom educational instruction. The teaching value of supervised industrial work-experience has become an important component of well-planned teaching environment of the operation management studies in most universities. Recently, Higher education teaching models opened new line of teaching and learning researches relating to the analysis of teacher and student engagement and experiences within the learning management systems (LMSs). The framework proposed in this paper may be used for further studies in this area; for example, to study lecturer behaviour patterns as well.

In the current paper, Author presents a case study conducted at the High Colleges of technologies in The United Arab Emirates for four academic years started from 2015 to 2018, where the High colleges of Technologies HCTs used both the institutional work-experience and classroom educational instruction as a two mood of delivering the operation management modules. The obtained results are demonstrated using visual analytic techniques, and evaluated in order to detect trends and deficiencies in the use of the LMS by teacher, experts and students.

Keywords: Big Data Analytic, Management Learning Environment, learning management systems.

Introduction

The significant amount of data extracted from these platforms provide fundamental information that can aid both teachers and students in improving their educational goals. One of the main problems of data relating to the activity generated by users through the use of learning management systems (LMSs) is the large volume of data available in the teaching and learning environment, and the different formats of these data, particularly for the management of unstructured data (Azmi & Singh, 2015; B. Daniel, 2015; Elhoseny, Elhoseny, Riad, & Hassanien, 2018). The present study aims at designing and implementing an analytical framework based on educational big data technologies, the present study defines the following steps to design the framework (Bogarin, Cerezo, & Romero, 2018; B. Daniel, 2015; B. K. Daniel, 2019):

- Data pre-processing, by studying the data to be extracted from the LMS and its storage in a big data platform.
- Da(Bogarin et al., 2018; B. Daniel, 2015; B. K. Daniel, 2019)ta analysis and identification of pattern recognition techniques that may provide value in the educational context.
- Presentation of the obtained results according to suitable visual analytics techniques and tools (Elhoseny et al., 2018) .

The authors have considered data processing guided by e-learning analytics in the high college teaching and learning environment, both are learning analytics and visual (Elhoseny et al., 2018; Fathema, Shannon, & Ross, 2015) . And it also aids the present work in data processing for discovering connections among students, teachers and the learning process, with the purpose of creating recommendations in the educational environment. The author proposes and analyses of the LMS data extracted from user events generated during four final complete academic years in all courses for the three learning modalities at the HCTs, amounting to 120 GB of data. The present paper evaluates whether the results obtained by applying a big data analytical framework to these LMS data aid in detecting tendencies and anomalies in the use of these platforms in any learning modality. Several on-campus degrees have been offered since 2001, and within the past five years, the HCTs have consolidated its teaching and learning offer with several degrees which teaching operation management in online and blended modalities. The present study uses The Sakai LMS[1] . Which has been considered as a resource management and collaborative platform for all of the training modalities (Elhoseny et al., 2018; Fathema et al., 2015; Grover, Chiang, Liang, & Zhang, 2018).

Related work

Using the LMS as an essential methodological tool in educational environment is the standard and generating new needs and fields of study to aid in the design of new analytical framework through the knowledge obtained from the LMS data. It provides a large volume of data, while also generating the need for intelligent tools integrated within the LMS that aid in their interpretation and provide feedback of this information. The identification of the student behaviour helps in developing new teaching methodologies that aid and improve both student and teacher performance by means of analysing the data provided by the LMS and other tools such as surveys (Huda et al., 2018; Kumar, Shankar, & Saravanaguru, 2019) .

Recently the educational data produced by LMSs have increased considerably. Therefore, the current framework the new challenges faced by higher education institutions analysis techniques for LMS data must evolve and adapt. The Big data analytics offer the opportunity to reach a higher level in the use of LMS. Thus, it is possible to convert complex, unstructured data into actionable information, thereby aiding in identifying useful data and transforming it into valuable information for higher education institutions. Furthermore, the literatures demonstrated the benefit of applying big data techniques in higher education, such as, in which the student learning patterns were searched based on data extracted from forum tools integrated in massive open educational online courses (MOEOCs) (Huda et al., 2018; Limongelli, Lombardi, Marani, Sciarrone, & Temperini, 2016; Lochner, Conrad, & Graham, 2015; Miller, Ganster, & Griffis, 2018).

[1] https://sakaiproject.org/.

Therefore, lecturers can make specific remarks based on the classification, while students can quickly find the required content. , then a big data-based analysis and monitoring tool that implements a scoring system for students in the LMS. The score of the teaching and learning classrooms represents the student participation in learning activities, and low scores usually imply poor student achievements. Finally, demonstrated that interactions (Nakamura, de Oliveira, & Conte, 2017; Rodriguez & Da Cunha, 2018; Shin & Kang, 2015)with learning environments can be modelled and measured effectively. The framework evaluated the behaviour of students attending videoconferences by measuring their level of attention based on face and eye observation, using an attention-scoring model (Simović, 2018; Sin & Muthu, 2015; Zaharias & Pappas, 2016).

Our work extends this research line on the adoption of big data for analysing LMS data. The present study present a framework based on big data technologies to analyse large volumes of data from events generated in the use of every learning tool available in the Sakai LMS for the three main training modalities: on-campus, online and blended (De Mauro, Greco, Grimaldi, & Ritala, 2018; Grover et al., 2018; Kumar et al., 2019; Rodriguez & Da Cunha, 2018).

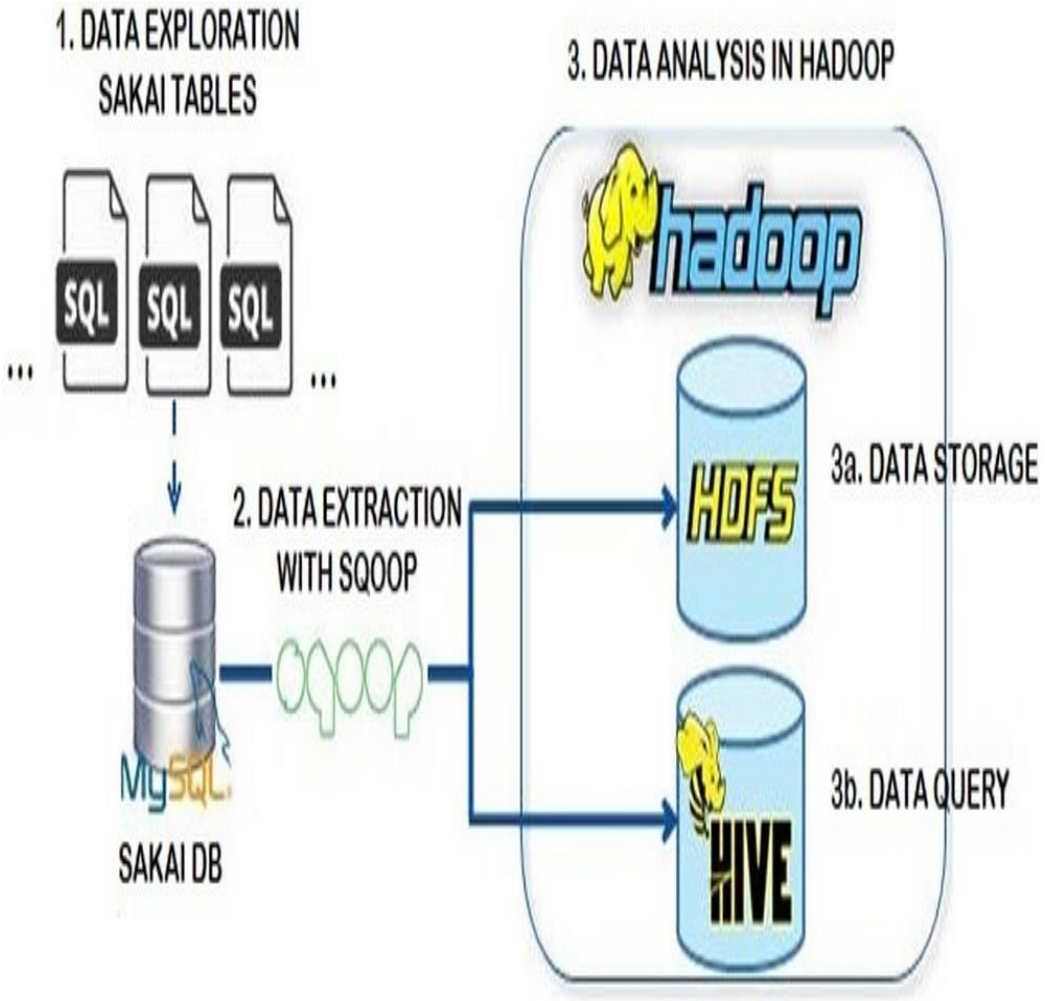


Figure 1 – Big data architecture for acquiring and storing Sakai data.

The proposed framework - on big data for analysing Sakai data

Data storage

In order to store the original working dataset in the Sakai LMS and extract it to a big data storage platform, a deep study related to the relevance of such tables with respect to study the student behaviour patterns were found to include the most important information for our study: Sakai_User, Sakai_Session and Sakai_Event.. Among these data are session id, event id, event date, and context (the course in which the event occurred). Relationships exist among these three tables, so it is possible to query session and event data for any user. Once the data sources have been selected, the data are anonymized in order to protect personal information such as names and emails. Next, the data need to be transferred from the Sakai database to big data storage. To this end, a big data solution based on Azure HDInsight[2] has been adopted, using its Hadoop distributed file system (HDFS) implementation. The tool used to transfer data from the Sakai database is Sqoop
(Shin & Kang, 2015; Simović, 2018; Sin & Muthu, 2015; Zaharias & Pappas, 2016)

Methodology

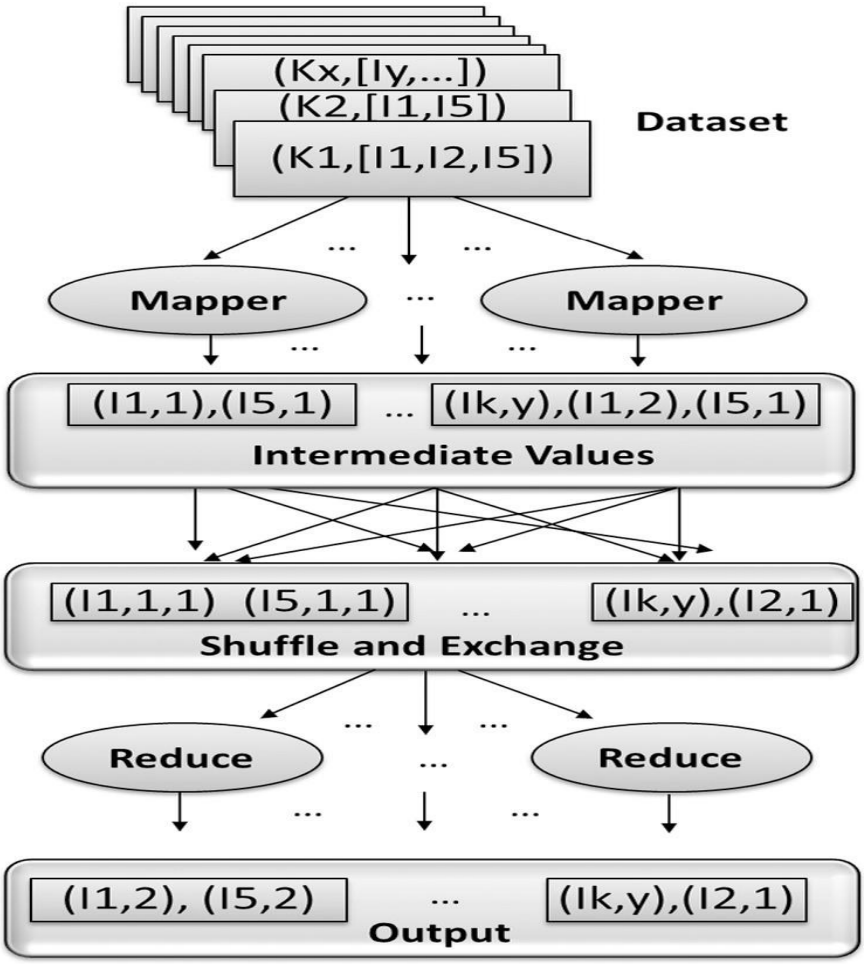
The present study performs a quantitative analysis using HiveQL, which is the ad-hoc query system for Hive. With this analysis, we are able to calculate the following information items.

- Tool ranking: This analysis studies the tools that are used more by each student in each session. A session is defined as the time lapse for which a student is connected to the elearning platform. For each tool, we analyse the most-used events per tool. Moreover, during this process, we analyse the correlation between events in a session. This correlation will be used and analysed together with the Apriority algorithm. The purpose of this correlation process is to determine which events are related during the same session, in order to determine student behaviour patterns. Therefore, the Pearson correlation coefficient is calculated by means of a Hive function (Gorur, Sellar, & Steiner-Khamsi, 2018).
- Event ranking: This process analyses the events carried out by a student in each course, in order to identify not only the most frequent events in each course, but also the absence of certain events. It is aimed at detecting courses with high or low activity, along with a global ranking of events occurring in each training modality.
- Event trends: The intention of this query is to analyse the timeline related to events of interest in the e-learning platform (for example, an event for connection to Sakai), in order to identify certain significant cyclical patterns. By using the *time series analysis* technique offered by Hive, it is possible to identify periods with high or low activity in the e-learning platform (De Mauro et al., 2018).

Conclusion

[2] https://azure.microsoft.com/en-us/services/hdinsight/.

These values are obtained using the methods provided by the MapReduce API and the capability of HDFS and Hive to handle this algorithm in a distributed manner(Fathema et al., 2015; Lochner et al., 2015).



The framework proposed in this paper may be used for further studies in this area; for example, to study lecturer behaviour patterns as well. It can also be employed in other fields, such as smart cars, to identify good (or poor) driver behaviours, or smart homes to study the energy usage of inhabitants.

Limitations and Recommendation:

The framework proposed can also be employed in other fields to identify good (or poor) driver behaviors, or smart homes to study the energy usage of inhabitants.

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Impact of Business-Students Subconscious in Ethical-Decision-Making

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Abstract

A usual management task in organizations is decision-making, and some of the most important decisions made by business leaders involve ethical components. Our behavioral-ethics-field research explores the business students (BS) subconscious influence in the ethical decision-making processes applying cases reporting ethical dilemmas. A questionnaire with neutral or non-neutral images acting as subliminal stimuli was administered to 30+30 BS trying to find out about the ethical maturity level in decision-making processes and the subconscious influences in these decisions. Cognitive biases and BS metacognitive strategies were identified when non-neutral images were present. The effects of subconscious in BS ethical decision-making are discussed.

Keywords: Business students, Ethics education, Business Ethical decision-making biases

Introduction

After so many corporate scandals in the global economic scenario, research on ethical behaviour has progressively growing within the business general area. Ethical decision-making (EDM) has increasingly gained significance in the management literature (Tenbrunsel and Smith Crowe, 2008) and now a broad and consistent body of research exist, either with a theoretical or an empirical approach. Business scholars and social psychologists nowadays are dealing with the emotive, instinctive, and intuitive reactions importance in EDM process (Dane and Pratt, 2007) and it seems that these intuitive and emotional processes (the moral intuition expression) deeply and firstly influence the decision maker in such contexts (Provis, 2015). In contrast, conscious and rational processes (the moral reasoning expression) in such situations may instead occur in a later phase to offer a 'rationale' or a 'sense' for behaviors and decisions undertaken (Haidt 2001).

Findings of Damasio (1995) clearly point to the fact that emotions are part of the decision-making process and they are necessary to make the decision choice itself. Other studies show

a link between emotional intelligence and decision-making process (Lumina, Scott and Bulent, 2011) as well as a relation of decision-making process and analytical-intuitive style of decision making (Sarmány-Schuller, Kuračka, 2012). Murphy and Zajonc (1993) studied the influence of subliminal stimuli in the ethical decision. Other author's evaluation addressing influence of subconscious in EDM in business find that under pressure, emotions rather than rationality affect the process of decision-making and without them, the decision would take a long time (Baron, Zhao and Miao, 2015).

The ethical decision-making in business, either as an intuitive process (moral intuition) or a traditional rational approach, might generate a conflict in a business strategic decision, between adding value and causing no damage. In fact, unethical behaviour might be a very attractive short cut to organisational success despite practice codes, regulation and social pressure (Bazerman and Tenbrunsel, 2011; De Cremer, 2010).

While the motivation for taking the most strategic decisions in business originates from various sources (such as competition, social responsibility, lost opportunity cost, sustainable policies, effect on resources, return on investment, image and brand impact, stakeholders, international policy), the final decision still resides with the main organizations' decision-makers. These deciding managers seek and evaluate information and alternatives before concluding. However, do the unconscious thoughts of those individuals affect the EDM process when dealing with complex decisions, delaying the aware conscious experience?

Rather than deriving from conscious deliberation or cognition, the EDM is often drawn almost automatically. It is like an instinctive impulsion, rather than a reasoned or calculated inclination. This type of impetus is consistent with large bodies of research on the prevalence of powerful, instinctive drives whose origins (be they psychological, genetic, epigenetic, evolutionary, or environmental) tend to elude consciousness (Dijksterhuis and Aarts, 2010; McManus, 2016; Zeni, Buckley, Mumford and Griffith, 2016).

Ethical decisions involve learning and knowing what is correct or incorrect, and only then does a sustained decision addressing the circumstances in evaluation arise. However, the *correct thing* is not as easy to find as the business ethics literature appears to state. So, how to increase the next generation of managers' consciousness towards sustainability and business ethics? Can ethics be taught and learned? EDM is an extreme learning-goal to achieve in BS formation because there is a latent BS tendency to instil a certain level of non-rationality into their decision-making when facing real business situations and it is deeply influenced by priming, subjectivity, and bias in one's memory and feelings (Huang and Ho, 2018). Thus, cognitive biases resulting from BS subconscious influence the EDM processes.

In literature, the extent to which subjective feelings (as the ones related with political ideals aversion/sympathy) influence managers and EDM moral judgements remains unclear. This constitutes a gap, which we address. This, along with the significance of EDM education in Business Schools, and the importance of subconscious in EDM of business students, who will be future managers, makes room to the following research questions:

RQ1. Are BS able to apply moral principles to business ethics issues in sustainability or corporate responsibility?

RQ2. Do subliminally presented stimulus influence ethical decision making in BS?

With these questions in mind, the purpose of our exploratory research is to identify biases in BS perceptions (under subliminal stimuli) and ethical decisions towards business ethics and sustainable operations in cases reporting ethical dilemmas. The chosen analysis tool utilized is an adaptation of the one developed by Brenner and Molander (1977).

Literature review

Ethics in business world

Ethics is an "inquiry into the nature and grounds of morality where the term morality is taken to mean moral judgments, standards and rules of conduct" (Hunt and Vitell, 1988). It deals with what is morally correct and incorrect. In business, ethics embraces not only the moral values and responsibilities of the profession itself, but also the existing values and expectations of the larger society (Michael, 2006). Considering business ethics (BE) all decisions should be made, taken and defended based on underlying moral philosophy and these moral philosophies present guidelines that allow both, conflicts resolution and the optimization of mutual benefit of people living in groups (Ferrell and Fraedrich, 1991).

The ethical decision-making process consists of (i) ethical awareness, (ii) ethical judgment, and (iii) ethical action (Lumina et al, 2015). The first step involves recognizing the ethical nature of the situation at hand, a task that activates specific parts of the brain associated with emotional processing. Awareness will more likely arise if prompted by social environment, ethical language "framing" the situation, or the potential for serious harm to others. As with awareness, neuroscience research is finding that ethical judgment is a unique form of decision-making. Cognitive biases often block an ethical judgment, impairing how to gather facts, how to think about consequences, how to evaluate integrity, and how use intuition. Unconscious biases affect how to valuate different people (e.g young/old, black/white), and emotions while necessary for ethical judgment can interfere with good decision-making when they overcome the rational ability (Lumina et al, 2015; Robert et al, 2015; Vykinta et al, 2013). Managers should use these cues to promote ethics.

Doug Wallace and John Pekel (2006) explain that attention to business ethics is critical during times of fundamental change – times much like those faced nowadays by businesses, either non-profit or for-profit. In this context, values that were previously taken for granted are now strongly questioned and many of these values are no longer followed. Consequently, there is no clear moral compass to guide business managers and leaders through complex dilemmas about what is right or wrong. Nevertheless, ethics in the workplace should be part of decision making of both leaders and staff. Perhaps, most important, attention to ethics in the workplaces helps to ensure that when leaders and managers are struggling in times of crises and confusion, they retain a strong moral compass.

The business world today and its related scientific and technical professions have a special responsibility both in this regard and in operations under a TBL approach. In fact, the knowledge and technologies that are developed have huge impacts on natural environments, economies, and on the empowerment of citizens and societies. Moreover, their efforts to succeed in a highly competitive, global context and the attained achievements continue to produce both positive and negative effects, at present, as well in the future.

Numerous issues are threatening businesses – from financial crises, to climate change from local land issues to financial lobbying. Companies face difficulties to set appropriate strategies and operations for sustainable innovation in an environment of tough competition. Moreover, several issues can cause a breakdown in business ethics, such as lack of integrity, organizational relationship problems, conflicts of interest, and misleading advertising. Thus, companies need guidance on how to evaluate the implementation of a strategy, both for disclosure purposes, for strategic planning and for sustainable business managing.

An ethical culture might support sustainable growth by adding value to a brand, whereas failure in ethics may cause social, economic and environmental damage, undermining the

company's long-term development. Thus, ethics must be embedded in business models, organisational strategy and decision-making processes. Despite business people awareness of the requirements for ethical decision rules and moral behaviours, some contexts are sufficiently compelling for almost anyone to engage in unethical behaviour (De-Cremer, 2010). Short-term gains, incentives and temptation may promote an ethical dilemma in the decision and decision process of an individual (Tenbruse and Smith, 2008). Despite codes of practice, regulatory oversight and ever-increasing public pressure, multiple control and monitoring systems, the decision-making process in many firms routinely ignores ethical considerations (Bazerman and Tenbrunsel, 2011). This can undermine the wider economy, the society values and cause irreparable damage. Therefore, the resulting massively profitable entities, despite their impressive initial results, may turn out to be unsustainable.

Applying ethics to business and to operations management is a particularly vital endeavour, as this field provides one of the few forces that can serve as a counterweight to profit seeking and self-interest by balancing the ways in which managers' act, the policies they approve and the role companies play in society (Brenkert 2010). This is, therefore, an attempt to ensure that the operations function is taking a forward and progressive sustainable approach, not damaging the consumer or the society and ensuring an economic welfare. This is far from being a simple, easy and peaceful task.

Moral Decisions and the Subconscious Effect in EDM

Moral decisions abound in organizations: builders choose between durable and cheap materials; salespeople choose to reveal or conceal available discounts; and accountants decide when creative becomes deceptive. The adverse effects of unethical-decisions upon individuals, organizations, businesses, and society are substantial: employees lost jobs, retirement funds, and health benefits; stockholders lost share value; consumers' corporations boycotts increase; and suppliers lost significant business.

Corporations' scandals such as the Volkswagen's emissions or the Facebook scandal drew attention from public to unethical business conduct and heightened the interest in EDM, raising obvious questions about the basic, underlying causes of these corporations' decisions. Research on EDM in operations-management (OM) is incipient. EDM is a very complex process and even though some influencing factors have already been recognized (such as gender, culture, and organizational aspects), an effort to identify all factors that contribute to ethical decisions in corporations – and which may be relevant in OM – is not readily apparent in the literature, which constitutes another knowledge gap.

Master's Business-Students (BS) are the future generation of managers and constitute an important group with strong potential impact on the everyday business practice. Therefore, it is essential to identify on BS, (a) the ability to draw up and defend arguments on specific business ethical decisions; (b) the potential barriers to these decisions; and (c) the factors that may short-circuit the EDM process through reductions in moral issue recognition, minimization of moral judgments or the feeling of no obligation to act upon a moral issue.

Some authors argue that Ethics-Education in-Business-Schools could improve the students' moral reasoning, which is an essential driver of EDM (Almeida and Silva, 2016), and foster the ability to ethically evaluate questionable situations, and to make ethical-decisions, by taking appropriate actions (Baker, 2017). However, as we state earlier, EDM is a very hard achieving learning goal due to the influence of priming, subjectivity and individual's memories that involuntary bias the decisions (Huang-and-Ho, 2018). This irrationality further generates a dilemma in decision-making in ethically questionable issues

because such decisions are associated with an individual's empathetic and emotional responses towards the situation.

In addition, biased beliefs frequently lead to wrong decisions, discriminatory action, and inhibit emotional, ethical and cognitive development. Such beliefs also serve as perceptual screens that constrict thoughts, limit experience, and diminish the possibilities of constructing useful meaning about real circumstances (Greene, 1995). The process of making meaning which supports the EDM regarding ethical issues, is a situation that it is limited by previously associated positive, negative or neutral connotations (moral, social, cultural, political, or environmental values, among others) held in one's mind (Almeida and Silva, 2016). To propose problematic business situations in a class, which raise strong ethical issues *vs* economic development importance, provides dissonance (Jarcho, Berckman, Elliot and Lieberman, 2011), and contradiction (Newark, 2018) if a quick decision regarding the problem is requested to the students. Such dissonance is an internal imbalance that causes students to seek new understandings to restore cognitive equilibrium (Piaget, 1970).

Our interest in finding dissonances and contradictions amid a BS ethical decision-making process comes from the established view, that behavior, in general, and decisions, in particular, are directed by goals (Dijksterhuis and Aarts, 2010) that if not well defined or not, they could be triggered by underlying factors. The concept is simple: goals drive persons to pursue required end states, such as improving life quality, the accomplishment of a duty or find an answer for a dilemma. Research on goals has highlighted the intentional, conscious search of end states. For a long time, it was nearly contradictory to propose that goal pursuit may well occur outside of consciousness since all decision-making process were placed at the level of consciousness. Still, some authors have demonstrated that goals can be inevitably activated by environmental/external cues and then shape behaviours and decisions without any apparent intent or awareness (Bargh et al., 2001). Also, such nonconscious goal pursuit and the related decision-making process are widely considered to be an example of a class of mental processes not reachable to conscious awareness (Dijksterhuis and Aarts, 2010).

Based in the literature review about understanding the nonconscious goal pursuit and EDM process (Bargh, Gollwitzer and Oettingen, 2001; Carlson, Tanner, Meloy and Russo, 2014), two most common proxies could be identified: (i) explicit behaviors known to be driven by the goal in question, and (ii) reaction to goal-related words or images in a lexical decision task. While such proxies are enough for underpinning that a nonconscious activated prime trigger a hypothetical change in behavior (response and decision making), they are less useful for identifying which specific goal, from a potentially large set of possibilities, was activated by a congruent or incongruent environmental stimulus, such as vivid situation (Craigh, 2004), visual threats (Liu et al, 2018), or any stress-leading condition (Janak & Tye, 2015). In Business, individuals do differ noticeably in their ability to recognize and deal with managerial and ethically divergent questions, a difference that has been linked to variability in perceived arousal (Barrett, Quigley, Bliss-Moreau, and Aronson, 2004), emotional awareness (Craig, 2004), and emotional intensity (Herbert, Pollatos, and Schandry, 2007). According Schnall, Abrahamson, and Laird (2002), individual differences in the perceptual abilities influence the way people experience emotions that trigger the making of decisions.

Ethical Business Teaching in Business Schools and its impact in BS

Ethics involves learning what is correct or incorrect, and then make a sustained decision addressing the correct thing. However, the correct thing is not as easy to find as the business

ethics literature appears to state. So, how to increase the next generation of managers' consciousness towards business ethics and sustainability? Can ethics be taught and learned?

Business schools are important drivers of the economy, government, business and the whole society (Vilas-Boas and Leandro, 2014). Consequently, business schools should pay attention to the world's important issues as their graduates play an important role as initiators and managers of the global society (Araç and Madran, 2014; Vilas-Boas and Leandro, 2014). Accordingly, business schools have the intellectual capital, creativity and entrepreneurial vision to contribute to powerful solutions that are globally needed (Maurizio et al, 2013).

The business world not only has a financial crisis issue, but it also struggles with problems such as resource depletion, deforestation, climate change, wealth/power distribution, poverty, hunger, social and gender exclusion, domination by corporations, market domination, religious conflicts, media domination, mass epidemics, decreasing biodiversity, and lack of education (Almeida and Craveiro, 2011; GI, 2015). In this framework, business schools have a critical role to play in choosing whether to focus on market share, international opportunities, competition and increasing profit, or emphasising social benefits and a caring society to solve urgent global issues (Rayment and Smith, 2013).

Knowledge, skills and attitudes are significant components of management education for fulfilling both paradigms: business ethics and sustainability in operations. The main expected outcomes from these components, are as follows: graduates that comprehend business ethics issues, that have the skills to act in an ethical framework, and that have the right attitude to make a better world, both personally and as business people (Stubbs, 2013).

Case Study - *Methodology*

Design approach

This research purpose is exploratory, mainly because the scope of the study focus on the situation under analysis and no concerns for generalization are made explicit at this stage.

The study was conducted using a purposeful sample of 60 business students from first-year masters' (MMST [i]) students in ISCTE Business School[ii]. ISCTE-IUL is a medium-size Public University located in Lisbon, and its Business School has already been recommended for AACSB accreditation[iii]. A short case-study regarding corporation's ethical, sustainability issues and final corporation decision was purposefully introduced in a coursework to seek the extent of the influence of subjective feelings in moral judgments and in EDM of BS, when faced with a corporation ethical dilemma. BS were randomly assigned to two groups before being subjected to case study presentation which presented subliminal stimulus, i.e., either neutral (Group and scenario A) or highly politicized (Group and scenario B) images concerning the topic under discussion. A questionnaire developed for a business case study was designed considering the RQs described above. BS ethical decision taken under competitive pressure in business (the case study), influenced by political feelings triggered by subliminal images, was operationalized as a manipulated variable while the variables were self-reported. This approach allowed us to analyse each of the observed variables in both Groups, with high and low subliminal-induced competitive pressure in decision-making. In the case study presentation, we used a vignette approach with two scenarios representatives to manipulate competitive pressure and examine students' responses to a typical ethical dilemma in global world: to drill or not to drill oil in an environmental protected area, source of regional wealth through fisheries and ecotourism. Business managers often must balance their responsibility to meet the profit goal of the organization they are working for with the

legitimate interests of other stakeholders (Lund, 2000). The scenarios depict the conflict of interests of local fishermen's, ecotourism entrepreneurs and residents that are interested in higher standards for the environment and safety versus the vested interest managers and stockholders have in the economic success of their Oil company investment. Subjects had to decide whether to allow the prospection, which could be destructive to the environment and potentially hazardous for marine ecosystems. Two scenarios reflected different degrees of competitive subliminal pressure (CSP) for this decision. The two vignettes contained the following basic information: Whereas the impact of the decision to drill or not to drill for oil is the same in both scenarios for the ecosystem and the local community, the CSP was designed to be higher in scenario B. All subjects were presented with both scenarios allowing us to analyse their responses in both high and low CSP situations. Each questionnaire (A and B), with the same questions and the same case, contained the respective scenario (Group A: low-profile images, with a null political connotation; Group B: powerful images, with a strong extreme political connotation) and a total of 5 questions. It took most respondents between 30 and 45 minutes to complete the answers.

The undertaken evaluation used a framework to analyse the contents of BS considerations. The research follows a grounded approach, emphasizing the understanding of the subjective feelings effect in BS perceptions from qualitative data gathered as shown above.

Sample and Data Gathering

The data were collected in 2019, few months after the social upheaval that resulted from the approval given by Portuguese Environment Agency (PEA) to the ENI/Galp consortium to carry out an oil prospecting survey in 46 km off the coast of Aljezur, in a protected area, without Environmental Impact Assessment[iv]. It was not a blind-prospection since a study made by the consortium for the exploration of the Vicentina coast estimates a potential recoverable volume of oil ranging between 1,000 and 1,500 million barrels, equivalent to 17 years of oil imports, with a clear impact on Portuguese trade balance.

In a class of the 1st semester, BS were asked to answer a few questions about a business ethics situation, and to give their opinions about the presented case. The administration of the questionnaire included a cover story of the case suggesting that the purpose of the study was to survey students pertaining to global business issues. Participation was mandatory.

Findings

There are three dimensions' individuals should bear in mind to make ethical decisions (Betzgen, 2007; Lumina, 2015). (i) Awareness, i.e. the ability to define and describe ethical issues and, to recognize and analyse the impact of the ethical decisions, which concerns the ability to anticipate second and third order effects a very important element of strategic thinking (addressed in RQ1); (ii) Judgement, i.e. the ability to objectively look at alternatives, and reasonably decide what is adequate to the specific situation (RQ2).

Next subsections present the findings obtained within the research scope.

Preliminary Data Analysis

A manipulation check was conducted to evaluate the ability of the vignettes to increase perceived CSP. Data were treated and examined by using the content analysis framework of Brenner and Molander (1977). Our conceptual approach was based on behavioural models. We created a coding scheme with two main categories: 1) The BS identify and interpret conscientiously ethical issues; 2) Presence of cognitive biases due to influence of CSP on BS

EDM. The BS analyse and appraise ethically the decisions in the business case study. The sub-categories were derived inductively from the data. Inductive coding was used to ensure that our analyses comprehensively represented the content written by the BS. The categories were ordered within a taxonomy, where each category received a specific definition. The codes were developed successively and were revised or deleted and new codes added as the analyses proceeded. Table 1 contains the comparison of mean scores for the two scenarios. For all four variables, respondents perceived significantly more CSP in scenario B, indicating a successful manipulation.

Table 1 – Manipulation Check of Competitive Subliminal Pressure (CSP) of Scenarios A and B

Variable	***Group A Low CSP Mean***	***Group B High CSP Mean***	***t-value***	***Sig***
Pressure to act in the best interest of the consortium	2.535	3.333	10.717	0.000
Pressure to be responsible for the well-being of Ecosystem	2.686	5.535	10.310	0.000
Pressure to act in the best interest of communities	2.478	2.937	6.162	0.000
Pressure to act in the best interest of stockholders	2.484	3.066	7.092	0.000

Ability to define and describe Ethics and Sustainability concepts (RQ1)
Prior to the presentation of the ethic case study, the business students exhibited awareness of Ethics and Sustainability concepts and related frameworks. The answers showed a good ethics notion (90.4 %, considering the answers with minor errors) *vis-à-vis* the result achieved when BS address the sustainability notion (71.3 %).

Ability to recognize and analyse the ethical decision impacts (RQ1)
One might conclude for a general agreement across the two BS groups, from the perceptions of students concerning ethics issues reported in the presented case study. The majority of students (89.8 %) clearly pinpoint the problems in the presented case studies. In contrast, 10.2 % fails to adequately address the problem. The "Yes" sample of students concerning their ability to analyse the ethical impacts of the decisions rooted in the case study scenario (89.8 %) was further detailed. The results identified the differences amongst students' responses, as follows: more than half of business students (BS) succeeded in making a correct reasoning and around one third has also achieved good results, but with minor errors.

The Impact of CSP on Ethical Decision-making (RQ2)
Table 2 provides the data addressing RQ2 (Do subliminally presented stimulus influence ethical decision making in BS?). The increase in CSP had a major impact on students' EDM behaviour and ethical appraisal of the case study resolutions.

In the Group A, with scenario A (low CSP) it was noticeable that there is a slightly advantage to supporting drill decision, with BS presenting reasonable/weighted arguments and evidence to justify their opinion. However, in the Group B (high CSP), the one with extreme political connotation images, only 30% of BS were willing to drill, against an overwhelming consensus among the BS that use strong arguments to reject the oil prospection, defending the environment and populations.

Table 2 – The Impact of subliminal stimulus in BS ethical appraisal of the case study resolutions

	Group A Low CSP Mean			***Group B High CSP Mean***		
	Drill	**Do not Drill**	***Total***	***Drill***	***Do not Drill***	***Total***
All students	16	14	30	9	21	30
%	53,3	46,6	100	30	70	100

The gender variable was not considered at the beginning of our research. However, a brief cross-tabulation analysis was conducted. Comparing male and female BS answers, it was found that in both low and high CSP situations males were more likely to drill than females.

Discussion

Ethical behaviour and intentional behaviour found two different scopes: individuals making both intentional and unintentional, and ethical and unethical choices (Tenbrunsel and Smith-Crowe, 2008). For instance, research in decision-making attitudes reveal that good people occasionally do bad things (Bersoff, 1999), and may not even understand that they are doing wrong decisions. Studies on ethical fading (Tenbrunsel and Messick, 2004) asserts that people do not see the moral components of an ethical decision, not because they are morally uneducated, but because psychological processes fade the ethics from an ethical dilemma.

Based on the findings, we argue that despite BS having revealed reasonable level of ethical maturity and perceptions towards sustainable practices in business (sustainable operations management, corporate and social responsibility, and organizational environmental impact) they do not display consistent answers and BS do exhibit notorious ambiguities concerning the perception of ethics importance in business. The BS answers related to the presented case study reveal a strong love-or-hate feeling and a compulsion to extreme their decisions considering the problem resolution if previously submitted to a specific subliminal stimulus.

We suggest that, when specifically triggered, EDM could rise in BS from depths of nonconsciousness thought. BS behaviour and decisions are guided by targets and targets drive them to pursue. For the most part, research on goals has emphasized the intentional, conscious pursuit of targets toward end states (Dijksterhuis and Aarts, 2010). However, our results comply with other researchers demonstrating that decisions are activated, automatically, either by environmental cues or by subliminal stimulus, and then influence behaviours without any apparent intent or awareness (Bargh, Gollwitzer, Lee-Chai, Barndollar, and Trötschel, 2001). Some authors (Dijksterhuis and Nordgren, 2005; Hassin, 2005; Kastrup, 2017) state that the unconscious has the means to perform every fundamental high-level cognitive function performed by consciousness, such as cognitive control, pursuit of goals, information broadcasting, and reasoning. This large amount of unaware operations that the brain can perform is not disconnected from but has an important impact on the aware operations. Other findings show that subliminal information, such the above referred, can drive executive functions (Lau and Passingham, 2007) and that subliminal priming of stimuli changes how one's felt about an issue when he is dealing with (Monahan, Murphy and Zajonc, 2000). Other examples confirm the fact that the unconscious plays a significant role in shaping the conscious experiences, like attributions of agency (Aarts, 2007), actual choice (Strahan, Spencer and Zanna, 2002), and even political attitudes (Hassin, Ferguson, Shidlovski and Gross, 2007). Corroborating that premise, our results show answers with a

strongest reaction justified through sound reasoning, either supporting or rejecting the prospection, in the Group B, were non-neutral images stood present. The students use strong party-political claims either to reject the oil prospection, defending the environment and populations (most of the BS) as to defend the consortium and the need to explore Portuguese natural resources which could trigger the hoped-for economic development (30% of BS).

Stepping back to consider what we have previously presented as regards the answers and mental frameworks responsible for business students' EDM behaviour and ethical appraisal of the case study resolutions, the type of incidental emotion carryover observed appears most consistent with what Wilson and Brekke (1994) refer to as *mental contamination* and Arkes (1991) calls *association based errors* – processes wherein swaying, such as the BS cognitive biases resulting from subconscious influence (incidental emotion carryover) arises because of mental processing that is unconscious or uncontrollable. Thus, the best strategy for reducing such biases would be to control one's exposure to biasing information in the first place. This is a difficult task for the decision maker, mainly if it is a student, a BS, with all the immaturity inherent in his young learner status.

Conclusions

As regards RQ1, business students can use common sense to understand the idea of Ethics in its majority (≈90%), while only ≈70% showed awareness of the Sustainability concept. On the other hand, from the ≈90% of the students that were able to recognize the problems in the presented case studies, more than 80% could make a correct reasoning and show potential to analyse the impact of ethical decisions. This exhibits a natural ability to apply ethical principles and ideas to business ethics.

As to RQ2, business students Groups exhibit stout ambiguities in the perception of the case issue revealed in different behaviours and shown in their answers. This leads us to conclude that the subliminally presented political stimulus influence students' EDM, and BS compliance or defiance with the decisions presented in the case study. We also intend to stress the hypothetical BS easiness feeling of take this "guts-feeling" as guarantee of a quick and fair decision without considering all the facts since, unconsciously, BS perceive some of them as not being in line with unconscious thoughts, memories, feelings, and wishes.

We suggest some syllabus developments in business schools, in order to introduce a robust conceptual basis concerning ethics, ethical decision and sustainability, the cornerstones of sustainable business models. The presentation and discussion of cases concerning corporate scandals and unethical behaviour corporations, could overcome this weakness. It will be also useful in order to minimise the problem of subconscious impact in ethical-decision making and the resulting cognitive biases.

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A3- vs. 8D-report
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A case study for the investigation of the effectiveness of problem solving methods within assembly

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Abstract

The purpose of this paper is to demonstrate the effectiveness and applicability of the most popular problem-solving tools, the A3-methodology and the 8D-methodology. To investigate which method is more effective for internal problem-solving within a company the model factory in Koblenz developed a pre-test of a case study to investigate the following research question: “Which of the selected problem solving tools is more effective”. This investigation serves as a first pre-test of the case study. Data were analyzed statistically by descriptive statistics and hypothesis tests and showed only minor differences due to the application of the two methods.

Keywords: A3-methodology, 8D-methodology, quality management

Introduction

Businesses are confronted with the challenges of globalization and technological progress. These megatrends are accompanied by increasing customer requirements. To meet all these challenges, companies need an effective process management (Dombrowski/Crespo, 2008). For an effective process management, the philosophy of lean management is increasingly implemented in companies. Part of lean management is the continuous improvement of processes. This requires not only a problem detection of the process by the employees, but also root-cause analysis (Sobek/Smalley, 2008). For problem-solving, a structured approach is recommended (Schmitt, 2015). For this purpose, a numbers of methods have been developed which offer a structured approach. The most common methods are the A3- and 8D-method, the PDCA cycle (Plan-Do-Check-Act), Six Sigma and TRIZ (Theory of Inventive problem solving) (Cloft et al., 2018). Literature review shows that the A3- and 8D-method are the most widely used approaches in practice (Schmitt, 2015). Both, A3- and 8D address the same purpose. They aim to provide a structured approach for a problem-solving process (Gisi, 2018). However, there is no evidence within literature which of the two methods is more efficient and more effective or better applicable. The academic study aims to close the research gap by systematically analysing a problem-solving process and answer the following question.

"Which of the selected problem solving tools is more effective?"

For this, a pre-test of a case study which supports the assessment of the usage of the problem-solving methods was developed. An assembly process was simulated and a fictitious problem-solving process initiated. With the help of quantitative data, first insights about the effectiveness and applicability of the A3- and 8D-method can be obtained. Thus, we receive first indications about the effectiveness of the most common problem-solving methods.

Literature Review

Almost every company faces problems and complaints. For this, companies have often developed their own problem-solving process (Cloft et al., 2018). But not every process ensures an efficient and sustainable problem-solving. That is why companies often rely on the most common problem-solving methods: The A3- and 8D-method (Schmitt, 2015).

A3-Report

The A3-method is a lean management tool for problem-solving and was introduced by the Toyota Motor Corporation (Leyendecker/Poetters, 2018). The result of the problem-solving process using the A3-method is the A3-report. The term A3-report describes the documentation for the methodical guidance of a problem-solving process (Kroeger, 2018). The report is used for the communication within the organization and is based on a single DIN A3 sheet (Liker/Meier, 2008). It was decided to use a DIN A3 sheet as this is the largest format that could be faxed (Liker/Meier, 2013). It not only forces the employees to make assumptions, but also finding the real cause of the problem by analysing the initial situation (Liker/Meier, 2008). The aim is to obtain a representation in which a specific problem as well as all relevant activities and contents for a solution are mapped (Dombrowski/Mielke, 2015). The A3-report can be seen as a template which shows employees what steps are important in order to solve a problem (Gorecki/Pautsch, 2018). The advantage of this template is that all facts and aspects of the problem-solving process are in presented in a short and clear manner (Schewe/Herbig, 2015).

The A3-report has its origins in the logic of the PDCA cycle (Dombrowski/Mielke, 2015). This means that the A3-report is structured into the phases “Plan”, “Do”, “Check” and “Act” (Vetterli/Hollenstein, 2016). “Plan” could be found on the left side of the A3-report. The phases “Do”, “Check” and “Act” are on the right side of the report (Sobek/Smalley, 2008).

During the Plan phase the problem has to be defined. Furthermore, a description of the current situation must be made, preferably with quantitative data and graphs. The use of diagrams reduces the complexity of the problem and is therefore recommended (Liker/Meier, 2013). Subsequently, the target status must be described and substantiated with key figures (Vetterli/Hollenstein, 2016). Within the next steps various tools of the Lean Management are used in order to analyse the root cause of a problem. These tools are the Ishikawa diagram, FMEA (Failure Mode and Effects Analysis) and the 5-Why method (Sobek/Smalley, 2008).

The next steps of analysis are assigned to the Do, Check and Act phases and focus the initiation of countermeasures (Matthews, 2016). The problem-solving section, which is part of the A3-template, is about developing concrete solutions (Gorecki/Pautsch, 2018). It is crucial to solve the causative problem and not to treat symptoms (Vetterli/Hollenstein, 2016). Within this section concrete activities and responsibilities are defined (Sobek/Smalley, 2008). A cost-benefit analysis shows the effectiveness of the troubleshooting (Dahm/Brueckner, 2017). This include for example a comparison of the achieved status and the target key figures. The last step of the A3-report concerns follow-up measures that help to prevent this or a related problem from occurring in the future (Vetterli/Hollenstein, 2016).

The A3-report is a living document, which should be a constant companion during the problem-solving process (Dombrowski/Mielke, 2015). It is not only an instrument for solving individual problems. Employees gain a deeper understanding of the problems (Niermann/Schmutte, 2017). In this way they are given competence to design sustainable solutions that can be implemented into daily business (Womack/Jones, 2005). The A3-report is a simple and efficient instrument for solving problems within processes in a structured way (Forbes/Ahmed, 2011).

8D-Report

The 8D-report is a systematic model which should lead quickly and in a structured way to the solution of a problem within a process (Jung et al., 2015). Within companies the 8D-method is often used in context of complaint management (Junker/Griebsch, 2017). It is used to handle complaints of internal and external customers and thus serves to ensure quality (Kuntsche/Boerchers, 2017). The aim of the method is to eliminate the problem permanently (Kaschek/Schumacher, 2015). The term 8D refers to eight disciplines or process steps that are necessary to systematically identify and solve the complaint or the arisen problem (Krausz, 2018). This guide is used for problems that require not only sustainable problem solution but also immediate action in order to prevent further damages to the customer. The most frequent used of the 8D-report are customer complaints, production stops and industrial accidents (Jung et al., 2015). The eight disciplines are as follows (Barsalou, 2015):

- D1: Team
- D2: Problem description
- D3: Immediate containment action
- D4: Root Cause
- D5: Planned corrective action

- D6: Implemented corrective action
- D7: Actions to prevent reoccurrence
- D8: Congratulate the team

The report documents the results of the disciplines and ca be exchanged between the supplier and the customer (Daum et al., 2018). The structure of the report supports the systematic problem-solving and helps the customer to understand the measures taken to remove the problem (Bertagnolli, 2018).

In the first discipline a team has to be arranged which is responsible for carrying out the problem-solving process. It is crucial that all team members have the appropriate product and process knowledge and all skills and competencies to apply the methodology (Kaschek/Schumacher, 2015). Within the second discipline the team describes the arisen problem. This description should be as specific as possible, as all other disciplines build up on this (Schmieder et al., 2018). Afterwards immediate action will be taken in order to protect the customer from further damages caused by the problem or error. These are only temporary measures (Mueller, 2014). In the fourth discipline the team use mind maps, brainstorming and an Ishikawa diagram for the first collection of the possible cause of the problem. Afterwards the real cause must be found. For this various tools can be used, such as the 5-Why method (Jung et al., 2015). Discipline five requires the development of appropriate corrective actions. These are of indefinite duration and are intended to replace the immediate measures adopted in discipline three (Nied/Draexler, 2015). The corrective measured introduced in discipline five will be organizationally anchored in discipline six (Brueckner, 2011). Within discipline seven the collected insights, experiences and measures as part of the problem-solving process are transferred to comparable products and processes (Gorecki/Pautsch, 2018). This ensures that the problem does not occur with other products or processes and that the cause has been permanently eliminated (Brueckner, 2011). Finally, the team leader informs the team about the successful completion and recognizes the individual achievements as well as the team performance (Kaschek/Schumacher, 2015).

Case Study and Methodology

This paper investigates and compares the effectiveness and applicability of the A3- and 8D-method. Therefore, a pre-test of a case study was constructed. This pre-test is used to check if the A3- and 8D-method can be used in a case study. Furthermore, the case study process is monitored to ensure the smooth running of a future research with a lager sample size.

A case study is a qualitative approach that can be used for social science research in field of business and education. Furthermore, important aspects of a real-life event can be depicted, and it is used, when the events cannot be controlled by the investigator (Yin, 2009). The aim of a case study is to gain a deep understanding of a problem. Moreover, it is about the exploration of a complex and unique project (Simons, 2009).

3.1 Design of the Case Study

The pre-test of a case study was conducted within the model factory of the University of Applied Sciences Koblenz. The model factory was set up to simulate business processes and makes them tangible. For this purpose, it represents an exemplary value chain in a compact format of the fictitious company “OptiTruck GmbH”. In this case, the following miniature truck is considered to be the product (figure 1).

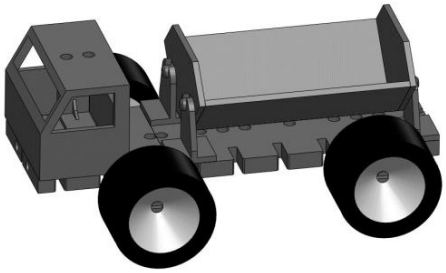

Figure 1 - Product

In addition to this truck, the OptiTruck GmbH also produces a second crane truck. The two trucks are manufactured in two separate production lines. The products require different construction components, which are delivered into a central warehouse. An incoming goods inspection is carried out, so that no defective parts enter the production process. Since the components are delivered to a central warehouse, a picking process must be carried out. This is assumed by a temporary work agency.

At the end of the production the final quality control takes place. Recently there are strong quality issues with the target product of the case study. Wheels drop of from the truck when rotated. Due to incoming goods inspection, a fault on the part of the supplier can be excluded. The OptiTruck GmbH focuses on a high quality standard. Therefore, no components are reused after incorrect assembly. This resulted in a 3% increase in material costs within one week. As complaint have already arrived from numerous worldwide customers, a fast solution for this problem must be provided.

3.2. Procedure of the Case Study

Eighteen students majoring in “Operations Management“ participated at the pre-test of the case study. First the students got a short introduction into the procedure. As part of this introduction the A3- and 8D-method as well as the instruments Ishikawa diagram and 5-why method were presented. This was followed by the division of the students into four groups. Two of the four groups applied the A3-method, the other two groups used the 8D-method. The groups were separated in different rooms in order to avoid manipulations. Subsequently the participants received the case. The groups that used the A3-report received a template with the sections of the A3-method. The 8D groups have been provided with a flip chart. The participants also received the components and a standard work sheet to assemble three trucks. This should allow the participants to experience the problem. This provides the participants the opportunity to go to the place of the event in order to analyze the problem more closely. All in all, the students got a time limit of one hour to solve the case study and thus to find the problem.

At the end, participants completed a questionnaire to measure subjective perceptions. Hereby, the effects of the A3- and 8D-method should be measured by comparing the survey results of the different groups. The first two questions of the questionnaire refer to the level of awareness of the two methods. These questions only could be answered with “yes” or “no”. For the following questions the participants should assess these statements according to their degree of agreement. For this purpose, a 4-point Likert-scale from (1) “completely agree” to (4) “completely disagree” was used. As part of the interval-scaled measurement, a numerical rating scale was adapted, enabling the classification of the participants based on a multi-stage scale (Scharf et al., 2012). An even number of scale points was chosen, since the middle category is often chosen as the "escape category" for an odd scale (Porst, 2014).

Results

In order to prove possible differences between the effectiveness and applicability of both methods, the collected data were analysed using descriptive statistic and hypothesis tests in Minitab statistics software (version 18.1).

A total of eighteen participants answered the questionnaire. Due to the differentiation of the questionnaires between the methods, a total of nine questionnaires for the A3-method and nine questionnaires for the 8D-method can be evaluated.

The first part of the questionnaire refers to the level of awareness of the A3- and 8D-methodology. Following questions were used for the study of previous knowledge:

- Question 1: The method was known me before this case.
- Question 2: I have already used this method before.

Question 1 and 2 could only be answered with yes or no. The results are shown in table 1.

Table 1 - Level of Awareness and Practical Use

Variable	Yes	No
Question 1 A3	77,77%	22,22%
Question 1 8D	33,33%	66,66%
Question 2 A3	11,11%	88,88%
Question 2 8D	11,11%	88,88%

Regarding the given results, the publicity of the A3-method among the participants is higher than the familiarity with the 8D-method. An examination of the results of the A3-group shows that 77,77% already knew this method before the execution of the case study. In contrast, 66,66% of the participants of the 8D-group did not know the 8D-method before. A Chi² test is used to examine the observed and expected values. On a significance level of 5% there is no statistically significant difference within the level of awareness between the A3-method and the 8D-method, $X^2(1, N=18)=3,6$, $p=0,058$. However, this p-value is borderline, an increased sample size may well show different levels of familiarity.

The percentages of question 2 shows, that both methods were rarely used by the participants. Particular noticeable is that for this question no differences in the percentages between both methods are recognizable. Regarding the level of awareness and practical use there are no differences between the A3- and 8D-method.

For the following questions the students should assess the statements according to their degree of agreement from 1 (“completely agree”) to 4 (“completely disagree”).

The second part of the questionnaire serves to determine the participants understanding of the respective method. Questions 3 und 4 addresses the comprehension of the methods:

- Question 3: I understood the basics of the method.
- Question 4: I could apply the method using the tools.

Table 2 - Comprehension

Variable	N	Mean	StDev	Median
Question 3 A3	9	1,111	0,333	1,000
Question 3 8D	9	1,222	0,441	1,000
Question 4 A3	9	1,333	0,500	1,000
Question 4 8D	9	1,222	0,441	1,000

Table 3 shows the mean values of question 3 which reflect a slightly better comprehension of the A3-method in the sample. However, since there is only a small deviation of the means and the median is the same, the participants seem to have a very good understanding after explaining the basics. In order to solve the case and apply the methods the students got an introduction into the needed tools. Also for tool application, there is only a small difference between the A3- and 8D-method.

Hypothesis testing for question 3 and 4 lead to the following result: The null hypothesis for question 3 states that there is no difference within the understanding of the basics between both groups. The two-sample t-test results in a p-value of 0,556. This value is higher than the given significance level (0,05). Differences in the basic knowledge of the respective methods between the A3- and 8D-group can not be detected. The null hypothesis for question 4 states that there are no differences in the applicability of the tools. The p-value for this test is 0,624. The null hypothesis can be retained as well. There are no significant differences within the applicability of the tools. In summary, no distinctions in the comprehension of the methods can be identified. However, sample size considerations lead to the conclusion, that the power of these tests was low. For example, a potential difference of 0.5 between both groups for question 3 resulted in a power value of only 62%

The third part of the questionnaire was constructed to check the problem identification. The following questions were considered:

- Question 5: The cause of the problem can be detected by the application of the method.
- Question 6: I could solve the problem with help of the method.

Table 3 - Problem Identification

Variable	N	Mean	StDev	Median
Question 5 A3	9	2,556	0,882	3,000
Question 5 8D	9	1,778	0,972	1,000
Question 6 A3	9	1,889	0,928	2,000
Question 6 8D	9	1,778	0,833	2,000

Referring to table 4, questions 5 shows a differences within the applicability of the A3- and the 8D-method. The mean value for the A3-method is at 2,556 which leads to a median of 3. This median reflects a disagreement of the participants about the problem identification by using the A3-method. They could not easily identify the existing problem within the case study. In contrast to this, the median of question 5 for the 8D-

method amounts 1,778 with a standard deviation 0,972. But the median shows still an agreement of the students about a good problem identification by using the 8D-report. The null hypothesis for question 5 expresses that there are no differences between the A3- and 8D-method regarding the detection of the cause by the application of the methods. For this a p-value of 0,096 is achieved. The null hypothesis will be retained.

In relation to question 6, despite difficult problem identification with the A3-method, the case could be solved well with both methods. For the t-test of question 6, a p-value of 0,793 is generated. Thus, the null hypothesis, which states that there is no difference in problem-solving between the A3- and the 8D-methd, can be retained. For problem identification, no method turns out to be more effective. However, as mentioned above, also here sample size needs to be reconsidered.

The last part reviews the applicability of the methods. Question 7 and 8 address this part of the research:

- Question 7: The method is well applicable to the case.
- Question 8: I understood the case and could solve this without problems.

Table 4 - Applicability

Variable	N	Mean	StDev	Median
Question 7 A3	9	1,556	0,726	1,000
Question 7 8D	9	1,444	0,527	1,000
Question 8 A3	9	1,667	0,500	2,000
Question 8 8D	9	2,000	0,866	2,000

The results of table 5 show a mean value of 1,556 (A3-method) and 1,444 (8D-method) for question 7. This indicates that both methods were applicable to the case. The t-test for question 7 leads to a p-value of 0,716. Thus, there is no statistically significant difference between the two methods regarding the applicability of the respective method to the case.

Regarding question 8, differences in the means of the A3-method (1,556) and the 8D-method (1,444) are apparent. These differences do not lead to divergent medians. The participants understood the case and could treat them independent of which method was used. The null hypothesis for question 8 states that there is no difference in the problem-solving of the case with the respective method. Neither method turns out to be more applicable. Again, also for question 7 and 8, sample size needs to be reconsidered.

Discussion

The pre-test of the case study developed here proved to be suitable to investigate performance differences of problem solving methods. However, the results of the pre-test do not show any performance differences between the two methods. Overall, among the participants the A3-method was better known. Both methods have not yet been used by the participants in practice. For this reason, learning effects related to the application of the method can be excluded. Referring to the quantitative data of the questionnaire, descriptive statistics and hypothesis testing, there are little differences in problem identification and problem solving. The problem was more easily detected by using the 8D-method. However, the research team noted that the participants of the A3-groups

were very busy with the template of the A3-report and the aspect of problem solving faded into the background. In total, regarding this case the 8D-report may be more effective in order to identify to identify and solve a problem. However, based on the performed hypothesis tests, no significant differences between the two methods can be identified. This could be related to a small sample size as mentioned above.

Summary and Future need for Research

Continuous process improvement also includes troubleshooting. This not only means removing the problem, but also eliminating the causes. Cause elimination is central to avoid the same or similar problem to reoccur. Both in literature and in practice, the problem solving methods A3 and 8D show a high prevalence. But which method is more effective and better applicable, is not described in detail. To take on this problem in this research project the following question was formulated:

"Which of the selected problem solving tools is more effective?"

To test this hypothesis, the A3- and 8D-method were analyzed within a pre-test of a case study. The pre-test was conducted with eighteen participants. The participants completed a questionnaire to quantify the subjective perception of the applicability of the methods. These data were analyzed by descriptive statistics and hypothesis tests. A comparison of the effectiveness of the methods no performance differences can be demonstrated. Nevertheless, the 8D-report may be more appropriate method for problem identification and problem-solving.

As shown by the results of question 2, the participants have not used any of the methods in practice so far. This means that they have no experience in the methodology. They therefore had to familiarize themselves with the procedure and the instruments to be used. The missing experience and understanding of the methodology and instruments can also have an effect on the performance and effectiveness of the results.

The pre-test shows that the A3- and 8D-method can be used within a case study. The results of the pre-test cannot be generalized. Further studies should be performed to increase sample size. Also other types of products can be manufactured. Maybe a product with a higher complexity will have an impact on the results. In order to get more scientific valid results, the case study should be further developed. Participants should receive a deeper introduction to the methodology and tools. Through a better understanding in the application of the methodology, potential performance differences may become visible.

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Leveraging virtual environments and 3D models in a workspace design: implications and possibilities

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Abstract

This paper presents the initial test of two Virtual Environments (VE) and 3D models as learning tools for workspace design education. A quasi-experiment was designed in which 27 students were assigned to one of four groups (control, physical, digital, physical and digital) and were prompted to read a case and design improvements proposals with the materials available to them. Results showed no significant differences among the groups, which could be partially due to the experiment setting, since participants' comments highlight, they greatly appreciated the VEs and the activity in general, due to its practical, reality-based and team work nature.

Keywords: Virtual Worlds, 3D Printing, Factory Design.

Introduction

Workspace design has long been a field of interest in operations management, from the macro level aspects of plant location decisions and layout to the micro level of workstation design.

In the past decade, researchers have started to investigate the potential of employing novel technologies such as game engines (GE) to the design and simulation of productive systems (Braatz *et al.*, 2011; Gatto *et al.*, 2013; Carreira *et al.*, 2018; Paravizo and Braatz, 2019). GEs are a class of computer software that enable the development of 2D/3D games and applications using pre-existing modules and tools. There is also an interest in employing these technologies in educational contexts (Braghirolli *et al.*, 2016; Paravizo and Braatz, 2017).

In order to assess how educators and practitioners can employ these technologies, we developed a virtual environment (VE) in a GE that aimed to enable students to redesign the layout and furniture/equipment present in a workplace, considering a series of

problems and issues present in a case report. Besides the VE, the same scenario, layout and furniture/equipment were represented in a set of 3D scale models and a game board as well as a simple 2D sketch for handmade drawings.

This paper reports an initial test with 27 industrial engineering students aiming to validate a proposed experiment design that could enable researchers to better understand the potential and limitations of the VE and 3D scale models as tools for workspace design.

Materials and method

The basic material created was a case briefing, which explained to participants the case analyzed, the main issues and problems currently existing in the workspace and what was the work performed there. Participants also had a spreadsheet with a list of the available furniture/equipment that they could choose from. Besides this base material, a digital tool (VE) and physical tools (3D scale models & game board and simple hand drawing) were made available to participants. The virtual environment was created by the authors specifically for this study considering game design (Schell, 2014) and gamification strategies (Werbach and Hunter, 2012) and followed the four major axes delineated in (Paravizo and Braatz, 2019). The VE designed was an evolution of a VE designed for the analysis of the workspace reported in (Paravizo and Braatz, 2019). An overview of the materials is presented on Table 1.

Table 1 – Design tools and materials developed for the workshops

Design methods	Materials and tools	Description	Application mode
Digital tool	Unreal Engine 4.18	The VE aimed at enabling participants to redesign a workspace, including changing the layout, installing equipment and furniture and even adding workers to the scenario. Figure 1A shows the design view of the VE and 1B shows the participant's character exploring the environment they just designed	During this design stage, participants could explore their design proposal with their character, inside the VE, in real time. The VE ran on a PC and participants could interact with it using keyboard, mouse and a wireless joystick.
Physical Tools – 3D scale models and board game	Models drawn in CAD 3D and printed in 3D printer (ABS plastic). Board game printed.	A set of 3D scale models representing the furniture (desks, chairs, partition wall panels, etc.) and a board game representing the base layout of the workplace. Figure 2A.	The participants could draw and sketch their design proposals on it using whiteboard markers and positioning the scale models.
Physical Tools – handmade drawing	Sheets of paper and pencils	A simple two drawing on a sheet of paper. Figure 2B.	The participants used pencils to draw their proposal on the sheets.

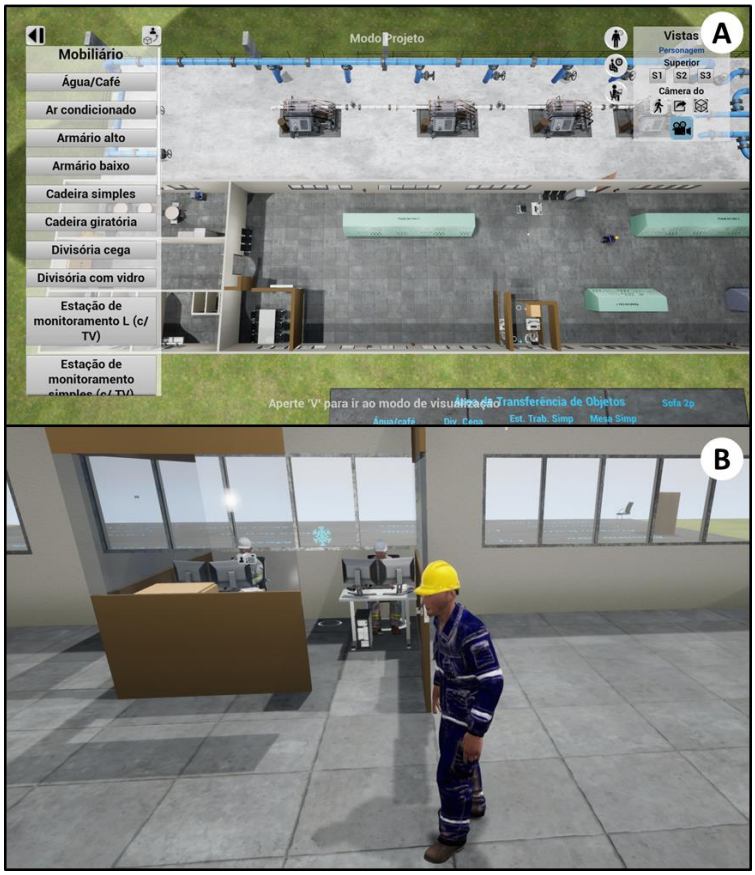

Figure 1 – The VE developed to design (A) and explore (B) possible solutions

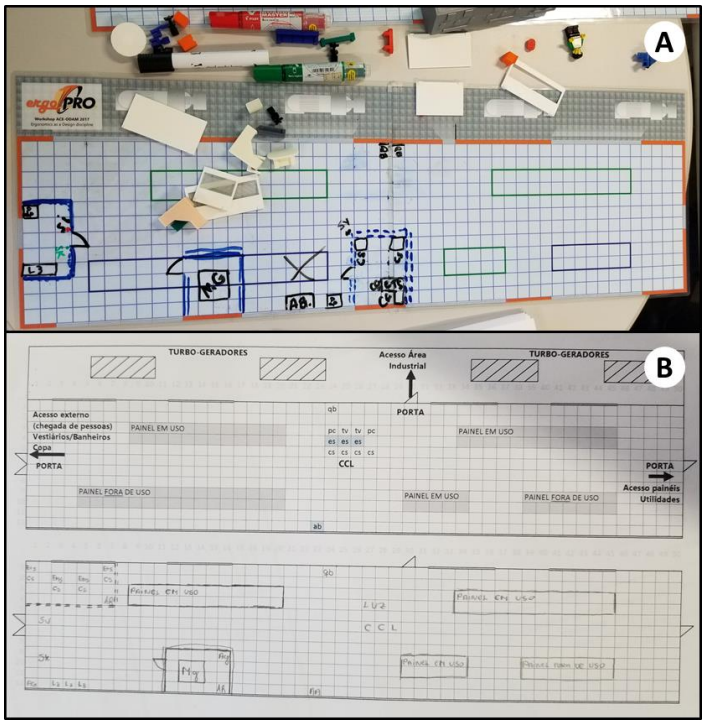

Figure 2 – 3D scale models, game board (A) and paper sheet for drawing by hand (B)

Experiment Design

The experiment design that was intended to be validated in this study is presented in Figure 3. Considering that participants were students from the engineering courses who volunteered, and thus a multitude of external factors was impossible to control, this study design is closer to a quasi-experimental design.

The idea was to have participants to use the different available materials to understand a case and assess how well these materials supported participants' design activities. The facilitators were responsible to give a brief overview of the research project, and hand to the participants the materials they would use, prompting them to read the case description, discuss it among themselves and then propose a solution.

After the workshop session, participants were asked to fill out a feedback questionnaire on their perception of the activity and the tools. The feedback questionnaire had 5 main sections: section 1 focused on participants' background, section 2 inquired about their understanding of the issues presented in the case, section 3 inquired their perception of the suitability of the materials they used for the task and if they saw the need of other resources, section 4 asked for comments on the materials and overall activity and section 5 was only for those who used the digital tools, inquiring about usability aspects of the VEs.

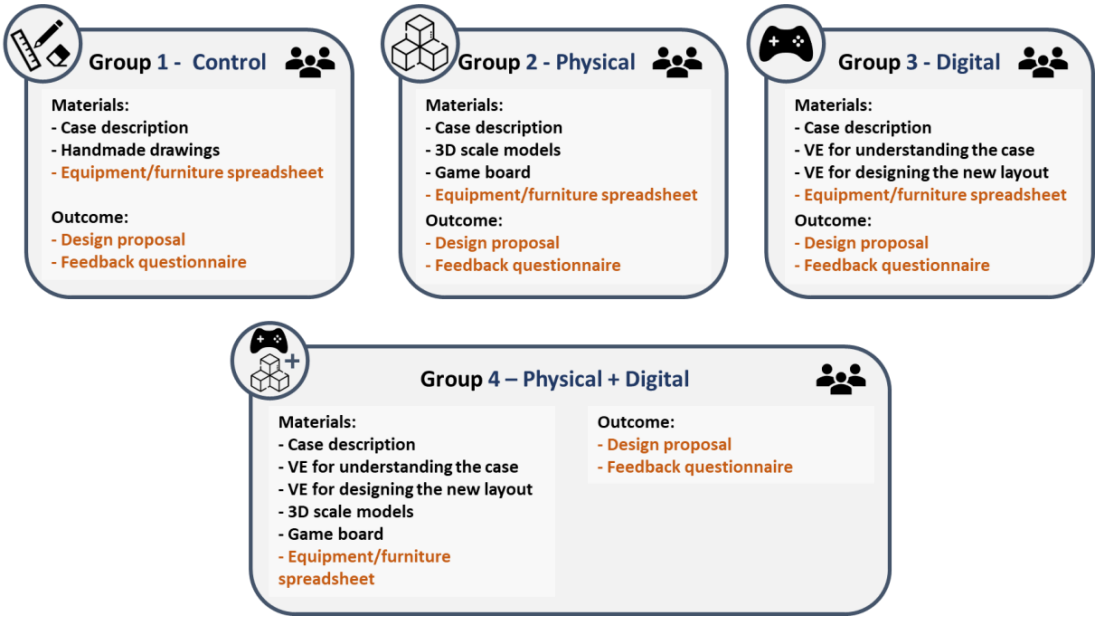

Figure 3 – Experiment design

Results and discussion

In total 27 students in Industrial Engineering courses of two federal Brazilian universities participated in the 2 hours-long workshops occurred in 8 different moments during July and August 2018. All participants voluntarily agreed to take part in the study, having signed consent forms prior to the activity. The 27 filled out the feedback questionnaires were retrieved via Google Forms, and subsequently analyzed.

One of the main focus of this study was to assess if there were significant differences among the groups in terms of their understanding of the case and the perception of the suitability of the tools employed (sections 2 and 3 of the questionnaire). However,

analysis of the results from the questionnaire showed that there were no significant differences among the groups.

Considering these results, emphasis will be given on the analysis of participants' comments in order to try to better understand their perception of the activity and the tools they employed. The general inductive approach for qualitative data analysis (Thomas, 2006) was followed for the coding of the participants comments. In total, 65 segments were coded to one of 18 codes. A summary of the coding analysis is presented on Table 2, focusing on the 9 most recurrent codes, which amount to 80,2% of the total codes.

Table 2 –Participants' comments analysis overview

Category	Code	Count	% Codes
General-Positive	Overall good impression	14	21,5%
General-Positive	Practical nature of the activity	7	10,8%
VE-Positive	Detailed scenario	5	7,7%
VE-Positive	Helps to simulate work aspects and layout	5	7,7%
VE-Positive	Immersion in the VE	5	7,7%
General-Negative	Short duration	4	6,2%
General-Positive	Better understanding of the topics	4	6,2%
VE-Positive	Helps to visualize	4	6,2%
VE-Negative	Usability aspects	4	6,2%
	Total	**52**	**80,2%**

Participants comments show an overall good impression of the activity in general and also the materials employed. The impact of the workshop was such that participants commented they became more interested in the topics approached. One participant from the control group (G1) commented: *"Excellent activity. It gave me a better understanding of ergonomics, factory design and simulation. A comprehension level much larger than any theoretical lecture"*.

The practical nature of the activity was in itself a highlight of the workshop. Participants commented they liked that the activity was based on a real case and that they actually had to put their knowledge on the topics in practice, in a team work setting. Another participant in a control group commented: *"Great activity to improve our team working skills, to broaden our knowledge by facing 'real' work situations, to put in practice the knowledge we acquire in the classroom and to get to know novel platforms for simulation/ergonomics"*.

In terms of the VE employed by participants assigned to groups 3 and 4, comments focused mainly on the high-fidelity visuals that led to a high degree of immersion on the situation and different interactions possible inside the VE (with non-playable characters - NPCs, equipment, environment, etc.) that enabled them to simulate work aspects and different layout proposals. One participant assigned to the digital group commented: *"The utilization of the virtual scenario allowed a different immersion in the problem at hand. This environment allows the interaction with the structural aspects of the physical space, as well as presenting the personal issues from workers, which are fundamental in any improvement project, since they are actors directly involved in the process."*

Overall, the main improvement points participants indicated were related to the short duration of the workshop and the usability aspect of the VE. One of the participants in a digital and physical group commented: *"The virtual environment was not used a lot because there was little time, but it is very detailed. The environment has a nice visual presentation but need to be more intuitive and easier to use."*

Furthermore, going back to the initial assumption that there would be significant differences among the groups in terms of their understanding of the case and perception of the materials available to them (which was not verified through the data collected), two comments can bring more context to this. The first one, from a participant in a control group: *"My team only used the handmade drawings of the place and it was enough for us to have an idea of the space and allow us to create and present an improvement proposal. I think a virtual environment would enrichen the experience and give more precision, however this basic resource was enough."*. The second comment, from a participant on a physical only group: *"The activity showed that we can't only imagine that the simulation is something digital, but rather we can see it with models and objects. And thus, we can show how the layout of an organization would be"*.

These two quotes in particular highlight participants perception that the tools they have are enough, however these participants did not used the VEs so they do not have a basis of comparison against which to compare the available materials. Furthermore, the mere setting of the workshop – as a practical activity – is, in itself, something that students tend to like, regardless of the different types of materials used as highlighted in the comment's analysis. These aspects must be taken into account when designing future similar experiments.

As expected, usability aspects of the VE impacted participants perception of its utility. Although the VE was easy enough so that they were able to use it to propose improvements and scenarios (as seen in Figure 1B, for instance), it still could be greatly improved.

Conclusion

This paper reported the development and pilot test of a study aiming to achieve a better understanding o the impact of using VEs and 3D models for workspace design. Despite the lack of significant evidence to substantiate the claim that one tool would be better than other, we find that participants greatly appreciated the virtual environment and the activity in general, due to its practical, reality-based and team work nature

Future experiments could be designed taking into account the issues raised here, particularly, assuring that all participants have a more symmetric standpoint to compare the tools assessed and also the overwhelmingly good impression of a practical activity that could end up flattening out the effect of differences between the groups analyzed.

Further refinements on experiment design could be useful to realize the full potential of employing VEs and 3D models in engineering design practice and education. The VE developed can be customized and employed in a wide range of industries and contexts for fostering design communication, participation and stakeholder involvement as well as bringing practical activities to the design disciplines.

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